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Analysis of dental wear and pathological conditions in human teeth from the Neolithic site of Grutas Artificiais do Tojal de Vila Chã (Estremadura, Portugal)

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the degree of Master of Arts

Department of Anthropology

Edmonton, Alberta

Spring 1993

ISBN 0-315-81994-4

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Cidália Maria Pereira Duarte

TITLE OF THESIS: Analysis of wear and pathological conditions in human teeth from the Neolithic site of Grutas Artificiais do Tojal de Vila Chã, Carenque (Estremadura, Portugal)

DEGREE: Master of Arts

YEAR THIS DEGREE GRANTED: 1993

Nov 13/92

Rua Rainha D. Luísa de Gusmão, 7-5º I, Lisboa

P - 1600 PORTUGAL

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Analysis of wear and pathological conditions in human teeth from the Neolithic site of Grutas Artificiais do Tojal de Vila Chã, Carenque (Estremadura, Portugal)" submitted by Cidália Maria Pereira Duarte in partial fulfilment of the requirements for the degree of Master of Arts.

Dr. Owen Beattie (supervisor)

Dr. Nancy Lovell

Dr. Gordon Thompson

Date NOV 13/92

To my family in Lisbon and 'ma soeur au Canada'.

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Abstract

In western Europe the presence of a cereal based economy has characterizated the definition of the Neolithic and Chalcolithic periods in the archaeological literature. This subsistence pattern contrasts with the hunting and gathering economic strategy of the previous Mesolithic period. Recent research suggests that, in Western Europe, this transition was not as abrupt as it appears and that the adoption of an agricultural subsistence was a slow process, with mixed economies playing an important role for a long time.

In this study a sample of human teeth from a Neolithic/Chalcolithic site located in Estremadura (Tojal de Vila Chã) was analyzed; wear patterns and pathological conditions of the dentition were assessed and quantified in order to identify patterns that could indicate similarities and differences with populations of known dietary patterns. The amount of wear of the occlusal surface was quantified for all the tooth sectors, in both <u>in situ</u> and in loose teeth. The slope of the occlusal surface in the molar sector was registered in the loose specimens and its variation with increasing occlusal wear was estimated. A metrical method based on trigonometry was used as a way of quantifying the variation of this slope. Comparison was established with results obtained from sites identified as pre-agricultural and agricultural in the circum-Mediterranean area. The presence of dental caries was quantified in order to evaluate its relevance in the identification of agricultural subsistence strategies in the Estremadura prehistory. The frequency and age distribution of linear enamel hypoplastic defects were recorded. Hypercementosis was assessed in the loose teeth.

The conclusions of the thesis indicate that the wear patterns visible in Tojal de Vila Chã are in agreement with results obtained by other researchers in Neolithic sites in Estremadura, which suggests no significant differences in subsistence patterns between the Neolithic and the Chalcolithic periods but a marked contrast with the Mesolithic dentitions. The analysis of dental caries confirms that the current views regarding differences in the presence of cariogenic elements in

the diets of pre-agricultural and agricultural populations cannot be applied to all archeological samples and that regional tendencies must be considered when prehistoric skeletons are analyzed.

ACKNOWLEDGEMENTS

Permission for the analysis of the dentition from Tojal de Vila Chã was given by Dr. Francisco Alves, director of the Museu Nacional de Arqueologia e Etnologia in Lisbon and by Dr Bairrão Oleiro from the Instituto Português do Património Cultural in Lisbon. Ana Isabel Santos, Ana Cristina Araújo and Teresa Duarte helped me in Lisbon with the preliminary data collection and Maria do Carmo Vale gave me access to library information on the site and sent important articles from Portugal. Joaquim Franco made some of the illustrations in my thesis and helped me gain the courage to start my graduate program.

The research for this thesis was made possible by the funding provided by the Department of Anthropology and the Faculty of Graduate Studies and Research of the University of Alberta and by the partial funding from the SSHRC research grant 410-84-0030 and 410-86-2017 awarded to Dr David Lubell, Dr Chris Meiklejohn and Dr Mary Jackes for the project on the "Archeology and Human Biology of the Mesolithic Neolithic Transition in Portugal".

I am thankful to all the members of my committee, to Arne Carlson and in particular to my supervisor for the good criticisms on my thesis which made it readable and to Dr Linda Fedigan for her good advice and understanding that helped in the completion of my graduate program.

I deeply appreciate the contribution of Dr Lubell, João Zilhão and Ana Cristina Reis da Silva Araújo in the initiation and development of my graduate career and the trust they deposited in my academic capabilities. Without them, this thesis would not have started. Dr Lubell kindly provided unpublished information on his current research and good criticisms that greatly contributed for the success of the present work.

In Canada many friends helped me coping with the work and the hard conditions. Pam Mayne was there from the beginning, helping me to understand the Canadian academic system. Jeff Bailey, Paul Vasey and Jim Woollett initiated me in the computer world and were constant companions in this long journey. Jack Brink helped me in many circumstances with his advice and friendship. Dr Schweger always made me think that it was worthwhile and immensely contributed to the mental construction of this thesis. Darlene, Harvey and all the secretaries in the department were always supportive and kind. Grace Morgan helped by giving me financial and moral support in all occasions. Ping Lai accompanied the making of the thesis with a helpful smile and Andrew Johnson gave me invaluable advice on dental anthropology and statistical procedures. Sheree Ronaasen edited parts of my thesis and helped me survive the last months of the writing process.

A special word to Darryl for his companionship and sweet presence and for giving me his hand and understanding in the difficult moments.

I would like to thank Dr Owen Beattie for his constant and reliable support. He helped me build the necessary confidence to complete my thesis and stood beside me at all times. His advice and patience were invaluable throughout my whole degree.

Finally, a very special word to Murielle Nagy, who supported me through the dire straits of my 'séjour' in Edmonton. Not only she gave me financial support but, more important, she provided the constant and reliable friendship and solidarity that made my life possible in a foreign country and made my sad days happier. Thank you!

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CHAPTER ONE

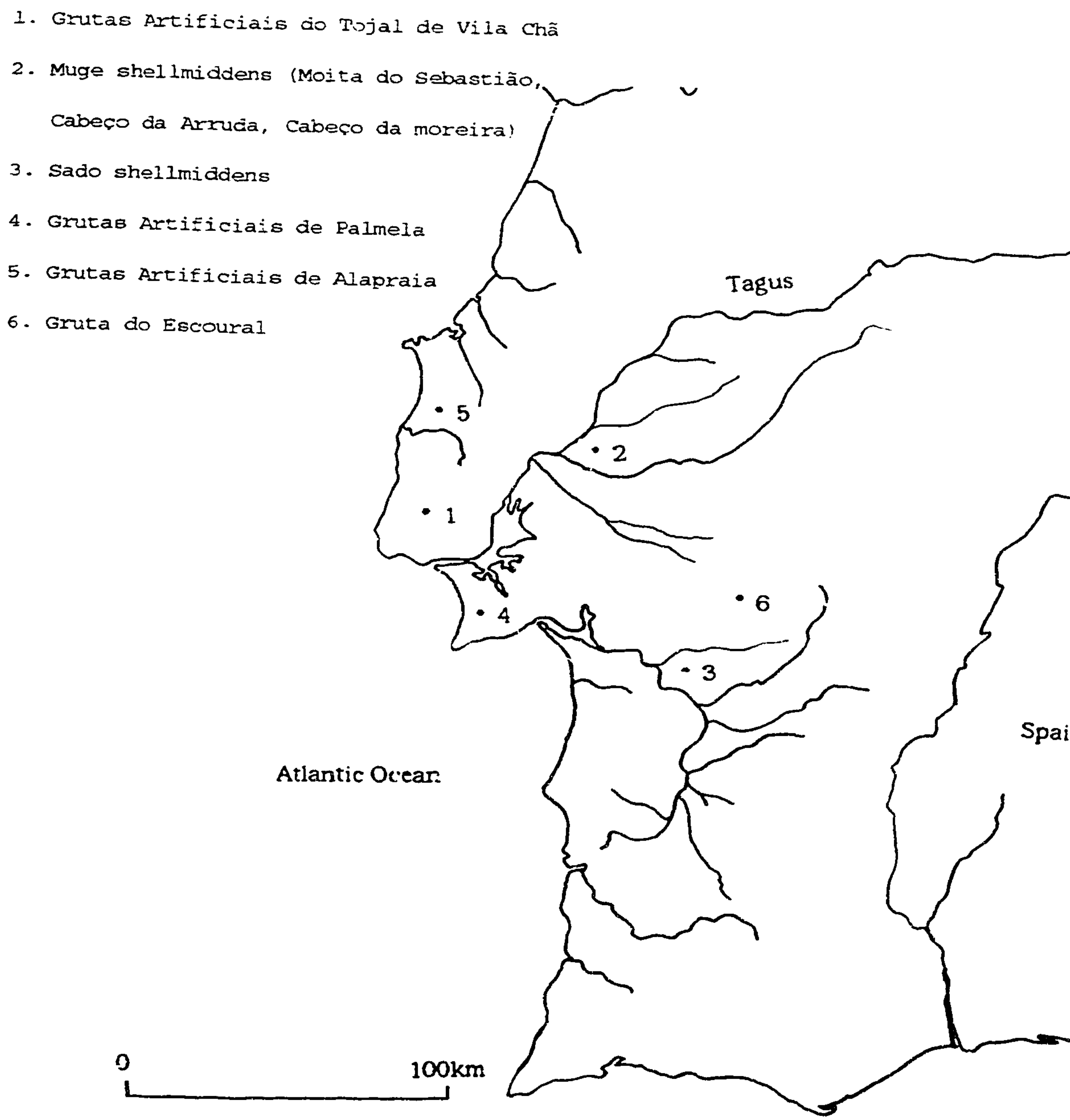
INTRODUCTION

This thesis is a contribution to the understanding of the mechanisms of transition from hunting-gathering to agricultural/pastoral economic strategies in the province of Estremadura (central coastal Portugal), through the analysis of human dental remains. This period is identified as the Mesolithic-Neolithic transition and is dated around 6800 to 5000 BP (Zilhão, 1992). A sample of approximately 3,000 human teeth from the site Grutas Artificiais do Tojal de Vila Chã (Carenque, Estremadura) (Fig. 1), was studied for the identification and definition of dental attrition patterns and pathological lesions. The site has been classified as Neolithic/Chalcolithic (Heleno, 1933) and has been dated at 3930 BC. ± 190,± 340, (5880 BP.) by thermoluminescence analysis of potsherds (Whittle & Arnaud, 1975:19).

The introduction of agriculture into Portugal has been extensively discussed in the archaeological literature and integrated in a more general debate on the spread of plant domestication and herding in the western Mediterranean (Ammerman,1987; Ammerman & Cavalli-Sforza, 1971;1973; 1984; Arnaud,1982; 1985; Bailloud, 1978; Burkitt & Childe, 1932; Chapman, 1986; Childe, 1958; 1960; 1981; Cohen, 1977; Cohen & Armelagos, 1984; Dennel, 1983; Ferreira & Leitão, 1981; Fonton, 1966; Garralda, 1973; Geddes, 1984; Guilaine, 1979; Guilaine & Ferreira, 1970; Higgs, 1976; Lewthwaite, 1981; Lubell, 1984; Lubell & Jackes, 1988; 1988; Lubell, Jackes & Meiklejohn, 1988;1988; Meiklejohn et al., 1984; Meiklejohn et al., 1988; M.N.A.E., 1989; Renfrew, 1987; Serrão, 1978; Sokal et al., 1991; Zilhão, 1984; Zilhão, 1990). The technological, cultural and biological mechanisms that led to the adoption of an agricultural economy by pre-agricultural groups have not yet been made clear from modern archaeological research.

Culture historical interpretations were for a long time the dominant theoretical approach to this question among archaeologists doing research in Portugal. The transition was - and still is - associated with the introduction of Cardial pottery and sites are

Fig. 1. The Mesolithic and Neolithic sites in Estremadura



defined as Neolithic by the presence of this type of ceramic ware (Arnaud, 1982; Gonçalves, 1978; Lubell, 1984; Silva e Soares, 1982;). The transition from a hunting-gathering/ fishing economy to the adoption of agriculture has been identified predominantly through the comparison of artifact assemblages and, for Estremadura, it has been dated between 6000 and 5500 before present (Zilhão, 1992).

Recent research on the introduction of agriculture in Portugal (Arnaud, 1982; Lubell, 1984; Zilhão, 1990) has been based on an interdisciplinary approach, incorporating contributions from palynology, geoarchaeology, archaeozoology, and physical anthropology. The interpretations created by these studies have resulted in the development of new models describing the introduction of agriculture in this geographical area and concentrating on settlement patterns and seasonality in the use of food resources. However, the intensity of agricultural activity in Estremadura has reduced the possibility of identification of settlement sites in the areas of rich alluvial deposits, where early farmers were more likely to have settled and cultivated. Hence, the data available for the Neolithic period consists mostly of human remains recovered from collective burial sites.

The presence or absence of pathological conditions in human teeth are not per se indicators of the circumstances that led to the adoption of agriculture; however, knowledge of the occurrence of those conditions in pre-agricultural and in agricultural populations can be useful in the identification of food habits in transitional periods, for which dietary strategies and settlement patterns are not well established by the archaeological research.

Rhythms of transition can be better understood through the analysis of human health status in periods of dietary shifts and more specifically through the characterization of dental health (see Lukacs, 1989 for review). The increase of stress indicators, such as linear enamel hypoplasias (see chapter four for discussion) in the transition from hunting-gathering subsistence strategies to the adoption of agriculture has been recognized in North American skeletal samples.(e.g.

Hutchinson & Larsen, 1990). Caries, the demineralization of the tooth enamel and/or dentine, is directly dependent on protein/carbohydrate intake (Nikiforuk, 1985:80), and its presence or absence can therefore account for the interpretation of dietary habits in prehistoric populations; the increase in the frequency of caries with the introduction of maize agriculture has been identified in North American skeletons(e.g. Patterson,.1984).

The differences in the development of dental wear between populations adopting diverse economic strategies has been recognized as a means of assessing dietary strategies in prehistorical skeletal samples (see Smith, 1984 for review). The formation of wear facets on the surface of the tooth enamel is caused by different factors (Hillson, 1986:183) and it is diagnostic of certain aspects of life styles in prehistoric skeletons (Patterson, 1984: 58). The wear on the occlusal surface of the teeth varies not only in degree but also in shape. Populations with diverse diets develop different occlusal slopes, with increased wear (see chapter four for discussion). The variation of this slope is measurable in archaeological human remains but it requires the use of distinct methodologies depending on whether in situ or loose teeth are being observed.

In Portugal, it is only recently that physical anthropology has joined the debate over the introduction of agriculture, and therefore the work of physical anthropologists in this area is as yet scarce. Dental studies were published by Sueiro, Brabant and coworkers earlier in the century, but they concentrated on the observation of Mesolithic and megalithic samples (Brabant, 1968; 1969; 1970; 1971; Brabant & Brichard, 1962; Brabant & Lecacheux, 1973; Brabant & Sahly, 1962; Brabant & Twisselmann, 1964; Sueiro & Frazão, 1957; Sueiro & Vilela, 1947). The methodology used in these reports, and in particular the methods for the quantitative analysis, are very rarely defined. Consequently, the possibilities of comparing those results with recent studies are limited. Recently, some prehistorians have developed research projects in the area of dental anthropology. In 1984, a joint Canadian/Portuguese research project, investigating the Mesolithic-Neolithic transition, was initiated under the direction of Dr. David

Lubell, from the University of Alberta. Preliminary results of the analysis of human skeletal remains have been published (Jackes, 1988, 1991; Jackes & Meiklejohn, 1992; Lubell, 1984; Lubell & Jackes, 1988; Lubell, Jackes & Meiklejohn, 1988; Lubell et al., 1992).

The scarcity of habitation sites in the Portuguese Neolithic that could provide information on available and used resources (and more specifically for the Estremadura region), creates a need for the use of skeletal indicators in the identification of patterns of subsistence and the identification of food items consumed by early agriculturalists. Since the classification of Neolithic sites is archaeologically based on artifact assemblages, and little is known about the life styles of the early farmers/ herders in the area, speculation and induction are used in the characterization of Neolithic communities. In the analysis of Chalcolithic (Copper Age) sites, it is assumed that they were created by farmers with a higher technology and wi greater accumulated wealth compared to the earlier agriculturalists. In Estremadura, the large number of human remains stored in museums and the burial sites available for excavation justify the urgency in defining patterns (morphological, pathological, demographic) identifiable in the skeletons from sites that have been attributed different time periods. Because Neolithic collective burials include a large number of loose teeth, there is a need for the development of techniques suitable for the analysis of such samples. Information on wear patterns and pathological lesions is particularly important in the definition of dietary strategies and can be used in the interpretation of life styles of the people who have been identified as 'Early' and 'Late' Neolithic.

Nature of the sample

In this thesis the wear patterns and pathological lesions of a sample of approximately 3,000 teeth from the site Grutas Artificiais do Tojal de Vila Chã (Carenque, Portugal) are analyzed. The site has been described as a Neolithic-Chalcolithic collective burial (Ferreira & Leitão, 1981; Heleno, 193?; IPPC, 1986; M.N.A.E., 1989; Savory, 1968). It is composed of three distinct artificial caves with similar architectural structures (chamber and passage) excavated in the limestone below ground level.

The taphonomic processes that generated the concentration of a large number of loose teeth (83% of the total sample) are not clear. The tombs were completely excavated in the 1930s by M. Heleno and neither the archaeological procedures used nor the burial patterns encountered were recorded. A visit to the site in the summer of 1989 revealed that there are no sediments left in the burials. The in situ teeth (i.e. still articulated) are not associated with individual skeletons and represent only 17% of the total sample; only three of the jaws were complete and could be sexed by the qualitative methods accepted in the anthropological literature (e.g. supraorbital ridges, gonial angle, mental protuberance). The use of metrical methods for sexing the mandibular and maxillary fragments was inadequate since the Neolithic values for the sexually dimorphic osteometric variables have not been established for this geographical area.

The use of loose specimens as a source of information has significant limitations. Sex and age, the basic data needed for the construction of palaeodemographic profiles, is difficult to assess from loose teeth, unless comparable samples of specimens in situ, and associated with post cranial remains, are available. Although the information provided by disarticulated teeth is in some aspects limited, there are some features that can be more easily observed if a tooth is isolated. Interstitial wear - the development of wear facets on the mesial and distal contact areas of the enamel surface , can be more easily diagnosed and scored or measured. Interproximal caries - the demineralization of the tooth on the mesial and distal surfaces (Nikiforuk, 1985:4), is more easily diagnosed in loose specimens, since the contact between adjacent articulated teeth obscures the assessment of its presence, especially at a rudimentary stage of the development of the lesion. Pathological conditions of the root - such as hypercementosis, can only be diagnosed through X-ray in in situ samples. The quantification of such conditions is therefore limited when articulated teeth are analyzed, and the number of scorable units potentially reduced.

Although loose teeth can provide information that is difficult to diagnose in articulated specimens, the methods published by anthropologists for the analysis of dental attrition have been predominantly developed for *in situ* dentition and therefore are not useful in the study of samples of disarticulated teeth. Since the 19th century, thousands of loose human teeth have been recovered by archaeologists from Neolithic burial sites in Estremadura. A method for the definition of patterns of dental attrition in both loose and *in situ* dentitions needs to be developed and standardized, in order to provide wide and replicable data bases that can be used in inter-site and temporal comparison for this region.

The purpose of this thesis is to :

- describe *dental health and attritional status* of the sample from 'Grutas Artificiais do Tojal de Vila Chã', thereby contributing to the construction of a database on the dental conditions of the Neolithic/Chalcolithic populations of central coastal Portugal;

- determine *patterns of dental attrition* which characterize the sample and relate them to specific subsistence patterns;

- compare the *incidence of pathological lesions* in the present sample with those from other sites of the same area and the same time period.

-document and present *methodological approaches* that can be useful in the analysis of dental wear in loose teeth;

- *discuss the validity* of the use of data from dental attrition and pathology as a means for assessing diet in different geographical areas;

-integrate the results of the analysis into models for the introduction of agriculture in Estremadura.

The remaining chapters present the development of the investigation in the following order:

Chapter two is a synthesis of the archaeological research that has been done in Estremadura with emphasis on models developed for the introduction of agriculture in central coastal Portugal, and discusses the problems surrounding the definition of the Neolithic and the Chalcolithic. Chapter 3 presents the available data on human osteological research done in Estremadura and in Portugal, in the context of the transition between Mesolithic and Neolithic. Chapter 4 discusses the characteristics of the sample, and describes the methods adopted in this research. Chapter 5 presents the results of the analysis and discusses them in the context of the use of dental data as sources of information on paleodiet in the transition from hunting/gathering to agriculture. Chapter 6 summarizes the conclusions of the analysis. The standards used for the classification of loose teeth and the data sheets used for the preliminary data colection are given in the appendices.

CHAPTER TWO

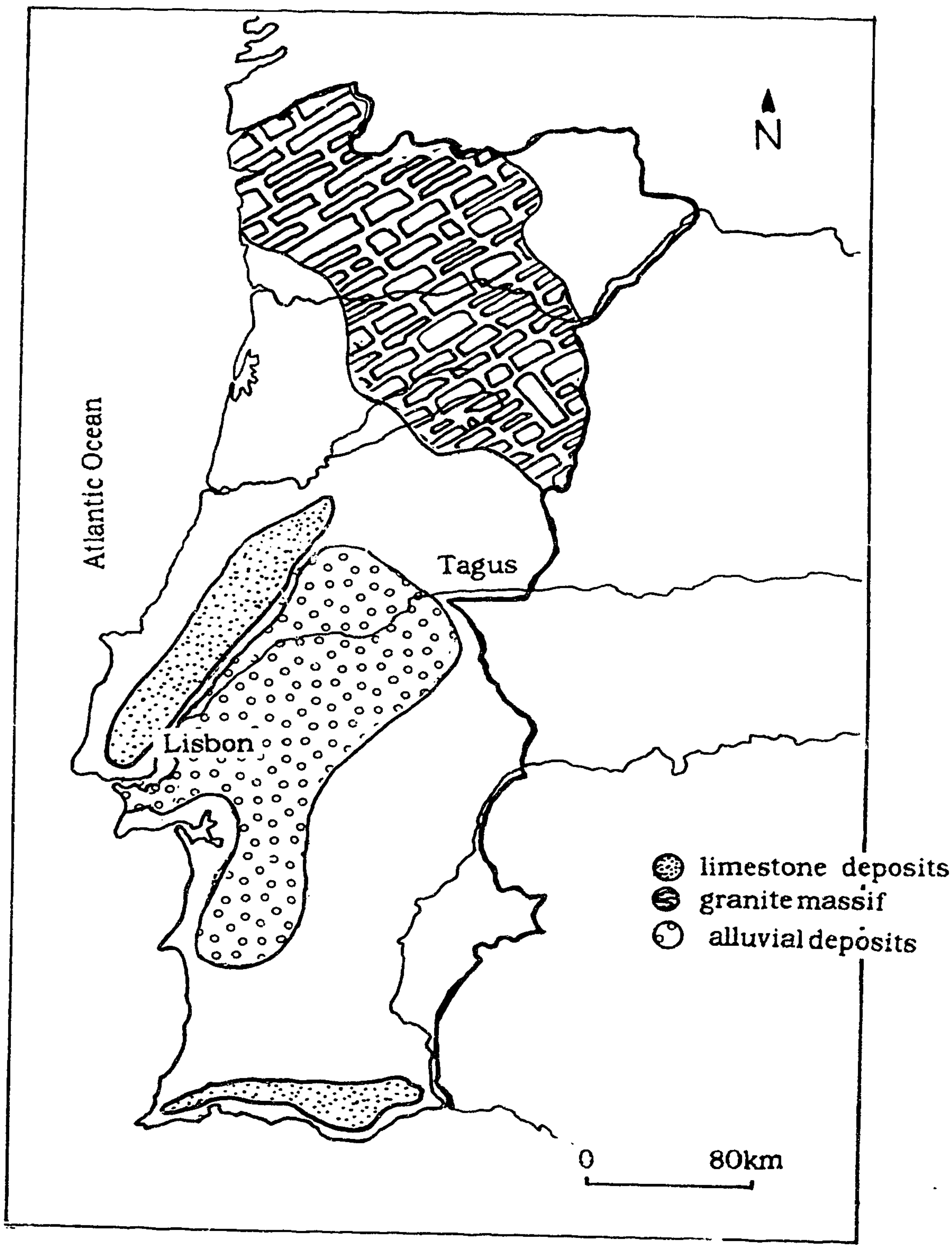
THE BEGINNING OF AGRICULTURE IN PORTUGAL AND THE NEOLITHIC / CHALCOLITHIC OF ESTREMADURA

In this chapter, a discussion of the Mesolithic-Neolithic transition in the Estremadura is presented. The geography and geology of the province are summarized, with special emphasis on early Holocene environmental data. The concepts of Mesolithic, Neolithic and Chalcolithic are discussed. The existing models for the introduction of agriculture in Portugal are integrated in the general discussion on the transition between hunting/gathering/fishing and agricultural subsistence strategies.

Geologically, Portugal can be divided into three zones: the granite massif of the Northern half of the territory is part of the Iberian meseta (Fig.2). The central western (Estremadura) and southern coast (Algarve) zones are mainly Triassic, Jurassic and Miocene limestone beds. The southern central (Alentejo) zone is dominated by Quaternary alluvial deposits (Barnett, 198-:2). It is in the limestone massif of Estremadura that Tojal de Vila Chã is located.

Estremadura is a transitional area between the North and the South. The word literally means "area on the edge of a country" (Dicionário Moraes,1952). It is bounded by the Atlantic Ocean on the West and by the Tagus valley on the East (Fig. 1). On the northern part of the province there is an extended limestone massif. Unlike the North and a large central area of Portugal, Estremadura lacks granites and schists. It contains a narrow band of Triassic sandstones which extends from the North to Tomar. Westward and southward of these, lies a broad band of limestones of Jurassic age, broken by considerable areas of Cretaceous sandstones and conglomerates. The differences in resistance to weathering of the limestones, sandstones and volcanic rocks has produced a region with great variety of form (Bradford, 1973:16-17; Caldas & Loureiro, 1966; Stanislawski, 1959). The present climate of the Estremadura is Atlantic, with cool summers and rainy winters. Its most

Fig. 2. The geological areas of Portugal



important river - the Tagus - has irregular flow and common floods during spring (Worldmark Encyclopedia of Nations,1984:221; Le Million, 1969: 207). The knowledge of climatic variations in Portugal during the Quaternary is very limited because local research on Iberian paleoclimates has mostly concentrated on Spain (see Daveau,1986).

Systematic archaeological survey has not been undertaken in Estremadura but it is known to be an archaeologically rich region, having been occupied since the Late Pleistocene (600/700 thousand years ago (MNAE, 1989:21). Early hominid sites have been identified and integrated into culture-historical sequences, according to artifact assemblages (see Table 1) (Chavaillon, 1982:21; Ferreira & Leitão, 1981:67-60; MNAE, 1989: 19; Raposo & Carreira, 1986). The majority of pre-Holocene sites identified in the area are associated with Solutrean and Magdalenian tool assemblages. Faunal remains excavated from Solutrean cave sites have provided some idea of available and hunted game: red deer, horse, ibex and chamois in the alpine niches (Zilhão,1988:151). Archaeologists have suggested that it was during this period that Estremadura became more densely occupied, with the use of caves, rockshelters and open air sites as short occupation camps for hunting, gathering or tool making (MNAE, 1989: 21: Zilhão, 1988:153-154). However, the lack of systematic survey precludes a clear understanding of how extensively the area was occupied before and during the Upper Paleolithic.

More intense occupation seems to have occurred in the Holocene period (after 10,000 years before present), in the Estremadura. The area is particularly rich in archaeological evidence for this period. However, any assessment of a population increase, based on the number of sites of the post-glacial period, must take into consideration the variation of the sea level. In Portugal, as along the Atlantic coast of Europe in general, the Flandrian transgression provoked a retreat of the coastal line of about 30 kilometers, since 10,000 years b.p. to the present (Arnaud, 1982:31; Daveau, 1980). Consequently, any interpretations of the settlement patterns for the Epipaleolithic and Mesolithic in the coastal fringes of Portugal, must take into consideration the possible disappearance of sites along the coast.

Table 1. Pleistocene sites in the Estremadura

Upper Paleolithic	Vale de Porcos (Aurignacian) Casal do Filipe Terra do Manuel (Gravetian) Vale Comprido (Gravetian) Vascas (Solutrean) Carneiro (Solutrean) Vale da Almoinha (Solutrean) Caldeirão (Solutrean)
Middle Paleolithic	Casal do Monte Calçada dos Mestres Foz do Enxarrique Gruta Nova da Columbeira
Lower Paleolithic	Seixosa (pre-Acheulian) Monte do Famaco (Acheulian) Cabeço da Mina (Acheulian) Milharós (Acheulian)

(adopted from M.N.A.E., 1989)

Research on the changes in the coastline in the area north of the city of Porto revealed a coastal reduction of about 20 kilometers since the last glaciation to the present (Granja, 1991; Granja & Carvalho, 1991; Rodrigues et al., 1991). Regional changes in the depth of the river valleys have been identified for the Algarve region and dated to recent years (Chester & James, 1991; Devereaux, 1981), but no systematic analysis of the variation of the coastal profile has been undertaken. In Estremadura, no research has been done on the alterations of the coast during the Holocene. However, the values should not differ significantly from the situation visible in the northern part of the country. Today, along the coast of Estremadura, many natural harbours and long beaches allow the exploitation of marine resources by a large percentage of the population. The region is the meeting ground between the Atlantic North and the Mediterranean South, where cultural, geographic and climatic elements from both areas are presently combined.

In the early postglacial period, the estuaries of the Estremadura area were densely occupied by Mesolithic populations. The term Mesolithic was introduced by Westrop, in 1872 and referred to time in between (meso) two periods - the Paleolithic and the Neolithic. At the time, some writers interpreted the apparent hiatus between Paleolithic and Neolithic as the result of the extinction of Paleolithic people and their replacement by a well-armed Neolithic race (Czarnik, 1976). When researchers started to recognize that there were some remains from intermediate periods, they identified them as 'Mesolithic'. In contemporary archaeology, the concept generally refers to a 'cultural adaptation to post-Pleistocene environments' (Czarnik, 1976:60,61). The term was maintained but the environment was introduced as a variable in its definition and was associated with specific artefact tool assemblages. However, as Butzer emphasized (1971:530), the climatic changes operating in the Holocene had already begun in the Pleistocene period, and they were not sudden. Some common variables are now accepted by archaeologists as necessary for the definition of Mesolithic. It is a period of adaptation to post-glacial environments, with occupation of estuarine and coastal areas, and exploitation of marine and estuarine resources. There was a reduction in the size of the stone tools, with the adoption of geometric forms (rectangles, triangles), presumably functionally more efficient for the hunting of the smaller game wh: . expanded throughout Europe at the time (Binford, 1968; Czarnik, 1976).

As a coastal area, Estremadura is rich in archaeological evidence for this time period, particularly in shellmiddens. The Mesolithic levels of the Estremadura sites in the Tagus valley (Fig.1) have been excavated sporadically since 1865, but the major part of the excavations were done in the 1950s and 1960s by Jean Roche. The sites were occupied for an extended period of time, approximately from 7,000 to 4,000 b.p., when Neolithic communities were already established in the same area. Mesolithic populations in Portugal based their diet on large and small mammals, fish, birds and certainly shellfish; there is no archaeological evidence for the use of plant foods (Lello,1990:56; Lentacker, 1986) in the Tagus shellmiddens and consequently no comparison with Neolithic sites can be established. The faunal remains from the Muge sites are extremely varied, with wild pig, deer, horse and auroch, different fish species and birds. Carbon isotopic analysis of human remains from "Moita do Sebastião" (Fig.1) revealed that the human diet was equally distributed between marine and terrestrial resources (Lubell & Jackes, 1988). It is from this time period that extensive burial sites have been identified and excavated. The cemeteries were located within the area of the shellmiddens. The burial pattern was singular, many of them covered with ochre, and lying in different positions (legs flexed, arms flexed or crossed). The bodies were ornamented with shells, mostly Neritina fluviatilis, perforated non-human teeth and other objects (MNAE, 1989: 24-29).

Contrasting with the Mesolithic burial patterns, during the Neolithic in Estremadura the caves and rockshelters were extensively used as collective burials. The term Neolithic was introduced by Lubbock in 1865 (Bray & Trump, 1982:171). The word derives from the Greek neo (new) and lithos (stone) referring to the appearance of a new technology, characterized by polishing of stone tools. Neolithic was also identified as the period of invention of ceramics. Culture-historical approaches were first applied to the definition of Mesolithic and Neolithic, as two different phases of Prehistory and chronologically consecutive. The distinction between these two phases was mostly based on stone technology (flaked versus polished).

In the 1930s, V.G.Childe introduced a different approach to the concept of Neolithic. The borders between Mesolithic and Neolithic were defined in economic terms (Childe, 1932; Childe, 1940:31; 1956:68-93; 1960:36-53; 1962:34-42). Together with certain technological improvements, Neolithic started to be identified as the beginning of food production (Childe,1932:195). Following a Marxist historical approach (Green,1981:7), Childe characterized the Neolithic system as productive and occurring at different times in different places around the world. A revolutionary shift between hunter-gatherer subsistence strategies and agricultural practices should therefore be identified through the differences in the archaeological record of Mesolithic and Neolithic sites. The Neolithic populations were seen as self-sufficient, producing their own food and not depending on trade for the acquisition of technology (Childe,1932:195). With the application of agriculture as the border line between Mesolithic and Neolithic, the transition was seen as a change from a 'parasitic' human existence - hunting/gathering/fishing, to an active partnership with nature - domestication of plants and animals (Childe 1960:36).

After this change in the concept of Neolithic, archaeologists generally assumed that the presence of ceramics and polished stone tools indicated the shift in subsistence strategies to the beginning of agriculture. Food production, domestication, sedentism and village settlement were inferred from that artefact assemblage.

Although some contemporary researchers still work under the theoretical assumption that the beginning of the Neolithic is a revolution in subsistence patterns accompanied by new stone and ceramic technology, the whole group of characteristics usually associated with each of the subsistence types has been dismantled by subsequent research (Dennell, 1983). Pottery, polished stone tools, substantial settlements and domesticated dogs have been identified and recovered from pre-Neolithic sites. Fired pottery is known to have existed since the Perigordian, in the Upper Paleolithic (Arnal, 1981:43). Moreover, species that are morphologically wild have been identified in Neolithic sites (Dennell, 1983: 188).

Independent of the changes in the definition of Neolithic, different models have been created for the explanation of its appearance in Europe. Diffusion was, and partially still is, the most popular explanation (Meiklejohn & Zvelebil, 1989:2). The colonization model assumes that culture change occurs by population movements and by introduction of new elements into indigenous societies. In a culture-historical approach, the indicators of change are then easily provided: the diverse artifact assemblages are associated with different ethnic groups and different peoples. Consequently, similarities in material remains are interpreted as evidence of physical contact between different groups and, if necessary, of conquest and colonization. V.G. Childe's model assumed that agriculture in the European context had been created in the Near East (The Fertile Crescent) and had then expanded to the West by colonizers, advancing through Europe, searching for new areas for cultivation. This model has prevailed to the present among many archaeologists and it still tends to exercise a powerful influence on explanations of the Mesolithic-Neolithic interface (Dennel, 1983:155). A recent model supporting diffusionism - the 'wave of advance model' - was created by A.L.Ammerman & L.L.Cavalli-Sforza (1971,1973,1984) and developed by Sokal (1991) who argue that farming came into Europe not through the acquisition of the necessary plant and animal species by the pre-existing Mesolithic populations, but rather through successive movements, over many generations, of peasant farmers from the Near East; this displacement is even calculated in terms of rates of advance (Ammerman & Cavalli-Sforza, 1971) in the wave model. The assumptions behind this model are that the Mesolithic groups were mobile, had low population densities and were egalitarian. It also assumes unpredictable food supplies, placing them at risk from dietary stresses; declining food resources increased stress and led to the adoption of farming. In contrast, Neolithic groups were seen as more sedentary, with far higher population densities and more stratified social organization due to the increase of productivity, predictability and quality of the food supply. The wealth of the farming economic system was seen as responsible for population movements, in search for unfarmed areas (see review in Meiklejohn & Zvelebil, 1989).

The alternative to the colonization model was developed by several researchers, within a wide range of theoretical approaches. Bosch-Gimpera (1944,1969,1975), attempting to justify the antiquity of the Iberian nations, searched for a local development of the Neolithic, basing his argument on the distribution of burials in Europe. Guilaine and Ferreira, while not denying some foreign influences (ideas circulated more easily than men), supported a local development hypothesis and maintained that the native Mesolithic populations, in adapting to particular ecological conditions, gradually adopted Neolithic practices (Guilaine,1979:22). The supporters of this theory emphasized that, archaeologically, there is no perceptible cultural break between the final Epipaleolithic industries and the first

Neolithic industries (Guilaine, 1979:22). The continuity between the Mesolithic and Neolithic lithic industries is easy to support, since the reduced size of the tools is a common characteristic of both periods. Ceramics have only recently been analyzed with the purpose of identifying regional differences and continuities. The origin of ceramic technology (creation of pottery containers fired after modelling), has in recent publications been located in the Eastern Mediterranean (Arnal, 1981:44). Guilaine (1979:25) emphasized that even if rapid diffusion of the technique seems to be apparent from the archaeological data, it must be admitted that the earliest pottery in the Western Mediterranean is very different from its hypothetical origins, with marked regional variation. As Renfrew noted, for the Western Mediterranean, the wave of advance model is hard to support by the archaeological evidence:

> In the west Mediterranean, however, it is much easier to question the wave of advance model and to stress the resilience of the pre-existing mesolithic populations, and the very long time which the process of 'acculturation' - i.e., the adoption of a farming economy -took. Indeed, most of the best qualified recent writers stress these features, and prefer to think in terms of largely indigenous processes (Renfrew,1987:267).

Dennell (1986:189) suggested that the processes that led to the use of cereals, legumes and sheep (as well as pottery) over much of prehistoric Europe are probably better described as a 'wave of assimilation' than as one of advance. The early Neolithic, as it is traditionally identified over most of Europe, probably embodies yet another instance of the adaptability of hunter-gatherers to changing opportunities and circumstances.

In Portugal, the introduction of the Neolithic has been defined strictly on typological grounds. Because of the absence of paleobotanical and zooarchaeological data that would confirm the presence of domesticated species, Portuguese archaeologists have identified the beginning of the Neolithic by the presence of Cardial impressed ceramics; that is, pottery decorated with Cardium shells (Fig. 3) (Arnaud, 1982; Gonçalves, 1978; Silva & Soares, 1982). However, as Barnett emphasizes:

> (...) the state of knowledge on the Portuguese Early Neolithic is best characterized by a lack of it. Early Neolithic material has in the past been limited either to Museum collections from early excavations or isolated finds, both without adequate provenience information. (Barnett,198-:2)

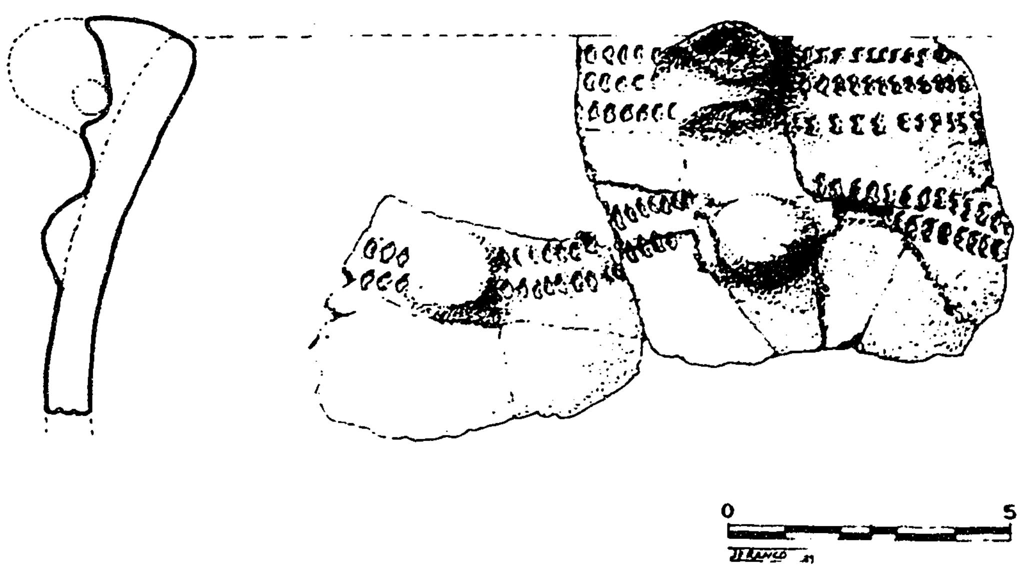
And the situation extends to Iberian archaeology in general,

> The study of Neolithic cultures in Iberia has traditionally been based upon a combination of unstratified material and unpublished excavations. Recent work has done much to ratify this state of affairs. (Chapman,1986:151)

For a long time, archaeologists working in Portugal considered the presence of ceramics as the only determining indicator of Neolithic sites. Whenever pottery decorated with Cardium shells was identified in a site, the other components of the economic system (domestication and agriculture) were then inferred as present.

Recent research in different areas of the country has raised various questions about the mechanisms that led to the introduction of agriculture and about the real contrasts between Mesolithic and Neolithic occupations. Data have been integrated into different models,

Fig. 3. Neolithic potsherd with 'Cardial' ware from Gruta do Caldeirão



with emphasis on the role of local populations in the development of agriculture (Arnaud, 1982; MNAE, 1989:31; Zilhão, 1990). The hypothesis of the existence of a mixed economy dominating a long transitional period has been proposed:

> Nesta fase antiga do Neolítico, as comunidades humanas teriam ainda uma economia mista, em que a par de uma agricultura incipiente e da pastorícia, predominavam as actividades de recolecção, caça e pesca - o que explica o carácter sazonal de alguns destes *habitats*, e encontra reflexo no tipo de equipamento tecnológico existente: ao lado de intrumentos de pedra polida e das chamadas cerâmicas cardiais, regista-se uma importante indústria lítica de carácter microlaminar e geométrico, de tradição mesolítica (M.N.A.E.,1989).

However, archaeological evidence for such economic changes is still missing. Lubell and coworkers remark that the presence of human skeletal pathological lesions traditionally identified as agriculturally derived, and the possible presence of domestic dog at Samouqueira, a site identified as Mesolithic in the Southern coast of Portugal (Fig. 1) and dated at 5060±130 b.p. from mammal bone collagen (Lubell & Jackes, 1988), "... may raise the crucial issue of how one defines Mesolithic as opposed to Neolithic" (Lubell & Jackes,1984:10). Carbon isotopic analysis of Moita do Sebastião, a Mesolithic site in the Tagus valley (Fig.1), shows that the human diet was equally divided between marine and terrestrial foods. Mortality in this population was extremely low, due in part to the success of their subsistence regime. Rather than a dramatic shift to Neolithic, all indications are of continuity and gradual ransition (Lubell et al., 1988). Pottery recovered from several sites seems to support this hypothesis. Guilaine's date for the appearance of cardial pottery was established at 7,000 b.p. (Guilaine, 1979). Moita do Sebastião (Fig. 1) has no pottery and has been attributed the same age. Cabeço da Amoreira and Cabeço da Arruda (Fig.1) were dated slightly later but had small amounts of pottery. Medo Tojeiro, on the Atlantic coast of Alentejo, was dated at 6820± 140 b.p and 5420±160 b.p., with pottery and ground stone and microliths and with the presence of marine shells which were probably food sources (Lubell, 1984:9).

> If we accept the Medo Tojeiro midden as Neolithic, we support the hypothesis that the Neolithic came in as a slow introduction of new elements into a basically strong and continuous Mesolithic economy (Lubell & Jackes, 1988:17-18).

The construction of models for the introduction of Neolithic in Portugal is very recent. J.M.Arnaud (1982) has developed two alternative scenarios for this transitional period, to be tested in the Sado area, in the south of the province (Fig.1), where both Mesolithic and Neolithic sites are present. Both his models hypothesize that agriculture was introduced from the coast, either through the movement of groups from the coastal to the interior areas, or through the acquisition of agricultural techniques, by the populations in the interior, through contact with coastal sailors. Archaeologists working on the Neolithic sites in Sines (an area close to the Sado Mesolithic shellmiddens) propose that these sites represent a centre of local development of the Neolithic, with impressed ceramics, but not of the Cardial type (Silva & Soares,1987; Soares e Silva, 1979). More recently, Zilhão (n/d) has propcsed a local introduction of the Neolithic in northern Estremadura, with a hypothetical expansion from north to south, which would explain the presence of a different type of ceramic in the Sines sites.

While different models for the introduction of the Neolithic in Estremadura have been hypothesized, archaeological research has yet to prove the economic components of the transition from Mesolithic to Neolithic. So far, the dominant definition for the transition is still the presence or absence of ceramic in the archaeological assemblages. The rich alluvial deposits of Estremadura, where the early agriculturalists probably cultivated the crops, have been the prime choice for farmers until the present, resulting in a lack of evidence for early cereal agriculture. As Zilhão (n/d) emphasizes, the Neolithic people buried at Caldeirão must have cultivated the rich alluvial soils of the Nabão river, south of the place where they buried their dead and where they hunted wild boar and pastured sheep during spring/summer.

Identification of Neolithic habitation sites is difficult because of their probable destruction over thousand of years of consecutive cultivation. Analysis of human bones, and specifically dental wear patterns and pathologies can be used as an effective indication of the dietary changes operated during the transition Mesolithic-Neolithic. Stable isotopic analysis of human collagen from Mesolithic and Neolithic sites in the area indicates a dietary difference between populations of both periods (Lubell & Jackes, 1992); while the food resources seem to have been maintained in Mesolithic and Neolithic sites, there is a homogeneity of diet in the Neolithic and preference for terrestrial food items (Lubell & Jackes, 1992).

Several models have been proposed for the changes operating during the Neolithic in Portugal. The majority of these are based on the analysis of artefact assemblages. Linear chronological approaches have been presented for the changes occurring over time within Neolithic communities. J.Guilaine and O.V.Ferreira divide the Portuguese Neolithic into a chronological sequence of Early, Middle and Late Neolithic. The Early Neolithic is identified by the introduction of cardial pottery. The second period is characterized by the presence of impressed and incised pottery and the latest stage - Epicardial - is characterized by a smooth megalithic type of ceramic (Guilaine & Ferreira,1970:321). A different explanation for the presence of different types of pottery was presented by Bosch-Gimpera, in the 1960s. Supporter of the indigenous development of the Neolithic, Bosch-Gimpera viewed two different 'cultures' as responsible for the two types of ceramic: the 'Cave Culture', with impressed pottery, was the predecessor of the 'Campaniforme' pottery (Bosch-Gimpera, 1966). The 'Portuguese Megalithic Culture', with smooth pottery, is seen as contemporary with the Campaniforme.

The latest debates in Portuguese Neolithic archaeology have been monopolized by these two different views - linear sequence for the different decoration types of Neolithic ceramic versus presence of two contemporary 'cultures' responsible for each of those manifestations (e.g. Ferreira & Leitão, 1981; Guilaine & Ferreira, 1970). They both support an indigenous responsibility for the changes in ceramic decoration, but they do not integrate an economic analysis of those changes as part of the models. The recent excavations in "Gruta do

Caldeirão" (Tomar), support Guilaine's theory that the Cardial ceramic precedes impressed and incised pottery (Zilhão, 1991). The appearance of undecorated wares was identified by Guilaine as Middle Neolithic in the Western Mediterranean and dated at approximately 6,000-5,800 b.p. (Guilaine, 1979). In Portugal, these wares are associated with the first megalithic tombs (Zilhão, 1991). According to Guilaine & Ferreira (1970) even the "Campaniforme" ceramic was developed by indigenous groups:

> "S'il ne semble en fait plus possible d'envisager une paternité directe du Cardial pour le Campaniforme, que sépare un fossé de plus de deux millénaires, peut-être pourrait-on évoquer l'enracinement prolongé de certains styles céramiques autochtones à décor incisé comme pourrant prétendre jouer un róle dans cette génèse". (Guilaine & Ferreira,1970:321)

Within the chronological type of approach to the changes occuring in the Neolithic, other models have been proposed. Serrão presents three periods to characterize the Neolithic stratigraphic sequence: Neolithic I, beginning at around 7,000 b.p.., with Cardial ceramic, an indigenous Neolithic. Neolithic II, after 6,400 b.p., with two different phases, and Neolithic III, between 5,800 and 5,000 b.p., with expansion towards the coastal areas of the 'interior megalithic culture', schist plaques, the indigenous populations suffer the influence of 'Mediterranean elements'. (Serrão,1978:149-150).

The site "Grutas Artificiais do Tojal de Vila Chã", which is the subject of the present study, has been classified as Neolithic-Chalcolithic in Portuguese archaeological context and has been cited by several scholars as part of the 'megalithic' complex (e.g. Ferreira & Leitão, 1982; Savory, 1974). The term Chalcolithic refers to a period of Prehistory characterized by the presence of metal objects in archaeological sites - gold and predominantly copper. The concept itself is strictly associated with artifact technology. It was first defined as the period in which the stone tools were replaced or enriched by the presence of metal tools, primarily copper. Presently, the role of copper in the early sites is not clear. It was probably being used preferentially for trade or decoration purposes , rather than for the production of tools. Also, as Serrão emphasizes, the appearance of copper in sites is not enough evidence to indicate a knowledge of copper technology (Serrão,1978:160).

The economic differences between Neolithic and Chalcolithic have not been established, and there is no archaeological data that suggest a significant change between the two periods. Archaeologists have associated the presence of copper in prehistoric sites with developed defense structures and large village settlements (e.g. Pinto & Parreira, 1978:135; Cardoso, 1989:139,140). Models for the introduction of copper metallurgy in Portugal follow the same two major patterns as those created for the introduction of agriculture in the Western Mediterranean - external influences versus local development. Different chronological subdivisio s for the transition between Neolithic- Chalcolithic, have been created. The term Eneolithic is used as a synonym for Chalcolithic in many Iberian and French publications; according to this terminology, the term Neoeneolithic is used for the period of transition between Neolithic and Eneolithic. These subdivisions are created as chronological explanations for diversity between different archaeological sites; tool assemblages that do not totally coincide with a given chronological stage, are assigned a transitional period, and the periods are still defined in terms of material culture.

In Portugal, beginning in the 1970s, archaeologists started analyzing Chalcolithic sites in economic terms (Serrão,1978:161), and began relating the appearance of spatially more complex sites to the changes occuring within the Neolithic communities. Some Marxist interpretations of the Chalcolithic as a development of the Neolithic were published (e.g. V.Pinto & R.Parreira, 1973). These models were predominantly a reply to migrationist approaches. Large fortified sites, such as Castro do Zambujal were interpreted as the result of social stratification and not as 'colonies':

> "Pode supor-se que o aparecimento de novas formas de produção tenha exigido novas relações sociais e novas formas de autoridade que não cabiam já dentro do quadro exíguo das relações de parentesco. Por outro lado, à medida que a organização económica e social se complexifica, assiste-se a necessidades cada vez maiores de afirmação da comunidade como unidade social e de defesa perante os perigos que, do exterior, ameaçam a sua coesão". (Pinto & Parreira, 1978:142)

However, these models were constructed with no support from the archaeological data. According to these authors, there were commercial contacts with the east, but these were simply contacts; therefore, the so called 'feitorias' (trading stations) outlined by Blance (1961) were not to be interpreted as such. They are only the result of local developments (Pinto & Parreira, 1973). This model, identifying the internal change of the Neolithic communities as the major factor contributing to the emergence of fortified villages, has inspired more recent research:

> After the Late Neolithic and Early Chalcolithic, as a consequence of important economic and social changes populations started building habitation structures in the high areas of Estremadura (Zilhão,1984:33).
>
> A new use of the animals lead to the so called "revolution of the secondary products" and to the contact between different cultures, with the development of groups of specialized workers, progressively separating from agricultural activities (M.N.A.E.,1989:41).

Although generally accepted by archaeologists, the current characterization of Chalcolithic in Portugal has not been ratified by archaeological data. Chapman emphasizes that the 'low surface survey intensity' is largely responsible for the state of knowledge of the Chalcolithic in Iberia (1986:164). The beginning of copper metallurgy is less well dated in Iberia than in southeast Europe or Italy (Chapman,1986:158). Santos remarks that the reduced research on Portuguese Chalcolithic seems to be the result of difficult access to the literature, and of scarce attempts of a global interpretation, together with old methods of archaeological research combined with new research questions (Santos,1987:1). The predominant research on the Portuguese Chalcolithic has been done by the supporters of the colonization model (Santos, 1987). No work on settlement patterns has been developed, with the exception of Santos' recent work that has yet to be published. His preliminary conclusions indicate that accessibility and defense strategies are not supported by the data as important factors in the definition of settlement distribution (Santos, 1987). The South seems to indicate more variability in resource exploitation than the area in the North of the Tagus (Santos,1987:7). V. Oliveira Jorge (1986) argues that proximity to the rivers, and an elevation of 550-850 meters could be identified as patterns of settlement for the Northern Chalcolithic sites. However, from four sites excavated in the area of Chaves (northeast area of the country), only one seems to present defensive structures. The radiocarbon dates for these sites range between 4,500 and 3,500 b.p., which is more recent than the Chalcolithic in the area of Estremadura (Jorge, 1986). For the latter, Arnaud, Oliveira & Jorge (1971:102) presented a distribution map for the habitation sites which seem to be located in areas near tributary rivers, but not along the Tagus.

The question of whether progressive change of the local communities under external pressures or whether a cultural break with the previous civilizations gave rise to the appearance of fortified settlements (Guilaine & Ferreira;1970) has to be answered by extensive archaeological research in the area. Although the arguments have centred on questions such as changes in pottery types and appearance of copper metallurgy, there seems to be no replacement of stone tools by copper tools during the so called "Chalcolithic" period, and lithic technology seems to have improved considerably (Serrão,1978:160).

There is a lack of definition of the differences between Neolithic and Chalcolithic. In an economic context, they appear to be very similar. However, further research on the introduction and development of the Neolithic in the Iberian Peninsula is needed before the changes that accompanied the introduction of copper can be identified.

Burial sites in the context of Neolithic/Chalcolithic settlements

Although burial sites of the Western Mediterranean Neolithic have been the object of extensive debate in archaeological literature, their excavation and interpretation have been separated from research on socio-economic topics, and the study of burial distribution has been divorced from the more general debate over settlement patterns of the Neolithic communities, and their movement and change over time. This situation is due partly to the fact that the Neolithic/ Chalcolithic period was characterized predominantly by the use of collective burials which were for a long time categorized by archaeologists as 'megaliths'. Megaliths were the focus of interest since the Romantic era and consequently their excavation over time greatly diminished the potential information they could provide. There are thousands of books and articles written on the 'megalithic phenomenon', some of which reach the most extreme research and interpretative orientations.

The concept of 'megalith' is a complex category created by 19th century archaeologists. It includes any construction built with large stones. Megalithic structures include menhirs and alignments, stone circles, certain henge monuments and many kinds of chamber tombs. The term 'megalithic tomb' is often used loosely for any above ground chamber tomb, whether built of large or small stones (Bray & Trump, 1982:154). The term has been too broadly used, so that differences between the tombs are ignored, and general common features are accepted as identifiable variables of a 'megalith'. Consequently, the time span attributed to the 'megalithic phenomenon' is extremely wide; collective burials (not megalithic) have been dated at 9,000 b.p. (Whittle, 1985:33). The range of dates obtained for the Iberian megaliths suggests their generalized presence from 5500 b.p. to 4,500 b.p., accompanying the presence of Neolithic and Chalcolithic artefacts (Pellicer, 1986).

Different interpretations of the 'megalithic phenomenon' have been attempted from the last century to the present. Evolutionists categorized the different types of megalithic construction into different stages which represented chronological sequences. In the 20th century, 'orientalist' theories identified these burials as local constructions built by the colonizers coming west, from the eastern Mediterranean, in search of copper (Childe, 1932). In the 1930s , Fleure & Peake interpreted the megaliths from Iberia as degenerative examples of the oriental models - the 'tholoi' and artificial caves - to the passage graves and simple dolmens (see Jorge, 1983:211). Daniel supported the orientalist view in his first publications (Daniel, 1941; 1958), until radiocarbon techniques provided earlier dates for the burial structures in Iberia than for their parallels in the eastern Mediterranean (Daniel, 1971). Although the radiocarbon revolution has demonstrated the antiquity of the megalithic tombs in Western Europe, some authors have recently published orientalist views on the issue. In 1969, Brabant postulated the introduction of copper into Southwestern Europe by the 'megalithic religion' (Brabant,1969:430).

More recently, the megaliths have been reinterpreted by both processualist and post-processualist archaeologists. A focus on diversity seems to be dominant over the homogenizing approach in the analysis of megaliths. British archaeologists have developed different models for the expansion of the 'megalithic phenomenon'. Chapman and colleagues, working with Iberian materials (Chapman,1986:151) proposed a spatial analysis of the distribution of megaliths and laid emphasis on their diversity, rather than on their homogeneity (Chapman,1981). Renfrew (1976) assigned a social role to the megaliths as territorial markers, because of greater population stress as a result of the expansion of agriculture right to the ocean and the confrontation with hunter-gatherers communities. More recently, Shanks & Tiley (1982) concentrated on the question of ideology as a dynamic variable in the determination of burial practices rather than limiting the interpretation of funerary structures to a direct reflection of social relations. Hodder (1984) has interpreted the megaliths in a symbolic way and has attributed to them the image of the household, supposedly reproduced in the burial designs. The structure of the burials is identified as a reflection of the relationship between men and women, in the control of the offspring through lineage descent groups (Hodder,1984:62).

In Portuguese archaeology, megaliths have been associated with the Neolithic/Chalcolithic (Arnaud, 1978; Ferreira & Leitão, 1982; Savory, 1968). This association is based on comparison of artefact assemblages from Neolithic habitation and burial sites and on some dates randomly obtained through radiocarbon and thermoluminescence techniques (see Whittle & Arnaud, 1975). The physical anthropological aspect of the burials has been minimized, when not totally ignored.

In Estremadura, Neolithic populations extensively used a collective type of interment, in natural caves, in artificial caves, in dolmens and in 'tholoi'. Artificial caves are rounded tombs excavated in limestone outcrops, as it is the case of Grutas Artificiais do Tojal de Vila Chã (Carenque), Casal do Pardo (Palmela) and S. Pedro do Estoril (Cascais) (Fig.1). Dolmens are very diverse burials in form, built with a series of vertical flagstones that are covered with one or several horizontal stones. Other burials, the 'tholoi', have been associated with the Neolithic and Chalcolithic and have been included in the larger classification of 'megaliths'. The three general types of burials (artificial caves, dolmens and tholoi) have been included in the megalithic category, independently of their diversity.

If the number of habitation sites excavated for the Neolithic period in Estremadura is not abundant, a different situation characterizes the study of burials of the same period. Collective interment sites associated with Neolithic artefact assemblages have been extensively excavated throughout the 19th and 20th centuries. However, the excavation of these sites was rarely included in a research project and the procedures used in their excavation are in many cases unknown. Megaliths were the object of interest of a Romantic view of archaeology and they were excavated in most cases by the supporters of the diffusionist models, in search of *fossiles-directeurs* that would satisfy the idea of colonization of the Western Europe by Near Eastern populations. The integration of the megalithic burials into a wider discussion of the introduction of Neolithic in Portugal, and more specifically in Estremadura, is very recent (e.g. Arnaud, 1978; 1990; Jorge, 1978; Zilhão,1984).

The introduction of these burials in the Estremadura has been interpreted in different ways in more recent archaeological research. Serrão hypothesizes that it is probable that the beginning of the megalithic phenomenon started before 6,500 b.p. (Serrão,1978:158), that megalith builders must have started building the burials very early, and that they were later used by subsequent occupants. In this model, the first builders of megalithic tombs are identified as the same populations who used the natural and artificial caves as burials (Serrão,1978:159). It was for a long time assumed that the megaliths expanded from the interior areas of Portugal to the Estremadura. According to Zilhão (1984) this hypothesis cannot be supported by the data; the similarity between the material cultures in both areas can be explained in two different ways: through acculturation of the interior Epipalaeolithic population - by the Neolithic communities in the coastal area looking for raw materials such as amphibolite and schist, which is supported by archaeological data; or by colonization of the densely forested and inhabited interior areas by groups of coastal populations. Actually, the date obtained for Lapa do Fumo (3090± 160 B.C.) , a Neolithic site on the coast of Estremadura, is (after calibration) older than those obtained for the Alentejo dolmens. In Lapa do Fumo there are already schist plaques, which are traditionally associated with megalithic tombs (Zilhão,1984:35). The presence of cardial ceramics in Gruta do Escoural (Fig.1) demonstrates the occupation of the area by a Neolithic population before the 'dolmenic' settlement. This can be taken as evidence of the influence that the coastal populations had on the early megalithic period (Zilhão,1984).

The [illegible] of association of megalithic burials with habitation sites in other areas of the country is the product of the lack of systematic archaeological survey and of the intensity of agricultural activity. The fact that megaliths are visible, and occupy a relatively small area, might have been an influential factor in their preservation, while their visibility might have resulted in their identification and consequent excavation by archaeologists over the 19th and 20th centuries. The study of the human remains recovered in these burial sites is practically nonexistent (cf. Chapter 3).

<u>Grutas Artificiais do Tojal de Vila Chã</u> is a burial site composed of three artificial caves excavated on the limestone outcrops in the Estremadura. The site is located in the surroundings of Lisbon (Fig.1) and has been dated to the Neolithic and Chalcolithic periods. The

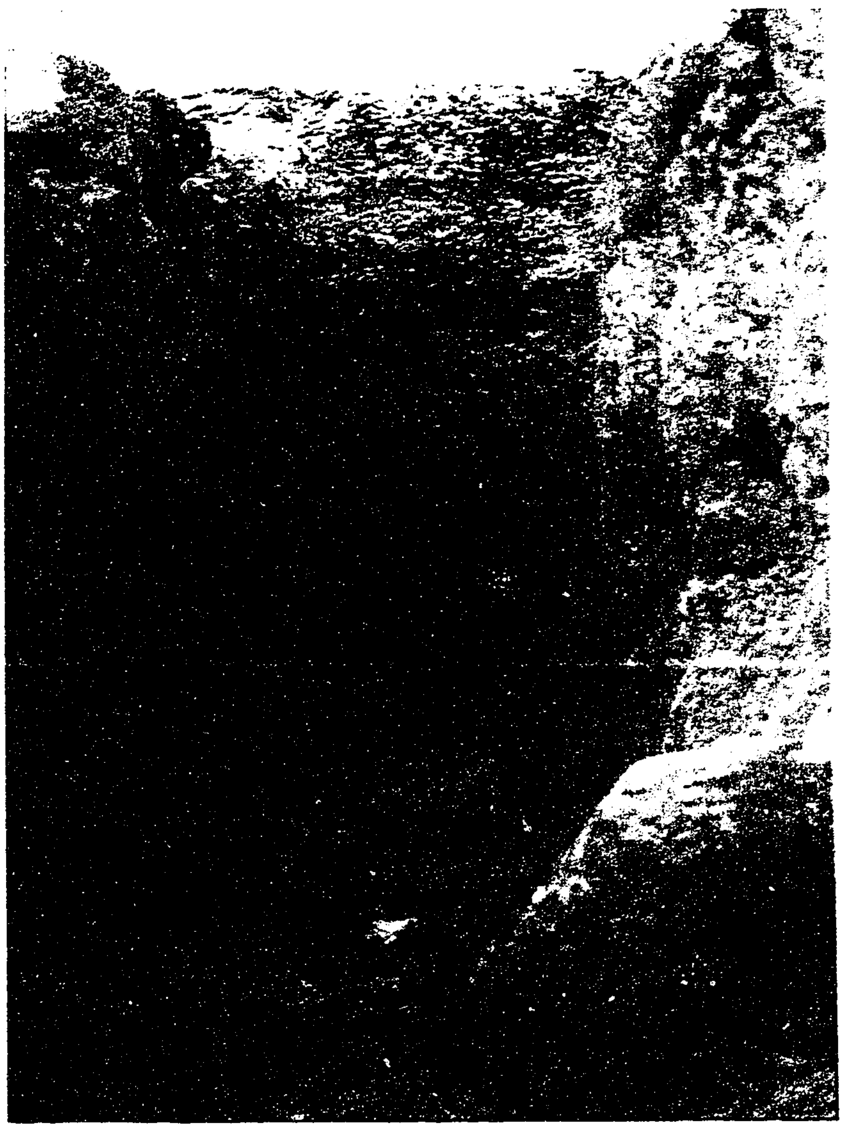
artificial caves were excavated in the limestone beds and were used as tombs (Plates 1,2,3). They are located at about 200 meters above sea level, close to the Ribeira of Carenque (creek), circa 1,500 meters east of Carenque, in the county (freguesia) of Belas. The site is situated approximately 400 meters from the windmills of Tojal de Vila Chã and is the property of E.P.A.L., the company that supplies water for the area of greater Lisbon. The three tombs are located on the summit of a small hill, with a N-S long axis bounded on the west by the Jamor river, on the east by the Carenque creek, between the towns of Pendão (south), Carenque (east), Belas (northwest) and Casal Pelão (northeast) (Arnaud & Gamito, 1972:123).

The site is composed of three tombs with similar architecture; a narrow passage leads to a circular chamber of approximately 1.5 metres in diameter. Two of the burials (Gruta 2 and 3) open towards the southeast, while Gruta 1 has its entrance facing northeast, and a passage approximately 1.3 metres higher than the other two tombs (Heleno, 1933).

The region of Carenque is rich in archaeological sites, dating from 22,000 to 4,000 years ago. Upper Paleolithic stone tools have been recovered in the area, including flint arrow heads in Serra das Éguas. References to the Grutas Artificiais do Tojal de Vila Chã are scarce in the literature. Georg and Vera Leisner (1965:80), in the inventory of megalithic burials in the Estremadura, describe the site as part of the megalithic complex. Some of the archaeological materials recovered from the site have been mentioned by several authors but only recently have they been systematically studied by Dr. Victor Gonçalves (Departamento de Clássicas, Faculdade de Letras de Lisboa). However, the results of these analyses have yet to be finalized and published. Arnaud and Gamito (1972) mentioned the presence of schist-plaques and limestone 'idols' in the burials, artefacts that have been identified as *fossiles-directeurs* for the Chalcolithic in the Iberia. Bubner (1986:93) emphasized the architectural similarity between this site and Grutas Artificiais de Casal do Pardo (Palmela) and Grutas Artificiais de Alapraia (Fig. 1), all classified as Late Neolithic/ Early Chalcolithic, based on the typology of the burial goods (Bubner,1986:94).

Plate 1

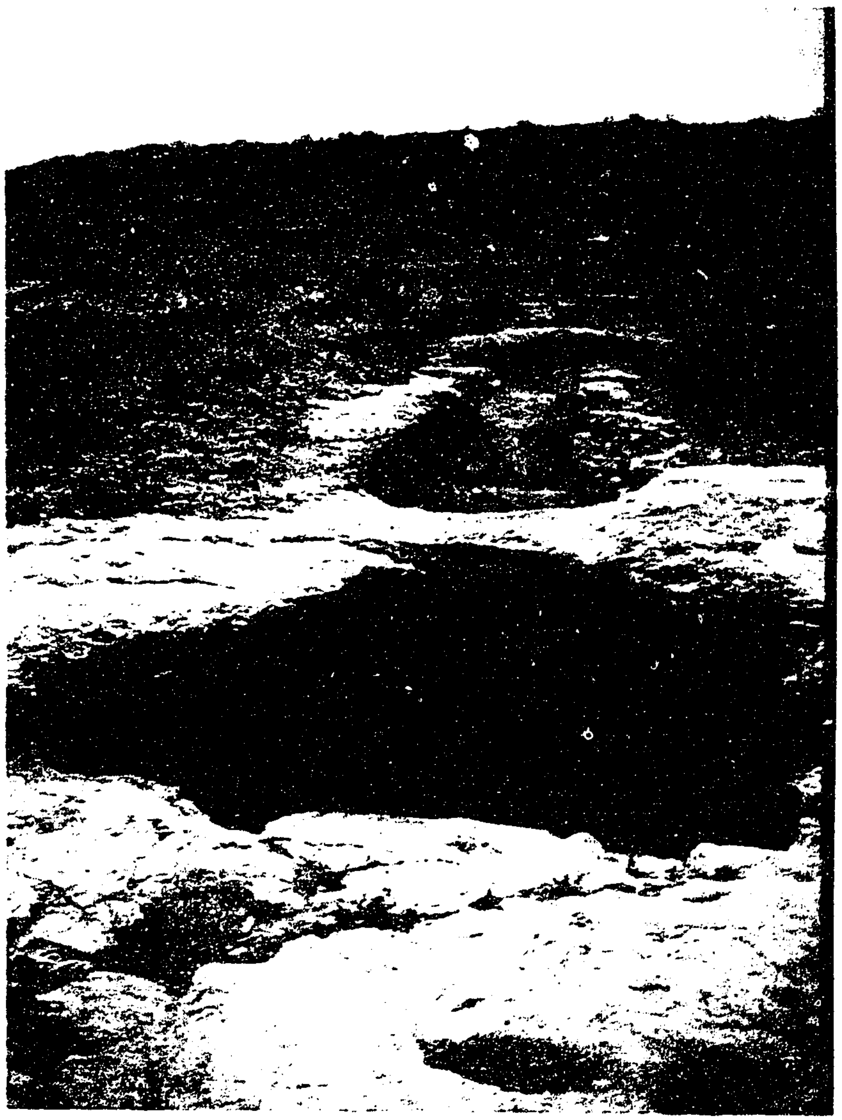
Tojal de Vila Chã. Gruta 1.



The corridor is about 1.5 metres high and the entrance of the chamber faces northeast.

Plate 2

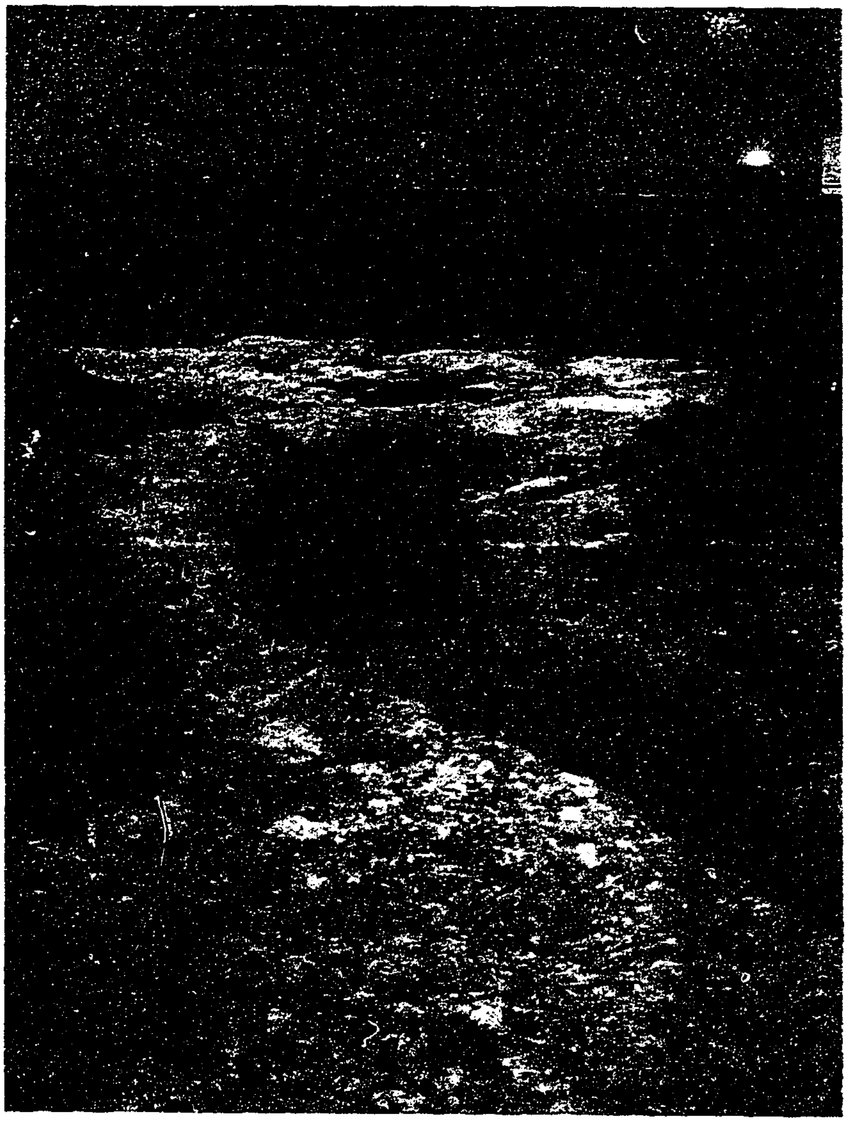
Tojal de Vila Chã. Gruta 2.



The corridor is about 0.8 metres at its highest point and the entrance of the chamber faces southwest.

Plate 3

Tojal de Vila Chã. Gruta 3.



The corridor is about 0.8 metres at its highest point and the entrance of the chamber faces southwest.

Furthermore, Bubner emphasized that this particular form of burial is only found in south Estremadura. He associated the site with the Almerian and Los Millares 'culture' (Bubner,1986:94), interpreted as an intrusion from the Near East in the models that view the introduction of Neolithic in western Europe as the result of a colonization movement.

Arnaud and Gamito (1972) reported the presence of a Neolithic and Early Copper Age site, known as Serra das Baútas, on the hill-fort opposite Grutas Artificiais do Tojal de Vila Chã. At the time of discovery, the site had already been destroyed by a quarry. However, a tentative date of approximately 5,500 to 4,000 b.p.was established, on the basis of artifacts collected still in situ. A thermoluminescence date of 3930± 340 B.C. was obtained from ceramic fragments recovered in Gruta #2 (Whittle & Arnaud, 1975:8).

Overall, the Neolithic and Chalcolithic periods in Portugal are associated with the presence of megalithic burials. The current models for the expansion of the Neolithic habitation sites into sedentary villages where defense apparently became an important aspect of the settlement strategy, were recently synthesized by Cardoso (1989). The first hypothesis interprets the Chalcolithic fortified villages as constructions built by populations coming from the Near East. This model is based on the analysis of architectural similarities and comparison of artefacts. The second hypothesis interprets the presence of copper in Iberia as the result of commercial contacts with populations coming from the eastern Mediterranean. The presence of 'foreigners' looking for raw materials provoked the changes within the native Neolithic societies, namely because of the increased demand for copper and subsequent accumulation of wealth by the native populations. The third hypothesis, more recently created, views the development of the Chalcolithic large settlements as the result of local economic processes. The presence of copper objects is interpreted as the result of trade contacts that merely functioned as a catalyst in the appearance of new economic and social relations that were already developing within the local Neolithic communities (Cardoso, 1989:140). This third model has lately been adopted by archaeologists working in Portugal, since the archaeological data in recently excavated sites do not support the idea of rupture between populations nor the abrupt change of artifact assemblages.

The limited information on the excavation of Tojal de Vila Chã, the characteristics of the artefacts recovered from the site, and the date obtained for Gruta 2 support the idea of continuity between Neolithic and Chalcolithic. In fact, although copper objects and other artifacts traditionally identified as Chalcolithic are present in the burials, some of the ceramic material is identified as Middle Neolithic, according to the chronology based on pottery morphology. More so, the date obtained for the potsherds analyzed by thermoluminescence falls in the Middle Neolithic time span and is clearly earlier than the dates obtained for the large Chalcolithic settlements.

The diachronical homogeneity of prehistoric populations within a given geographical area can be confirmed through the analysis of human skeletal remains. As a site of presumably long use, Tojal de Vila Chã should present similar characteristics to the known Neolithic populations of the Estremadura, buried in natural caves. If the people represented in Tojal de Vila Chã adopted the same or similar subsistence strategies as those represented in the natural caves of the Early and Middle Neolithic, their teeth are expected to reflect the same dental attritional patterns and the same dental lesions. When compared with Mesolithic and Neolithic dentitions from sites in central coastal Portugal, the sample from Tojal de Vila Chã should illustrate the similarities of the Neolithic and Chalcolithic economic strategies, and their contrast with an economy based on almost exclusively marine and estuarine resources. If the idea of a population movement from the Near East is to be rejected, the wear patterns and pathologies visible in Tojal de Vila Chã should demonstrate different patterns from those identified by anthropologists in Neolithic Eastern Mediterranean skeletons.

Summary

Funerary practices in the Neolithic and Chalcolithic of Estremadura are generally characterized by the existence of collective burials in natural or artificially excavated caves, in dolmens, or in 'tholoi'. With the exception of the natural caves, these burial sites have been classified as part of the megalithic phenomenon. Their excavation and analysis have been dominated by the observation of artifact assemblages and thus incorporated in different chronological models for the introduction and development of the Neolithic in Portugal and the western Mediterranean. With a few exceptions, Neolithic burials have not been integrated into the more general discussion of economic changes and settlement patterns for this time period. The knowledge of the subsistence patterns adopted by the Neolithic populations in Portugal, and specifically in Estremadura, is very limited. In the absence of systematic palaeobotanical and zooarchaeological research, the interpretations of the introduction and development of agriculture in the area are based predominantly on the analysis of artifact assemblages. The site of Tojal de Vila Chã, which is the object of analysis in the present study, has equally been incorporated in the general classification of megaliths. It is an artificially excavated burial, with three associated tombs. Its classification as a Neolithic/Chalcolithic site is based on the presence of artifacts associated with these archaeological periods and on the basis of one date obtained by thermoluminescence analysis of pottery fragments, which dated the site at 3930± 340 B.C. (Whittle & Arnaud, 1979).

Because of the lack of information on the distribution of Neolithic/Chalcolithic habitation sites in the Estremadura, archaeozoology and paleobotany have provided little information on the availability and use of food sources in the area at the time. Consequently, the abundance of burial sites and human remains constitutes an important source of information on the dietary patterns of Neolithic/Chalcolithic populations. The human teeth recovered in this site allow the comparison of wear patterns and incidence of dental pathological lesions with those observed in samples from Mesolithic and Neolithic context of the same and different geographical areas.

CHAPTER THREE

REVIEW OF PREVIOUS STUDIES ON DENTAL PATHOLOGIES AND ATTRITIONAL STATUS OF TEETH FROM MESOLITHIC AND NEOLITHIC POPULATIONS IN ESTREMADURA

Archaeological human remains from Estremadura have been studied by physical anthropologists since the introduction of the discipline in Portugal, in the late 19th century. The interest in the Portuguese archaeological collections rose mostly because of the involvement of researchers in the study of the Mesolithic shellmiddens of the Tagus valley (see Fig.1). This chapter presents a summary of the work developed by physical anthropologists on human remains from Mesolithic and Neolithic sites in Estremadura, with special emphasis on research done on human teeth, from the nineteenth century to the present.

In Portugal, the development of physical anthropology follows the general trend of its history in other countries in Europe. Introducing the discipline in the country in the late nineteenth century, physical anthropologists developed the first research projects concentrating around the foundation of anthropology institutes in Coimbra and Porto, and on the assemblage of research collections. The introduction of the fascist regime in 1928 led the discipline to accompany the general movement of European physical anthropology, concentrating then on the search for the origins of the Portuguese 'race'. The pursuit of the roots of national identity extended to the prehistoric period and a continuity between the Neolithic populations of western Iberia and the modern Portuguese people was sought in anthropological research. The anthropologists of the time were part of the ruling élite: an example was Professor Mendes Corrêa, who organized the Congrès International d'Anthropologie et Archéologie Préhistorique in Oporto, in 1930. He was a deputy of the National Assembly, member of the Corporative Chamber and mayor of Oporto between 1936 and 1956 (Hodder, 1991:3).

It was not until 1974 that the corporative state was overthrown and archaeological/anthropological research was revolutionized. With the development of the National Archaeological Service, and the collaboration with international researchers, Portuguese archaeologists integrated, for the first time, other disciplines in their research methods that had long been accessory to archaeology in North America. Palynology, analysis of faunal remains, and sedimentology were then introduced as aids in the explanation of archaeological questions. However, to date, these disciplines have not been incorporated in academic programs.

Physical anthropology was no exception to this general trend, and it is not taught in two of the major universities in the country, Lisbon and Oporto. The exception is the University of Coimbra, where the discipline has continuously been offered since its introduction in the Institute of Anthropology by Tamagnini, in the late nineteenth century. The presence of a large collection of human bones of known age and sex in the Instituto de Antropologia in Coimbra have attracted researchers throughout the twentieth century. Both in the University of Coimbra and Porto, physical anthropology has never been divorced from the cultural component of the discipline (Areia, 1984: 51). However, the holistic view which characterizes the North American model is absent in Portugal. Primatology, paleopathology and dental anthropology are topics explored by Biology departments in the University of Lisbon (see Amoedo & Lopes, 1984; Lopes, 1984), and are not integrated in Anthropology departments.

Physical anthropology in the analysis of Estremadura sites

Since very early in the history of physical anthropology in Portugal, Estremadura was the focus of research, due to the archaeological importance of the Muge shellmiddens, as noted above. These Mesolithic sites, located on the Tagus valley (see Fig. 1), were first surveyed by Carlos Ribeiro in 1863. Later, in 1880, the same archaeologist intensively excavated the sites, and recovered circa 120 human skeletons, but no record of where the bones were recovered exists (Santos, 1982:133). From the 1860s to the 1960s, these sites were excavated on an irregular basis (Roche, 1972). The skeletons were stored in the Geological Survey in Lisbon and in Porto and were subsequently studied by different anthropologists.

In spite of the absence or uncertain location of notes on the archaeological procedures used in the Muge sites, several anthropologists - both Portuguese and foreign researchers - analyzed the human remains recovered by Ribeiro. The first analysis of these remains was published by Pereira da Costa, in 1865 (see Santos, 1982:132). Between 1881 and 1882, Paula e Oliveira wrote several reports on the Muge skeletons. His research was directed towards the definition of cranial morphological types. He concluded that there were two groups in the Muge assemblage: a predominant dolicocephalic group, and a less common brachicephalic one (see Santos, 1982:133). Ricardo Severo, in 1888, published an article in which the existence of the two 'races' was confirmed. The debate over the existence of different racial types in the burials of the Muge shellmiddens was continued during the late nineteenth century and extended until as recently as 1974. The presence of brachicephalic skulls in Muge was still the topic of discussion by several researchers (Corrêa,1956; Athayde, 1950; Ferembach, 1965; 1974). Vallois (1930) refuted the existence of brachicephalic skulls in Muge and attributed their identification to errors in the reconstruction. This debate was integrated in the more general discussion over the expansion of the brachicephalic populations. The identification of brachicephalic crania among the Muge sample would support the existence of a more 'evolved' type of population, in the general scale of craniometric typology. Other researchers worked on the anthropology of the Muge remains, mostly concentrating on craniometric questions (Athayde, 1950).

The problem of the mechanisms of transition between Mesolithic and Neolithic has only very recently been addressed by Portuguese archaeologists (cf.chapter 2). Although previous research had been done in the Mesolithic shellmiddens, and in spite of the fact that many of the Neolithic burial sites in the Estremadura had been excavated, the question of transition was never addressed in a systematic way until the 1980's.

Furthermore, until recently, with the exception of some analyses of cranial indices and site reports (Fernandes, 1990), the study of the human remains from numerous Neolithic burial caves was practically nonexistent. In a survey of the work published in Portugal, on human prehistoric osteology between 1950 and 1982, Farinha dos Santos (1982:156) mentions only five publications, all descriptive, and none integrated into any organized research program. In 1888, Paula e Oliveira published a report on the craniometry of the human remains from some Neolithic burials in Estremadura, but no conclusions were presented (Santos,1982:133). In 1973, Garralda published a comparison between the cranial characteristics of the Neolithic and Chalcolithic populations of Portugal and those from 'the rest of the Iberian Peninsula' (Garralda, 1973:115), in which racial types are identified on the basis of craniometry; some of the materials from Estremadura are included in her analysis. The analysis suggested that the skulls seem to be somewhat larger in the Meseta or the Eastern Iberian area than in the Atlantic area. However, the splanchocranial dimensions of the male sample seem to be smaller, namely the facial height and the bizygomatic breadth; the females presented larger dimensions of the facial measurements. She concluded that the Neolithic populations of the Atlantic Iberia belonged to the gracile Mediterranean classification, dolico-mesocephalic. According to Garralda, there are no differences between Mesolithic and Neolithic populations. In 1981, Farinha Isidoro reported on the human remains from the Gruta do Escoural, with a description of the crania. Some dental data are presented, but no analysis was performed, and information on pathologies is given only for some of the specimens, with no quantification that would allow any comparison. Cranial capacity was estimated for the skulls, the long bones were measured, and the mean stature of the population represented in the sample was calculated (Isidoro,1981). Other reports on Neolithic burial sites from Estremadura have concentrated on craniometry (Athayde, 1933; Corrêa, 1949; Cunha & Neto, 1958; Isidoro,1964).

In the 1980s, a joint Canadian-Portuguese project directed by Dr. D. Lubell from the University of Alberta began the analysis of the transitional period between Mesolithic and Neolithic in Portugal (Lubell, 1984). The project included the analysis of human remains from Mesolithic and Neolithic sites both in Alentejo and Estremadura. The goal of the physical anthropologists on the team was to understand the differences in health and demography between both periods, in order to assess the impact of the introduction of agriculture into the hunting and gathering populations (Lubell, Jackes and Meiklejohn, 1988). Cranial and postcranial remains from collections stored in the national museums were analyzed. Skeletons recovered from Mesolithic sites that were excavated by the same team were included in the study for comparison, as were Neolithic skeletons recovered from recent excavations in Estremadura (Feteira, Caldeirão) by Zilhão (1991,1986).

Analysis of some Neolithic sites in Estremadura by these researchers led them to suggest that the Neolithic populations were under greater risk of early death than those from the Mesolithic. The stable Mesolithic subsistence strategy with low mortality was succeeded by a Neolithic society in which mortality was much higher, but there was some population increase since fertility rates were also higher (Jackes, 1988a:154). From the Mesolithic samples, results from the analysis of dentition (dental wear distribution), femoral trabecular resorption (Singh's index, Singh et al., 1972), and osteon counting indicates that life expectancy at birth was about 30 years and that almost one-third of the population died by age 20 (Lubell, Jackes & Meiklejohn, 1988).

Population stature and robusticity was assessed from the skeletons. Analysis of metrical data on femora and humeri from the Mesolithic site of Moita do Sebastião demonstrated that the population was smaller and less robust than modern Portuguese (Lubell, Jackes & Meiklejohn, 1988), but it was not clear if the Mesolithic Portuguese differed in size or robusticity from their contemporaries in other European sites. According to Bianchi and coworkers (Bianchi et al., 1980), the Italian materials were more gracile than either the Portuguese or the North Africans. Compared to the Neolithic and Chalcolithic specimens, Mesolithic skeletons appear to be consistent in general robusticity, when the female femur and the humeral distal breadth are compared between populations of the three periods (Lubell, Jackes & Meiklejohn, 1988). The sexual dimorphism of the Mesolithic in Portugal (estimated as male stature/female stature * 100) was about 11.2, little different from that of modern Portuguese or the Visigothic populations (Lubell, Jackes & Meiklejohn, 1988).

The Neolithic samples from Estremadura have been the subject of more intensive study by the Canadian-Portuguese project. The site Gruta do Caldeirão (Tomar) has provided data regarding sex and age for a small sample. The collagen extracted from human ribs was analyzed for delta 13C and delta 15N and the values obtained suggest a Neolithic diet based largely on foods of terrestrial origin. This is in contrast with the Mesolithic diet as determined on the basis of coastal and estuarine sites, in which foods of marine origin were more frequent (Jackes & Lubell, n/d).

The human remains of Tojal de Vila Chã have not been the object of systematic study, with the exception of the data published by Bubner (1986). Cranial measurements and stature estimation were obtained for the skeletons from Gruta # 3. According to Bubner, this was the burial with more complete human remains, in comparison with Grutas # 1 and # 2, in which the bones were extremely fragmentary (Bubner,1986:93). Based on the measurement of femora, humeri, tibiae and radii, Bubner estimated the stature of a number of skeletons from Gruta # 3. Stature estimation was based on the tables developed by Pearson, Manouvrier, Breitinger and Lorke (Bubner,1986:96). For males, the average height obtained was 1.54 m for males and 1.53 m for females. Sex was diagnosed on the basis of the robusticity of muscle attachments on the long bones, but this assessment is problematic at this stage of knowledge of the occupational stresses in this particular sample, and among Neolithic/Chalcolithic populations in Portugal in general. Bubner's study concentrated on the analysis of cranial indices and their integration into cranial typologies.

Research on dental remains from the Estremadura sites

The Neolithic burial sites in Estremadura have provided thousands of loose teeth. This abundance of disarticulated dental remains has not been explained by archaeologists nor by physical anthropologists and it is unknown if burial practices or taphonomic processes are responsible for this high concentration. However, archaeologists have reported the presence of loose teeth in several sites in Estremadura. Delgado (1867:46) mentioned a predominance of mandibular remains over maxillary, and the incidence of loose teeth, in the site of Casa da Moura (Torres Vedras, Portugal). The same abundance was observed by M. Jackes, (4,125 loose teeth catalogued in the site, with 86.7% of mandibular teeth loose). Although the site has been completely excavated (Delgado, 1867; Straus et al., 1988), the excavation techniques utilized may not have permitted the recovery of all of the human remains present in the site; recent analysis of the backdirt left by the archaeologists who excavated the cave last century, revealed that 50% of the material recovered were human loose teeth (Jackes, 1988a: 152). Grutas Artificiais do Tojal de Vila Chã also provided a large majority of loose teeth (circa 2,500 specimens). Gruta da Galinha (a Neolithic burial) provided hundreds of disarticulated specimens (João Ludgero, personal communication). In Gruta da Feteira, a secondary Neolithic burial (Zilhão, 1986), the number of mandibular first molars found loose constitutes 64% of the total (Jackes, 1988a: 148).

The analysis of Neolithic teeth from the Estremadura area was initiated in the 1960s by Brabant and coworkers (Brabant, 1967; 1968; 1969; 1970; 1971; Brabant & Brichard, 1962; Brabant & Kovacs, 1962; Brabant & Sahly, 1962; Brabant & Twisselmann, 1964; Brabant & Lecacheux, 1973). This research was incorporated within a wider comparison of dental remains from different megalithic sites in Europe. The hypothesis proposed by Brabant was that the introduction of megalithic tombs in the Southwestern area of Europe had been performed by colonizers, who had brought this burial ritual as they occupied the Western territories. This idea was shared by other scholars as it was presented in the previous chapter. Although recent knowledge has led to the refutation of Brabant's model for the construction of megaliths, it should be recognized that it was the first time dental data were used for comparison of populations in an archaeological context in Southwestern Europe.

Earlier in this century Sueiro published a series of articles on the physical anthropology of Portuguese populations (Sueiro, 1927; 1930 a) b); 1936; 1938; 1943; 1948 a) b); Sueiro & Fernandes, n/d) and more specifically on dental pathologies of prehistoric samples from different sites in Portugal, with special emphasis on the remains from the

Mesolithic shellmiddens (Sueiro & Vilela, 1947; Sueiro & Frazão, 1959). More recently, special emphasis has been directed towards the dental remains from the Neolithic ossuaries of Estremadura, and the Mesolithic remains from the Tagus valley (Jackes, 1988, 1991; Jackes & Meiklejohn, 1992; Lubell, 1984; Lubell & Jackes, 1988; Lubell et al., 1988, 1992; Meiklejohn et al., 1988; Meiklejohn & Zvelebil, 1989; Jackes, 1989). Metric analysis of the dentition from Mesolithic sites in Portugal (Moita do Sebastião) suggests that they may be larger than those of their northern contemporaries (Lubell, et al. 1988).

Dental wear patterns in Mesolithic and Neolithic Estremadura sites

The majority of the material published on dental remains on Portuguese prehistory concentrates on the differences in wear patterns and dental pathological lesions, between Mesolithic and Neolithic samples. Data for the establishment of differences between pre-Neolithic and Neolithic dental wear patterns are not abundant. Although recent research on the topic provides some comparable data, one must caution that wear patterns for the Portuguese prehistoric dentitions are not yet established (Jackes & Lubell, n/d). The majority of the studies show a lack of consistency in scoring techniques. However, there is some work published which provides limited data for comparison of attrition and caries frequency (Sueiro, 1957; Brabant, 1967, 1968, 1969, 1970, 1971; Brabant & Sahly, 1962; Brabant & Twisselmann, 1964; Brabant & Lecacheux, 1969). In the samples recovered from Neolithic burial sites, the fact that the majority of the teeth have been found loose complicates interpretation (Jackes & Lubell, n/d).

Sueiro and Frazão (1957) describe the occlusal wear patterns for incomplete samples of Portuguese Mesolithic dentitions from Cabeço da Arruda, Moita do Sebastião and Cova da Onça. The molars showed the most severe wear in the sample. The wear levels (the successive stages or attrition on the occlusal surface) were classified into four different scores, from absence of wear or slight polishing (score 0) to intense wear, with more than half of the enamel surface worn down (score 3).

Cabeço da Arruda showed 49.2% intense wear in adults; Moita do Sebastião with 82.9% intense wear and Cova da Onça with 88.9% intense wear.

Lefèvre (1973) described the occlusal wear patterns of the Mesolithic population represented in Moita do Sebastião and Cabeço da Arruda. Using a scoring technique with four levels, similar to the one developed by Broca, his results indicated that the majority of the molars were at stage II (where dentin is exposed but not coalescing): 49.8% if we exclude the third molars. The author concluded, by analysis of cranial suture closure, that the population was young, and that the type of wear was much more intense and premature than for contemporary European populations (Lefèvre,1973:328). Ferembach (1965) estimated the age of the Muge population as between 20 and 30 years of age.

The results obtained by Sueiro (a higher percentage of intense wear) do not coincide with those reported by Lefèvre (higher percentage of level II). Although the scoring techniques used by both researchers were similar, the results are not consistent. Whether the differences are due to different samples analyzed or to methodological problems, it is difficult to determine, since the results were published in their final form, with no comments on the methods applied nor on the nature of the sample.

For the European Mesolithic, interstitial wear has been analyzed only for the presence or absence of wear facets. In the Muge shellmiddens, Lefèvre concluded that, for the first and second molars, 48.3% of the teeth had mesial facets and 20.8% had both mesial and distal. He explained this frequency by the youth of the population represented in the sample (Lefèvre,1973).

Brabant & Sahly (1962) analyzed interproximal wear facets in European Neolithic samples. They recognized that European Neolithic populations showed a more pronounced interstitial wear than modern Western people. The hypothesis of sand in the food items or generalized bruxism being responsible for the presence of interstitial wear was refuted (Brabant & Sahly,1962:334-335), but no alternative explanation was presented. Brabant & Lecacheux state that the Neolithic samples they analyzed revealed that the majority of the skeletons were between 20 and 40 years old (Brabant & Lecacheux,1973:132). However, there are no comparative studies on the frequency or dimensions of interproximal wear facets in pre-Neolithic and Neolithic dental samples for European skeletal populations.

In the Mesolithic samples from Portugal, an unusual type of wear has been diagnosed (Lefèvre, 1972). It has been described as '<u>signe du cordonnier</u>' (Alexandersen, 1987; Lefèvre, 1973; Peña y Basabe, 1987) and it is characterized by a polishing of the lingual surface on the maxillary anterior teeth. The same kind of wear was identified by M. Jackes (1988:5) on the Neolithic teeth from 'Casa da Moura'. Overall, lingual polishing occurs in 49% of upper left and 62% of upper right canines. The side difference is highly significant (Chi-square= 6.64 at 1 df) (Jackes, 1988:6), which can support the idea of occupational stresses as being responsible for this type of wear. However, the teeth from Casa da Moura are mostly loose.

Dental lesions in the Mesolithic and Neolithic Estremadura sites

A higher incidence of caries in Neolithic populations has traditionally been used as a means of differentiating pre-agricultural from agricultural skeletal samples (see Meiklejohn <u>et al</u>., 1984; Turner, 1979). The assumption is that the higher consumption of carbohydrates with a cereal-based diet provoked a more intense development of carious lesions (cf. Chapter four for a discussion of cariogenic factors). Caries frequencies were then reported as lower in the Mesolithic than in the Neolithic (1.9% versus 4.2%). However, more recent work suggests a more complex pattern, including a lack of geographic uniformity (Meiklejohn, Baldwin & Schentag, 1988). Analysis of Scandinavian Mesolithic series shows a high incidence of calculus but caries is virtually absent. A protein based diet is suggested (Meiklejohn & Zvelebil, 1989:8). In the Mediterranean samples, both calculus and caries are present, indicating a mixed protein and carbohydrate diet. From this base, the authors suggest that considerable dietary variation can be predicted over geographical space in the Mesolithic (Meiklejohn & Zvelebil, 1989:9).

The first reports on caries incidence in the Mesolithic sites of the Estremadura were published in 1947 and 1959 by Sueiro an his coworkers. Some of the human dental remains from Cabeço da Arruda, Moita do Sebastião and Cova da Onça were analyzed and results were compared. Unfortunately, the method of analysis is not clear, and the sample sizes analyzed for Cabeço da Arruda and Moita do Sebastião do not coincide with the total number of teeth later observed by Jackes (Jackes, 1991). Furthermore, the frequency of caries is estimated by individual and not by tooth count, which impedes a comparison with the sample analyzed in this study (e.g. Sueiro & Vilela, 1947; Sueiro & Frazão, 1959). Sueiro reports the presence of caries in the sample, as 'not very frequent' and 'not very severe' (Sueiro & Frazão, 1959:199) and states that caries was observed in neither children nor adolescents. Premortem tooth loss was also diagnosed from the remodelling of the alveolar surface visible in some of the specimens. Of 85 individuals, 3 (3.5%) had carious lesions. Carious lesions were also quantified by Lefèvre (1973) and they were assessed as "present but with low frequency" (p.332). Although the results were presented by tooth count, the sample size is not given and consequently comparison is difficult to establish.

Brabant and his coworkers report that 2% to 8% of observed teeth from Mesolithic sites have been diagnosed as carious (Brabant & Sahly, 1962: 321), but no difference in caries frequency between pre-Neolithic and Neolithic dentitions was reported (Brabant, 1969; Brabant & Sahly, 1962; Brabant & Lecacheux, 1973).

In more recent studies on the Mesolithic materials from the Tagus valley, 13% of the teeth have been diagnosed as carious (n=648), a level higher than any other reported for a Mesolithic European sample and higher than many Neolithic samples (Lubell, et al., 1988). The absence of caries in deciduous teeth reported by these researchers is consistent with the information collected by Sueiro (see above) (Lubell et al.,1988; Meiklejohn, et al., 1988). In Moita do Sebastião, 12% of the teeth showed carious lesions and in Cabeço da Arruda 7% of the teeth were carious. Incisor and canine caries account for only 7.3% of the carious teeth (14, n=192). Caries was visible on all tooth surfaces.

Occlusal caries dominated, though mesial and distal caries was also common. Various forms of demineralization were reported, including pit and fissure caries on the occlusal surface, interproximal caries, and neck caries at or near the cemento-enamel junction (Meiklejohn, et al., 1988:273).

Jackes & Lubell (n/d) stated that the Neolithic sites in Estremadura have demonstrated that the frequency of dental caries is not a good indicator of dietary differences between pre-agricultural and agricultural samples, because of the high percentage of carious teeth in the Mesolithic populations; they suggest that other factors could be involved in the distribution of caries in prehistoric populations in the area. Combined Caldeirão (Neolithic) pathology rates are similar to those of Cabeço da Arruda (Mesolithic) and Casa da Moura (Neolithic), but lower than those of Moita do Sebastião (Mesolithic), Feteira and Melides (Neolithic). Thus, no clear Mesolithic-Neolithic distinction can be made (Lubell & Jackes, 1988). However, they emphasize that until samples sizes large enough to determine the age structure of the populations considered are defined, dental pathology rates cannot be compared (Lubell & Jackes, 1988). Meiklejohn and coworkers (Meiklejohn, et al., 1988:277) suggest that caries frequency is a good dietary indicator but that European regional variations must be considered.

The apparent greater importance of carbohydrates in the late Mesolithic diet of the Mediterranean has been explained by some researchers as the result of indigenous plant husbandry, of pulses, nuts and grasses, for which there is some archaeological evidence at sites such as Balma Abeuradour in southern France, and Vlasac in Yugoslavia (Meiklejohn & Zvelebil, 1989). More specifically in Uzzo, Sicily, fig (*Ficus*) and carob (*Ceratonia*) have been recovered in a Mesolithic archaeological context. Unfortunately, for the Portuguese Mesolithic, the lack of palaeobotanical data makes it impossible to confirm the presence of such items among the foods consumed. However, fig has been identified as part of the burnt wood samples at the Samouqueira and Medo Tojeiro sites, together with pistachio and stone pine (Meiklejohn et al., 1988: 8). An alternative hypothesis for the higher percentage of caries in Mesolithic samples suggested by Meiklejohn and coworkers

(Meiklejohn & Zvelebil, 1989) is the higher consumption of suboptimal foods, denoting population pressure during the Mesolithic.

Dental enamel hypoplasia in Mesolithic and Neolithic Estremadura sites

Meiklejohn et al. (1984) previously suggested that enamel hypoplasia was almost universally absent in the European Mesolithic and Neolithic. This view has been refuted on the basis of work done on Portuguese and Danish Mesolithic dental samples (Meiklejohn & Zvelebil, 1989) which suggests that high levels of enamel hypoplasia are present in both periods. The authors propose that the condition is the reflection of local conditions, rather than any general problem faced by Mesolithic populations in general (Meiklejohn & Zvelebil, 1989:7).

In the Portuguese Mesolithic, enamel hypoplasia is uncommon in deciduous teeth (6.5%; n=46) but is present in almost half the permanent teeth (48.2%; n=515); it occurs with equivalent frequencies amongst males and females, but is more common in maxillary than mandibular teeth (Lubell, et al., 1988). The high percentage of enamel hypoplasia and the relatively high frequency of dental caries, combined with a high life expectancy has been explained as demonstrative that these populations survived childhood stresses and lived longer, and thus were more likely to develop dental caries than other Mesolithic populations. On the other hand, the incidence of abcessing and periodontal disease rates are not comparatively high, perhaps indicating good general health and nutrition (Lubell, et al., 1988).

Analysis of the Caldeirão dentitions revealed an incidence of slight enamel hypoplasia in 20% of the teeth (n=60). The condition is most common in the maxillary canines, and is much higher than at Moita do Sebastião and Cabeço da Arruda (Jackes & Lubell, n/d).

Summary

The analysis of human remains from archaeological sites in Estremadura was initiated in the last century, with the discovery of the

Mesolithic cemeteries in the Tagus shellmiddens. Although the majority of the publications have concentrated on cranial indices and racial typology, recent research has focused on the identification of subsistence strategies and health conditions of these populations. Interest in the mechanisms involved in the transition from hunting/gathering to agricultural subsistence strategies and the presence of large samples of human teeth from Mesolithic and Neolithic sites led to the systematic observation of dental wear patterns and pathologies in samples from sites of both periods in the area. Research has shown that occlusal wear is more intense in dentitions identified as Mesolithic than in the Neolithic. Neolithic anterior teeth exhibit some wear on the lingual surface.

Contrary to Northern Europe, analysis of dental caries has demonstrated that a high number of lesions cannot be used to identify the presence of agricultural diets from skeletal samples. The data suggest that local factors determine the presence of a high caries frequency among the Mesolithic populations of Southern Europe and that different patterns should be established for the assessment of subsistence strategies from human dental remains.

CHAPTER FOUR

MATERIALS AND METHODS: NATURE OF THE SAMPLE AND METHODOLOGICAL APPROACHES FOR THE ANALYSIS OF WEAR AND PATHOLOGICAL LESIONS

Introduction

In the study of dental wear patterns and pathologies, inter-sample comparison is sometimes difficult to perform, because each researcher uses different methods of observation and data quantification. The analysis of _in situ_ teeth requires the use of methodologies that are not suitable for the study of isolated specimens. _In situ_ teeth can be scored for occlusal wear taking into consideration the eruption sequence; the amount/type of wear in adjacent teeth at one given point in time can be observed; the functional occlusal plane can also be measured with the use of a protractor when _in situ_ teeth are analyzed. Given the dual nature of the sample observed in this study (teeth that are loose and teeth that are in the jaws), methodologies that were applicable in both conditions were preferred. In this chapter the variables observed in the human dental remains from "Tojal de Vila Chã" are described. The various methods developed by previous researchers for scoring these variables are discussed, and the specific methodology used in this study is presented. The data collection forms employed in the present analysis are included in Appendix A. The method used for the identification of loose teeth is presented in Appendix B.

Whether concentrating on morphology or on dental wear and pathological lesions, anthropologists need to adopt methods that can be replicated and can therefore legitimate the comparison of a series of samples, analyzed by several researchers. Methodological problems are the major obstacle to the effectiveness of comparative studies, and they have been denounced by several scholars in the last decades. Methods that are not reproducible which result in high levels of interobserver error (Lukacs, 1989:264) constitute an impediment to comparative analysis and to the development of definitive conclusions. Unclear presentation of the methods utilized in each study (Lukacs, 1989:271) and unspecified quantitative methods of analysis used by each researcher, also limit paleodental studies.

Often, the methodology adopted for data presentation is not explicitly stated (Lukacs, 1989:271). In most cases, percentages of frequencies of wear grades and/or lesions are given, without specifying if they refer to the total number of teeth in the sample in which a specific variable is being identified (tooth count method) or if they refer to the number of individual skeletons in which the feature is identified (individual count method). Generally, when the analysis is based on *in situ* dental specimens, the results are given by individual count, that, is by skeleton. This method has some limitations; for example, if the presence of carious lesions is quantified by individual, the known results are limited to the number of individuals in which the pathology is present, or to those with complete dentitions that lack caries, and skeletons with some teeth missing postmortem are usually disregarded or included in the category visible for the teeth still present in the jaw at the time of observation. However, paleodemographic studies give preference to the individual count method, since it is the information per individual (and not per tooth) that enables the construction of demographic profiles. The analysis of loose specimens restricts the methods of quantification to tooth count. In a sample of this nature, there is no association of the teeth with the skeletons, and therefore no individuals can be identified. The use of the tooth count method negates the possibility of analysis of antimeres variation because the teeth can be identified as left and right, but they cannot be identified as belonging to one specific individual. However, the poor preservation of skeletal remains frequently impedes the analysis of both sides of the jaw, even when teeth are *in situ*. Therefore, researchers often choose to analyze only one side or to simply ignore the side in the final analysis (e.g. Hutchinson & Larsen, 1990; Liñaza & Basabe, 1987:8).

Sample definition and tooth identification

Teeth have been reported to be one of the most important sources of information derived from remains found in an archaeological context

(Patterson, 1984:54). As they are usually preserved beyond the period of bone deterioration, they are very often the only remains left in burial sites, at the time of excavation (Bass, 1971: 210). In Grutas Artificiais do Tojal de Vila Chã this is not the case; preliminary cataloguing of the sample revealed that over 10,000 human bone fragments are preserved and stored in the Museu Nacional de Arqueologia e Etnologia in Lisbon. In the search for dental remains in the storage room, 133 boxes with human remains were found, organized according to different parts of the skeleton and divided into groups identified as Gruta 1, 2 and 3 respectively. Some of the human remains are cranial, but the vast majority are postcranial. The overall state of preservation is poor; most of the bones are fragmented. However, it was noted that the bones of the hand and foot were quite well preserved. After excavation in the 1930s, the dental remains were kept separately, in card boxes containing sometimes up to five hundred specimens each. Only three disarticulated teeth were found in the boxes containing postcranial remains. In spite of the poor storage conditions, the preservation of the dental sample is good, allowing the analysis of wear patterns and caries, as well as of morphological traits. Although the possibilities of analysis of periodontal disorders are restricted by the nature of the sample - in large majority, loose teeth - dental measurements were easier to obtain, and interstitial wear and caries were more easily diagnosed.

The presence of a large number of loose teeth in the Estremadura Neolithic burial sites has been recognized (cf.chapter 3). No research has been directed towards explaining how these samples were formed. They might be the result of post-burial processes, or the consequence of the practice of secondary burial - the interment of bones after defleshing of the body (Camps,1980; Ubelaker, 1989:20), or the product of poor excavation techniques. The latter hypothesis is difficult to sustain, since _in situ_ teeth and a large number of well preserved postcranial remains are included in the collections recovered by the same archaeologists, at other sites.

Taphonomic processes have only recently been discussed in the literature and they concentrate mostly on early Hominid assemblages in

East Africa and carnivore activity (Behrensmeyer, 1975; Boaz & Behrensmeyer, 1976; Klein, 1975; Kruuk, 1972; Schaller, 1972; Shipman & Phillips, 1976). Some recent work has been developed on human remains (Haglund, 1990) but it concentrates mostly on forensic aspects for determination of elapsed time since death and cause of death in medical legal investigation. Morlan (1980) summarized the taphonomic agents that are involved in site formation processes and bone deterioration and emphasized that an extensive set of factors can influence the formation of the site, and the analysis of the recovered remains (Fig. 4) The determining factors begin to operate while the animal is still living (biotic factors), depending on population concentration and shape and resistance of the body and bones (Morlan, 1980:30). Subsequently, factors related to cause of death, age at death, burial conditions, weathering and erosion, determine the fossil assemblage throughout time, until the site is finally excavated. With excavation and curatorial work as last factors (sullegic and trephic) influencing the potential fossil record, the final form of the paleontological collection is shaped (Morlan, 1980:33).

The analysis of taphonomic processes in Tojal de Vila Chã is impeded by lack of sufficient information. There is no known record of the methodology employed by the archaeologist in the excavation of the site, and the positioning of the skeletons at the time is unknown. Following Morlan's model (Fig. 4), only trephic factors of analysis can be controlled, i.e. the methods used for the classification and analysis. The characteristics of the sample of teeth recovered from Tojal de Vila Chã limit the assessment of paleodemographic information. However, because a large number of Neolithic burial sites in the area have provided similarly large assemblages of loose teeth, it is important to develop methods of analysis and determine patterns of wear and pathology that can be used for future comparison. No identification

Fig.4. Model of factors and assemblages pertaining to the taphonomic history of vertebrate fossils (adapted from Morlan, 1980: 31)

Biotic factors (life assemblage)

Thanatic factors (cause of death)

Perthotaxic and taphic factors (burial)

Anataxic factors (weathering and erosion)

Collection

Trephic factors (laboratory)

of sex or age was possible, because there was no association with postcranial remains, and very seldom with crania. When the teeth were found in the jaw, the remains were too fragmentary for an estimation of sex and age to be established. However, future research on sites that have not been completely excavated and in which individuals are identifiable can be used for establishing the association between osteological data and dental characteristics of the populations so that demographic profiles can be inferred.

Given the limitations of the information that can be obtained from a sample of loose teeth, this study concentrates on determining the patterns of dental wear that characterize the population buried in the site, and the frequency of pathological conditions, independently of age or sex of the individuals. Although the information recovered is consequently limited, the general characteristics of dental attrition and health can be assessed for the population represented in these burials and it can provide data for future comparison with other commingled remains recovered from Neolithic ossuaries. The implicationsof the nature of the sample on the results obtained from its analysis are discussed in Chapter five.

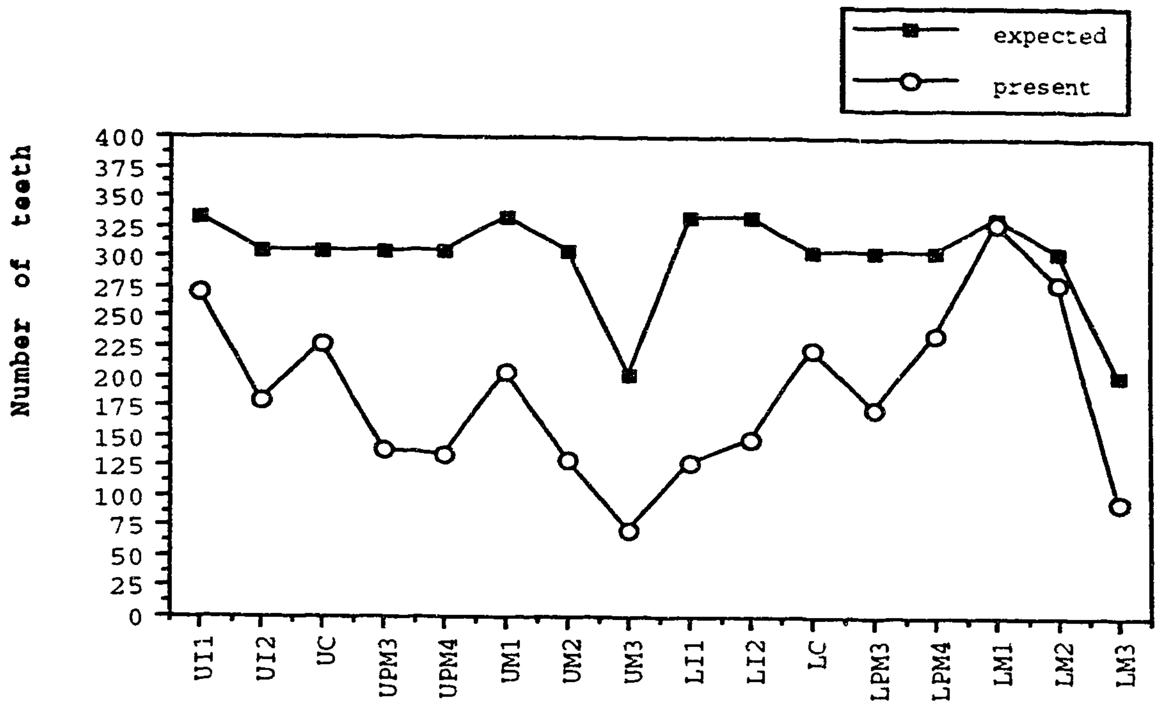
The minimum number of individuals (MNI) represented in the sample is 167 individuals, estimated from the number of right mandibular first molars, following procedures suggested by Klein & Cruz-Uribe (1984). The initial number of individuals (Poplin, 1976) might not coincide with the MNI but only future analysis of the skeletons recovered from the site should contribute to the clarification of this issue. The distribution of <u>in situ</u> and disarticulated specimens is given in Table 2.

The most commonly represented tooth is the mandibular first molar (n=328), which is an accordance with the expected values, since it is the first tooth of the permanent dentition to erupt. However, the number of maxillary first molars does not coincide with this value (n=203). Since other tooth categories were recognized as beingunderrepresented, an analysis of expected versus present number of teeth was conducted; mandibular incisors and maxillary premolars appear to be underrepresented (Fig.5).

Table 2. Total number of permanent teeth observed

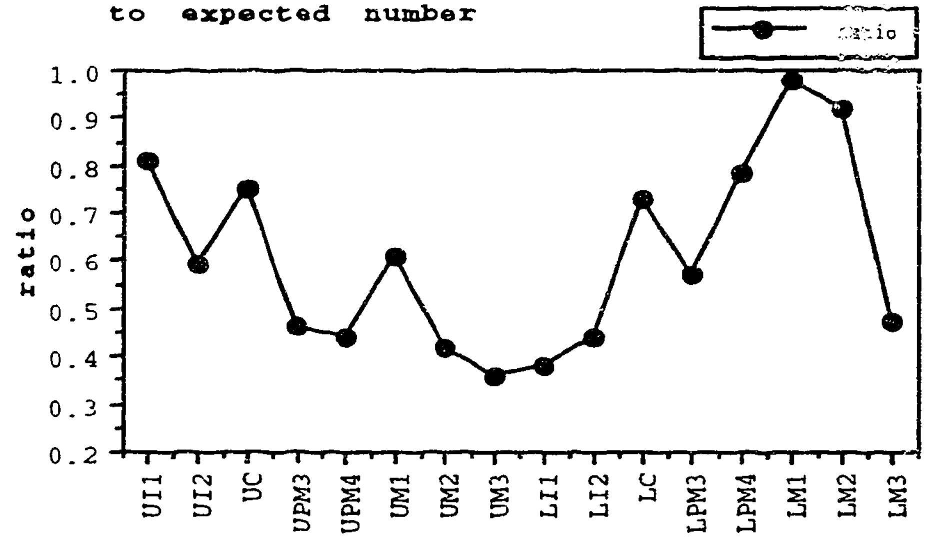
	Teeth in situ					Loose teeth					
	Righ	Left	Uns	Subt	%	Righ	Left	Unsi	Subt	%	Total
Maxillary central incisors	3	0	0	3	1.1	132	126	9	267	98.9	270
Maxillary lateral incisors	0	0	0	0	0.0	86	91	2	179	100.0	179
Maxillary incisors unclas.	0	0	0	0	0.0	0	0	0	0	0.0	0
Maxillary canines	3	3	0	6	2.6	102	117	3	222	97.4	228
Maxillary first premolars	7	4	0	11	7.9	69	58	1	128	92.1	139
Maxillary second premolars	8	6	0	14	10.5	52	62	5	119	89.5	133
Maxillary premolars unclas.	0	0	0	0	0.0	0	0	1	1	100.0	1
Maxillary first molars	24	18	0	42	20.7	77	83	1	161	79.3	203
Maxillary second molars	15	11	0	26	20.2	52	51	0	103	79.8	129
Maxillary third molars	8	3	0	11	15.3	29	32	0	61	84.7	72
Maxillary molars unclas.	0	0	0	0	0.0	1	0	5	6	100.0	6
Mandibular central incisors	6	6	0	12	9.4	63	52	0	115	90.6	127
Mandibular lateral incisors	5	8	0	13	8.8	60	74	0	134	91.2	147
Mandibular incisors unclas.	0	0	0	0	0.0	3	3	5	11	100.0	11
Mandibular canines	12	20	0	32	14.3	97	94	0	191	85.7	223
Mandibular first premolars	11	20	0	31	17.9	79	63	0	142	82.1	173
Mandibular second premolars	19	19	0	38	16.1	98	95	5	198	83.9	236
Mandibular premolars unclas.	0	0	0	0	0.0	0	1	5	6	100.0	6
Mandibular first molars	59	69	0	128	39.0	108	92	0	200	61.0	328
Mandibular second molars	46	57	0	103	36.9	85	91	0	176	63.1	279
Mandibular third molars	20	21	0	41	43.2	27	27	0	54	56.8	95
Mandibular molars unclas.	0	0	0	0	0.0	0	2	18	20	100.0	20
Subtotals	246	265	0	511	17.0	1220	1214	60	2494	83.0	3005

Fig.5. Expected versus present number of permanent teeth



Estimation of the ratio of expected to observed number of teeth (Fig. 6) revealed that premolars, second and third molars, mandibular incisors, and mandibular third molars are the categories that are underrepresented in the sample. The underrepresentation of the maxillary posterior teeth is visible in both in situ teeth (only 18.6% of the total number of jaw fragments are maxillary) and in loose teeth (only 37.7% of the loose posterior teeth are maxillary). The reasons for this underrepresentation are not explainable with the information available on the site. The extremely low ratio (0.35) obtained for the mandibular third molar might be explained by the fact that its time of eruption is very variable and therefore the expected value established for this group might be overestimated for this population. The same reason would explain the low value obtained for the mandibular third molar (0.45). The reduced number of mandibular incisors might be the result of loss during excavation or destruction while the remains were buried, since they are the smallest teeth and the most fragile of the human dentition, and single rooted anterior teeth are commonly lost when they fall out of the jaws during excavation. Multiple rooted posterior teeth are less prone to this process.

Fig.6. Ratios of present teeth in relation to expected number



In spite of the under representation of some tooth sectors in the sample, which can be due to burial conditions, excavation techniques, storage or misidentification, the total number of teeth is large enough to allow the definition of patterns and the assessment of dental health in the population represented. Further research in the same collection (MNI estimation from skeletal components) will clarify some aspects of the underrepresentation of some tooth sectors.

Given the nature of the sample, the method used for quantification of results was the tooth count method. Each variable was observed on each tooth, whether in the jaw or not, after its classification as incisor, canine, premolar or molar. Consequently, all frequencies and correlations presented here refer to the individual tooth specimens, and percentages of a given variable refer to the total number of teeth in which the variable could be scored, not to the total number of specimens present.

The loose dentition was observed several times, given the extensive period of access to the sample, from 1989 to 1992 at the University of Alberta. The in situ dentition, on the contrary, was observed only once, in Lisbon, in the summer of 1989. All the measurements and tooth wear scores, as well as the observation of pathological lesions, were performed on these materials at that time. Consequently, intraobserver error was not assessed for the results obtained from the in situ dentition.

The classification of the teeth was first done in 1989. Identification of in situ specimens was generally facilitated by the observation of their relative position in the jaws. Loose teeth, however, are usually more difficult to identify (Jackes, 1989; Linaza & Basabe, 1987), due to morphological variation between individuals. Careful comparison of isolated specimens within the sample partially reduced such difficulties. The first step in the analysis of the loose teeth was to separate them into groups of incisors, canines, premolars, and molars, following the methods proposed by Bass (1971). They were then catalogued (see Appendix A) and given a series number of five digits; the first digit refers to the number of the burial (1, 2, or 3, respectively) and the following digits refer to the number of the specimen for each burial. The second step consisted of separating the teeth into maxillary and mandibular groups, and the first siding was attempted. On a third step teeth from the same sector were separated as central from lateral incisors, first from second premolars, and first, second and third molars. For the identification of individual loose teeth the methods suggested by Beek (1983), Woelfel (1982), Brescia (1961), Scott & Symons (1977), Carlsen (1987), and Fuller & Denehy (1974) were synthesized in a single key.

After classification and cataloguing were completed, scoring of dental wear and pathological lesions was performed. The analysis of dental wear concentrated on variables that could be used for comparison with data known from other sites in the Estremadura and from the same time period. The results should provide information on the distribution of wear scores within the sample and on the variation of the angle of the occlusal surface with increasing wear. The analysis of pathological conditions concentrated on caries, hypercementosis, and enamel hypoplastic defects and they were not analyzed in order to define the age distribution of the population, since skeletal age indicators were not associated with the teeth. Attention was drawn to the characterization of variables that have been associated with specific dietary habits in prehistoric skeletal samples.

Dental wear

It has long been recognized that specific types of diet produce different dental wear patterns (e.g. Alexandersen, 1988; Molnar, 1971; Molnar et al.,1989; Richards,1990; Smith,1974;1984). Teeth have therefore been used as a source of information for the identification of dietary strategies in skeletal samples (cf. chapter five).

Dental wear has two components: attrition and abrasion. These terms have been defined in different ways. Some consider attrition as the formation of well defined wear facets where teeth meet in chewing, often with parallel scratches resulting from the abrasives in food and therefore being related to diet, while abrasion occurs outside the occlusal zone and in teeth which do not meet during chewing (Hillson, 1986:183). Other authors refer to attrition as the diminishing of dental tissues through functional contact with other teeth and to dental abrasion as being produced by food, foreign particles contained in food, or foreign items (Campbell, 1925:64 in Reinhardt, 1983:227; Lukacs and Pastor, 1988:377; Moorrees, 1957; Silvana et al., 1985;). For analysis of skeletal samples, the nuances of the definitions are irrelevant. It is the effect of both processes (tooth to tooth contact and foreign particles) that is observed on the tooth surfaces, whether in the form of facets, striations or chipping. The combination of different factors (food items and foreign particles) creates the wear pattern developed with a given dietary strategy and it can be used for identification of changes in subsistence in prehistoric samples.

The use of dental wear for the reconstruction of dietary habits from skeletal remains has been challenged because of the absence of standardized scoring methods that can ensure the comparability of results obtained by different researchers (e.g. Lukacs, 1989; Scott, 1979). The lack of a sufficient number of reports on dental wear patterns in extant populations with diverse dietary habits also constitutes an obstacle for paleodental research.

Two distinct manifestations of dental wear have been used for the identification of specific dietary habits - occlusal wear and interproximal facets. Occlusal wear is the erosion of the surfaces that are in contact with the teeth of the opposing jaw during mastication movements (Patterson, 1984:56). It is the type of wear more widely explored by anthropologists in the analysis of skeletal samples. Interproximal wear is the erosion of the surface between adjacent teeth (Wolpoff, 1971a: 205) and is characterized by the formation of facets on the mesial and/or distal surfaces of the tooth.

Occlusal wear

Research on occlusal wear has concentrated on two different components of its development: the amount of erosion and the slope of the occlusal surface. The amount of attrition, visible on the surface of the enamel or exposure of dentin, is more frequently reported by anthropologists (e.g. Dahlberg, 1963; Hinton, 1981; Scott & Turner, 1988; Y'Edynak,1989). Other researchers have concentrated on the variability of the slope of the occlusal contact surface and its variation with increased wear (Ackerman, 1963; Anderson, 1965; Campbell, 1925; Jackes, 1988; Molnar, 1971; Molnar & Molnar, 1990; Smith, 1984).

The first method developed for the classification of occlusal wear was published in 1879 by Broca and has been the basis for subsequent research methods. In Broca's original work a series of five scores (from 0 to 4) defined different stages of wear of the tooth crown, ranging from absence of wear (level 0) to complete disappearance of the tooth crown (level 4). Even if different tables were created by later researchers, the principle of assigning scores to the amount of attrition visible on the tooth was maintained. In some cases, the number of scores was kept, but the details of the definition of each of the scores were transformed (e.g. eattie, 1981; Brabant & Sahly, 1962;

Moorrees, 1957). In other instances, the number of scores was extended to eight levels (Hinton, 1981; Linaza & Basabe, 1987; Smith, 1984; Y'Edynak, 1989), but the principle of classifying the amount of occlusal wear qualitatively was maintained. A more detailed method, for molars only, has been developed by Scott (1979): the tooth is divided into four quadrants and a scale from 0 to 10 is applied to score attrition in each quadrant of the occlusal surface and a mean for all the quadrants is estimated.

Broca introduced the quantification of occlusal wear into physical anthropology, but the imprecision in the definition of each of the scores has created difficulty in applying his scale to the study of archaeological specimens (e.g. level 3 is defined as 'a part of the tooth worn away'). The absence of categories that can incorporate the higher levels of attrition also constitutes an obstacle in the application of the method to prehistoric samples (e.g. level 4 is defined as 'the crown completely worn to the cementoenamel junction at the cervix'). It has to be assumed that wear more severe than level 2 (dentin exposure) can only be characterized by erosion of 'part of the crown' (level 3) or its near total disappearance (level 4). Since archaeological specimens are known to exhibit higher and often more complex levels of wear than living western populations, the scale is not applicable to skeletal samples because it is not sufficiently precise.

Tables for the classification of wear which maintained the number of levels considered by Broca have been developed subsequently and have partially eliminated the problem of inconsistency in the definition of each score (e.g. Moorrees, 1957). But the absence of higher levels that might incorporate the type of wear visible in prehistoric samples still constitutes a problem for their use; the range of the amount of wear between scores is still imprecise in many of the developed scales (e.g. between levels 3 = cusps completely worn, hollow indentations left; 4 = one half to nearly complete loss of crown) (Moorrees, 1957).

Recently, more detailed ranking methods, in which different categories are defined by degrees of enamel erosion and dentin exposure, have been employed for scoring dental wear (e.g. Hinton, 1981, 1982;

Linaza & Basabe, 1987; Molnar, 1971; Scott & Turner, 1988). These scales have maintained the principle adopted by Broca but, to obtain more precision in the analysis of wear variation and distribution, they include a higher number of scoring levels and have introduced specific descriptions for each tooth sector (incisors, canines, premolars, and molars) separately. These tables have eliminated the problem of absence of higher scores and present specific descriptions of the amount of wear in heavily worn teeth. However, in some cases, the problem of lack of specification for each score has been transferred to the lower levels. Hinton (1981) defined eight categories for the characterization of occlusal wear, with different keys for the incisor and canine, the premolar and molar sectors, but he did not consider the existence of a level 0 of attrition (e.g. level 1 includes unworn to polished or small facets). The definition of a level 0 of attrition becomes relevant when a sequence of attrition levels between adjacent teeth needs to be established; it is important to know at which stage of wear the first molar is, when the second molar has no visible wear, and can therefore be considered as just having erupted. Reinhardt (1987) created a nine point scale, through the addition of level 9 (no crown enamel, roots functioning in occlusion, all teeth very short, and multirooted teeth dehisced or nearly so) to the table created by Molnar (1971). Meiklejohn and coworkers (Meiklejohn et al., 1989) telescoped the attrition levels developed by Jackes (Lubell & Jackes, 1989; Lubell et al., 1988) into four categories, in order to establish a comparison with the work done in other European samples by Maat and Van der Velde (1987).

Smith (1984) developed a method for the analysis of wear scores which incorporates eight distinct levels, with definition of specific sequences for each of the sectors of the dentition (incisors and canines, premolars, and molars) separately. However, it does not include a level 0 for absence of wear (i.e. level 1 is defined as unworn to polished or small facets). The method was developed through the analysis of in situ specimens but the wear scores were defined by tooth sector and therefore it is possible to apply the scale to loose teeth without the need to analyze the total dentition simultaneously such as occurs in other tables (e.g. Lovejoy, 1985).

In the sample from Tojal de Vila Chã, the analysis of occlusal wear required the use of a method which can be applicable in both in situ and loose teeth. Therefore, the scores have to be defined specifically for each tooth sector and independently of one another. The metrical analysis of the variation of the slope of the occlusal surface with increased wear required the definition of the inclination when wear is absent. Therefore, a level 0 had to be considered. The method developed by Smith (1984) for the analysis of hunter-gatherer and agriculturalist dentitions was therefore adequate, provided a level 0 for absence of wear would be considered. However, the levels of wear used by Smith on the anterior teeth were difficult to apply to the sample analyzed in this study. It was recognized that the difference between levels 4 and 5 was difficult to establish for incisors (level 4 is defined as 'moderate dentin exposure no longer resembling a line' and level 5 as 'large dentin area with enamel rim complete'). The difference between levels 5 and 6 (level 6= large enamel area with enamel rim lost on one side or very thin enamel only) was also difficult to establish because of the high frequency of chipping on the labio-incisal edge. These levels are based on the observation of attrition from an occlusal/incisal view. A definition of scores from this view (method used by Smith) was combined with an analysis of the proportion of the crown height eroded by wear (method used by Molnar). A combination of both tables was used for the qualitative scoring of both loose and in situ anterior teeth in the sample (Table 3). For the qualitative analysis of occlusal wear on the posterior dentition, Smith's method was used, but the definition of some of the levels was modified. In the mandibular molars, the difference between levels 2 and 3 was difficult to establish (level 2 is defined as 'moderate cusp removal, with no more than one or two pinpoints of dentin exposure', and level 3 is defined as 'full cusp removal, with pinpoint to moderate dentin exposure'; level 4 is defined as 'several large dentin exposures, still discrete'). After preliminary analysis of some of the specimens contained in the present sample, an additional characteristic was included in the definition of level 2 (cusps usually removed on the buccal side, for the mandibular molars). The distinction between levels 3 and 4 was established through the adoption of Jackes' definition of level 3 - fissure pattern present but not clear (Jackes, personal communication). The final scale used for the scoring of wear of the occlusal surface is presented in Table 3.

Table 3

<u>Method for scoring occlusal tooth wear</u>

<u>Anterior teeth</u>

0= no wear present

1= Polished or small facets (no dentin exposure)

2= Point or hairline of dentin exposure

3= Dentin line of distinct thickness but still a line

4= Moderate dentin exposure no longer resembling a line (crown height still more than half)

5= Large dentin area with enamel rim complete (crown height less than half)

6= Large enamel area with enamel rim lost on one side or very thin enamel only (crown height about third)

7= Enamel rim lost on two sides or small remnants of enamel remain (crown height less than one third).

8= Complete loss of crown, no enamel remaining; crown surface takes on shape of roots.

9= Unscorable

(Adapted from Molnar, 1971 and Smith, 1984)

<u>Posterior teeth</u>

0= no wear

1= occlusal surface polished; small wear facets on the occlusal surface, but cusps present; no dentin exposure.

2= moderate cusp removal (not all the cusps); pinpoint dentin exposure can occur; cusps usually removed on the buccal side, in mandibular molars.

3= full cusp removal (all cusps) and/or some dentin exposure, pinpoint to moderate; fissure pattern still present, but not clear.

4= several dentin exposures, still discrete.

5= two dentinal areas coalescing

6= three dentinal areas coalescing

7= dentin exposed on entire surface, enamel rim still intact

8= severe loss of crown height, with breakdown of enamel rim

9= unscorable

(Adapted from Smith, 1984 and Jackes, 1987)

The first scoring of wear of the occlusal surface in this study was made in the summer of 1989, for both anterior and posterior dentitions, using the methods described above. The second, third and fourth repeat scorings of wear levels were done in September 1990, November 1990, and January 1991, respectively. The same methodology was used at all times, and access to the previous observations was always proscribed so that intraobserver error could be estimated.

The variation of the angles of the occlusal surface with increased wear has been explored in more recent studies as a means for the assessment of dietary habits in skeletal populations (e.g. Jackes, 1988; Molnar, 1971). The fact that the maxillary dental arch is slightly larger than the mandibular arch accounts for the vestibular inclination of the mandibular bevels and a lingual inclination of the maxillary ones (Moorrees, 1957: 129-130). In humans and apes, lingual cusps of maxillary posterior teeth mostly contact buccal cusps and not central fossae of the lower teeth, with the exception of the third molars. This occlusal shape has been termed 'helicoidal occlusal plane' (Murphy, 1964; Osborn, 1982; Tobias, 1980). With attrition, one or more of the most distal mandibular molars retains its lingually downward inclination but mesially from there the occlusal plane shifts, helix-like, toward buccally downward inclination (Reinhardt, 1983:228).

Smith has emphasized (1974; 1984) that both agriculturalists and hunter-gatherers have abrasive diets; therefore, the amount of wear of the occlusal surface per se does not differentiate the two subsistence strategies. Taylor (1963) and Brace (1962) were among the first to suggest that food preparation, which accompanied the adoption of agriculture, would produce more oblique patterns of wear than hunter-gatherer subsistence strategies. Molnar (1972:512) argued that "... the inclination of the worn occlusal surfaces, found on the teeth of Middle Pleistocene fossils "...probably remained very similar until the Neolithic" (1972:512). Smith hypothesized that

> "An oblique wear is the 'pattern' expected from near or actual tooth-to-tooth contact in chewing. Puncture-crushing, on the other hand, should contribute to wear on the entire crown surface and lead to a flatter wear plane" (Smith, 1984: 40).

Testing this hypothesis and applying it to prehistoric research questions, Smith analyzed ten samples from hunter-gatherer and agricultural populations (1983,1984) and compared the angle of the occlusal surface on the mandibular molars of each group. The materials analyzed were exclusively skeletal and they were in the jaw. For the hunter-gatherer groups the food supplies were potentially heterogeneous but the five agriculturalist groups analyzed " ... were known to have made extensive use of grinding stones to grind some grain crop, and to have used water tight, fire-resistant containers (pottery) to cook food for long periods in water" (1984:43).

Smith used a modified protractor to measure the angle of the occlusal surface and found significant differences between hunter-gatherers and agriculturalists. The Mesolithic and Neolithic samples, which can be compared with the sample analyzed in this study, showed a significant difference in the slope of the occlusal surface. The Mesolithic values were between -5° and +10° (positive values arbitrarily indicate slopes to the buccal and negative values indicate slopes to the lingual), while those for the Neolithic ranged between -7° and +23°. The difference between the two ranges is 15° (30° - 15°), the occlusal surface showing steeper angles in the Neolithic teeth. The sample size for both groups was similar: n=13 for the Mesolithic sample and n=14 for the Neolithic (Smith, 1984:49).

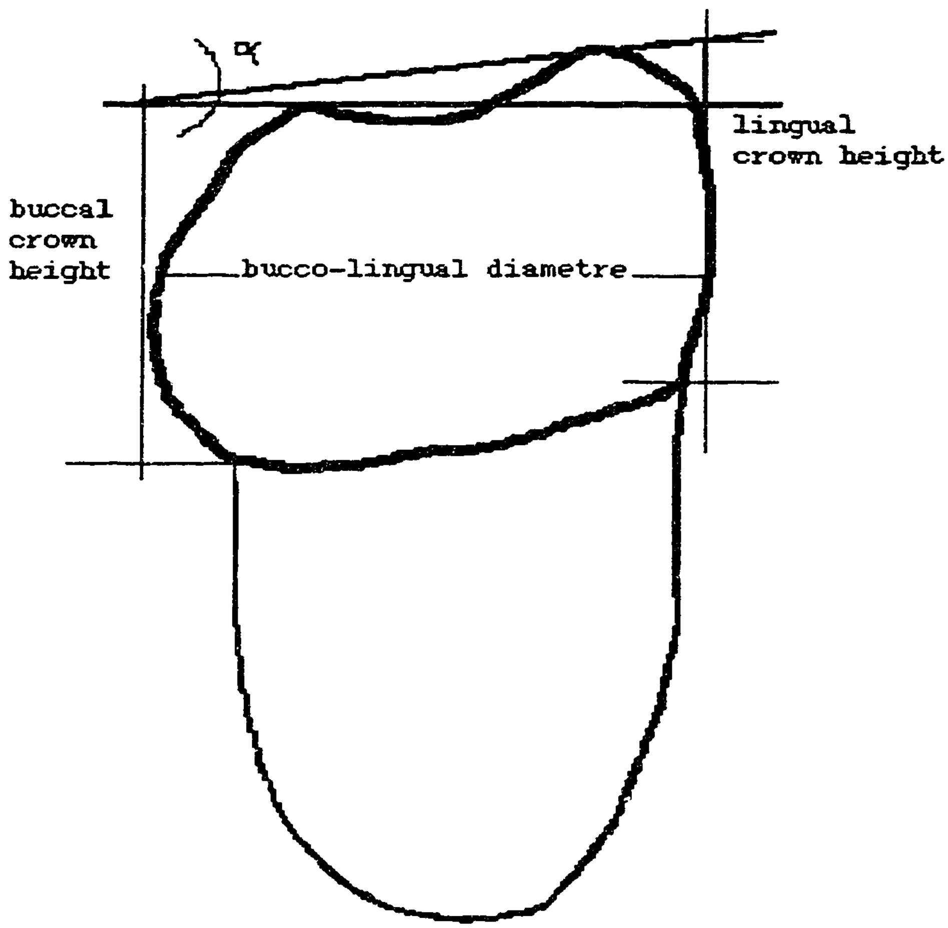
First molars erupt with a lingual orientation of the crown. This is typical of mandibular molars in general, which show increasingly severe lingual inclinations from mesial to distal molars (Dempster et al., 1963). Occlusal wear, typically concentrated on the buccal half of mandibular crowns, tends to flatten the occlusal surface angle and finally to reverse it (Smith, 1984:46). It is this principle of change of the angle of the occlusal surface throughout life that rules the analysis of its variation within a population and the inference of dietary patterns from the steepness of the occlusal angle. A heavily grinding type of diet produces a flatter wear than a diet in which food items are consistently processed before consumption. In the case of "Tojal de Vila Chã", it has been assumed by archaeologists that the population buried in the site practised agriculture, and ceramic fragments have been recovered in the burials (cf. Chapter two). The presence of grinding stones, which would suggest the consumption of ground cereals, is not reported (Heleno, 1933) but they are not expected to be found in a burial context.

The use of the modified protractor is not adaptable to the metrical observation of loose dentition; therefore, an alternative method for the quantitative analysis of the occlusal slope was employed in the present study. A similar methodology was used in the assessment of dental wear in loose mandibular molars from Neolithic skeletal samples from Portugal by Jackes (1988) based on trigonometric principles for the measurement of the slope of the occlusal surface. The same principle was used in the study of the teeth from Tojal de Vila Chã. Although the trigonometric analysis of the slope of the occlusal surface may not produce the same values as the protractor analysis of in situ dentitions, the range of the angles observed within the sample should reflect the same range in both cases if the same wear patterns are in effect. Additionally, the data obtained can be used for future analysis of other archaeological samples consisting of isolated teeth.

The method is based on the estimation of the angle of the occlusal surface of molars, through the use of trigonometric procedures. Three measurements were taken from the crown of loose mandibular and maxillary molars: buccolingual diameter, crown height at the lingual surface, and crown height at the buccal surface of the crown. Buccolingual diameter was measured perpendicular to the mesiodistal length, at the widest point (Linaza & Basabe, 1987:5), with the fixed arm of a dial caliper resting on the lingual surface and the movable arm on the buccal surface. The amount of attrition was not a constraint to the measurement of this variable for quantification of the occlusal angle. Crown heights at the buccal and lingual surfaces were measured with the fixed arm of the caliper on the tooth neck and the movable arm of the caliper at the highest point of the occlusal surface (Linaza & Basabe, 1987:5). It was noted that, as occlusal wear increases, it becomes more difficult to measure the crown height, since the enamel rim tends to break down, as described in the level 8 of the scoring method for the attribution of wear scores (see Table 3). These three measurements allow the definition of a triangle, the hypotenuse of which corresponds to the occlusal surface (Fig. 7). The angle of the occlusal surface was then determined. The steps for the calculation of the angle were as follows. Firstly, lingual crown height was subtracted from buccal crown height, in order to obtain the exact measurement of the opposite side of the angle to be analyzed. Secondly , the tangent of that angle was calculated, by dividing the opposite side by the adjacent side of the angle, which corresponds to the buccolingual diameter. Thirdly, the arctan of the angle was calculated in radians, and translated into degrees, by multiplying arctan of the angle by 180 and dividing it by Π (3.141592).

Fig.7.

Measurements used in the estimation of the angle of the occlusal surface in molars.



After the values of the angles were obtained, a regression line was plotted to estimate the relationship between the wear scores and the value of the angle of the occlusal surface. Since the purpose of this analysis was to evaluate how much the occlusal slope was dependent on wear increase, the qualitative wear scores were considered as the independent variable X, and the angle of the occlusal surface as the dependent variable Y. Pearsons' r correlation coefficient was then estimated for each group of molars separately.

Incisal/labial/lingual wear

Anterior teeth have a different masticatory function from the posterior dentition and consequently the interpretation of their wear patterns has to concentrate on different aspects from those used in the analysis of posterior teeth. Incisors are designed for cutting, and canines for tearing, while premolars and molars are responsible for the chewing activity and constitute the large grinding surface of human dentition. The fact that teeth are "...used for grasping, holding, exorting torsion, and other manipulative functions..." (Wolpoff, 1971:1), has led several researchers to the identification of the use of teeth as tools in different populations of <u>Homo sapiens sapiens</u> from the wear patterns visible on the teeth (Black, 1895; Howard & Manley, 1948; Jackes, 1988; Wolpoff, 1970,1971). Anterior dentition seems to be more relevant for the identification of occupational differences, while posterior dentition (specifically molars) is more likely to reflect dietary habits (Jackes, 1988; Lukacs & Pastor, 1988; Molnar, 1971; Wolpoff, 1971).

The presence of rounded incisal wear in Neanderthal remains was interpreted by Wallace (1975) as the result of grit in the diet. The same sample was analyzed by Brace (1967) and by Smith (1976) and the unusual wear pattern was explained as the result of the use of teeth as tools and the wear was described as "...the buccal incisal edges in the lower teeth are rounded downward and outward, whereas in the upper teeth the edges are rounded upward and outward" (Smith, 1976:167). Another explanation for the same type of wear in the Neanderthal fossil remains has been offered by the analysis of microstriations of the labial surface, as the result of scratching of the enamel by the use of flint knives for cutting, while holding the object between the anterior teeth and "... inadvertently scratching the enamel at the same time" (Castro <u>et al</u>, 1988:403).

Anterior teeth have shown particular forms of wear in distinct extinct populations supposedly due to differences in occupational use of the teeth (Alexandersen, 1988). Larsen (1985) identified the transverse grooving of the incisal-occlusal surface in the incisors and canines from a pre-contact sample from the Western Great Basin. Documentation on these populations indicated an adaptation that involved the use of plant materials in the production of a variety of utilitarian objects, such as fish nets, basketry, funerary bags, and rope. Larsen identified the type of wear recognized in the Great Basin prehistoric sample as the result of the use of anterior teeth as tools. In European prehistoric samples, a specific type of wear of the lingual surface of the incisors, which cannot be explained by functional attrition (Linaza & Basabe, 1987:7), has been identified and was designated as 'signe du cordonnier' (Lefèvre, 1973).

Anterior teeth have not been as widely used for prehistoric dietary reconstruction as the premolars and molars, because the posterior dentition is more likely to reflect the consistency of the food items than the incisors or the canines. Consequently, the discussion of methods for scoring incisor and canine wear is not as extensive in the literature. Anterior teeth have generally been scored with the same keys as the posterior dentition and it is only recently that different scales have been created for the anterior and the posterior sectors (Hinton, 1981, 1982; Molnar, 1971; Smith, 1984). However, these methods do not consider the labial and lingual surfaces in the analysis of wear, nor do they contemplate the existence of specific patterns of erosion of the incisal surface that characterize the use of anterior teeth as tools. In the analysis of the sample from Tojal de Vila Chã, it was recognized that the labial and lingual surfaces were moderately to heavily worn. Therefore a scale for the qualitative classification of wear in these surfaces was developed and used (Table 4).

Table 4

<u>Method for scoring labial and lingual wear or anterior teeth</u>

0= no wear

1= surface polished

3= wear erasing morphological features (ridges and /or cingulum)

4= wear exposing dentin

9= unscorable

Because a number of anterior teeth exhibited a rounding or chipping of the incisal-labial edge, an additional scale was used for the classification of the labio-incisal surface on the maxilary and mandibular incisors (Table 5).

Table 5

<u>Method for scoring labio-incisal wear on the incisors</u>

0= no wear

1= chipping of the labio-incisal/occlusal edge

2= blunting/rounding of the labio-incisal/occlusal edge.

9= unscorable

Interproximal wear facets

Diet assessment from the analysis of dental wear patterns in prehistoric populations has mostly concentrated on occlusal wear patterns (see Linaza & Basabe, 1987:7). However, in some instances, interproximal wear facets have also been considered (Hinton, 1982; Jackes, 1988; Scott & Turner, 1988). The mechanisms of the development of interstitial wear facets (the erosion of the contact surfaces between adjacent teeth) has been widely discussed (see Wolpoff, 1971). Metrical analysis reveals that hunter-gatherers have much wider interproximal facets than agriculturalists, when stratified by level of occlusal wear (Hinton, 1982).

In the sample from Tojal de Vila Chã, the presence of interproximal wear facets was assessed for both the mesial and the distal surfaces. The same method was applied for anterior and posterior dentition and the results were used for the assessment of rates of occlusion erosion between different teeth.

Error analysis

Intraobserver error was estimated for wear categories. Replicability of qualitative methods in the analysis of wear has been discussed in the literature. In the present sample, the different scores obtained for each tooth were compared. The readings were done by the same observer but with a large time interval between them that would allow a minimum bias in the consecutive observations and access to previous readings was proscribed at all times. Intra-observer error was estimated using the formula utilized by Patterson (1984:123), in the analysis of Pre-Iroquois and Iroquois dentition.

$$E = \frac{\sum xd}{N}$$

where xd = observed error or difference

N = total number of observations

The value obtained is a ratio that expresses the proportion of the unequal readings in relation to the total number of observations. The advantages of this method are that the results are easy to understand, and it is possible to identify specific areas where the error is more frequent (e.g. a specific set of scores for occlusal wear where inconsistencies are more common).

In this thesis, the error ratio was used to assess replicability of the method used for scoring dental wear qualitatively.

Summary

The use of loose teeth as sources of information on wear patterns and dental health in skeletal samples requires the use of different methodologies from those adopted in the study of in situ specimens. In this study, dental wear was analyzed in the anterior and posterior dentition, both in in situ and loose teeth. On the anterior dentition, labial, incisal, and lingual wear were observed and were scored qualitatively. Because of the high frequency of labio-incisal chipping and blunting on the maxillary incisors, the condition was observed and quantified separately. On the posterior dentition, both a qualitative and a quantitative methods for scoring occlusal wear were used; an adapted version of H. Smith's method (1984) for recording dental wear was used in the qualitative analysis of attrition. The angle of the occlusal surface on the molars was measured, using the method suggested by H. Smith (1984) for in situ dental samples and used for loose teeth by Jackes (1988), using trigonometry for the measurement of the slope of the occlusal surface in the molars. Interproximal wear facets were observed for their presence, on the mesial and distal surfaces of each tooth.

Pathology

Dental paleopathology is the study of the origin, nature and course of dental and jaw diseases in skeletal samples (Lukacs, 1989:261). Dental diseases can be classified into four different categories (the result of infectious, degenerative, developmental or genetic processes) according to the mechanisms that lead to their appearance (Table 6). In this section, the dental pathological lesions observed and analyzed in this study (caries, enamel hypoplasia, and hypercementosis) and the methodology utilized for their classification, are presented. Their characteristics, development and the methods that have been used by anthropologists for scoring these conditions in skeletal samples are discussed.

Table 6. Classification of dental diseases

Category	Dental disease
Infectious	Antemortem tooth loss (abscess or caries induced)
	Dental abcesses
	Dental caries
	Periodontal disease
	Pulp chamber exposure (caries induced)
Degenerative	Antemortem tooth loss (attrition induced)
	Periodontal disease
	Pulp chamber exposure (attrition induced)
	Calculus accumulation (tartar)
	Trauma
Developmental	Gross enamel hypoplasia
	Fluorosis
	Microstructural defects
	Dental crowding
	Malocclusion

	Secondary dentine deposition Hypercementosis
Genetic	Dental agenesis (hypodontia) Cleft palate Supernumerary teeth (hyperodontia) Malocclusion

(adapted from Lukacs,1989:264)

Caries

Caries is a disease of the mineralized tissues of the teeth, namely enamel, dentine, and cementum. It is caused by the action of microorganisms and fermentable carbohydrates (Kidd & Bechal, 1987:1), and is characterized by a progressive, focussed demineralization of these tissues (Mandel, 1979). Enamel, in its adult stage, is acellular, avascular, and has no nerves or vital elements. In view of the unique characteristics of the tooth it may be anticipated that dental caries does not fall into any of the well-recognized pathological classifications of diseases. The carious process cannot elicit an inflammatory reaction in the enamel; caries is obviously not a neoplasm or degenerative condition (Nikiforuk, 1985:1).

Depending on its location, caries can be classified into three categories - pit and fissure caries (on the occlusal surface of molars and premolars), smooth surface caries (on the smooth enamel surfaces or on the root), and recurrent or secondary caries (at the place of restoration) (Kidd & Bechal, 1987:8; Loesche, 1982:232; Paterson et al.,1991:11). According to the severity and rapidity of the development of the lesions, caries can be subdivided into rampant and arrested caries. Rampant caries is characterized by a rapid involvement of the whole dentition in the demineralization process and it is most commonly related to therapeutical methods, such as radiation induced in the treatment of cancer patients (Kidd & Bechal, 1987:9). This type of caries is also visible in North American populations living in non-fluoridated communities, where about 5% of the pre-adolescent population is affected by rampant caries (Nikiforuk, 1985:4). Arrested caries is more common, and it is characterized by a partially reversible demineralization process, which can be interrupted when the environmental conditions of the oral cavity (salivary, bacterial and dietary) are changed.

In epidemiological studies, the incidence of caries in a population is commonly defined by the DMF count (Dunning, 1980:309; Kidd & Bechal, 1987:9) - number of decayed teeth with untreated lesions (D), number of missing teeth (M), and number of filled teeth (F). It can be estimated considering the number of teeth involved -DMF(T) or considering the number of surfaces involved - DMF(S) and it is estimated as the average of carious lesions or teeth per individual in a given period of time (Dunning, 1980:68). In skeletal samples, the estimation of the DMF index is not always feasible because of the impossibility of identifying the mechanisms that have led to the loss of a given tooth - periodontal disease, apical abcessing, trauma. Adjustments for the estimation [illegible] index in skeletal samples has been proposed in the literature (Hardwick, 1960); a 25% antemortem tooth loss due to caries should be accepted when the caries rate is under 5%, and 33% antemortem tooth loss due to caries when the caries rate is over 20%. However, these adjustments do not take into account the age factor, and they consider the total dental sample as a whole (Patterson, 1984:74). The most accurate way of enunciating caries presence in skeletal populations is by percentage of individuals showing any evidence of caries (Dunning, 1980:308). Another constraint to the assessment of caries rate in skeletal specimens is the difficulty in identifying demineralization in the early stages of its development. However, even in living populations, the definition of a carious lesion is, according to the World Health Organization a "... cavity with a detectably soft floor and/or some undermined enamel or a breakdown in the walls of a pit or fissure" (Dunning, 1980: 308).

The carious lesion of the enamel begins with the appearance of a whitish opacity, due to the loss of hydroxyapatite from the surface (Paterson et al., 1991:63). As the lesion develops, cavitation occurs - the surface zone eventually breaks down and a cavity forms (Kidd &

Bechal, 1987:27; Paterson et al., 1991). Plaque then forms within the cavity and may be protected from cleaning aids (Kidd & Bechal, 1987:21: Paterson et al., 1991). It is only at this macroscopic stage that its diagnosis in skeletal samples is possible. Some workers recommend that caries should be scored only when demineralization has formed a distinct cavity in the tooth (e.g. Walker & Erlandson, 1987).

The unequal susceptibility of different tooth sectors to caries has been recognized and reported in the literature, both in living and in skeletal samples. There is an agreement that molars (especially mandibular) are more likely to develop carious lesions than any other teeth (Krogman, 1935; Loesche, 1982:233; Nikiforuk, 1985; Patterson, 1984:67; Turner et al., 1985). For the remaining sectors of the dentition, there is no agreement on which tooth type follows the molars in susceptibility to caries. In living populations, premolars follow the molars in the frequency of carious lesions, and the anterior dentition seems to be less vulnerable to cariogenic factors (Loesche, 1982:233). This can be due to the morphological features of the teeth (only molars and premolars have pits and fissures) or be attributed to their function in mastication (chewing) and the more prolonged exposure to food items. The position of the molars in the jaw also increases the difficulty of access in dental hygiene procedures.

Caries etiology has been extensively discussed in the literature. There is a general consensus that its development is the result of a multifactorial process (Patterson, 1984:62). In order for the disease to occur, cariogenic micro-organisms have to be lodged in a susceptible tooth, under a suitable oral environment (Patterson, 1984:62-63).

Genetic factors have been identified in the development of carious lesions. Monozygotic twins have exhibited similar caries experience, while dizygotic twins do not share the same caries incidence. This difference has been explained as the result of similarity in fissure anatomy, sweet preferences, and salivary glucoproteins between monozygotes (Loesche, 1982:239). A correlation has been identified between blood group O individuals and a high incidence of caries (Loesche, 1982:240). Smaller teeth, with simple crown morphology, have also been identified as more resistant to caries than larger teeth (Anderson et al., 1977). In spite of the identification of correlations between genetic similarities and caries incidence, other factors seem to surpass the genetic determinant in the development of the lesions, since they can better explain the epidemiology of the disease and its expansion among certain population groups.

The relationship between caries and the age of the individual has been recognized. The fact that enamel caries has a higher incidence in the first two years after the eruption of the tooth has led to the conclusion that caries is a disease of children and young adults in most populations (Patterson, 1984:68). Consistent with this idea is the fact that there is higher incidence of caries in females than in males, when the same age group is considered. The earlier eruption of teeth in females - approximately five months before the males - can be a valid explanation for this difference between the sexes (Patterson, 1984:68; Nikiforuk, 1985:35). However, the development of root caries does not follow this pattern and it is, in fact, associated with middle age and closely related to the recession of the gingivae (Patterson, 1984:65; Turner et al.,1985).

A relationship between certain geographical areas and the high rate of caries has been identified. Caries seems to be more common in high latitudes and seacoast populations (Loesche, 1982:242; Nikiforuk, 1985:35). Although the correlation exists, the cause of this higher incidence has not been well defined; it has been explained as the result of Vitamin D deficiency, due to the reduced number of hours of exposure to the sunlight in those geographical areas. However, the phenomenon can also be due to the higher population concentration in those regions and to the nature of the diet (Loesche, 1982:242). Caries frequency seems to be lower in African and Asian countries than in America and Europe (Nikiforuk, 1985:35). However, this incidence should not be explained in terms of geographical influence, but instead should be analyzed considering the economical and social context affecting the populations in those areas. In fact, caries has been associated with chronic malnutrition in Indian children, due to a decrease in salivary secretion in malnourished individuals (Johansson et al., 1992). The fluoride content of water is a geological determinant in the development of resistance to caries, as demonstrated by studies done in Colorado on tooth crystal formation in high fluoride content water (Loesche, 1982:241). Geochemical factors seem to interfere in the effects of fluorine in water, as tested in a sample of 6,500 school children in different areas of Missouri (Hildebolt et al., 1988). In the western hemisphere only those living in areas where water supplies contain significant levels of fluoride have a caries prevalence comparable to those living in the Far East (Nikiforuk, 1985:35). Food items such as seafood and tea have proved to be the principal dietary sources of fluoride ions. In fish, it is the skin and bones which contain significant amounts of fluoride (Kidd & Bechal, 1987:89). There is little if any evidence that nutrition (as opposed to diet), aside from influencing the mineralization of teeth during their development plays any significant role in caries etiology (Imfeld, 1983:1; Nikiforuk, 1985:182).

Genetic and environmental factors appear to be minor contributors to dental decay compared to the well-documented importance of dietary, bacterial and salivary factors (Loesche, 1982: 242). There is broad agreement that caries is initiated by repeated disturbances of the equilibrium of dental hydroxyapatite and the calcium and phosphate ion concentration of dental plaque. This occurs when bacterial fermentation of dietary carbohydrates causes the pH level of plaque to fall to low levels (Imfeld, 1983:192). The development of caries is therefore directly related to dietary factors. Although other elements are involved in vulnerability to caries development, diet is a major contributor. The ratio between protein and carbohydrate intake partially determines the development of cariogenic agents in the mouth. These agents are in contact with the tooth surface through plaque, the bacterial colony that develops around the cervical portion of the crown, in contact with the gingivae. If not removed, it expands along the crown, apically and occlusally.

Carbohydrates are a source of energy in the human body and they can be obtained from several food sources - e.g. fruits, sugar, milk, molasses and starch. Their inclusion in human diet prevents proteins from being used as a source of energy, and directs their function into repairing wasted tissues and producing new tissues (Ehrlich, 1987:61). The profile of protein/carbohydrate intake and the capacity of the immune response to control invading bacteria determine the development of cariogenic agents and the appearance of lesions in both crown and root. When plaque bacteria metabolize carbohydrates, they produce lactic acid as a waste product. When protein is metabolized, alkaline waste is produced. As a result, periods of acidity alternate with alkalinity. When high content sugar products are consumed, high acidity conditions are produced in the oral cavity. If acidic periods outnumber alkaline periods, mineral destruction begins under the plaque. If alkaline episodes outnumber acidic periods, extra mineral is deposited and crystallizes plaque-calculus, which develops quite extensively, when teeth are not cleaned. Dental calculus and caries tend to be mutually exclusive, due to the relationship of alkalinity/acidity conditions. The ultimate immune response to the invasion of infectious bacteria is developed by blood cells invading the infectious cells in conditions of hypersensitivity (Hillson,1979; Morita & Watanabe,1986).

The role of bacteria in the development of caries has been explored in the literature, and caries has consequently been considered an infectious and contagious disease. Streptococcus mutans, S. sanguis, and several Lactobacillus species are involved in the development of pit and fissure caries; Enterococci and Streptococci, because they produce dextrans that adhere to the surface of the enamel, are identified as being responsible for the demineralization in the smooth surface caries. Actinomyces viscosus and A. naeslundi are identified as cariogenic agents in the root caries, near the cemento-enamel junction, a type of shallow carious lesion which develops around the tooth neck or apically rather than penetrating (Patterson, 1984:63-65). Dental caries is therefore considered an infectious disease because "... bacterial organisms become concentrated on specific tooth sites in the form of an adherent gelatinous mat known as bacterial plaque" (Lukacs,1989:265).

The remineralization capacity of saliva in the control of carious lesions is determined by its high content in calcium and phosphate ions. This capacity is enhanced when the fluoride ion is present. At the time of tooth development, saliva is a determinant in the formation and mineralization processes (Niswander, 1975; Stewart & Spencer, 1976). Saliva also influences the pH level of plaque as well as the composition of plaque microorganisms (Kidd & Bechal, 1987:7). Its flow is also important in the dissolution of the sugars and bacterial components of plaque (Loesche, 1982: 242). The reduction of saliva flow, visible in patients with several metabolic disorders, is highly correlated with the development of rampant caries (Kidd & Bechal, 1987: 64).

In living populations, the determination of cariogenic agents in the diet has concentrated on the analysis of the capacity of certain food items to produce acidic conditions in the oral cavity, immediately after their consumption. Some plaque bacteria are capable of fermenting a suitable dietary carbohydrate substrate (sucrose and glucose) to produce acid, causing the plaque pH level to fall to below 5 within one to three minutes after its contact with the teeth. Repeated falls in pH in time may result in the demineralization of a susceptible site on a tooth surface (Imfeld, 1983; Kidd & Bechal, 1987). Diet has been identified as the determining factor in the reduction of caries observed in European and Japanese populations during World War II. The decline in calories, animal proteins, processed foods and sucrose consumption has been indicated as the determinant factor in this reduction (Loesche, 1982:249).

Given the importance of diet as a factor in the creation of suitable conditions for the development of caries, the frequency of the disease has been used in archaeological context as a means of identifying dietary patterns. In fact, the simple presence of the bacteria responsible for the development of the disease does not seem to be a determinant agent in the appearance of carious lesions. S. mutans is present in Guatemalan Mayans, in natives of New Guinea, in Morrocans, Tanzanians and natives living in the headwaters of the Amazon. This suggests that S. mutans has a worldwide distribution in the oral cavity, where it probably exists as a member of the supplemental plaque flora. The ascendency of S. mutans to levels where it becomes an odontopathogen presumably follows from frequent sucrose ingestion and resultantly precedes the outbreak of caries (Loesche, 1982:249).

In spite of the large number of studies performed on the identification of cariogenic elements in human diet, the understanding of the mechanisms leading to the development of the disease in prehistoric populations is limited. The study of cariogenic dietary components concentrates, in most cases, on industrially processed food items. Processed foods have been identified as cariogenic agents in studies of living subjects but their discussion is not relevant in the study of prehistoric populations. However, non-sweetened cereals, dried dates and dried raisins are food items that were probably consumed by prehistoric peoples and they have demonstrated the capacity of creating acidic conditions in the oral environment (Imfeld, 1983: 110, 181). While most fruits prove to be acidogenic, tested dried apricots and apples and fresh oranges were hypoacidogenic (Imfeld, 1983:195). In general, the presence of sucrose and or fructose in the food seems to be the major determinant, since individuals with hereditary fructose intolerance or congenital sucrose isomaltose deficiency are caries-free (Loesche, 1982:240). While plaque acidogenicity of a food item, i.e., its potential to cause low pH values in plaque, cannot be directly equated with cariogenicity, which is a clinical epidemiological finding, non-acidogenic or hypoacidogenic products can with high probability be considered non-cariogenic or hypo-cariogenic no matter how frequently they are consumed (Imfeld, 1983:195). Animal experiments have yielded conflicting results showing starch products with cariogenic levels ranging from very low (Imfeld, 1983:4) to comparable to that of glucose. Heating at temperatures used in cooking and baking causes a partial degradation of starch so it is possible that cooked starch may be capable of fermentation to acid in the mouth. This has been confirmed by plaque pH studies (Kidd & Bechal, 1987:71).

Although there are many factors related to the cariogenicity of carbohydrates, the most important factors seem to be the form and frequency of carbohydrate consumption. Foods that are thick and sticky form dextran substances, which allow a thicker more tenacious plaque to form (Bibby, 1966; Cawson, 1968). Foods that are raw and fibrous reduce the caries incidence both by their cleansing action and the stimulation of salivation (Patterson, 1984:69).

The methodologies used in the analysis of caries in skeletal populations have varied considerably; different scoring systems have been created for samples of different nature (i.e. in situ as opposed to loose teeth). Inconsistency, imprecisions and omissions in the description of scoring methods have been recognized as a barrier in the effectiveness of comparative studies (Hillson, 1979). Carious lesions in skeletal populations have been identified by exclusively macroscopical methods. Consequently, the early stages of demineralization are never diagnosed because the discoloration visible in teeth that have been subjected to burial for extended periods of time disguise the whitish opacity which characterizes the first stage of caries development.

The possible methods for quantifying carious lesions in skeletal samples are limited. Caries can be assessed by the number of carious teeth per individual, the number of carious lesions per individual, the percentage of individuals or specimens with one or more carious teeth or lesions, the percentage of carious teeth, calculated either for all the observable teeth or for specific tooth types, and the number of carious teeth and antemortem missing teeth per individual or specimen (Patterson, 1984:72). Given the nature of the sample considered in this study, the quantification of caries is limited to the percentage of carious teeth for all the scorable specimens and the number of lesions for the total number of scorable teeth per tooth sector.

The methods for scoring carious lesions in skeletal samples do not vary considerably in the literature. The most important methodological changes detected when comparing earlier reports with more recent literature are a more precise specification of the methods of analysis and quantification, as well as a definition of the severity of the lesions. There are, however, exceptions to this general trend. Turner and coworkers ascribed four different levels for scoring caries in the analysis of oral health of the Medvedev Russian Party in 1764, Alaska, without describing each of the scores - 0 to 3 (Turner et al., 1985:212). Hall & German (1975) used a method in which caries degree and location are presented - pit, real carious lesion with three different degrees of severity - but the levels are not defined. Sueiro

(1957) analyzed caries obtained from Portuguese Mesolithic shellmidden remains considering only the presence or absence of lesions on each tooth.

Most methods for classifying carious lesions concentrate on the severity of the lesion, using a qualitative scale. Metress and Conway (1975) developed a method for scoring dental caries, which defines the size of the observable lesion (pit or small fissure; less than 1/2 of the tooth crown destroyed; more than half of the crown destroyed; complete destruction, with only roots remaining); the method has been used in subsequent research (Lukacs,1989).

Other methods have concentrated on the severity of the lesion, as well as on its location. Hillson (1979:155) defined five categories for the classification of caries, according to the depth of the lesion in relation to the enamel, dentine and pulp areas. A macroscopic definition of the scores was given (1/2 the enamel depth affected; whole enamel depth affected; dentin involved in the lesion, with secondary dentin repair; no repair, exposure of pulp cavity). In addition to the definition of severity of the lesion, its location - occlusal, mesial interproximal, distal interproximal - was also defined in his method. However, the difficulty in assessing the rate of the destruction of the enamel, and in identifying secondary dentin repair creates problems for the adoption and successful use of this method. Jackes (1988) defined 9 categories for the analysis of caries in the Casa da Moura sample, a Neolithic burial site in central coastal Portugal (pit and fissure; approximal on crown; both occlusal and approximal; neck or cervical at CEJ; root below CEJ level; occlusal and cervical; shell of enamel left; root open; no crown remains). Moore & Corbett (1978) used a classification by area of incidence for the small lesions (interproximal, at cementoenamel junction or at contact area, buccal surface in the cemento enamel junction or in the fissure, occlusal surface in the fissures). Kelley and coworkers (1987) also classified caries by severity (incipient, small pit, medium, pit not extending into the pulp chamber and generally less than 2mm in diameter, gross, pit involving the pulp chamber at minimum and total crown destruction at maximum), and location (occlusal, buccal-labial, interproximal area, contact area, and cervical, unknown). Molnar & Molnar (1985) used a similar key for the scoring of carious lesions, separating occlusal from interproximal caries in the crown area, cervical and cemental lesions for the root area, and a separate category for massive lesions, with unknown origin.

From the analysis of the various methods used for scoring dental caries in skeletal populations, it is recognized that there is no consistency between investigators in the presentation of results. Some emphasize the location of the lesion (Jackes, 1988; Molnar & Molnar,1985; Moore & Corbett, 1978), while others concentrate on its severity (Hillson, 1979; Mettress & Conway, 1975). Recent methods of analysis have equally concentrated on severity and site of the carious lesions (Kelley et al., 1987). The use of terms such as pit or fissure to define the severity of a carious lesion is misleading, because of the categorization commonly given to the two types of caries (smooth surface caries and pit and fissure caries), which refer to the location of the demineralization and to the bacteria involved in the process (see discussion above). In this study, the location of the carious lesion was considered, as well as its severity, as described in Table 7. This method was used because the categories considered can be incorporated in other scoring methods presented above and therefore comparative study of the sample can be performed.

Table 7

Method for scoring dental caries

Type of carious lesion

0. absent
1. small lesion on the enamel, characterized by a small pit or line of dark color.
2. medium lesion on the enamel, with less than half of the crown destroyed.
3. large lesion on the enamel, with more than one half of the tooth crown destroyed.
4. massive lesion on the enamel, with complete destruction of the tooth crown
5. small lesion on or below the cemento-enamel junction, involving only a thin layer of the root surface
6. medium lesion on or below the cemento-enamel junction, with exposure of the pulp cavity
7. extensive lesion, with origin unlocalized.
9. unscorable

<u>Location of the carious lesion</u>
0. absent
1. mesial
2. distal
3. labial/buccal
4. lingual
5. occlusal
6. multiple lesions
7. origin unrecognizable
9. unscorable
(adapted from Lukacs, 1989:267)

The teeth were observed with an illuminated fluorescent magnifier with a 3 diopter lens and a 114 cm reach. Each tooth was considered individually. Teeth exhibiting extreme wear were considered non-carious when there was no evidence of demineralization. It is possible that the lesion might have existed and that it might have been erased by attrition but demineralization is not possible to assess after the surface is worn down. Whenever the identification of a carious lesion was dubious, due to postmortem erosion of the tooth surface the score 9 (unscorable) was given to the tooth. In the final quantification of caries in the present sample, all the results refer to the total number of the observable teeth for caries. When a tooth was broken or severely damaged, a score of 9 was attributed for caries presence, since it is not certain that a lesion was present or absent before breakage occurred after death.

Enamel hypoplasia

Dental enamel is an almost purely crystalline structure which arises as a product of cellular activity and covers the external surface of the tooth crown. In humans, its formation is the result of three processes occurring simultaneously within a single tooth germ: the formation of an enamel matrix and its initial mineralization, the resorption of this matrix, and the secondary mineralization or maturation of the crystalline structure. The initial product of the ameloblasts is the enamel matrix. Tooth enamel is the mineralized and matured end-product (Schroeder, 1991:38). After it is formed, enamel does not repair itself if subjected to trauma or erosion.

Enamel is formed in layers. The sequential phases of development produce appositional lines that can still be easily recognized after tooth formation is completed (Schroeder, 1991:25). In almost every human tooth a few structural defects that arise naturally during enamel formation are visible. A reduction in enamel tissue resulting from an undetermined metabolic injury to the formative cells - the ameloblasts - characterize the enamel defects (Nikiforuk, 1985: 186). Among these are enamel spindles and the neonatal line (Schroeder, 1991: 71). Enamel spindles are dark, club-shaped forms of various lengths which extend into the enamel from the dentin-enamel junction (Schroeder, 1991:71). The neonatal line occurs in all deciduous teeth and it can also be visible in the mesial cusps of permanent first molars. It marks the boundaries between prenatal and postnatal enamel and dentin. This line represents a widened incremental line of Retzius (the normal appositional lines that characterize tooth development) and shows a zone that is frequently hypomineralized but more seldom hypermineralized. It is considered to be the result of the metabolic disturbance caused by birth (Schroeder, 1991: 71)._Enamel cracks constitute a different type of enamel defect, which is not the result of metabolic disturbances but rather the product of rapid temperature changes and pressure changes (Schroeder, 1991: 71).

Enamel hypoplasia is a developmental anomaly, consisting of a disruption in the rhythm of tooth growth. This disruption creates scars on the enamel, operationally defined as a deficiency in thickness on the tooth crown, manifested by circumferential lines, bands or pittings (Goodman et al., 1980; Sarnat & Schour,1941), which after eruption acquire a yellow-brown stain (Nikiforuk, 1985: 187). Several forms of hypoplastic defects can be visible on the tooth surfaces and have been unequally reported in the anthropological literature. The most commonly analyzed form of hypoplastic defect is the linear enamel hypoplasia (LEH), characterized by lines parallel to the cementoenamel junction that run circumferentially around the crown of the tooth. However, pitting has also been observed and reported by some researchers (e.g. Lukacs, 1989; Y'Edynak, 1989). Pitting is characterized by the pinpoint indentations on the surface of the enamel, commonly occurring on the labial/buccal tooth surface. A different type of enamel defect has recently been identified by some researchers and it is characterized by the appearance of a circular enamel defect (localized defect) in deciduous teeth exclusively (Lukacs, 1991; Skinner, 1986, 1989).

Stress has been studied in a variety of anthropological contexts. Broadly defined, it can be considered as the friction between an individual and his social, physical, nutritional, and disease environment (Scott et al., 1990). Stress factors are assumed to elicit a physiological response for adaptive activity in the body. Although the stress response is initially adaptive, exposure to severe chronic or acute conditions overloads the body's ability to adapt continually and successfully to the proximate and causative stressors, thereby leading to a detrimental biological response (Scott et al., 1990). Physiological disruptions in the hard tissues are a result of a rerouting of essential nutrients from growth processes to maintenance functions in response to disease or dietary stress (Cohen and Hansen, 1962). A number of anomalies resulting from stress episodes have been identified in the human skeleton such as decreased stature, enamel defects, Harris lines (the transverse line densities in the metaphyseal ends of long bones), reduced vertebral neural canal dimensions, and growth retardation in general (see Scott et al., 1990 for review of the literature).

Unlike bones, dental enamel does not remodel when affected by trauma. Therefore, the assessment of stress episodes on the tooth is potentially more accurate than from bone specimens, since the hypoplastic defects can only be erased by heavy attrition or cariogenic factors (Goodman & Rose, 1990:59; Hutchinson & Larsen, 1990: 51). Enamel deposition begins at the occlusal tip of the tooth crown and occurs in a wavelike pattern that proceeds toward the cementoenamel junction at approximately 4 microns per day (Bhaskar, 1986). Because of the high degree of accuracy of age estimation from tooth eruption sequences, the age at which dental enamel defects occurred has been identified in many archaeological skeletal specimens (Lukacs, 1989; Scott et al., 1990), as a means of identifying the time of stress episodes occurring in prehistoric populations.

Although the specific biochemical determinant of enamel hypoplasia has not been definitely elucidated, recent evidence suggests that it is linked specifically to defects in the homeostasis of calcium (Nikiforuk & Fraser, 1981). The development of macroscopically visible growth arrest lines on the enamel surface (LEH) has been attributed to metabolic disturbances (e.g. gastrointestinal disorders), to infectious diseases (e.g. syphilis and tuberculosis), high fever, alloxan diabetes, hypocalcemia, and trauma (Hillson, 1979; Hutchinson & Larsen,1990). Many authors have suggested the action of malnutrition and infection as the most probable causative factors of the defect (see Nikiforuk,1985). The incidence of hypoplasia has been shown to be higher when Vitamin D deficiency occurs (Hillson, 1979) or in the presence of hereditary dependency rickets, hypoparathyroidism, and a wide spectrum of perinatal disorders (Lukacs, 1989; Nikiforuk, 1985:187; Y'Edynak,1989). They have been studied as an indicator of childhood stress, which includes nutritional deficiency and disease (Alexandersen, 1988; Fornaciari et al., 1985; Hutchinson & Larsen, 1990). Their correlation with known stressors has been reported as high by some researchers (Goodman et al.: 1980, 1984, 1987; Rose et al., 1985).

Some scholars have emphasized that linear hypoplasias can be caused by many factors and cannot be taken as indicative of lack of nutritional success per se. Hypoplasias can vary within the individual; they can be genetically controlled; they can be due to personal stress level, rather than to a socially shared pattern of nutrition; toxic substances can create hypoplasias; injuries to the tooth or pulp of a deciduous tooth can cause hypoplasia of a permanent tooth; childhood diseases causing high fever can also be responsible for its appearance; hypocalcification can also mimic hypoplastic decalcification (Neiburger et al., 1990: 231-232).

Hillson (1986) has provided a discussion of enamel formation, pointing out that hypoplasias are an exaggeration of perikymata and the mechanisms through which they are formed. While the enamel prisms, Retzius striae and Wilson bands might be more sensitive to metabolic disturbances, the possibilities of analyzing these features are limited, and involve destruction of the tooth specimens because they involve the microscopic observation of thin sections (Hutchinson & Larsen, 1990). Enamel hypoplasias, on the contrary, are macroscopically visible defects and can therefore be more easily observed in skeletal specimens, with no destruction required.

A recently developed model for the formation of enamel defects (Goodman & Rose, 1990) combines three groups of factors as involved in the appearance of linear enamel hypoplasias; the susceptability factors can be genetically controled and can weaken the ameloblasts, potentially contributing for the development of enamel defects; the nutritional factors, involved in an inneficient utilization and availability of nutrient resources, are likely to have an effect on ameloblastic disruption; and finally the illness history of the individual is foreseen as the decisive factor in the disruption of ameloblastic activity to the threshold line. The combination of the three types of factors contributes to the formation of enamel defects. According to this model, the age of the individual is also important, since the susceptability of enamel to ameloblastic disruption is higher at the middle third of crown formation (Goodman & Rose, 1990: 75).

In spite of the diversity of factors suggested as responsible for the development of linear enamel hypoplasias, they are frequently assessed by anthropologists analyzing prehistoric dental remains. Although the presence of hypoplastic defects is not diagnostic of dietary patterns, it suggests a stress episode in the life of the child, at the moment the tooth was developing. Anthropological research on enamel defects has followed different motivations, since the publication of the first comprehensive essay on ameloblastic disruption, published by Sarnat and Schour (1941). Prehistoric enamel first was the object of interest of some researchers who wanted to test the hypothesis that enamel had been stronger in human past than it is in modern times (see Goodman & Rose, 1990 for review of literature). Relationships between the presence of hypoplastic defects and given dietary strategies have been pursued as a difference between prehistoric populations. It has been proposed that a cereal diet during prenatal development, lactation, and weaning (e.g. oats), which is deficient in Vitamin D, can cause hypoplasias (Hillson, 1979; Y'Edynak, 1989). A number of recent reports analyze the difference in frequency of enamel defects between pre-agricultural and agricultural populations (see Goodman & Rose for review; also Hutchinson & Larsen, 1990). The results seem to indicate that there is an increase of linear enamel hypoplasias in agricultural samples. Some exceptions to this trend have been reported and seem to contradict the generalized view that chronic stress and endemic disease exposure increased with the introduction of agriculture. Alexandersen (1988) analyzed Mesolithic and Neolithic dentitions from Denmark and found a lower frequency of linear hypoplasias in the latter samples. It is suggested that the Mesolithic higher percentage of hypoplastic teeth was due to intestinal parasites from fish caught in the lagoons (Alexandersen, 1988: 201).

Although nutritional factors might not be the single contributors to the development of enamel defects, recent research in dentistry has associated the presence of hypoplastic lesions with low nutritional status of some school children in Australia, Nigeria, Mexico, and South Africa (see Goodman & Rose, 1990) and Tanzania (Matee et al., 1992).

Association of enamel defects with rampant caries has been tested in children from Tanzania. Whether linear hypoplasia makes teeth more susceptible to caries remains to be answered, but there seems to be a positive correlation between caries and hypoplastic teeth in the anterior deciduous dentition observed in Tanzanian children (Matee et al., 1992).

Goodman and Armelagos (1985) have shown that anterior teeth are frequently more hypoplastic than posterior teeth (also Y'Edynak, 1989). Most studies concentrate on the mandibular canine for the analysis of developmental defects on the enamel (Hutchinson & Larsen, 1990:51). Given these conditions - the predominant occurrence of linear enamel hypoplasias in certain tooth sectors and its macroscopic visibility - the methods for scoring enamel hypoplasia have mostly concentrated on the canines, and magnification is not always used for its diagnosis. In some teeth (when observed under a magnifying glass), rings of growth can be recognized and it is difficult to assess when a recognizable ring is to be considered a defect. Goodman et al. (1984: 26) have emphasized that "... there is no standard definition of the minimum requirement for scoring a hypoplasia".

The most commonly used method of detection and analysis involves the recording of identified defects on a single tooth, usually the canine (Goodman et al.,1984:26). In most cases, the defect observed is the linear enamel hypoplasia. The age at which the stress episode occurred is usually determined by the measurement of its distance from the cemento enamel junction (Lukacs,1989:267) or by its relative position on the crown (Goodman et al.,1984:26). A macroscopic identification of the different degrees of enamel hypoplasia was developed by Hillson (1979:155). The tooth crown was divided into five different horizontal sectors and the location of the defect was established in relation to the five sections.

Because of the diverse nature of hypoplastic defects (different manifestations of supposedly the same metabolic disturbance), a need has been recognized for the specification of the type of enamel defect, in addition to the assessment of presence/absence of the condition. Y'Edynak (1989) used a scale of 5 degrees to classify the presence of enamel hypoplasias, according to the number of lines present (none, one or two lines with pitting, two to four lines with pitting over most of the tooth, deep grooves). The use of an exclusively combined category for pitting and multiple lines makes the method difficult to apply, since pitting can occur independently of the linear type of hypoplasia. Jackes (1988) defined seven different categories (absent, slight or single line; lines of pits; lines and pits; circular defect; slight pits; unusual). The occurrence of a circular enamel hypoplastic defect on the deciduous canines has been identified in prehistoric samples from Portugal (Casa da Moura), Upper Paleolithic Europe and in Mediaeval Danes and has been interpreted as the result of "... trauma inflicted by children in the mouth" (Skinner, 1989: 173), while the tooth is forming, when calcium deficiency provokes a weakness of the cortical bone over the canine crypt (Meiklejohn et al., n/d; Skinner, 1983; 1986; Skinner & Hung, 1986, 1989). Other researchers interpret the occurrence of circular enamel hypoplasia as the result of genetic mechanisms (Jorgensen, 1956) possibly related with trauma caused by pressure on the tooth while in the crypt (Jackes, personal communication, in comments to Meiklejohn et al., n/d). Lukacs (1991) analyzed a sample of 113 schoolchildren from Harappa (Pakistan) and found no association between the presence of localized enamel defects and the social status of the children's families, nor with decreased stature. He concluded that the etiology of the localized defects is different from that of the linear hypoplasia (Lukacs, 1991: 521).

In the present study, the frequency of enamel defects was recorded considering two variables: the type of enamel defect (either line or pit) and the number of defects visible on the tooth surface, following a modified version of the method suggested by J.R.Lukacs (1989: 267), as shown in Table 8. All the teeth were observed using an illuminated fluorescent magnifier with a 3 diopter lens and a 114 cm reach. When an enamel defect was detected, its distance from the cemento-enamel was measured with a dial caliper, with a precision of 0.05 mm, as described by J.R. Lukacs (1989). When more than one defect was diagnosed, the distance to the cementoenamel junction was measured for the most occlusal and the most cervical, respectively. The age at which the growth arrest occurred was then estimated, using the tables developed by Massler and coworkers (Massler et al., 1941).

Table 8

Method for scoring enamel hypoplasia

Classification of the presence of enamel defects

0. no defects present
1. line or lines are present
2. pit or pits are present
3. lines and pits present.
9. unscorable

Classification of frequency of enamel defects

0. no defects present
1/6 . defines the number of defects visible
7. multiple lines present, where counting is not viable.
8. multiple pits present, where counting is not viable.

There are potential sources of error in the method used in this study. The presence of wear on the occlusal surface can eliminate hypoplastic defects, even in early wear stages when the occlusal tips of the cusps are worn down. As a consequence, the absence of early stress episodes might be incorrectly inferred from the observation of teeth that have suffered surface erosion (Scott et al., 1990:76). However, an exclusion of all of the specimens that exhibit an amount of wear greater than 2 would greatly reduce the sample and therefore, in the present study, only the teeth that were partially destroyed by breakage were excluded in the assessment of the presence of hypoplastic defects. The remaining teeth were considered as scorable.

Hypercementosis

Cementum is a mineralized, non-homogeneous connective tissue that covers the roots of the teeth. It anchors the collagen fibre bundles of the periapical ligament to the root surface. It carries out an adaptive and reparative process. It is not a uniform tissue (there are four different types of cementum) but it is different from bone in that it is not vascularized (Schroeder, 1991: 145-146).

Hypercementosis is described as the abnormal development of tissue in the roots of teeth, with extreme thickening of the cementum. It is also referred to as cemental hyperplasia (Schroeder, 1991:161). It can occur localized on certain areas of individual teeth, generalized over the apical portion of the entire root surface, or generalized over several or all the teeth of an individual (Schroeder, 1991:161).

Hypercementosis is caused by an over production of cementum. It occurs with developmental disturbances on retained teeth, resulting in the deformed roots or root tips. It can also occur in association with tooth movement, and with chronic periapical inflammation, in which case it results in the surplus deposition of cementum layers on the apical third of the root (Schroeder, 1991:162). It has also been associated with severe attrition by Comuzzie & Steele (1989), in a sample of teeth from prehistoric coastal populations in Texas where the roots were included in the occlusion process and exhibited cemental hyperplasia when the enamel surface was totally worn down,. Although the specimens analyzed were in situ, the roots were exposed either by abcesses or by dehiscence of the buccal alveolar border, "...causing the hypercementosis to be readily apparent" (Commuzie & Steele, 1989:13).

It is recognized that the majority of dental studies in skeletal samples are based on the observation of in situ specimens - as discussed in the beginning of the present chapter - hypercementosis is rarely reported in the anthropological literature. As a consequence, the methods for scoring the condition have not overcome the assessment of presence or absence, possibly due to the rare possibility of assessing the condition when the teeth are implanted in the jaws. Most researchers have used a binomial method of scoring (e.g. Commuzie & Steele, 1989; Jackes,1988).

Since the sample analyzed in this study is composed of 83% loose teeth - the diagnosis of hypercementosis was facilitated. Its relevance for comparative purposes is not well defined, since it is rarely reported in archaeological specimens. However, the relationship of hypercementosis with periapical abcessing and lesions of the alveolar border, might provide indirect information on the presence of such conditions, when loose teeth are observed. In fact, periapical abcessing is only observable in extreme cases, or through X-ray analysis, when complete jaws are studied. But they are located at the apex of the dental root and the inflammation is diagnosable on the root apex. In the present study, hypercementosis was scored for three different levels: absent, present, unscorable. A tooth was considered unscorable whenever the root was broken or sufficiently damaged for the condition not to be clearly diagnosed.

Summary

The analysis of dental health indicators in prehistoric teeth has been widely used for the identification of specific dietary patterns. Although there is controversy about the use of these indicators for characterization of prehistoric diets, the analysis of regional patterns can overcome some of the inconsistencies in this characterization. The most widely used lesions of the teeth in skeletal analysis (carious demineralization, enamel hypoplasias) were observed in the present sample following methods that have been discussed in the literature and that seemed appropriate to the observation of both in situ and loose teeth. Given the nature of the sample (mostly loose teeth) and the possibility of observation of the root apex in most specimens, hypercementosis was observed and quantified. Its relationship with certain dietary habits has not been defined and the condition has not been widely discussed in the literature. However, its association with alveolar recession and severe attrition in some prehistoric samples indicate that a relationship between food habits and cemental hyperplasia can be identified. Calculus was recorded for the loose teeth in spite of the unknown storage conditions of the sample.

CHAPTER FIVE

RESULTS AND DISCUSSION: WEAR PATTERNS AND PATHOLOGICAL CONDITIONS OF THE LOOSE TEETH FROM TOJAL DE VILA CHÃ AND THEIR SIGNIFICANCE IN THE ASSESSMENT OF PREHISTORIC DIETARY STRATEGIES

The abundance of loose teeth in Neolithic burial sites in Estremadura and the large number present in Tojal de Vila Chã justified a more detailed analysis of the isolated specimens than of the in situ dentition in the present study. However, occlusal wear was observed in some maxillary and mandibular jaw fragments for comparison with the loose teeth. In this chapter the results of the analysis of wear and pathological lesions in both loose and in situ teeth are presented and their utility as dietary indicators in this geographical region is discussed. The adequacy of the methods utilized in this thesis for the observation and analysis of the present sample is analyzed. The results obtained are presented separately for in situ and loose teeth. The use of samples of this nature for prehistoric dietary reconstruction is discussed and evaluated.

Attritional status of the in situ teeth

Analysis of dental wear provides information on the level of use of the tooth surfaces in a given sample of individuals, at the time of their death. The levels observed are the result of a combination of factors which include age, diet, individual biomechanics, dental health and morphology. When loose teeth are analyzed, little more than the general pattern of erosion present on each tooth at the time of death of its bearer can be assessed, and inferences taken from the data rely solely on quantification and identification of general patterns. Observation of in situ teeth can extend the level of analysis to the relative wear of the different sectors of the dentition in relation to one another and preferably in relation to the age and sex of the individual. In the case of Tojal de Vila Chã, as explained in the previous chapter, the reduced number of in situ teeth and their isolation from the cranial or postcranial skeletal parts limit the possibilities of analysis and reduce the amount of information that could otherwise be obtained. The number of in situ teeth is low for the anterior sector (cf. Table 2) and no additional information can be obtained from their analysis that is not provided by the loose teeth. However, the observation of molars that are still in the jaws can reveal relative wear of teeth that are adjacent to one another. Because information on rates of attrition is available for human skeletal samples of the Mesolithic and the Neolithic in Portugal, it is possible to compare them with the teeth from Tojal de Vila Chã and incorporate the site in a broader picture of the beginning of agriculture in the Portuguese Estremadura.

A diet consisting of tougher food items is expected to create more pronounced wear facets than one based on soft foods; the consistency of the diet is not only dependent on the nature of the items consumed but also on the food processing techniques utilized. The wear facets not only become larger and deeper with abrasive diets, but they also develop at a faster rate than with the consumption of soft foods. Hence the amount of wear visible on one tooth when its adjacent is at eruption stage (e.g. the first and second molars) can be used for comparison of toughness of diets. The in situ dentition of Tojal de Vila Chã was used to evaluate rates of attrition and relative wear in the molar sector. Jackes and Meiklejohn (1992) recently established a comparison between the wear scores of in situ molars from Mesolithic and Neolithic sites in Estremadura. Mesolithic mandibular first molars showed a high amount of wear (stage 3) in the occlusal surface when the second molar was just erupting. The number of jaw fragments with the three molars still in situ is minimal in the present sample, given the fragmentary state of the bones. However, from the total number of mandibular teeth still in the jaw, it was possible to isolate 8 bone fragments in which there were first molars adjacent to second mandibular molars that had no wear on the occlusal surface; all second molars were fully erupted but exhibited no wear on the occlusal surface. From the selected fragments, 6 (75%) exhibited level 1 of attrition on the occlusal surface of the first molar (occlusal surface polished; small wear facets visible, but cusps still present; no dentine exposure). One first molar showed a level 2 of attrition (moderate cusp removal, in some cusps; pinpoint dentine exposure can occur; cusps usually removed on the buccal side). One single first molar exhibited level 3 of attrition (full cusp removal and/or some dentine exposure, pinpoint to moderate; fissure pattern still present, but not clear). Although the sample size of the observed teeth is small, the wear rate is lower than that identified by Jackes in the Mesolithic, where the first molars exhibited a mean wear level 3 when the second molar was at eruption.

Analysis of the amount of wear on the surface of the first mandibular molar when the third molar is at eruption, revealed a less severe wear in Tojal de Vila Chã than in the Mesolithic samples analyzed by Jackes and Meiklejohn (1992). Although the number of mandibular fragments with the three molars is low, it was possible to compare the wear of first molar with an erupting third molar in 6 jaw fragments. All the first molars exhibited a level 3 at the moment of eruption of the third molar (100%), which is in agreement with the results obtained by Jackes and Meiklejohn (1992) for the Neolithic samples and differs from the Mesolithic teeth they analyzed, in which a wear stage 4 was more common for the first molar, when the third molar was at eruption. In 8 specimens, it was possible to identify the wear stage of the second molar, when the third was erupting; 4 specimens showed a wear level 2 in the second molar, and 4 exhibited a wear level 1. Analysis of the correlation between the wear scores of the first and second molars showed a value of $r=0.8$, with $y=.861x - .822$, suggesting that the amount of wear in the second molar is significantly dependent on the wear of the first molar and that it represents a time sequence of eruption.

The dependency of the occlusal wear of the mandibular second molars on the advancing erosion of the mandibular first molar solely means that dental wear is age dependent and the different times of eruption of the three molars determine the length of time the teeth are exposed to the abrasive and attritional mechanisms. However, comparison of the degree of this dependency between samples of diverse prehistoric contexts demonstrates that the rates of attrition are not dependent only on age and that diet or food processing techniques are important contributors to the development of different rhythms of dental erosion. In the case of Tojal de Vila Chã, and in spite of the reduced number of specimens available for the analysis of wear in adjacent molars, the results indicate that the sample can be incorporated in the Neolithic pattern; the dietary strategies that created the wear patterns analyzed by Jackes and Meiklejohn in sites characterized as Early and Middle Neolithic were maintained in the later periods of the Neolithic and into the Chalcolithic, if one accepts the culture historical characterization of Prehistory and conceives those periods as chronologically consecutive.

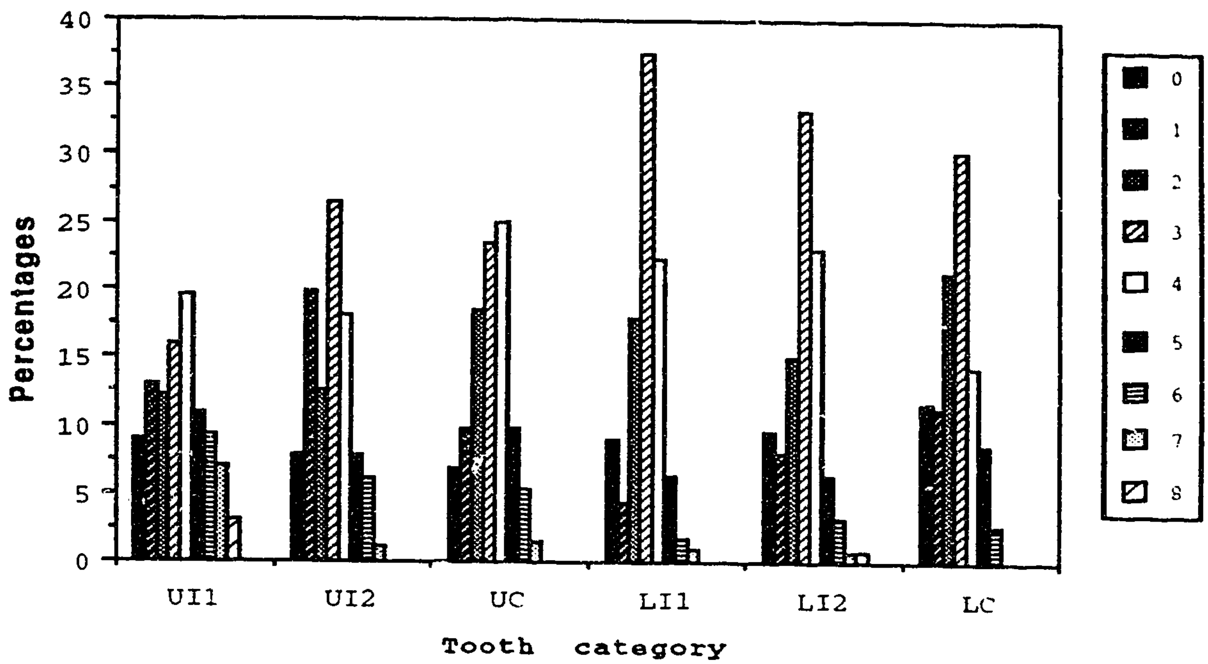
Attritional status of the loose teeth

The permanent loose dentition from Grutas Artificiais do Tojal de Vila Chã was scored for occlusal wear, following the methods described in chapter four. Since different methods were used for the analysis of wear on the anterior and on the posterior teeth (cf. chapter four) the results obtained for each of the two dental sectors are presented separately.

Anterior dentition/ occlusal wear

The anterior dentition did not exhibit homogeneous levels of attrition between different teeth but it can be generally characterized by slight wear of the occlusal surface, with cumulative frequencies concentrating on the lower levels of wear: more than 50% of the anterior teeth were scored below level 5 (Fig. 8). Although the majority of the anterior teeth exhibited a score 3 as a mode, there were two exceptions: the maxillary central incisors and the maxillary canines; both showed a higher frequency of level 4 as a mode on the incisal surface (moderate dentine exposure no longer resembling a line, but crown height still more than half), while maxillary lateral incisors, mandibular central incisors, mandibular lateral incisors, and mandibular canines showed a higher frequency of level 3 (dentine line of distinct thickness but still a line).

Fig.8. Occlusal wear on the loose anterior teeth



Although this difference is not significant, the results suggest a more intense use of the most protruding teeth in the anterior sector (the maxillary central incisors and the maxillary canines). Coherent with this observation is the fact that many of the maxillary central incisors and canines show chipping and/or blunting of the labio-incisal edge (cf. next sections), which might be interpreted as being related to the level of incisal wear observed and be due to more intense pressure on these teeth than on the less prominent maxillary lateral incisors.

A large majority of the maxillary central incisors was scorable for occlusal wear (95.9%). Of the 256 observed teeth, the results show that 69.5% had wear equal or lower than level 4 and the most common score attributed to their incisal wear was 4 (Fig. 8 and Table 9).

Table 9. Occlusal wear on the anterior dentition

		Wear scores distribution in percentages								
Tooth	**n=**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
UI1	256	9.0	12.9	12.1	16.0	19.5	10.9	9.4	7.0	3.1
UI2	166	7.8	19.9	12.7	26.5	18.1	7.8	6.0	1.2	0.0
UC	205	6.8	9.8	18.5	23.4	24.9	9.8	5.4	1.5	0.0
LI1	112	8.9	4.5	17.9	37.5	22.3	6.3	1.8	0.9	0.0
LI2	126	9.5	7.9	15.1	33.3	23.0	6.4	3.2	0.8	0.8
LC	188	11.7	11.2	21.3	30.3	14.4	8.5	2.7	0.0	0.0

Heavy attrition (levels 7 and 8) was only present in a small portion of the central incisors (26 teeth) (Fig. 8 and Table 9). Maxillary lateral incisors were scorable in 92.7% of the cases (166 teeth). The number of specimens with heavier wear is lower than in the central incisors, since 84.9% of the maxillary lateral incisors was attributed a score of 4 or lower (Fig. 8 and Table 9) and the dominant score was 3; however, the higher levels were as infrequent as in the central incisors. Maxillary canines were scorable for occlusal wear in 92.3% of the cases and showed a higher frequency of occlusal wear 4 like the maxillary central incisors, and the majority exhibits an occlusal wear level of 4 or less (83.4%). Teeth with heavy wear on the occlusal surface are not abundant (Fig. 8 and Table 9).

In the mandibular sector, 97.4% of the central incisors were observable for incisal wear. The most frequent score observed was 3 and 91.1% of the teeth exhibited level 4 or less of incisal wear and higher scores of wear were rare (Fig. 8 and Table 9). Mandibular lateral incisors were scorable for incisal wear in 97.7% of the cases. The mode for the mandibular lateral incisors was 3 and the majority of the teeth showed a wear level of 4 or less and only 14 specimens showed higher levels of attrition. Mandibular canines were scored for occlusal wear in 96.4% of the cases. The mode of wear on the occlusal surface was 3 and the majority of the teeth had wear levels lower or equal to that level. Only a few specimens (21) showed higher scores, and only at levels 5 and 6.

Although incisors and canines are infrequently observed in studies of dental wear patterns in prehistoric samples, some anthropologists have stated that anterior teeth wear down more heavily in hunter-gatherer populations than in agriculturalists (Molnar, 1971; Scott & Turner, 1988). Hinton (1981) examined a group of skeletal samples from different archaeological contexts and concluded that in hunter-gatherer populations the anterior dentition exhibited higher means of occlusal wear than the posterior dentition. The method of analysis used by Hinton is based on an eight score classification, similar to the one employed in the present study. Although the difference in scores between the posterior and anterior dentition was not the same for all the teeth, Hinton found a constant of heavier wear on the anterior dentition of hunter-gatherers and milder wear on the anterior teeth of agriculturalists. Hinton compared the score of the second molar with that of the canine for each jaw, and the score of the first molar with that of the central incisor, because they erupt simultaneously (or quasi); the anterior teeth consistently exhibited higher scores in the hunter-gatherer samples.

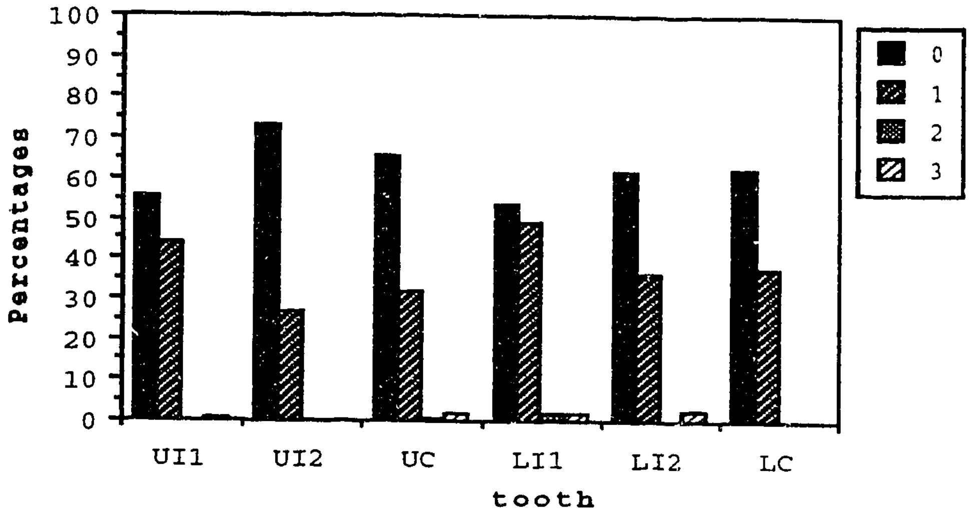
In Tojal de Vila Chã it is not possible to associate teeth with individuals, and the number of jaw fragments in which one of the two pairs of teeth (central incisor and first molar, or canine and second molar) were present is reduced (10 for the first pair and 7 for the second). When the wear levels are compared, the first molar exhibits higher scores than the central incisor in 6 cases (57.1%); in three cases, the wear scores are the same (42.9%). The second molar exhibited higher wear scores than the canine in four cases (40%); in four jaw fragments the canine exhibited a higher score (40%) and in two jaw fragments the scores were the same (20%). The data do not seem to be conclusive from the analysis of the observable <u>in situ</u> teeth that were observable. However, if the subsample of loose teeth is considered as a whole, and representative of the same individuals in the anterior and posterior dentition, the values obtained can be compared with the results presented by Hinton (1981).

Comparison of frequencies of wear scores between the maxillary central incisors and the mandibular first molars suggests that the anterior dentition of Tojal de Vila Chã has a more pronounced wear than the posterior dentition; the maxillary central incisors exhibit levels of wear that are similar to those visible in the maxillary first molars, and the maxillary canines exhibit higher scores than the maxillary second molars. However, since individuals cannot be identified from loose teeth, it is impossible to determine relationships between incisors and molars, or canines and molars. The only conclusion that can be drawn from the analysis of the loose teeth is that, overall, in the sample from Tojal de Vila Chã, the anterior dentition, and more specifically the maxillary central incisors and the maxillary canines, exhibit levels of wear that are similar or higher than those of the molars that erupted at the same time. If future analysis of in situ dentitions with a similar archaeological provenience (Neolithic/Chalcolithic) will be undertaken, further evidence of the relative wear of anterior and posterior teeth can be provided. In the present sample the heavier wear observed on the anterior teeth is due to the more intense utilization of the maxillary central incisors and maxillary canines, which exhibit a pronounced attrition, when compared to other teeth. The analysis of labial and labio-incisal wear, following, confirms these results.

Anterior dentition/ Labial wear

Anterior dentition was scored for labial wear, following the methods described in chapter four. Maxillary and mandibular central incisors showed the highest frequency of labial wear. While labial erosion is expected to be found in the mandibular incisors (since the labial surface is in contact with the lingual side of the maxillary incisors in normal occlusion) its high frequency in the maxillary central incisors is not a result of the regular cutting function of this tooth sector and it must be related to an intensive use of the teeth as tools. In the maxillary teeth labial wear was more frequent in the central incisors and canines (Fig. 9) and was also present in the lateral incisors.

Fig.9. Labial wear on anterior dentition



In the mandibular teeth, labial wear was more frequent in the central incisors and also occurred in the canines and lateral incisors (Fig. 9). The distribution of labial wear in the anterior teeth accompanies the values obtained for wear of the occlusal surface (higher incidence in maxillary central incisors and canines) which suggests an utilization of these teeth that would involve pressure on the incisal edge and on the labial surface.

In the maxillary central incisors, 91.0 % of the teeth were scorable for labial wear (Table 10). Most teeth did not exhibit any labial wear but there was some degree of polishing on the labial surface, not as intense as to delete any morphological features. However, in two of the specimens the labial wear was so intense that dentine was exposed (Fig. 9) on the surface of the tooth (Plate 4); the same type of wear was observed on 5 maxillary canines (Plate 5). In the maxillary lateral incisors, 91.1 % were scorable for labial wear (163 teeth). Only slight polishing of the labial surface was observed in some teeth. Labial wear was scorable in 89.2% of the maxillary canines (198 teeth); predominantly, they presented no wear on the labial surface; however, some teeth showed slight polishing or scratching. Heavier wear was identified in only 5 specimens (2.6%), in which there was dentine exposure.

Table 10. Labial wear on the anterior dentition

Wear scores distribution in percentages

Tooth	n=	0	1	2	3
UI1	243	55.1	44.0	0.0	0.8
UI2	163	73.0	27.0	0.0	0.0
UC	198	65.7	31.8	0.5	2.0
LI1	112	53.6	48.9	1.8	1.8
LI2	122	61.5	36.1	0.0	2.5
LC	116	62.7	37.3	0.0	0.0

Although the mechanisms that create the wear on the labial surface of the mandibular teeth are different from those responsible for the wear visible on the maxillary incisors and canines both groups were observed. The <u>mandibular central incisors</u> were scored for labial wear in 97.4% of the cases (112 teeth). The majority showed no labial wear (Fig.9 and Table 10) but in 48 specimens slight polishing of the labial surface was observed. Only 4 specimens showed a higher level of wear (3.6%), with dentine exposure, which can be explained by the heavy wear of the occlusal surface. <u>Mandibular lateral incisors</u> were scored for labial wear in 94.6% of the cases (122 teeth). The majority showed no wear of the labial side and some of the specimens showed polishing of the surface; only 3 cases exhibited severe wear, with dentine exposure. <u>Mandibular canines</u> were scored for labial wear in 94.8% of the cases. Most teeth did not reveal any wear but in 69 specimens a slight level of polishing of the labial surface was observed; higher levels of wear of the labial surface were not observed.

Plate 4.

Extreme wear (level 3) on the labial surface of maxillary central incisors.

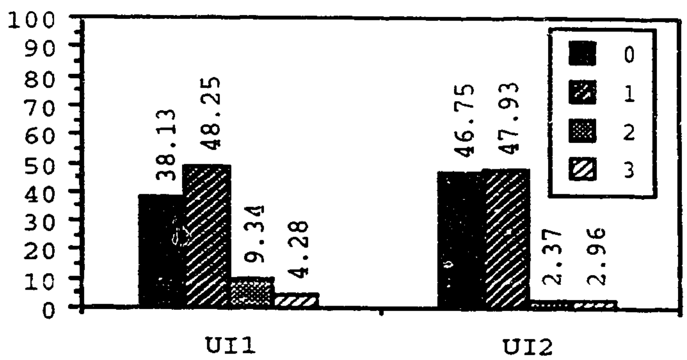
Plate 5.

Extreme wear (level 3) on the labial surface the maxillary canines

Anterior teeth/ Labio-incisal wear

The wear of the labio-incisal edge was scored only for the maxillary central and lateral incisors, in order to quantify the presence of rounding and chipping of the incisal edge, possibly due to the use of anterior teeth as tools. The results show that a large number of specimens exhibited chipping of the incisal edge, and some teeth showed blunting/rounding of the surface (Fig.10).

Fig.10. Labio-incisal wear on loose maxillary incisors (%)



Analysis of the relationship between the occurrence and severity of labio-occlusal wear and incisal wear revealed that although blunting of the labio-incisal edge clearly increases with incisal wear (Table 11), chipping seems to occur shortly after eruption; in two cases (one central incisor and one lateral incisor) there was chipping of the labio-incisal surface without any visible incisal wear. This suggests that the abrasive component of the diet or activity responsible for the formation of labio-incisal erosion was present in juveniles, adolescents and adults.

Table 11. Development of labio-incisal wear on maxillary central and lateral incisors in relaiton to incisal wear

CENTRAL INCISORS		Labio-incisal wear %			
		0	1	2	3
	0	95.8	4.2	0	0
Incisal wear	1	77.4	19.4	0	3.3
%	2	30.8	65.4	3.8	0
n= 257	3	29.5	61.4	9.1	0
	4	28.3	53.3	13.3	5
	5	16.2	56.8	18.9	8.1
	6	12.5	56.3	18.8	12.5
	7	9.1	72.7	0	18.2
	8	50	50	0	0

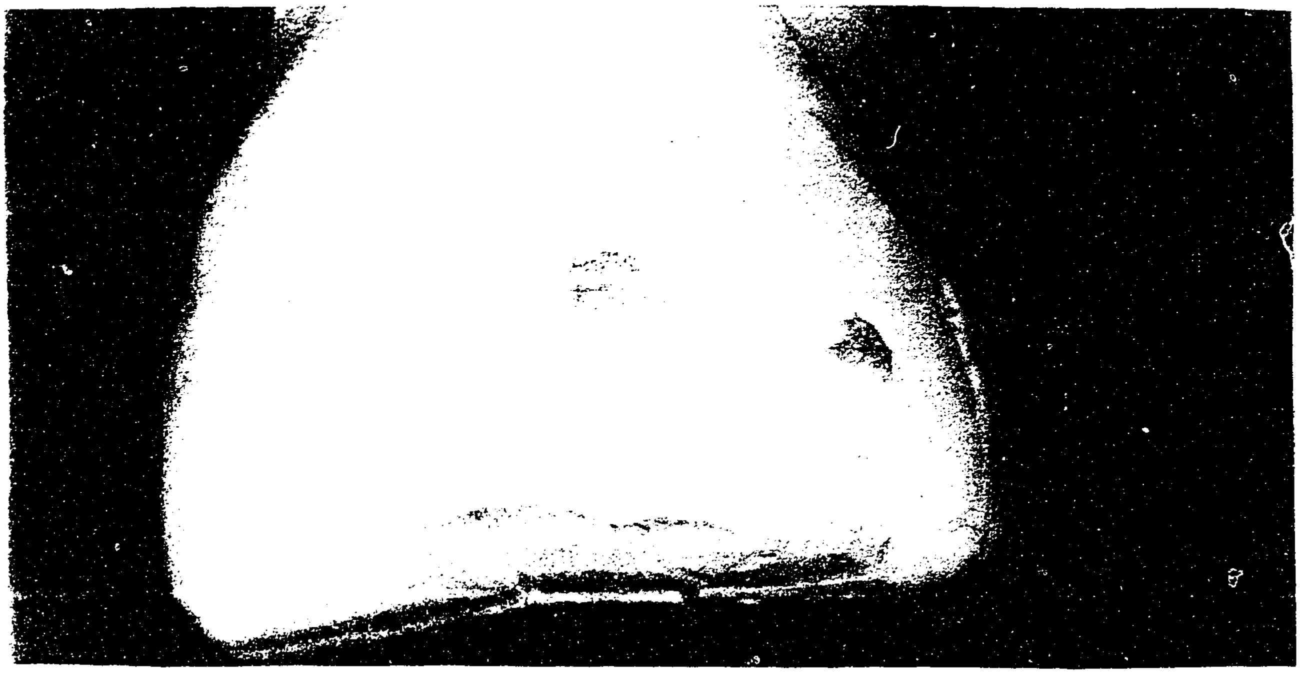
LATERAL INCISORS		Labio-incisal wear %			
		0	1	2	3
	0	92.3	7.7	0	0
Incisal wear	1	78.8	21.2	0	0
%	2	38.1	57.1	4.8	0
n=166	3	38.6	59.1	0	2.3
	4	24.1	58.6	6.9	10.3
	5	41.7	50	0	8.3
	6	11.1	77.8	11.1	0
	7	50	50	0	0
	8	0	0	0	0

For the maxillary central incisors, 96.3% of the teeth were scorable for labio-incisal wear (257 teeth). Chipping was frequent (Fig. 10) and some of the teeth showed blunting of the surface. Pearson's r correlation coefficient was calculated to evaluate how dependent the labio-incisal wear was on the increase of incisal wear in the maxillary central incisors and the regression line was estimated. The results show that there is a low correlation between both variables and that labio-incisal wear is not significantly dependent on the wear increase on the incisal surface (r=.45). This supports the idea that this type of erosion -labio-incisal- is not due to masticatory function but rather the result of the use of teeth as tools. The maxillary lateral incisors were scorable for labio-incisal wear in 92.7% of the cases (166 teeth) and they showed a similar distribution to that of the central incisors (47.9% with chipping of the labio-incisal edge) with less specimens with blunt surface (2.4%). Dependency of the labio-incisal wear on the increase of occlusal erosion was tested, by the estimation of Pearson's r correlation coefficient. The correlation between the two variables is lower than in the maxillary central incisors (r=.37), possibly because of the high incidence of labio-incisal chipping in early stages of incisal wear.

Blunting of the labio-incisal edge (Plate 6) has been associated in the literature with hunter-gatherer dental wear patterns. This association accompanies the more general debate on rates of attrition between hunter-gatherers and agriculturalists presented above (Hinton, 1981; Molnar, 1971). More specifically, the rounding of the labial surface was associated by Hinton (1984) with the samples of Inuit and Australian aboriginal teeth, while a cupped type of wear was visible on the anterior teeth of the dentitions from Libben Amerinds (with a mixed economy of hunting and fishing supplemented by maize cultivation) and the Southwestern Amerinds (with intensive cultivation of maize and other crops). The frequencies of blunting of the labio-incisal edge on the maxillary central incisors reported for the Inuit sample (circa 8%) are more similar to those found in the sample from Tojal de Vila Chã than in any of the other groups. However, for the maxillary lateral incisor the most similar values are those reported for the American Southwest. The labial surface was found to be dependent on increasing occlusal wear in the samples analyzed by Hinton, which is coherent with the observations performed in Tojal de Vila Chã. Unfortunately, chipping of the labio-incisal edge was not reported in Hinton's study and therefore, comparison cannot be established for this particular trait.

Plate 6

Blunting of the labio-incisal edge of maxillary incisors



Chipping of the labio-incisal edge (Plate 7) is similar to that reported by Turner and Cadien (1970) for the Eskimos and Aleuts which they interpreted as the result of the presence of bone in a meat based diet. However, Alexandersen (1988) reported the presence of pressure-chipping in teeth from the Southern Scandinavian Mesolithic, in 35% of the specimens analyzed. This figure is more similar to that observed in Tojal de Vila Chã than the one reported by the same author for Neolithic populations of the same area of Scandinavia (10-15%). Wallace (1975) observed the presence of a rounded incisal edge on the anterior dentition of Bushmen, which is similar to that observed in Tojal de Vila Chã; he explained the development of this type of wear as the result of grit in diet.

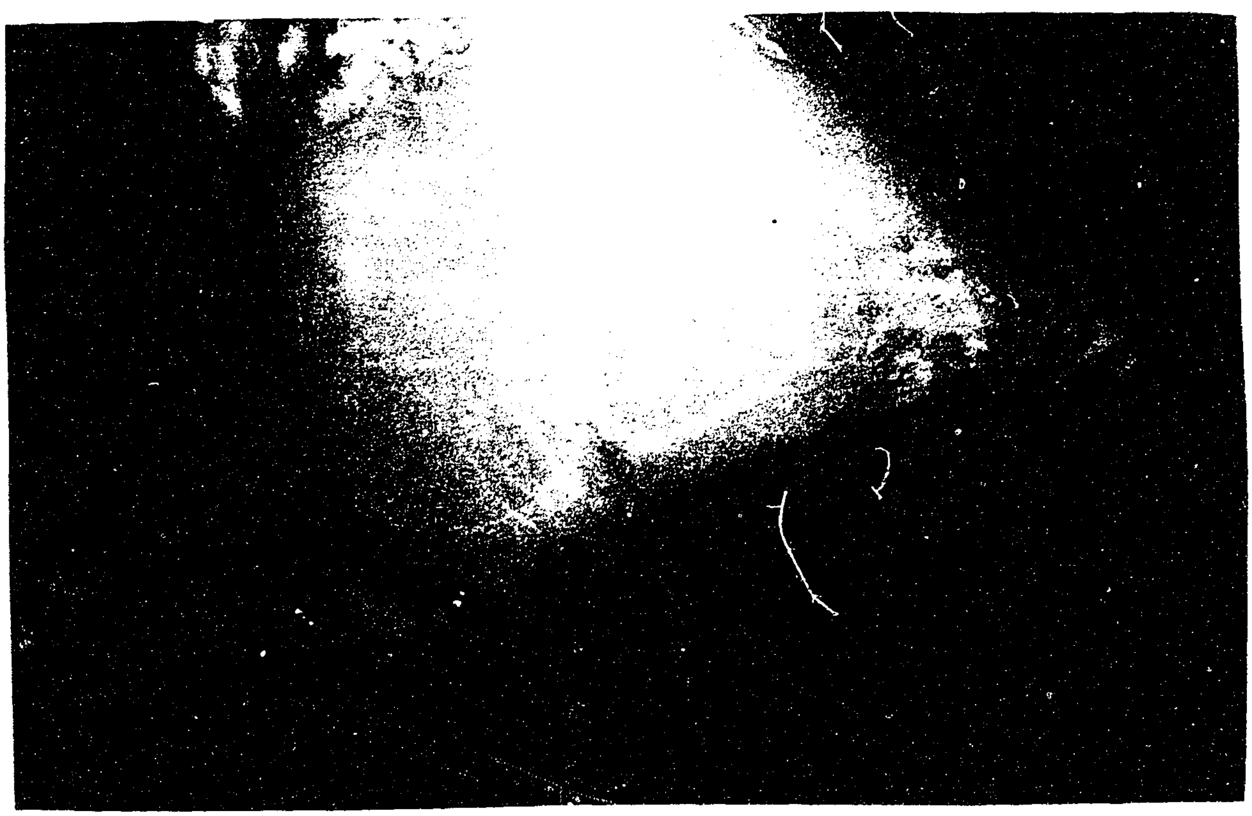
The use of patterns of wear on anterior teeth as indicators of food processing techniques has been reported as promising, if data from different samples will be available in the future (Molnar, 1971). For

Southwestern Europe, the absence of reports on wear patterns of the anterior dentition creates difficulties in the comparison of prehistoric populations.

From the analysis of the present sample of loose incisors and canines, some conclusions can be drawn; firstly, the incisal and labial wear of the anterior teeth seems to be as heavy or heavier than the wear visible on the posterior teeth (see next sections for comparison with posterior dentition); secondly, the labial wear visible on the maxillary anterior teeth is not due to normal mastication and must be related to the more specific labio-incisal wear; thirdly, the labio-incisal wear is mostly characterized by chipping of the incisal edge but it also shows some degree of blunting in the maxillary incisors.

Plate 7

Chipping of the labio-incisal edge of maxillary incisors.

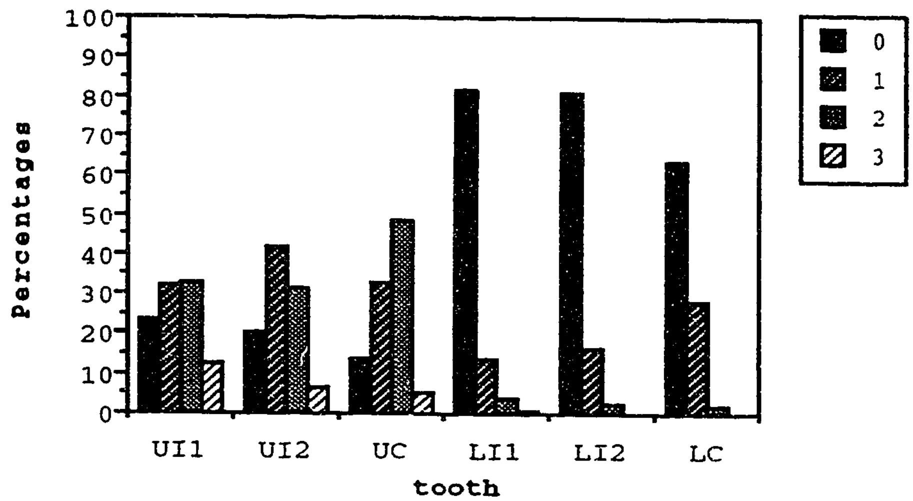


The incorporation of the wear patterns visible on the anterior dentition from Tojal de Vila Chã in a general map of the subsistence of which they might be diagnostic is difficult. It is impossible to say if the labial and labio-incisal wear are due to occupational stresses; in effect, sexually dimorphic patterns would likely be identified if the patterns were due to activities other than mastication (see Hinton, 1981) and for the present sample, there is no control over the sex of the individuals. Equally, the age dependency of the wear levels and wear types can only be tested for Tojal de Vila Chã in terms of their relationship with increased occlusal wear, since the age of the individuals is not known. Overall, only a general pattern can be defined, that will be useful for future comparison with samples that will provide more information. However, if compared with the known samples cited above for the American populations (in the absence of values for European prehistory) it is possible to conclude that the population represented in Tojal de Vila Chã is not similar to the cereal based groups analyzed by Molnar (1971) or by Hinton (1981) in that they exhibit lower levels of attrition on the anterior teeth and a lower level of blunting of the labial surface at the incisal edge.

Anterior teeth/ Lingual wear

Lingual wear was observed following the method described in chapt four. The majority of the maxillary teeth showed at least a minimal amount of wear on the lingual surface (Fig. 11). As a result of mastication movements with normal occlusion the maxillary anterior teeth exhibited more lingual wear than the mandibular teeth, but some of the lower incisors and canines show some polishing of the lingual surface. Analysis of the relationship between incisal wear and lingual wear on the maxillary teeth revealed that the latter increases with the erosion of the incisal surface (Table 12), and can therefore be attributed to normal occlusion and mastication stress. However, a specific type of wear that has been identified as 'signe du cordonnier' and that has been reported in European prehistoric samples was observed and will be discussed.

Fig. 11. Lingual wear on anterior dentition



In the subsample of the maxillary central incisors, 92.9% of the specimens were scorable for lingual wear and in the maxillary lateral incisors 92.2% of the teeth were observable. Although the majority of the teeth exhibit some degree of wear on the lingual side, none of the teeth which showed no erosion of the occlusal surface were diagnosed as polished on the lingual surface (Table 12). However, lingual erosion appears to develop rapidly and at level 1 of incisal wear polishing and erosion of morphological features was already visible (Table 12). Maxillary canines were scored for lingual wear in 90.1% of the specimens. The majority of the teeth showed some wear on the lingual surface. Similar to the maxillary incisors the lingual wear of the canines developed rapidly after eruption so that at level 1 of occlusal erosion there was polishing and deletion of the morphological features in a large number of teeth (Table 12).

The mandibular central incisors were scored for lingual wear in 95.7% of the cases . The majority did not present lingual wear and only some showed slight polishing of the lingual surface (Fig. 11). Only 5 specimens (4.55%) showed heavier wear. The mandibular lateral incisors were observable in 90.7% of the cases. The majority did not present any wear and only a few specimens exhibited some polishing of the lingual surface; in 3 of the teeth heavier wear was identified with the obliteration of the morphological features but with no exposure of dentine. The mandibular canines were scorable for lingual wear in 93.9% of the cases and the majority of the specimens showed no wear on the lingual surface with only slight polishing in 28.4% of the cases. Only 4 specimens revealed a heavier level of wear, with obliteration of the morphological features (Fig. 11).

Table 12. Development of lingual wear on maxillary central incisors and canines in relation to incisal wear

INCISORS		Lingual wear %			
		0	1	2	3
Incisal wear	0	100	0	0	0
scores	1	55.2	37.9	6.9	0
	2	40	52	4	4
n= 413	3	6.7	68.9	24.4	0
	4	4.3	35.1	56.1	5.3
	5	0	8.1	62.2	29.7
	6	0	0	50	50
	7	10	10	10	70
	8	0	0	0	0

CANINES		Lingual wear %			
		0	1	2	3
Incisal wear	0	100	0	0	0
scores	1	35	40	25	0
	2	13.9	47.2	33.3	5.6
n= 162	3	2.2	40	57.8	0
	4	2	24.5	67.4	6.1
	5	0	15.8	73.7	10.5
	6	0	45.5	27.3	27.3
	7	50	0	50	0
	8	0	0	0	0

Lingual wear on the enamel of anterior teeth can be explained by mastication processes on the maxillary dentition. In the mandibular teeth, lingual wear might be due to malocclusion and/or underbite (the contact of the labial surface of the maxillary teeth with the lingual surface of the mandibular dentition at occlusion) or by chemical erosion of the enamel surfaces. Recent studies in dentistry (Mair, 1992) have emphasized that acid substances, which are in contact with the tooth surface (through regurgitation, dietary or industrial processes) can provoke erosion of the enamel without the presence of abrasive food particles; this process can have different manifestations such as "... glazing of the enamel surface with loss of developmental ridges..." (Mair, 1992: 142). Although anthropologists cannot test the presence of acid substances in the oral environment due the limitations of archaeometric techniques applicable to skeletal samples, analysis of lingual wear and erosion of the enamel surface that should not be worn down by mastication movements has inspired several anthropological studies (Alexandersen, 1988; Jackes, 1988; Lefèvre, 1983; Liñaza & Basabe, 1981; Lukacs & Pastor, 1988). This type of wear has been mostly interpreted as the result of the use of teeth as tools and they are consequently identified as occupational indicators in prehistoric populations.

Several factors influence the formation of specific wear patterns. Molnar (1971, 1972) presented the first systematic survey on the effects that different aspects of human activity have on the attrition patterns of teeth. Since then, there has been an abundance of literature published on the cultural factors affecting dental wear. In Neolithic skeletal samples from Harappa (Pakistan), Lukacs & Pastor (1988) identified two types of anterior wear which they associated with the use of these teeth as tools - facial abrasion of maxillary anterior teeth and lingual surface abrasion of upper and lower incisor teeth. Lingual wear was explained as the result of "...forceful holding or pulling animal skin between the teeth for the purpose of softening it... " (page 397), but labial wear was not explained, even though some hypotheses were advanced, such as retouching stone tools, "stuff and cutting" method of eating meat, grasping the mouthpiece or bit of a bow drill, or splitting reed or bamboo stalks.

Lefèvre (1973) remarked the presence of the "signe du cordonnier" (lingual maxillary anterior wear) in human dentitions of the Mesolithic population from the Muge shell middens, in central coastal Portugal. He describes it as

> "Les couronnes conservent la présence des crêtes marginales, lesquelles delimitent une surface centrale incurvée mesio-distalement. Cette surface, parfaitement lisse, laisse apparaître souvent la dentine dans sa partie la plus concave" (Lefèvre,1973:323).

> (The crowns preserve the marginal ridges, which delimit a central surface curved mesio-distally. This surface, perfectly smooth, allows the exposure of dentine in the most concave portion)

This type of wear was interpreted by the author as the result of basket production with the help of the incisors as tools; however, it should be remarked that there is no ethnographic evidence for this type of attrition.

In two Mesolithic samples from Denmark, Alexandersen (1988) identified heavy lingual wear on the anterior dentition in about 33% of the teeth and suggested that it was due to "...holding and pulling hides or leather over the teeth, i.e. between the tongue and the upper anterior teeth..." (Alexandersen, 1988: 194). No sexual differences were found in the Mesolithic sample for this particular type of wear but it disappeared with increasing wear of the occlusal surface, when this changed into an horizontal masticatory surface. He identified it as the '"signe du cordonnier" and refers to Lefèvre's study in the Portuguese Mesolithic sample. However, the surfaces of the teeth are not concave and they are, in fact, extremely smooth.

The same feature was identified by Linaza & Basabe (1987), in a sample of Bronze Age dentition from the Guipúzcoa area in the Basque Country. The condition was defined as

> "... un tipo de desgaste específico de la cara lingual de los dientes anteriores del maxilar superior (...) que se define como una abrasión característica de la cara lingual es lisa y pulida en toda su superficie y que, por razones evidentes de articulación, no puede ser provocada por la atrición funcional..." (Linaza & Basabe,1987:7) .

> (... a specifically lingual wear of the maxillary anterior teeth (...) which is defined by an abrasion of the lingual surface that becomes completely smooth and polished, and that for obvious reasons cannot be provoked by functional attrition in mastication...)

The feature was found on 24.4% of the maxillary lateral incisors and on 19.3% of the central maxillary incisors in Guipúzcoa; it is proposed that it is the result of working with strips of leather; they identify this feature as typical of the Portuguese and French Mesolithic (Linaza & Basabe,1987:23).

If the two definitions are inconsistent (i.e. one defines the specific type of wear as the formation of a concave central portion on the lingual surface, maintaining the marginal ridges, and the second defines it as the polishing of the lingual surface), they both concentrate on the abnormal and extreme polishing of the lingual surface of the maxillary incisors, which cannot be explained by normal mastication processes.

Although the number of specimens that show this feature in Tojal de Vila Chã is lower than those reported by Liñaza & Basabe (1987) some of the anterior teeth showed this pattern of wear. Polishing was frequent (31.9% in the maxillary central incisors, 41.8% of the maxillary lateral incisors and 32.5% in the maxillary canines). Less frequent was the abrasion of the lingual surface so that the morphological features were obliterated (32.7% in the maxillary central incisors, 31.5% in the maxillary lateral incisors and 48.5% in the maxillary canines). However, a more extreme type of wear, with exposure of dentine on the lingual surface (Plate 8), was visible in 12.1% of the maxillary central incisors, 6.7% of the maxillary lateral incisors and 5% of the maxillary canines. Curiously, this type of wear has been identified as characteristic of the Mesolithic populations (Alexandersen, 1988; Lefèvre, 1973; Liñaza & Basabe, 1987), but it has been reported as present in skeletal samples from Neolithic burial sites in the Estremadura. Jackes observed the presence of lingual polishing on the maxillary canines (49.2% for the right side and 61.7% for the left side) in Casa da Moura, a Neolithic burial site in the Estremadura where loose teeth are more frequent than those *in situ* (Jackes, 1988). For the sample analyzed in this study a positive relationship between the development of lingual wear and the advancement of occlusal wear was identified and indicates that the process of erosion of the lingual surface of the anterior teeth is different from that observed by Alexandersen (1988) for the Danish Mesolithic. However, the fact that there is no association between upper and lower teeth limits the understanding of the process involved in the formation of this type of wear: if it were the result of passing strips of leather between the tongue and the lingual surface of the maxillary incisors, there would be no correspondent feature on the labial surface of the mandibular incisors; if, on the contrary, it were due to the fabrication of baskets (cordonnier), then the labial surface of the lower incisors should illustrate the condition. The labial surface of the mandibular incisors of Tojal de Vila Chã do not present extreme wear and only very few teeth exhibit more than slight polishing (cf. previous sections and Fig. 10)

Plate 8

Extreme wear on the lingual surface of maxillary incisors and canines

Although archaeological evidence does not allow any solid explanation for this type of wear, it is possible to speculate that previous arguments for the use of the maxillary teeth in the treatment of leather or their use as tools in weaving could be accepted. This argument seems more coherent than the presence of grit in the diet, because of the low attrition levels observed in the dentition of Tojal de Vila Chã in general, and more specifically on the anterior dentition. If the labial/lingual wear were due to an extremely abrasive diet, the occlusal wear that results from normal mastication movements would have accompanied the severe attrition of the lingual surfaces of the teeth. The levels of occlusal wear observed on the incisors and canines are generally consistent with results presented by other researchers for agricultural populations (Hinton, 1981; Liñaza & Basabe, 1987); however, they contrast with other agricultural samples in the heavier wear observed on the maxillary central incisors and maxillary canines when compared with the posterior sector (cf. Molnar et al.,1989; Richards, 1990; Silvana et al., 1985).

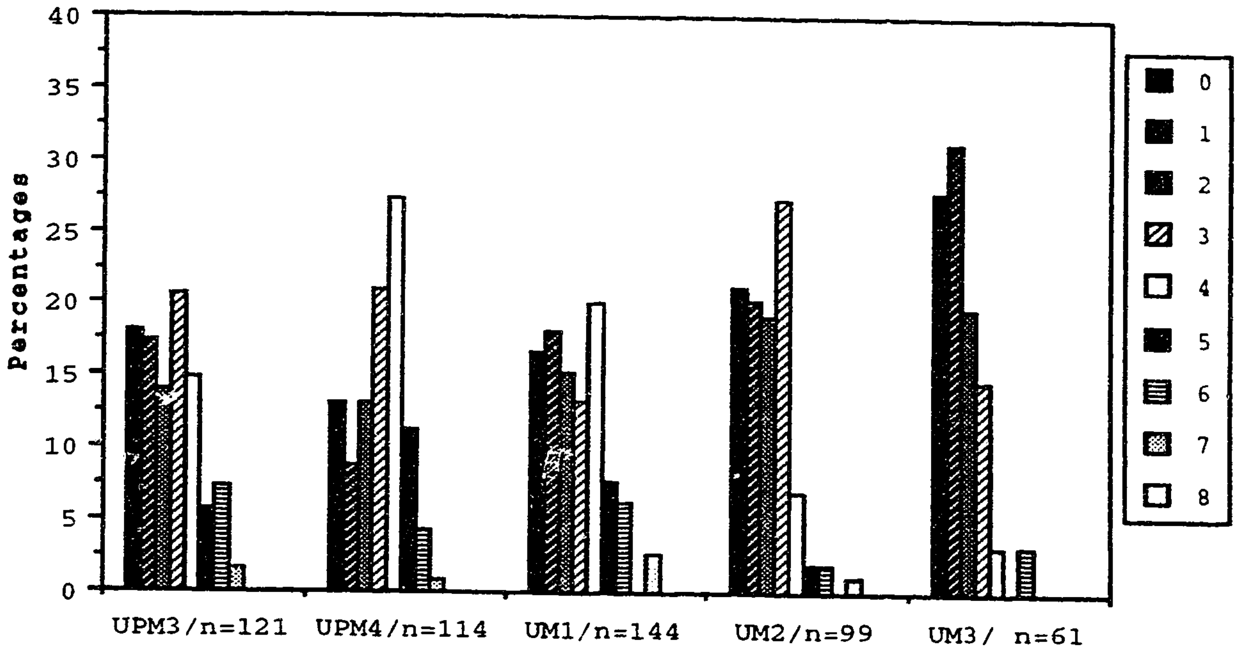
Summary

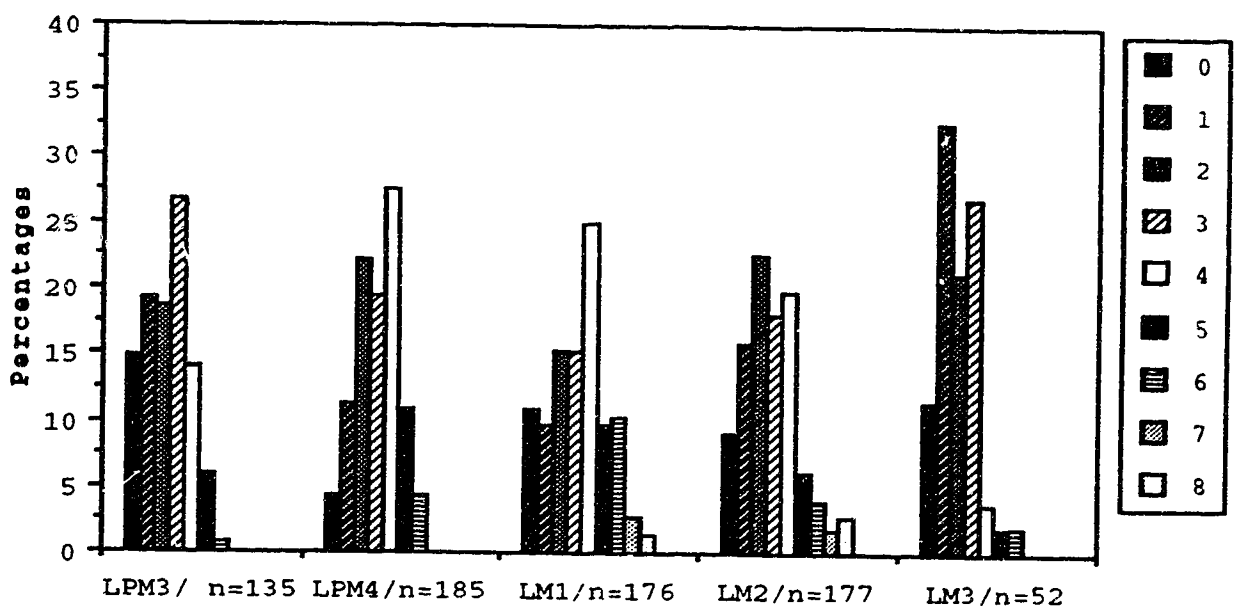
In the present sample, both maxillary and mandibular incisors exhibit slight labial wear, mostly characterized by polishing of the surface. There is visible wear on the labial surface of 44.0% of the maxillary incisors). More significant is the presence of chipping and polishing of the incisal edge. A large number of maxillary incisors (48.3% of central incisors and 47.9% of lateral incisors exhibited chipping of the incisal-labial surface. Less frequent was the presence of a rounded, blunt type of abrasion (9.3% of the central incisors and 2.4% of the lateral incisors). Both types of wear sometimes occur in the same tooth (4.3% of the maxillary central incisors and 3.0% of the maxillary lateral incisors exhibited both chipping and blunting of the incisal edge). Some anthropologists have stated that anterior teeth wear down more heavily in hunter-gatherer populations than in agriculturalists (Molnar,1971; Hinton,1981; Scott & Turner,1988). Also, hunter gatherers are often reported to show rounded labial wear on the anterior dentition, suggesting its use as tools (Brace, 1967; Hinton,1981; Scott & Turner, 1988). For the incisors and canines, Hinton (1981) defined the differences between a rounded and a cupped type of wear in populations with different subsistence strategies and confirmed that hunter-gatherers seem to have a more rounded labio-incisal margin than agriculturalists. The sample from Tojal de Vila Chã exhibits some characteristics that have traditionally been associated with hunter-gatherer populations, such as the heavy wear of the incisal surface of maxillary central incisors and maxillary canines and the chipping of the labial surface. However, recent work on the dentitions of Neolithic people from Estremadura suggest that these traits cannot be used in the same manner in a regional context as they have been for the American agricultural and preagricultural samples.

Posterior teeth/ Occlusal wear

The analysis of wear on the posterior dentition (loose premolars and molars) was performed following different methods from those used for the incisors and canines (cf. chapter four). While wear on the anterior dentition was only observed qualitatively, the attrition of maxillary and mandibular molars was analyzed quantitatively, for an understanding of the variation of the slope of the occlusal surface with increasing wear. The total number of posterior loose teeth analyzed in this sample can be drawn from Table 2. General analysis of posterior teeth shows that the second premolars and first molars (both maxillary and mandibular) exhibit the highest levels of wear (Fig. 12). Analysis of occlusal wear on the premolar sector reveals that each premolar (and both maxillary and mandibular) follows the patterns of attrition of its adjacent tooth; the first premolar exhibited patterns of wear that were more similar to those of the maxillary canine and the

Fig.12. Occlusal wear on the loose posterior dentition





second premolar showed wear values that approximated those of the first molar. This association can be related to the mastication functions performed by each of these transitional teeth. Although these results should be expected for the first molars, the second premolars should not exhibit such high levels of attrition, if they belonged to the same individuals, given the time difference in eruption between the two (± 6 years). However, analysis of the expected versus present teeth in the sample revealed that the mandibular premolar sector is underrepresented (cf. chapter four) and this might mean that the teeth with lower levels of attrition are not present. This does not explain the discrepancy of results obtained for the mandibular molars, where there seems to be a reasonable representation of teeth, when confronted with the number to be expected (Figs. 5 and 6). Analysis of the first, second and third molars reveals that the third molars have an overall lower level of attrition than the second molars and these lower than the first. If times of eruption are considered, this sequence is to be expected, since there is a span of approximately 6 years between the time of exposure to attrition of each of these categories. The results obtained for the premolars might be explained by the fact that the methods developed for the analysis of wear have mostly concentrated on the molar sector and on the anterior teeth (cf. chapter four) while the premolar sector has rarely been analyzed; the keys for their analysis might consequently have been less examined and their faults underestimated or simply ignored. In the sample from Tojal de Vila Chã no testing can be performed on the method utilized, since <u>in situ</u> teeth are scarce.

Overall, in the posterior loose teeth from Vila Chã there is slight wear of the occlusal surface, the majority of the teeth concentrating on levels between 0 and 4 (0 and 3 for the third molars). Analysis of the molar sector reveals that the first molars consistently exhibited more severe wear (level 4 more frequent) and that the severity was reduced from the most anterior molar to the most posterior, as expected. Overall, the characteristics of the wear of the posterior teeth were slight wear of the occlusal surface, even when interproximal wear facets were present (Tables 13 and 14). Comparison of frequency of interproximal wear facets with levels of occlusal wear demonstrates that the distal facets were visible on the maxillary first molar at

Table 13. Interproximal wear facets in relation to occlusal wear in maxillary molars (%)

FIRST MOLARS		Interproximal facets 0	mesial	distal	both
	0	95.8	4.2	0	0
Occlusal	1	28.6	52	0	9.5
wear scores	2	10.5	68.4	0	21.1
	3	0	26.3	0	73.7
	4	0	17.4	0	82.6
	5	0	22.2	0	77.8
	6	0	16.7	0	83.3
	7	0	0	0	0
	8	0	0	0	0

SECOND MOLARS		Interproximal facets 0	mesial	distal	both
	0	90.5	9.5	0	0
Occlusal	1	42.1	57.9	0	0
wear scores	2	0	88.9	0	11.1
	3	3.9	53.9	0	42.3
* n=1	4	16.7	16.7	0	66.7
	5	0	*100	0	0
	6	0	0	0	0
	7	0	0	0	0
	8	0	0	0	0

THIRD MOLARS		Interproximal facets 0	mesial	distal	both
	0	64.7	3.3	0	0
Occlusal	1	16.7	83.3	0	0
wear scores	2	9.1	90.9	0	0
	3	11.1 1	88.9	0	0
* n=2	4	0	*100	0	0
	5	0	0	0	0
	6	0	*100	0	0
	7	0	0	0	0
	8	0	0	0	0

Table 14. Interproximal wear facets in relation to occlusal wear in mandibular molars (%)

FIRST MOLARS		Interproximal facets 0	mesial	distal	both
	0	93.3	6.7	0	0
Occlusal	1	0	0	0	0
wear scores	2	0	68.75	0	31.25
	3	0	23.8	0	76.2
* n=4	4	0	10.7	0	89.3
	5	0	0	0	100
	6	0	0	0	100
	7	0	*50		*50
	8	0	0	0	0

SECOND MOLARS		Interproximal facets 0	mesial	distal	both
	0	0	0	0	0
Occlusal	1	88.9	11.1	0	0
wear scores	2	22.7	72.7	0	4.6
	3	4	44	0	52
	4	0	33.3	0	66.7
* n=2	5	14.3	14.3	0	71.4
	6	0	0	0	100
	7	0	0	0	100
	8	0	*50	0	*50

THIRD MOLARS		Interproximal facets 0	mesial	distal	both
	0	75	25	0	0
Occlusal	1	0	100	0	0
wear scores	2	0	100	0	0
	3	0	100	0	0
	4	0	100	0	0
	5	0	100	0	0
	6	0	0	0	0
	7	0	0	0	0
	8	0	0	0	0

level 1 of attrition in 9.5% of the teeth (Table 13) but was never visible at that level of attrition on the mandibular first molar (Table 14); for the latter, wear facets on both interproximal surfaces were only visible at level 2 of attrition. These results do not contradict those obtained from the analysis of in situ teeth, which suggested a level 2 of attrition of the first molar at the time of eruption of the second.

The maxillary first premolars were scorable for occlusal wear in 94.5% of the cases and the majority of the teeth showed a low level of attrition (equal or lower than 4) with no specimens exhibiting level 8 of attrition; only a small percentage exhibited levels 6 or 7 of wear (Fig. 12). The maxillary second premolars were scorable in 95.8% of the cases; the majority of the teeth (95) exhibited a wear score of 4 or less and only one specimen showed wear score 7. The mandibular first premolars were scorable for occlusal wear in 95.1% of the cases; the majority of the teeth presented a wear level of 4 or less and the highest score observed was 6. The mandibular second premolars were scorable for occlusal wear in 93.4% of the teeth; the majority exhibited wear level 4 or less and the highest score observed was also 6 (Fig. 12).

The maxillary first molars were scorable for occlusal wear in 89.4% of the total sample; the majority showed a low score, exhibiting level 4 or less of occlusal wear but some specimens had a wear score 8 (Fig. 12). Maxillary second molars were scorable for occlusal wear in 96.1% of the cases (n=99); the majority of the teeth exhibited low levels of wear on the occlusal surface (equal or below 3) while only one specimen was scored at level 8 (Fig. 12). On the maxillary third molars, 100% of the teeth were scorable for occlusal wear (Fig. 12). The most frequent score was 1 (polishing of the occlusal surface) and 93.6% of the specimens showed wear levels of 3 or less; the highest score observed was 6 (Fig. 12).

The mandibular first molars were scorable in 88% of the cases; the majority of the teeth showed a low level of wear (level 4 or lower) and very few specimens (1.4%) were scored at level 8 (Fig. 12). All the <u>mandibular second molars</u> were scorable for wear on the occlusal surface; the majority of the teeth showed a low level of wear on the occlusal surface, with 151 specimens falling under level 4 or less (85.3%); only a few teeth were scored at level 8 (Fig.12). The <u>mandibular third molars</u> were scorable for occlusal wear on 96.3% of the cases; wear of the occlusal surface was slight in this sector with most teeth showing an occlusal wear level of 3 or less (Fig. 12).

The qualitative analysis of wear on the posterior loose dentition revealed that the majority of the molars showed mild levels of wear, concentrating on levels below score 4 (several dentine exposures, still discrete). The low levels of attrition and the reduced number of first and second molars with both mesial <u>and</u> distal interproximal facets suggest that the population here represented either suffered high mortality rates at very early age, or it consumed a diet that was not abrasive enough to produce high levels of attrition nor did it demand enough masticatory stress to develop interproximal facets shortly after eruption of the molars. The second hypothesis is more likely to be true, and it can be supported by comparison of attrition stages on adjacent molars from <u>in situ</u> specimens (see above). However, this suggestion can only be confirmed if complete skeletons from sites of the same archaeological context are analyzed in the future.

The analysis of wear levels of the occlusal surface <u>per se</u> are not conclusive when loose teeth are analyzed. There are a number of inconsistencies which cannot be explained without an indication of the age and sex distributions of the individuals buried in these tombs. For example, the wear scores distribution of the maxillary second molars is not similar to that of the mandibular second molars; the maxillary teeth seem to exhibit lower levels of wear than the mandibular ones. Whether this is related to the number of teeth represented in the sample (the number of mandibular molars largely exceeds the number of mandibular) or to the fact that the maxillary and mandibular teeth do not belong to the same individuals or to the bias of the method utilized for their analysis cannot be evaluated and reflects the bias of the use of a sample of loose teeth. However, a general pattern of low attrition can be inferred as a characteristic of this sample.

Analysis of the dental wear on the occlusal surface of the posterior dentition from Tojal de Vila Chã supports the idea that the dietary patterns of the population there represented were similar to those adopted by other Neolithic groups in the same geographical area; the low number of teeth with higher wear scores is consistent with the data presented by Lubell and Jackes for the Neolithic samples from Estremadura; the Mesolithic samples exhibited higher levels of attrition (see Lubell & Jackes, 1988).

If studies of dental wear patterns are not abundant for European prehistory, research in other geographical areas has provided data that can be used for the definition of differences between hunting/fishing and gathering subsistence strategies and agriculturalists. Some researchers have emphasized that, although hunter-gatherers tend to have a more abrasive type of diet, carbohydrates can cause even greater attrition, as is the case with the heavy wear of Classic Egyptian skeletons, supposedly attributed to cereal grinding as the source of grit in food (Molnar, 1972: 513). However, Eskimos show pronounced wear due to the consumption of frozen or tough items that require heavy chewing (Scott & Turner, 1988:110). Moorrees (1957) analyzed the wear patterns in relation to diet of a population of Eskimos, in the Aleutian Islands. Although his research took place in the 1950s, the pattern of diet was analyzed and confirmed to be very similar to what it had been prior to White contact. Using Broca's 5 levels of wear, he found that, after the age of twenty, there was a severe increase in attrition of the occlusal surface. His analysis concentrated on complete dentitions and the adoption of the same score techniques for the incisors and canines could have biased the results for less amount of wear in total percentage than it is actually the reality for the molar sector. However, he still finds the wear levels "severe" and explains them "... in part by the fact that extensive use is made of the dentition for chewing of tobacco and hides" (Moorrees, 1957: 132).

Hall & German (1975) analyzed 26 dentitions of prehistoric residents of British Columbia and found a predominance of level 6 of wear in the dentition - secondary dentine moderate to extensive, with crown still surrounded by enamel. Molnar et al. (1989) identified a difference in degree of molar wear between Australian aboriginal groups relying on marine resources and those relying on riverine resources. Brabant and his coworkers (1962) found, for the Neolithic populations of Belgium and France, that wear score II (i.e. the cusps are more or less completely worn and dentine is partially exposed) was more common than wear III or IV. Wear II corresponds to scores 3,4, and 5 together, in the present study. Brabant and Lecacheux (1973) confirmed the same results in the study of a Neolithic burial in Normandy, in which level II of attrition was dominant for the molar sector..

Liñaza and Basabe reported wear patterns for a sample of Bronze Age dentitions from the Basque Country that are slightly different from those found in Tojal de Vila Chã. The scale used for the qualitative classification of wear was similar to that used in the present study and the results obtained were different for the first molars: the highest frequency observed was level 5 (three or four dentine areas coalescing) and for second molars the most frequent score was level 4; for the third molar the most frequent observation was score 2 which was characterized by the presence of wear facets involving only the enamel (Liñaza & Basabe, 1987).

While the study and quantification of wear on the occlusal surface of molars has been widely used in the characterization of prehistoric skeletal populations, the results obtained are not always consistent. While the American data on the differences between hunter-gatherer populations and agriculturalists seems to be conclusive, in Europe, the image appears to be different. In effect, the results obtained by Brabant in the 1950s and 1960s seem to be consistent with those obtained by Jackes and coworkers or by the present study. However, the results obtained by Liñaza and Basabe for the Bronze Age of Guipuzcoa suggest a somewhat higher attrition for a subsistence pattern that is theoretically similar to that of the Chalcolithic. The differences might be related to incompatibilities of the methods utilized in the several studies or might be due to regional differences in diet or in the use of teeth as tools.

Reports on levels of amount of wear on the occlusal surfaces of human teeth in skeletal populations are abundant but they have followed different methods of observation and classification (cf. chapter four). From the analysis of these reports, it is recognized that levels of wear per se are not clearly indicative of differences in dietary patterns. More recent studies have explored the variation of the slope of the occlusal surface of molars with increased wear, as a means for the assessment of dietary habits (Jackes, 1988; Molnar, 1971; Smith, 1984). However, only in the most recent publications has this slope been analyzed metrically.

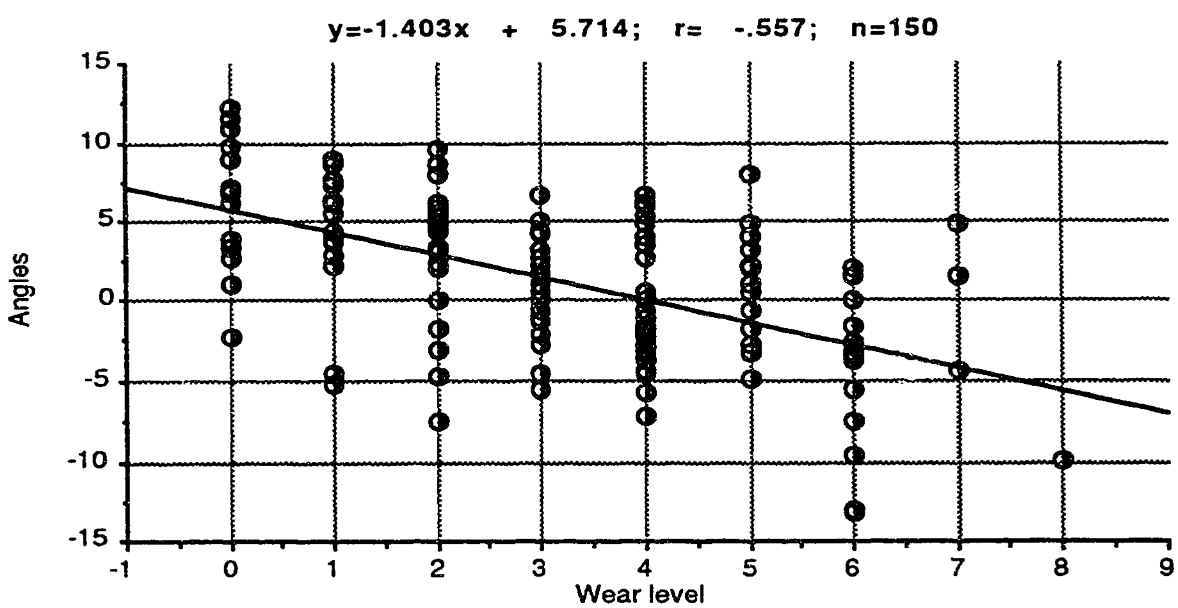
Metrical analysis of wear on the posterior dentition

Posterior dentition is more intensely involved in the mastication process than the anterior teeth. Therefore, metrical analysis of wear has been developed by several researchers only on the posterior dentition (cf. chapter four), with special emphasis on the molar sector. In this study, metrical analysis of the angle of the occlusal surface was performed following the methods described in the previous chapter.

After the teeth were measured, the dependency of the variation of the occlusal surface on the amount of wear was estimated. Pearson's r correlation coefficient was used as a means of evaluating how dependent the angle of the occlusal surface was on the increasing wear. The results showed that there was a dependency of the change of the slope of the occlusal surface on the reduction of the crown through increasing wear. Both mandibular and maxillary teeth were analyzed and as expected, the results were symmetrical. Comparison of the values obtained for this sample with published studies revealed that this method is promising as a means of comparison of different wear patterns in varied prehistoric subsistence strategies. The values will be presented for each molar (first, second, and third) in particular and for the three molars together, for each jaw.

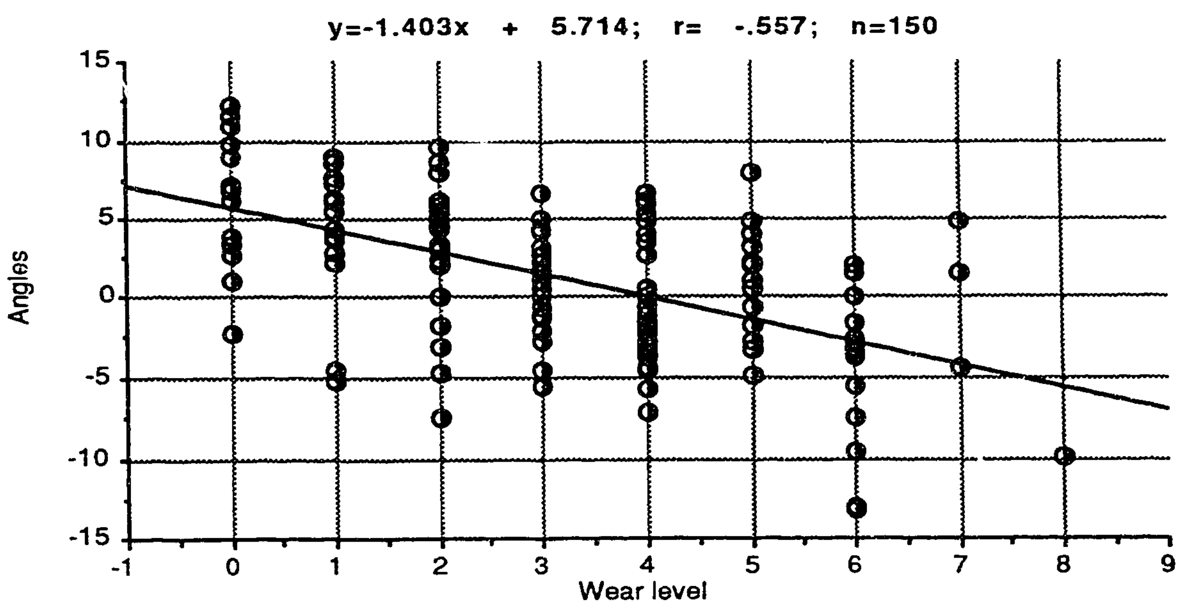
In the <u>mandibular first molars</u>, the results obtained show a dependency of the slope of the occlusal surface on wear increase. A value of r =.56 shows the dependency of the occlusal angle on the increase of occlusal wear. At level 0, the buccal crown height is higher than the lingual crown height. Therefore, the angle of the occlusal surface has a positive value and ranges between -2.2 and 12.2 degrees. As wear increases, the crown height at the buccal surface is reduced. The occlusal surface becomes flatter, predominantly on level 4 of wear. With further increase of the occlusal wear, the crown height at the buccal surface becomes more and more reduced. The angle becomes negative, with higher values on the lingual side than on the buccal side, with a maximum angle of -13.2 at score 6 of occlusal wear (Fig. 13).

Fig. 13. Dependency of the slope of the occlusal surface on wear increase in mandibular first molars.



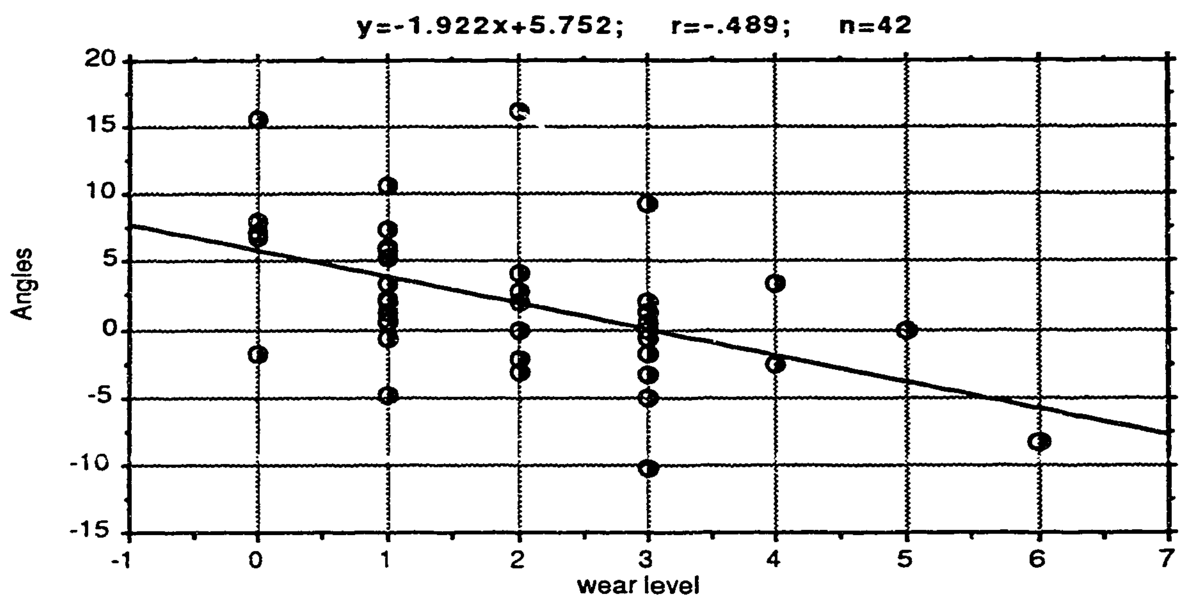
Although the first mandibular molars show a higher correlation between slope of the occlusal surface and wear increase, the second and third molars confirm the consistency of the change of the occlusal surface with wear increase (Figs. 14 and 15). Mandibular second molars exhibit the same general trend. However, the value obtained for the Pearson's r correlation coefficient is lower than for the mandibular first molars (r=.504). The angle of the occlusal surface ranges between 11.4 and - 17.1 degrees. As it is the case in the first mandibular molars, the height of the buccal crown is greater, when wear is absent. As wear increases, the buccal crown height is reduced, and the occlusal angle changes direction, with the appearance of negative values. As in the first mandibular molars, it is at level 4 of wear that the occlusal surface attains flatness, and the values start to change (Fig. 14).

Fig. 14. Dependency of the slope of the occlusal surface on wear increase in mandibular second molars.



On the third mandibular molars, the correlation is consistent with the results estimated for the first and second molars. The occlusal angles range from -10.3 to 16.2 degrees. When wear is absent, the buccal crown height is higher than the lingual crown height. As wear increases, the slope changes and at level 3 of wear, the occlusal surface attains flatness. As wear increases, there is a trend towards the reduction of the lingual height, compared to the buccal height (Fig. 15).

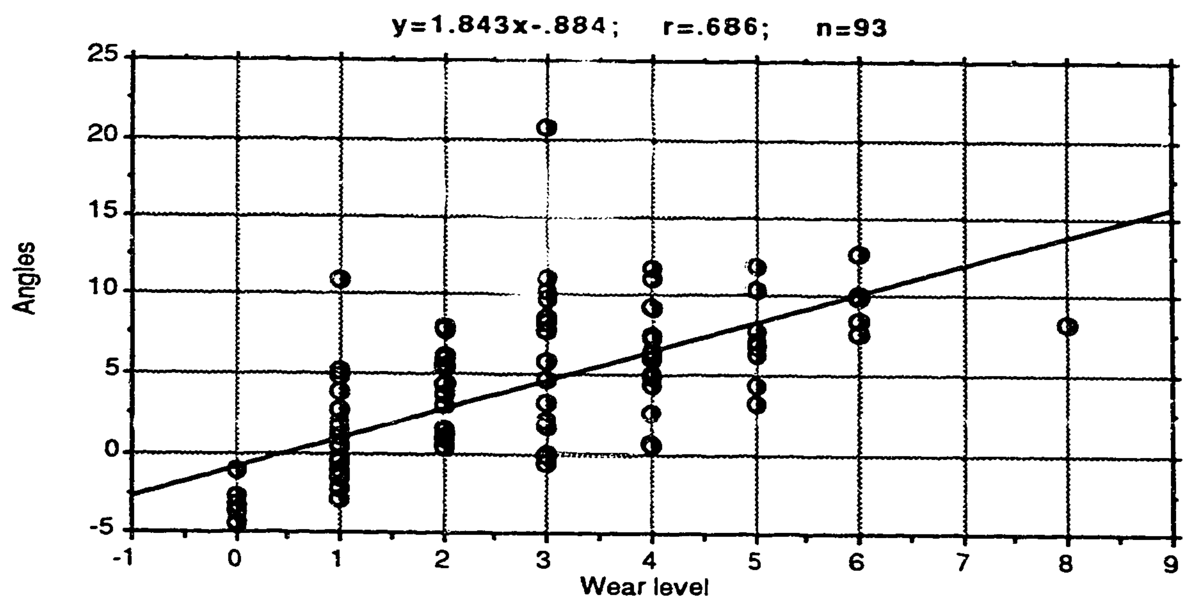
Fig. 15. Dependency of the slope of the occlusal surface on wear increase in mandibular third molars.



The changes detected on the mandibular molars were tested for the maxillary sector. If the changes operated on the mandibular molars were related to mastication processes, the opposite trend should be identified on the maxillary sector. Although the teeth analyzed are not identifiable as belonging to the same individuals, the pattern of change should be statistically consistent between the mandibular and the maxillary molar sectors, independently of the individuals.

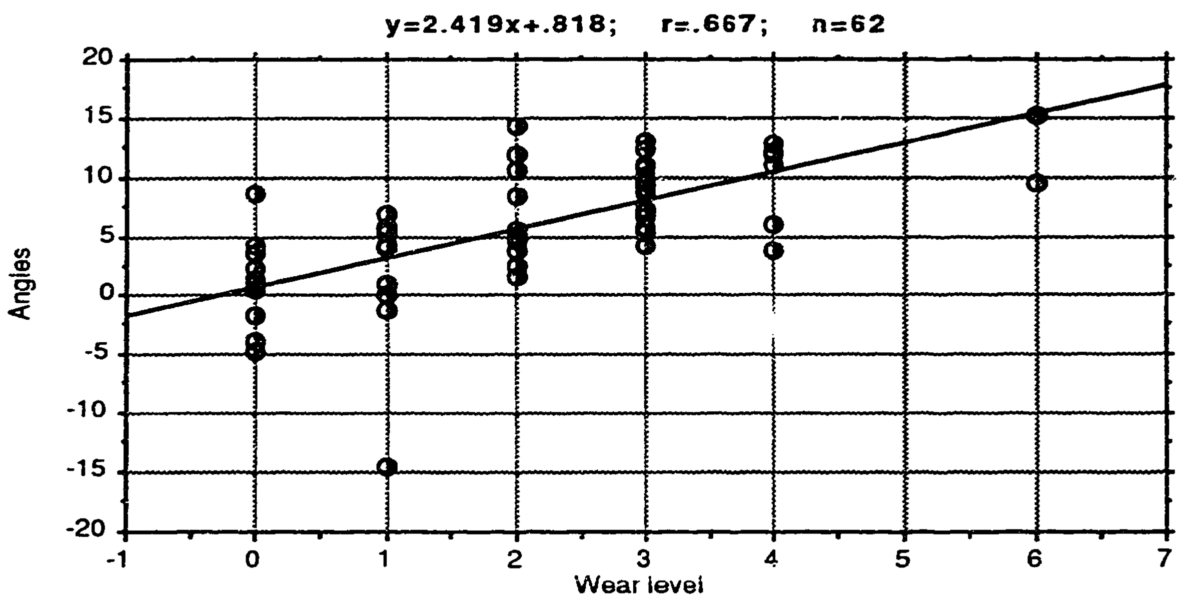
From the estimation of the Pearson's r correlation coefficient for the <u>maxillary first molars</u>, a value of r=.69 was obtained. The regression line (Fig. 16) illustrates the symmetry of the changes operated on the maxillary molars, compared to the changes operated on the mandibular sector. Buccal crown height is lower when wear is absent; as wear increases, the lingual crown height is reduced, and the occlusal angle changes from negative to positive values. The angles range between - 4.5 and 20.7 degrees.

Fig. 16. Dependency of the slope of the occlusal surface on wear increase in maxillary first molars.



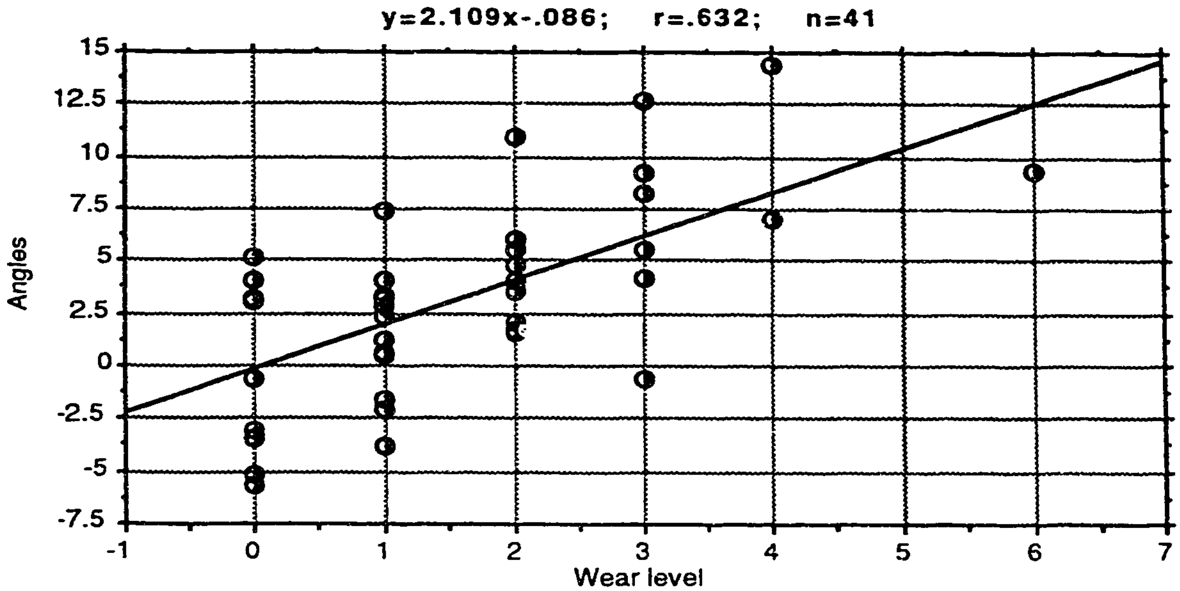
On the <u>maxillary second molars</u>, the same dependency of the occlusal angle on the increase of wear is demonstrated by the correlation value of r=.667 (Fig.17). Like in the maxillary first molars, in the second molars the buccal height is lower or identical to the lingual height, on the absence of occlusal wear. As wear increases, the slope changes and the angle becomes positive, the lingual height consistently becoming reduced and accommodating the changes operated with the corresponding wear on the mandibular sector. The angles range between -14.6 and 15.2 degrees.

Fig. 17. Dependency of the slope of the occlusal surface on wear increase in maxillary second molars.



On the <u>maxillary third molars</u>, the values obtained for the correlation coefficient are consistent with the results obtained for the other molar sectors. With a value of r=.633, the occlusal angle has values approaching zero, when wear is absent. As wear increases, the slope changes and the angle attains increasing positive values (Fig. 18). The values for the occlusal angle range between -5.7 and 14.4 degrees

Fig. 18. Dependency of the slope of the occlusal surface on wear increase in maxillary third molars



The analysis of the slope of the occlusal surface, in earlier studies, led to the creation of the concept of <u>helicoidal</u> wear. The concept is based on the principle that the molar occlusal surfaces in humans and apes become smooth and more or less bevelled, with a vestibular inclination of the mandibular bevels and a lingual inclination of the maxillary ones with increasing wear. This pattern is accounted for by the fact that the maxillary dental arch is slightly larger than the mandibular arch and, therefore, overlaps the latter (Moorrees,1957:129-130). Campbell analyzed the molar teeth of Australian aborigines and verified that the type of wear was different from that visible in Western populations (Campbell, 1925). Ackermann referred to this pattern of wear for the permanent maxillary and mandibular molars as helicoidal (Ackermann,1941). The differences were then interpreted as being due to diversity in the morphology of the jaws. However, other explanations, such as dietary characteristics (Brabant & Sahly, 1962), or masticatory stress (Reinhardt,1983), have been offered for the helicoidal type of wear. Roydhouse & Simonsen

(1975) analyzed a group of five different skeletal samples with different types of diet and verified they all exhibited the helicoidal plane; their conclusions were that this pattern of dental wear is characteristic of the human dental occlusion pattern and extremely efficient in the maintenance of the cutting edges of the molar sector, even with advanced wear. Their analysis revealed that aberrations in tooth wear are due mainly to accidental loss of enamel rim or a worn tooth with subsequent abrasion, or to the use of teeth as tools.

It is the variation of the helicoidal plane between populations with different dietary strategies that has to be defined as a potential means of comparison. For Neolithic French and Belgium populations, Brabant & Sahly report the predominance of a helicoidal type of wear, together with the *ad palatum* pattern, with more oblique wear on the first molar than on the other two, defined as "... la première molaire soit beaucoup plus obliquement usée que les molaires voisines" (Brabant & Sahly, 1962:334). Smith (1984) emphasized that both agriculturalists and hunter-gatherers have an abrasive diet and consequently the amount of wear on the occlusal surface per se does not differentiate the two dietary strategies. Taylor (1963) and Brace (1962) were among the first to hypothesize that food preparation, as occurred with the adoption of agriculture, would produce more oblique patterns of wear than hunter gatherer subsistence strategies. Molnar (1971) added to this idea that "... the inclination of the worn occlusal surfaces, found on the teeth of these fossils probably remained very similar until the Neolithic..." (1972:512).

The analysis of the slope of the occlusal surface of molars in skeletal samples has been mostly based on qualitative classification of the tooth surface (cf. chapter four) and only recently has the analysis become quantitative. The first metrical evaluation of the occlusal slope was obtained from in situ teeth (Smith, 1984). The principle was applied to loose teeth by Jackes (1988) who used a trigonometric method for the analysis of the variation of the occlusal angle on mandibular molars with wear increase. The sample analyzed was from a Neolithic site in the same geographical area as Tojal de Vila Chã, and mainly consisting of loose teeth. The results revealed that the point of transition from a larger buccal height to a larger lingual height is located at the same level of occlusal wear, as it is the case in Tojal de Vila Chã (when dentine patches are extensive, but they do not coalesce) (Jackes, 1988:149). Although there is no available comparable sample for pre-Neolithic populations in Estremadura, the similarities in the distribution of the angles of the occlusal surface per wear score between the two Neolithic sites, demonstrates that there is uniformity between the two samples.

The results obtained in the analysis of in situ teeth cannot be directly compared to those resulting from the measurement of loose teeth. In effect, the trigonometric method applied to loose teeth is based in the same principle of measuring the variation of the slope but what is in fact being measured is different. Smith (1984) used a modified protractor to obtain the measurements of the occlusal angle; it is the functional angle that is measured. When loose teeth are observed, it is the buccal crown height and the lingual crown height that are being measured. Given the morphological characteristics of the molars - in the mandibular molars the buccal crown height is larger than the lingual crown height, when there is no erosion of the tooth surface - the values obtained are dependent on that variable and do not reflect the actual functional angles. However, when comparison is established between two loose samples, the results should be compatible. Similarly, the range of variation of the occlusal angles and the erosion point at which the angle changes direction (buccal to lingual orientation) should be comparable between both methods, since the changes operated in the surface of the tooth with increasing wear should be in the same range whether it is translated into crown heights or into functional angles.

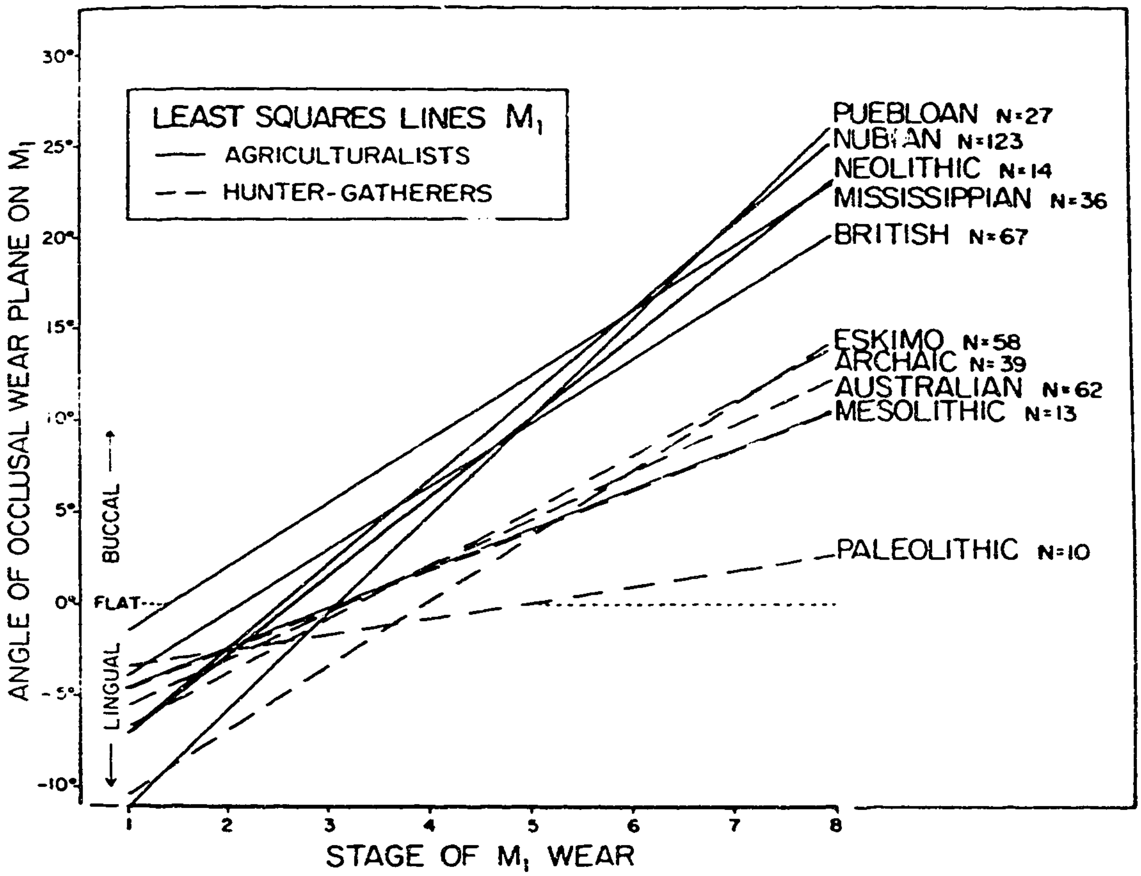
When comparison is established between the values obtained for Tojal de Vila Chã and the regression line obtained by Smith (1984) for the Neolithic samples (Fig. 19), the attrition level at which the angle of the occlusal surface changes does not coincide; in Smith's analysis, the turning point is at score 2.5 and in the present sample, the turning point is at score 4. Whether the difference is due to the fact that in situ and loose teeth were being measured cannot be tested here. When the present sample is compared to the results obtained by Jackes for

Casa da Moura (Neolithic site in the Estremadura) the score at which the angle of the occlusal surface changes is the same (Jackes, 1988: 148). Similarly, at level 0 of occlusion, Jackes reported an angle of 5 degrees, which is similar to the results obtained for Tojal de Vila Chã. The results demonstrate that the trigonometric method is useful in intersample comparison but the values obtained are of a different nature from those measured in <u>in situ</u> teeth.

It is possible to establish a comparison between the range of values of the slope of the occlusal surface obtained in <u>in situ</u> teeth and that observed in loose teeth. The range of the angles of the occlusal surface on the first mandibular molars from Tojal de Vila Chã was of approximately 25 degrees, between -13.2 and 12.2 degrees. In the results presented by Smith (1984) for the Neolithic sample the only source for determination of the angles of the occlusal surface is a regression line, but the values of the angles range approximately from 22° to -8°, a range of 30 degrees. The Mesolithic samples, in contrast, present a range of 13 degrees (from 9° to -4°), significantly different from the Neolithic samples. Although there is no equivalent metrical analysis of the angles of the occlusal surface for Portuguese Mesolithic samples, the fact that the range of values of the angles shows similarities with the results obtained by Smith in the study mentioned above, demonstrates that the method is reproducible and can be used for the comparison of prehistoric dental remains. The teeth from Tojal de Vila Chã show a similar range of values (although not equal) to those observed in the Neolithic samples analyzed by Smith, even if the absolute values do not coincide. The discrepancy between the angles obtained are expected, since the methods utilized are different in the two analyses.

Fig. 19.

Comparison of the dependency of the occlusal slope on wear increase in mandibular first molars from Mesolithic and Neolithic dentitions reported by H. Smith



(adapted from Smith, 1984:49)

The use of the trigonometric method of measurement of the occlusal surface has still to overcome certain inconsistencies. Jackes and Meiklejohn (1992) recently compared the angles of the occlusal surface in Mesolithic and Neolithic samples from Portugal. Several sites were combined and the results contradict those obtained by Jackes in an earlier study (1988); the Neolithic sites produced values between 4 and 0 degrees and the Mesolithic between -2 and -10. The authors do not explain why the slope of the occlusal surface is different at level 0 between the two groups of samples; morphological variation between the two populations might be responsible for differences in the values obtained, but they would have to be large enough to create slpes of negative and positive direction. Similarly, the differences between these results and those obtained by Jackes for Casa da Moura (1988) are not explained. While comparison between Tojal de Vila Chã and Casa da Moura showed consistent values of variation of the angles and shift in the direction of the slope, as discussed above, when the present results are compared with those published by Jackes and Meiklejohn (1992) for combined samples, no consistency is found. Future analysis of other samples of loose teeth can provide further insight on the variation of the angles within and between subsistence strategies and the reliability of the method.

Summary

In this section, the results of the analysis of dental wear patterns in the _in situ_ and loose dentition recovered from the Neolithic burial site of Tojal de Vila Chã were presented. Qualitative analysis of wear on the anterior dentition revealed a predominance of wear score 3 and 4, which is consistent with the wear frequencies observed in the posterior dentition, if third molars are excluded. Overall, the occlusal wear in the teeth analyzed is not severe, the number of specimens with pronounced attrition of the occlusal surface being insignificant.

Metrical analysis of the angle of the occlusal surface in the maxillary and mandibular molars revealed that the development of the occlusal slope is significantly dependent on the amount of attrition the occlusal surface is exposed to. The angles of the occlusal surface on the maxillary molars ranged from -14.6 to 20.7. The slope of the occlusal surface in mandibular molars ranged from -17.1 to 16.2.

Quantification of labial wear on the anterior dentition revealed that a significant percentage of the incisors and canines suffered some attrition, which resulted in the development of polishing of the labial surface. Analysis of the labio-occlusal edge in maxillary and mandibular canines confirmed this observation. Both maxillary central and lateral incisors exhibited a high frequency of chipping of the incisal edge, that started to develop shortly after eruption.

The occlusal wear of the sample from Tojal de Vila Chã is characterized by a moderate attrition on both anterior and posterior teeth, with significant trauma of the labioincisal edge on the maxillary incisors. The angles of the occlusal surface of the molars exhibits pronounced slope with wear increase.

Intra-observer error

Analysis of intra-observer error was performed following the method specified in chapter four. The analysis concentrated on the scores attributed for the wear of the occlusal surfaces bacause these are the methods that are more often utilized in comparison of samples. A reliable method has to be used in the assessment of wear. Although it was not possibe to use different observers in this particular evaluation the consistency of observations with one observer was evaluated.

The results are presented by tooth category as not all the teeth were observed the same number of times; the maxillary central incisors were observed five times between 1989 and 1992; the results obtained produced an error of 0.028 (2.8%) in the inconsistency of the scores attributed. This means that 2.8% of the times the score attributed was not consistent with the previous one for a given tooth. In the maxillary lateral incisors, the error obtained was 4.1% (0.041), possibly due to the irregular morphology of that tooth. The maxillary canines were observed only three times between 1989 and 1991. The results showed an error of 0.002 (0.15%), which is lower than for any of the other maxillary anterior teeth. Between three different observations done by the same observer on the mandibular central incisors the estimated error was 0.014 (1.36%) and between three different observations performed within a time period of 3 years on the mandibular lateral incisors the result was 0.039 (3.9%).

Higher than the error for the observation of occlusal wear was the intra-observer error for labial wear observations; although the number of scores possible was less than for the occlusal wear, labial wear observation was less consistent than incisal wear. The maxillary central inciros (labial) error revealed a 3.28% innacuracy (0.033) between two different observations performed within a time period of two years; for the maxillary lateral incisors labial wear the estimated error between two observations, the first performed in 1989 and the second in 1991, was 5.6% (0.06).

The inconsistencies in scoring labial wear are similar to those of scoring lingual erosion of the anterior teeth; for the maxillary central incisors the error estimated between two different observations performed by the same observer between 1989 and 1991 was 7.2% (0.072). However, for the maxillary lateral incisors, that value was significantly smaller and the estimated error between two different observations, one in 1989 and the second in 1991, was 0.006 (0.56%).

Pathological lesions

The adoption of agriculture by hunting-gathering populations in Europe can be better understood through the analysis of health conditions in both pre-agricultural and agricultural skeletal samples. The changes have to be understood in order to identify advantages and disadvantages of the economic transition. A traditional view, predominant until the 1960s, argued that the adoption of agriculture improved the health conditions of the groups involved in the process (Angel,1984:62). The underlying assumption behind this view was that food resources are more stable and reliable in agricultural economies, and labour demands decrease. After the work of Lee and DeVore with the Kung San of the Kalahari desert in the 1960s (Lee & DeVore, 1968), an alternative view of hunter-gatherer societies was created. Since then, several archaeologists developed models for prehistoric hunter-gatherer societies based on the observations and conclusions of Lee & DeVore (see Binford, 1968; Cohen,1977; Flannery,1969; Meyers,1971).

Recent research developed the idea that agriculture is an economic strategy created by the needs of high population densities among hunter-gatherers and/or by declining wild resources. Therefore, the adoption of agriculture is no longer portrayed as the search for an advantageous economic strategy, but rather as an alternative to a situation of population or environmental pressure. Agriculture has been identified by some researchers as a factor contributing to deficiency in protein, when compared to foraging, due to the heavy focus on cereal or root crops (Cohen,1984:2). Angel remarked the increase of pathological conditions in the skeletons from Neolithic Near East, where agriculture was earlier developed:

> The increased settling down of Mesolithic bands promoted health and longevity, especially of females, by reducing migration stress. But settling close to water or marsh facilitated the malarias and other diseases. (Angel,1984:60)

Angel admits, however, that no single location is to be identified as the point of 'origin' of agriculture and that not only population pressure (by the expansion of forests and the rise of sea level) would motivate hunter-gatherers towards the adoption of agriculture. Agriculture is, in this case, synonymous with stability and health. However, the archaeological data does not always support this hypothesis. Meiklejohn and coworkers (1984) emphasized that the differences in health conditions between pre-Neolithic and Neolithic populations within the same areas, do not reveal a particular trend (p.91). In more recent work, Cohen remarked that

> Most comparisons between hunter-gatherers and later farmers in the same locale suggest that the farmers usually suffered higher rates of infection and parasitization and poorer nutrition. Farmers may have suffered less from mild seasonal hunger (...), but they almost invariably suffered more severe episodes of stress (Cohen,1989:122).

In recent years, archaeology and physical anthropology have contributed to a clarification of this problem. Analysis of linear enamel hypoplasias has permited the identification of stress episodes during periods of tooth formation; caries frequencies have been discussed as evidence of dietary shifts and the presence of a high carbohydrate component in paleodiets (cf. chapter four).

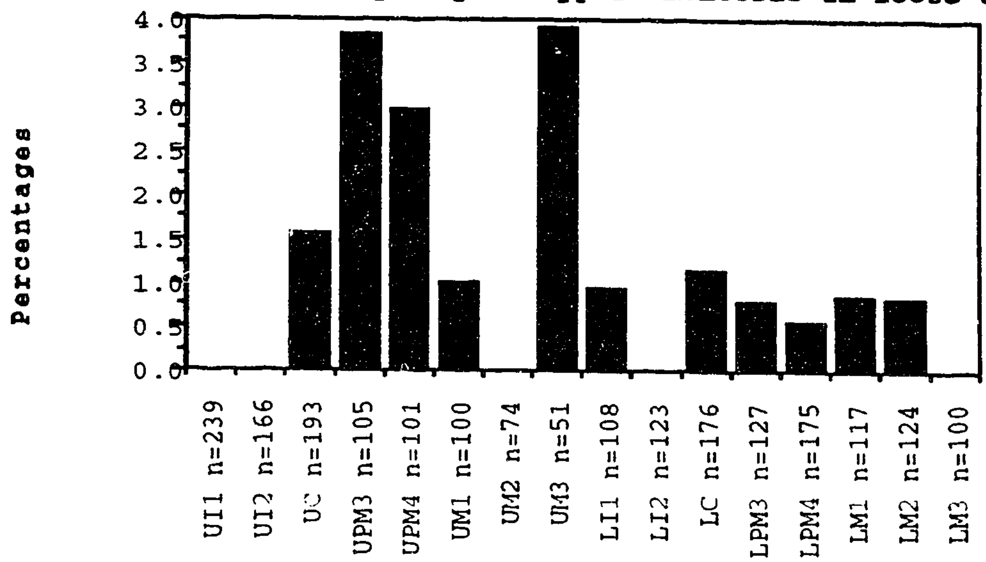
The analysis of dental pathological lesions has been used in the identification of dietary patterns. Types and quantities of foods, as well as their value, relationships between age/sex status and diet, are part of the patterns of food consumption and influence the total results in the analysis. The diagnosis of dental pathological lesions is usually based on the analysis of caries and on the assumption that cereal based diets cause higher incidence of carious lesions than other types of foods. Hence, the percentage of caries has been used as a means of differentiating pre-agricultural and agricultural subsistence strategies in skeletal samples (see Lukacs, 1989 and Scott & Turner, 1988 for review of literature).

Carious lesions, enamel hypoplasia, and hypercementosis were observed and quantified in the sample of loose teeth from Tojal de Vila Chã. The methods used for scoring each of these conditions were presented in chapter four and they will be presented separately in this section.

Hypercementosis

Hypercementosis has not been discussed extensively in the literature (cf. chapter four); however, the fact that the present sample is largely composed of loose teeth allowed the observation of root pathological conditions and the data obtained for this sample can be used in future studies of other Neolithic burial sites in the same geographical area. The presence of hypercementosis was assessed following the methodology presented in the previous chapter. Results are summarized in Fig.20.

Fig.20.Frequency of hypercementosis in loose teeth



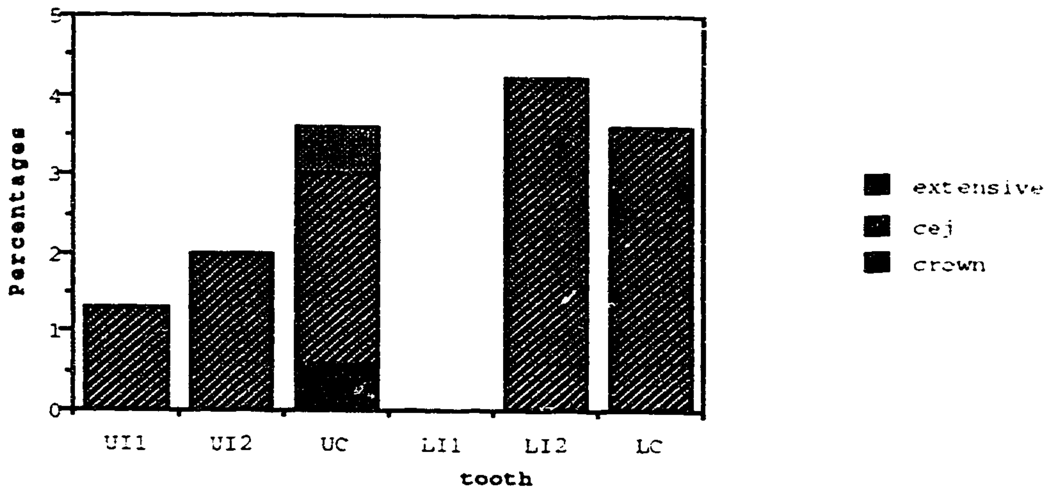
A total of 2025 teeth (81.2%) were scorable for hypercementosis. Whenever the apical end of the root was absent, the tooth was not selected for analysis. A total of 20 specimens exhibited an abnormal growth of the apical end of the root, 1.0% of the total sample. The incisor sector did not show any overdevelopment. Only maxillary third molars and maxillary premolars showed some significant percentage of hypercementosis. The maximum frequency was observed in the maxillary third molars (4%). Maxillary first and second premolars exhibited 3.8% and 2.97% frequency of overgrowth of the root surfaces.

The significance of the frequencies of hypercementosis found in the present study cannot be discussed since there are no published reports on the incidence of hypercementosis for the European prehistory. It has been associated with severe attrition (Commuzie and Steele, 1989) which is not confirmed in the teeth from Tojal de Vila Chã, where the teeth exhibiting overdeposition of cementum on the root surface do not show high levels of attrition. Further research will provide comparable data.

Caries

The presence of carious lesions was assessed taking into consideration the type of lesion and its location. Different tooth sectors (incisors, canines, premolars, molars) exhibited divergent frequencies of caries. Highest caries frequency was visible on the maxillary molars, followed by the mandibular molars and premolars (Fig.21). The anterior dentition showed lower percentages of carious lesions. From a total of 962 loose teeth in which the presence of carious lesions could be assessed, only 29 (3.0%) exhibited caries. Comparison with posterior dentition (Fig.21) reveals that caries is more frequent in molars and premolars; from a total of 1034 teeth in which caries could be assessed, 81 (7.8%) of the posterior teeth showed some carious lesions. If the frequencies estimated for the present sample reflect *per se* the expected values for Neolithic samples, it is clear that their severity is insignificant. From a total of 110 carious teeth (5.5% of the total sample), only 3 specimens exhibited extensive caries (Table 15), in which the area of origin was unrecognizable, because a large portion of the tooth surface was demineralized. The majority of the lesions are present at the cementoenamel junction (67.3% of the total number of carious lesions); crown lesions are less frequent in the sample. Since the presence of carious lesions was only assessed when the tooth was not fractured nor eroded, only a subsample of each tooth sector was scorable. In 89.6% (n=239) of the maxillary central incisors, it was possible to assess the presence or absence of carious lesions. From the total number of specimens observed, only 3 (1.3 %) showed the presence of one carious lesion, all at the cemento-enamel junction. The severity of the lesions was minimal, exhibiting the shape of a line. In the maxillary lateral incisors, the observation of caries was possible in 86.0% of the teeth (n=154). From these, only 3 teeth (1.9%) exhibited a carious lesion, with the same severity of the

Fig. 21. Frequency of carious lesions on loose teeth



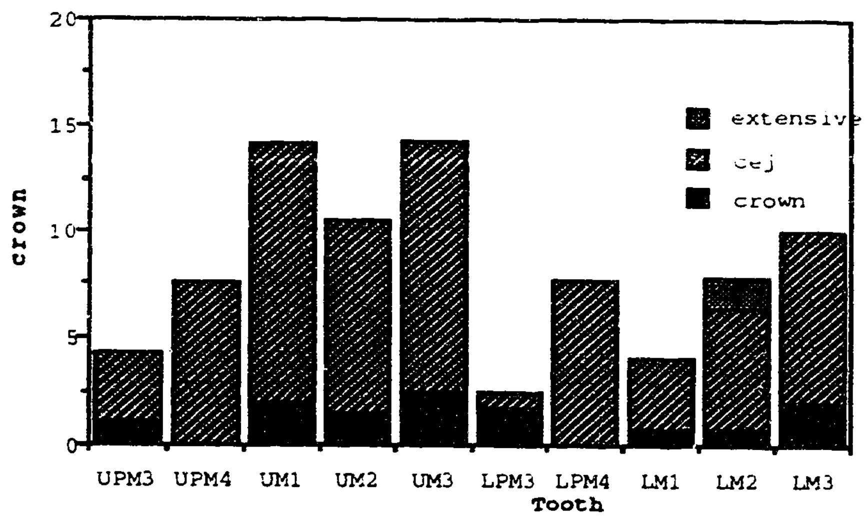


Table 15
Number of carious loose teeth

	Crown	CEJ	Extensive	Total	n=
[illegible]	0	3	0	3	239
[illegible]I2	0	3	0	3	154
UC	1	4	1	6	170
LI1	0	0	0	0	111
LI2	0	5	0	5	120
LC	0	6	0	6	168
UPM3	1	3	0	6	95
UPM4	0	7	0	7	93
UMI	2	13	0	15	106
UM2	1	6	0	7	67
UM3	1	5	0	6	42
LPM3	2	1	0	3	120
LPM4	0	13	0	13	169
LM1	1	5	0	6	151
LM2	1	8	2	11	141
LM3	1	4	0	5	50

maxillary central incisors, at the cemento-enamel junction, two on the distal side and one on the labial side. In 76.6% of the maxillary canines (n=170), it was possible to observe the incidence of caries. In 6 (3.5%) of these specimens some degree of caries was diagnosed (four linear type lesions, at the cemento-enamel junction; one slight lesion on the crown, and one extensive lesion). Three of these lesions were present on the distal side, one on the mesial side, and one of the lesions was extended to multiple surfaces. Only one of the lesions had developed on the smooth surface of the enamel, on the distal side of the crown.

In 110 specimens observed (95.7% of the total sample), the mandibular central incisors exhibited no caries. The mandibular lateral incisors were analyzed for caries in 89.6% of the specimens (n=120).

Only 5 (4.2%) teeth showed the presence of caries, all at the cemento-enamel junction and all exhibiting a linear type of lesion, not very severe. Two of the lesions were present on the distal side, two on the labial side and one of the lesions was not possible to locate, since the tooth could not be sided. Seven mandibular incisors were not identifiable as central or lateral. On these, no caries was diagnosed. In the total sample of mandibular canines 168 (86.2%) were observable for caries. In 6 (3.6%) of these teeth carious lesions were identified, all linear shaped, at the cemento-enamel junction. Two of the lesions were located on the distal surface, two on the labial surface and one of the lesions had expanded to more than one surface.

In the maxillary first premolars carious lesions were scorable in 95 specimens (74.2%). Only 4 (4.2%) specimens exhibited some degree of lesion, 3 of them on the cemento-enamel junction and 1 on the crown surface. The severity of the lesions is more pronounced in two of the specimens, in which they assume the shape of a shell. One of the lesions was located on the mesial surface, two were located on the distal side, and one was located on the labial surface. In the maxillary second premolars, 93 teeth (78.2%) were scored for caries. The majority of the teeth did not show any sign of carious lesion; however, 7 (7.5%) of the specimens exhibited some degree of caries, at the cemento-enamel junction, with variable severity, 3 exhibiting a linear type, and 4 reaching the shape of a shell. Six of these lesions were present on the distal surface, and one on the buccal surface. No lesion was clearly located on the smooth surface of the enamel; only in one of the specimens the interproximal carious lesion appeared to have started at the smooth surface of the crown. The maxillary first molars were analyzed for caries in 65.8% of the cases (n=106). From these specimens, 15 (14.2%) specimens showed the presence of caries, the large majority on the cemento-enamel junction; one of the specimens showed a carious lesion on the crown. Although the severity of the lesions was not very pronounced (mostly linear type), the percentage of teeth with caries is higher in maxillary first molars than in teeth anterior to it. Six of the carious lesions were located on the mesial surface, six on the distal surface, and two on the buccal surface; only two of the teeth exhibited smooth surface caries. In the maxillary second molars, 67 teeth were scorable for caries (65.1%); in 7 (10.4%) of these specimens caries was present. In six cases the lesions were observed at the cemento-enamel junction, assuming a linear shape and shell shape and only one lesion was located at te smooth surface of the crown. Two of the lesions were present on the mesial side, four on the distal surface, and one on the buccal surface. The maxillary third molars, exhibited a higher incidence of caries. In 42 analyzed (68.9%), 6 (14.3%) showed some degree of caries. In five cases the carious lesion was present at the cemento-enamel junction, and all on the mesial side; only one tooth exhibitec caries on the smooth surface of the crown. For the group of six maxillary molars which could not be classified as first, second or third, a group of 2 was scorable for the presence of caries. One of them had an extensive carious lesion, with origin unidentifiable.

Caries was observable in 120 mandibular first premolars (84.5%). From these, 3 (2.5%) specimens were identified as carious, 2 with a linear type of lesion at the cemento-enamel junction, and 1 with a medium sized lesion, with less than one half of the crown destroyed, on the coronal surface but extending to the cementoenamel junction. Two of the teeth were demineralized on the distal surface, and one on the mesial surface. The majority of the mandibular second premolars were observable for the presence of caries (85.4%). In 13 specimens (7.7%), demineralization was diagnosed as present. The lesions were all located at the cemento-enamel junction, 10 exhibiting a linear shape and 3 having expanded into a shell shape lesion. The majority of the lesions were present on the distal surface and in 3 of the specimens, demineralization had extended to multiple surfaces of the tooth. The mandibular first molars were observed for caries in 81.6% of the specimens (n=151). Only 6 teeth (4.0%) revealed some degree of demineralization, in the majority of the cases on the cemento-enamel junction. These lesions were shell and linear shaped and only one tooth exhibited a linear type of caries on the smooth buccal surface of the crown. Two of these lesions were present on the distal side, three on the mesial side and one on the buccal surface. The mandibular second molars exhibited a higher rate of caries; 141 (76.2%).specimens were observable. From these, a total of 11 (7.8%) specimens exhibit some degree of caries; 8 have lesions on the cemento-enamel junction (both linear and shell shaped), and one on the crown (medium lesion, with less than half of the crown surface demineralized). Three of the teeth were demineralized on the buccal surface, three on the mesial side and two on the mesial surface. Most of the mandibular third molars were scorable for caries (n=50; 92.6%). In 5 (10%) of these specimens, some degree of caries was diagnosed. The lesions concentrated mostly on the cemento-enamel junction (both linear and shell shaped). Only one specimen exhibited caries on the crown surface. Two of the teeth were demineralized on the mesial surface, two on the buccal surface, and one of teeth had been demineralized in more than one surfaces.

From the total sample of loose teeth available for study, 1996 specimens were observed for the presence of carious lesions (80.0% of the total sample of loose teeth). A total of 104 (5.2%) teeth exhibited some degree of caries. The overall analysis reveals that the anterior dentition is less affected by caries than the posterior sector; when percentages are compared, there is a consistent reduction of the number of healthy specimens, from the incisor to the canine, to the premolar and to the molar sector. The only exception to this trend is the difference in percentage of caries present in mandibular second premolars and mandibular first molars. The severity of the lesions also increases from the anterior dentition to the posterior; the only specimens diagnosed as assuming shell type of lesions were exclusively premolars and molars, both on the maxillary and mandibular dentitions.

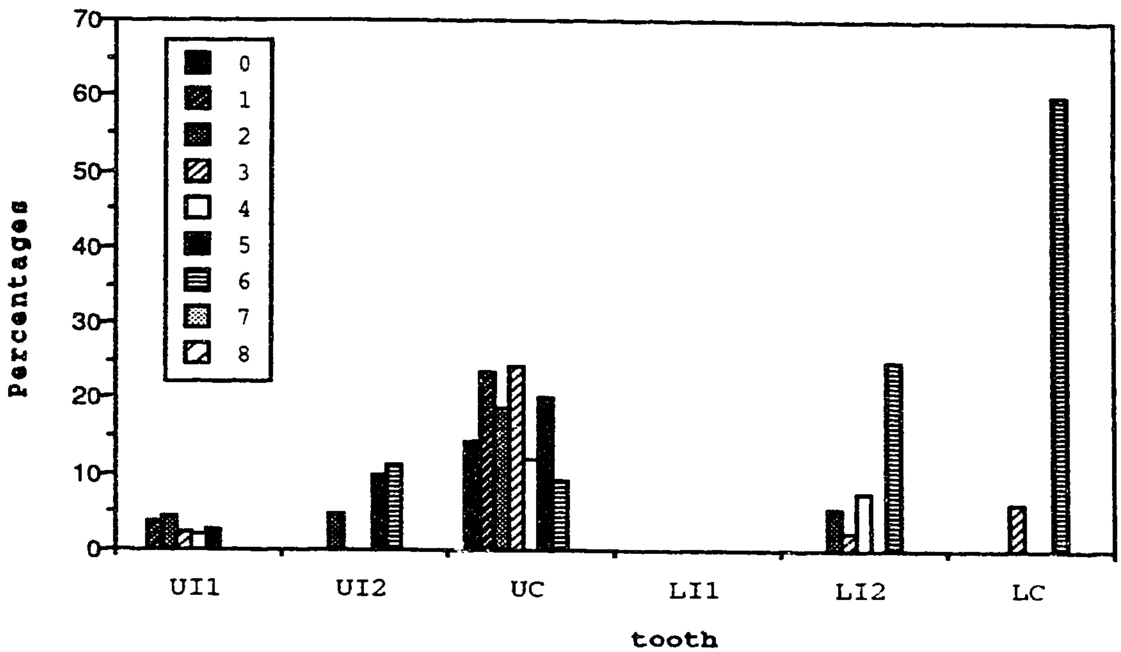
The large majority of carious lesions is present at the cemento-enamel junction. When present on the crown, the carious lesion was never occlusal. The distal surface is more frequently affected by demineralization, in all tooth sectors. Although caries is present in 5.5% of the sample observed, only 4 specimens (one maxillary canine, two mandibular second molars and one uncliassified mandibular molars (0.20%) revealed an extensive type of lesion, the origin of which could not be identified.

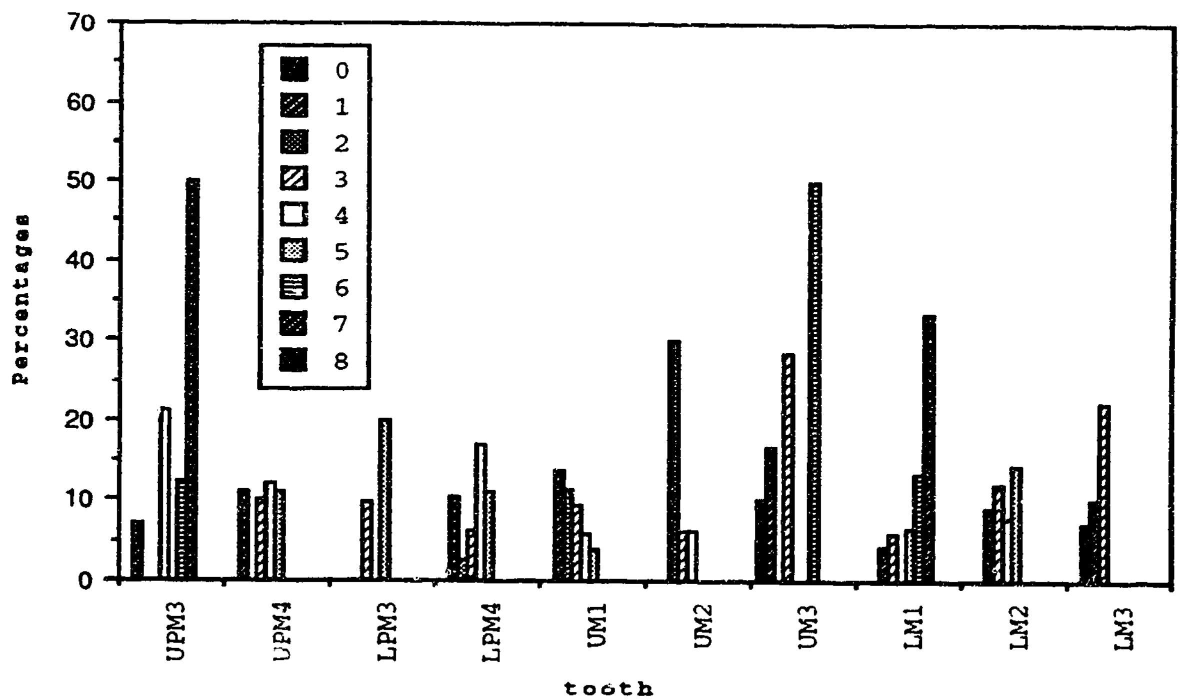
The relationship between caries frequencies and wear increase was analyzed in the sample of loose teeth. There is no general trend of increase of carious lesions with advanced wear (Fig.22). Some exceptions are possibly attributed to the small sample size of the higher levels of attrition (mandibular lateral incisors, mandibular canines, first maxillary and mandibular premolars and maxillary third molar) (Table 16). In general there seems to be no pattern in the relationship between prevalence of caries and wear increase.

Table 16. Number of teeth observed for caries on each wear level

	0	1	2	3	4	5	6	7	8
UI1	24	27	23	42	54	34	15	12	3
UI2	13	30	21	38	27	10	9	2	0
UC	14	17	37	45	42	15	11	2	0
LI1	10	5	20	39	24	7	2	1	0
LI2	10	10	18	40	27	0	4	0	0
LC	0	0	0	48	0	16	5	0	0
UPM3	19	14	13	17	14	3	8	2	0
UPM4	12	9	11	20	25	9	5	1	0
LPM3	13	24	19	31	21	5	2	0	0
LPM4	0	19	39	33	35	18	7	0	0
UM1	0	22	26	21	17	25	0	0	0
UM2	20	10	10	16	6	0	0	0	0
UM3	10	12	0	7	2	0	2	0	0
LM1	14	15	23	17	28	15	15	3	2
LM2	9	22	22	25	25	7	0	0	0
LM3	5	14	10	9	1	1	1	0	0

Fig.22. Frequency of carious lesions in relation to wear increase





The analysis of dental pathological lesions, and more specifically of the incidence of caries in the population represented in Tojal de Vila Chã, suggests that dental health conditions were improved from the Mesolithic to the Neolithic, in Estremadura. Upon quantification of the occurrence of carious lesions in the present sample, it becomes clear that there is a need for a definition of local trends in the changes between pre-agricultural and agricultural subsistence strategies, and that models generally used for other geographical areas cannot be applied to Estremadura prehistory.

As Patterson emphasized (1984:272), since Leigh (1925) it has been accepted that populations following a fishing-hunting and collecting lifestyle are broadly affected by periodontal disease, abcessing, and low amounts of caries, while those practising a horticultural economy exhibit moderate periodontal disease, high antemortem tooth loss, and high levels of caries. However, the mechanisms of development of caries, and other pathologies, are far from being fully understood, and different factors are known to be involved in its development (cf.chapter four). High caries rates have been associated with agricultural subsistence systems, which include soft, sticky, and sweet foods (Lukacs,1989:267). Lukacs (1989) reports differences in caries incidence between prehistoric populations with different subsistence strategies, and identifies agricultural samples as those with higher incidence.

Although most of the paleopathological reports associate high caries rates with the consumption of cereals, attention should be drawn to the fact that high carbohydrate diets are not exclusive to cereal based subsistence strategies. Aleut populations showed a higher incidence of caries after contact than in prehistoric times. This was the result of an increase in the consumption of sugars, introduced by Western colonizers, and has no direct relationship with the consumption of cereals (Turner et al. ,1985). As Hillson emphasized (1979), the presence of high sugar content products, such as honey, dried carob, dates and figs, must have contributed for the high incidence of caries in prehistoric Egypt. Whatever caused the high caries rate in Muge was characteristic of the adult diet, caries being absent in sub-adults.

Considering the total number of teeth analyzed, the percentage of teeth with carious lesions (by tooth count) was 12.0% and 7.2% in two Mesolithic sites studied by M.Jackes (1991). The Neolithic sites in the same geographical area showed values of 4%, 8%, 5%, 7% and 1.5% (Jackes & Meiklejohn, 1992). The Mesolithic values are extremely high when compared to other dental data from hunter-gatherers. Considering the mandibular molars, the results obtained by Jackes for the Mesolithic dentitions are higher than those reported by Lukacs for the Late Neolithic site of Sarai Kola in Pakistan (Lukacs, 1989). There seems to be no definitive trend in the changes in frequency of caries between Mesolithic and Neolithic samples.

The quantification of carious lesions in prehistoric populations from Estremadura reveals that the generalizations made for the American precontact transition to agriculture cannot be applied. Similarly, the values obtained for Northern European samples differ from those obtained for Southern Europe. Alexandersen (1988) observed carious lesions "... as cervical cavities facially or proximally in a few teeth .." (p.199) in a sample of teeth from Southern Scandinavia Mesolithic. Opposed to these are the results obtained by Silvana and coworkers for the Uzzo and Molara caves of the Italian Mesolithic in which 10% of the teeth were carious (Silvana et al, 1985); these results contrast with the Neolithic caries frequencies in the same area (about 2.5%).

Although the caries frequency in Tojal de Vila Chã is higher than that found in Southern Italy Neolithic (5.5% of the teeth are carious) the values are definitely lower than those found for the Mesolithic by Jackes and Meiklejohn (1992). As these authors emphasized, there seems to be no definite pattern in the percentage of caries frequency observed in several samples from the Portuguese Neolithic and even sites that are geographically associated do not exhibit the same values.

Different factors might account for the observation of inconsistent values in the caries frequency of the Portuguese Neolithic and for the differences obtained when it is compared to the Mesolithic of the same region. Frayer (1987) questioned the diagnosis of carious lesions in the Mesolithic samples performed by Jackes and coworkers.

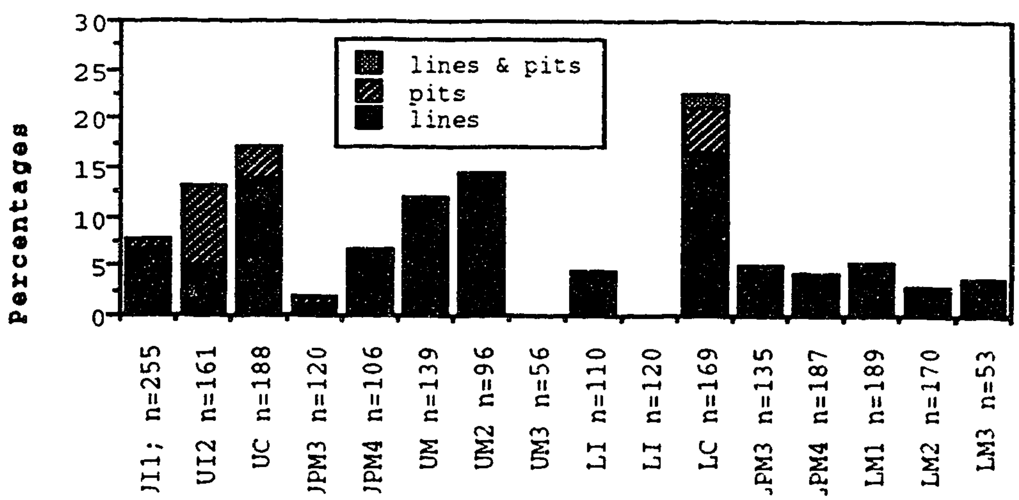
However, inter-observer error has extensively been tested by these researchers (Jackes & Meiklejohn, 1992) and several observations of the same samples reveal similar results; furthermore, the fact that the Mesolitic dentitions are mostly composed of in situ teeth and the Neolithic teeth are, in their majority, loose could have biased the observations towards an underestimation of the number of carious teeth in the Mesolithic samples rather than overestimate them. Substantial differences in the geochemistry of the water supplies of these populations do not make a convincing argument for the differences observed since some of the sites are located at short distances from one another and reveal different percentages of carious teeth. Differences in diet must be responsible for the observation of different caries frequencies in populations living in the same geographical area. However, these differences cannot be supported by archaeological data due to the absence of paleobotanical data that would provide information on the consumption of dried fruits, cereals, any source of sucrose or fructose that could be responsible for the increase of deminaralization of dental tissues. The hypothesis suggested by Silvana and coworkers (1988) and supported by Meiklejohn (1988) that figs (Ficus) and carob (Ceratonia) were consummed by the Mesolithic populations and were responsible for the high frequency of caries seems plausible. However, an explanation is needed to why, in the Neolithic, populations living in the same geographical area as the Mesolithic groups before them would have stopped eating these fruits.

The results on the observation of caries in Neolithic populations from the Portuguese Estremadura are consistent with the values obtained for other geographical areas (5.5%). It is the trend in the transition from Mesolithic to Neolithic that is reversed, when compared to other areas (Northern Europe and America). The carious lesions in the Neolithic seem to be more often located on the interproximal areas rather than on the occlusal surface; occlusal caries often occurs in the Mesolithic (Jackes and Meiklejohn, 1992; Meiklejohn et al, 1988). The results obtained for Tojal de Vila Chã are consistent with this observation. However, the frequency of carious teeth is not similar in all Neolithic sites of Estremadura. Jackes and Meiklejohn (1992) suggest that the different frequencies of dental pathologies in the Portuguese Neolithic are a reflection of the heterogeneity of the diets in the Neolithic. However, data obtained from the stable isotopic analyses of human bone collagen suggested that the Neolithic diets were more homogeneous than the Mesolithic (Lubell et al., 1992).

Hypoplasia

Hypoplasia was assessed on the loose teeth, following the methodology presented in Chapter four; when the teeth were scored for hypoplasia the type of lesion (pits, lines or both) was considered, and the results obtained are presented in Fig. 23. The teeth with higher percentages of linear hypoplastic defects of the enamel were the canines (both the maxillary and mandibular) followed by the maxillary incisors and the maxillary second molar. The most frequent type of defect was the single line, although a series of lines sometimes occurred. Lines and pits simultaneously found on the same tooth were only visible on the mandibular canines. Enamel defects were present in only two upper third molars (3.8% of the total number of maxillary third molars) which suggests that the stress episodes that caused the hypoplastic defects to form were present at an early age and were not significant after 8 years of age.

Fig. 23. Frequency of enamel hypoplastic defects on loose teeth



The sample selected for the diagnosis of growth defects is larger than that used for the assessment of caries because hypoplastic defects, when linear, can be observed all around the crown surface of the tooth. If the tooth is partially fractured, the presence of linear defects can still be identified from the remaining portion of the crown. The same is not possible for the assessment of pit type of hypoplastic defect. Therefore, the estimation of the percentage of the presence of pit hypoplastic defects might be biased, since it was assessed together with linear defects.

In the analysis of the results obtained for the presence of hypoplastic defects it should be taken into consideration that wear deletes the hypoplastic lesions, and teeth with wear score higher than 2 could have had hypoplastic defects that were eroded by attrition; therefore, the total percentages obtained should be considered as an underestimation of the actual frequency of enamel hypoplastic defects. Only teeth that were so badly damaged that the whole crown could not be observed (nor even at different surfaces) were removed from the the total sample.

In the maxillary central incisors, 95.5% of the teeth were scorable for hypoplasia and a total of 20 teeth with hypoplastic defects were observed. The crown of the maxillary central incisor is formed between 3 months after birth and five years of age which indicates that at some point in this time period there was a stress factor that created these defects. The maxillary lateral incisors showed a higher percentage of hypoplastic defects. A total of 161 (89.9%) teeth were scorable for the presence of hypoplasias. Among these, 13 specimens (8.1%) exhibited pit-like defects, while only 8 (6.7%) exhibited linear hypoplasias. A total of 13.0% of the teeth exhibited hypoplastic defects; the age of formation of the crown of the maxillary lateral incisor is similar to that of the maxillary central incisor (10 months after birth to 5 years). The maxillary canines were scorable in 84.7% of the cases. In 26 (13.8%) canines linear defects were observed, and in 6 (3.2%) teeth a pit shaped defect was detected. A total of 32 (17.1%) of the maxillary canines have developmental defects.

From the total sample of maxillary first premolars 93.8% of the teeth were observable and only six teeth exhibited hypoplastic defects. The maxillary second premolars were observable in 89.1% of the teeth and only 6.6% of the specimens exhibited linear hypoplastic defects; the age of formaion of the crown of the maxillary first premolars is between 1.5 to 6 years of age and the second premolar is 2.5 to 8 years. The maxillary first molars were scorable for hypoplasia in 86.3% of the specimens and a total of 12 (8.6%) teeth exhibited linear enamel hypoplasia. No pit shaped defects were observed; the age of formation of the crown is between birth to 3 years. The maxillary second molars were scorable for hypoplasia in 93.2% of the specimens. A total of 14 teeth (14.6%) showed linear enamel hypoplasia. No pit shaped defects were observed; the age of formation of the crown is between 2.5 to 8 years. From the total sample of maxillary third molars, 91.8% of the teeth were scorable for the presence of hypoplastic defects. None of the specimens developmental anomalies. From the unclassified maxillary molars one exhibited a linear hypoplastic defect.

The mandibular central incisors were analyzed for the presence of hypoplasia in 95.7% of the cases. Only 5 specimens (4.6%) exhibited linear hypoplastic defects. From the total sample of mandibular lateral incisors, 120 teeth were scorable for the presence of hypoplasia (89.6%). Only one specimen (.8%) exhibited one hypoplastic defect, pit shaped. The period of formation of the crown of the lower incisors is between 3 months and 5 years, which is the same as the maxillary central incisors. However, the frequency of hypoplastic defects in the lower incisors is much lower than in the upper incisors. Because the teeth are loose it is impossible to verify if this is due to the fact that the teeth do not belong to the same individuals or if differences in susceptibility between the two tooth types are responsible for this diversity. In 86.7% of the mandibular canines hypoplastic defects were scorable and the highest frequency of defects was observed: 28 specimens (16.6%) exhibited linear hypoplastic defects, and 8 teeth (4.7%) showed pit shaped scars on the enamel surface. Two of the teeth (1.2%) showed both types of hypoplastic defects (lines and pits) on the enamel surface. A total of 38 canines (22.5%) showed defects. The age of formation of the lower canines is the same as that of their maxillary counterparts (4 months to 7 years), and the frequencies of defects are higher in both teeth. Whether this represents an actual incidence of stress during that age span or the higher susceptibility of the canines to the formation of hypoplastic defects, it is impossible to test in this study but higher frequencies have been reported for the canines by several researchers (cf. chapter four).

The mandibular first premolars were analyzed for the presence of hypoplasia in 95.1% of the total sample. Hypoplastic defects were observed in 7 specimens (5.2%), 6 teeth (4.4%) with linear hypoplasia and 1 tooth (.7%) with a pit defect. From the total sample of mandibular second premolars, 94.4% of the specimens were scorable for the presence of developmental defects and only 8 teeth (4.3%) showed linear hypoplasia. The ages of formation of the mandibular premolars coincide with the ages of formation of the maxillary premolars and the values obtained for the two tooth categories are different (see Table 17). In the mandibular first molars, 94.5% of the teeth were observed for the presence of hypoplastic defects. Among these, 10 specimens were diagnosed as exhibiting linear hypoplastic defects, which corresponds to 5.3% of the total number of observable teeth. No pit shaped defects were detected. From the total number of mandibular second molars, 96.6% of the teeth were scorable for the presence of hypoplasia and only linear defects were detected in 2.9% of the teeth. The mandibular third molars showed a low percentage of hypoplastic defects. From the total sample 98.2% of the teeth were analyzed and only 2 teeth exhibited linear defects. No pattern appears to be visible on the distribution of hypoplastic defects on the posterior dentition; the results are not comparable between the maxillary and the mandibular sides.

Overall, the analysis of hypoplastic defects in the sample of loose teeth (n=2265), reveals that 8.3% of the teeth (189) have enamel defects. From these 82.5% of the specimens exhibit linear hypoplasia. From the results obtained, it is clear that the canine sector has the highest incidence of hypoplastic defects, a fact that has been generally recognized in the literature (cf. chapter four). The high percentage of pit defects on the maxillary lateral incisors might be an indication of false diagnosis of the condition. The presence of corono-radicular grooves on the maxillary lateral incisors can create the illusion of a pit type of developmental defect , when in fact it is a morphological feature.

Analysis of distribution of enamel defects by age reveals that the age sector more affected by growth disturbances is between 3 months and 7 years of age (maximum range of crown formation), period of formation of the canine crowns (Table 17). However, 19 second molars (10.1%) exhibit hypoplastic defects, which would have occurred between 2.5 and 8 years of age (maximum range of crown formation). Only two third mandibular molars show hypoplastic lines (1.1%). The data reveals higher stress during childhood, expecially between 3 months and 7 years of age.

Table 17.
Distribution of enamel hypoplasia by tooth and age of crown formation

UI1 (3 months to 5 years)	10.60%
UI2 (10 months to 5 years)	6.90%
UC (4 months to 7 years)	16.90%
UPM3 (1.5 to 6 years)	2.60%
UPM4 (2 to 7 years)	2.60%
UM1 (birth to 3 years)	5.80%
UM2 (2.5 to 8 years)	7.40%
UM3	
LI1 (3 months to 5 years)	3.20%
LI2 (3 months to 5 years)	0.50%
LC (4 months to 7 years)	20.10%
LPM3 (1.5 to 6 years)	3.70%
LPM4 (2.5 to 7 years)	4.20%
LM1 (birth to 3 years)	4.80%
LM2 (2.5 to 8 years)	2.70%
LM3 (8 to 16 years)	1.10%

The heterogeneous occurrence of linear enamel hypoplasias in different sectors of human dentition has been reported in the literature. In Vlasac (Mesolithic Yugoslavia), maxillary central incisors and maxillary canines manifested the most severe degree of linear enamel hypoplasias (Y'Edynak,1989:27). Goodman & Armelagos (1985) also identified a higher incidence in maxillary incisors and mandibular canines, with a lowest frequency in mandibular second molars, which is compatible with the results obtained in Tojal de Vila Chã. Rose et al. (1985) and Goodman & Armelagos (1984) agree that the appearance of hypoplasias on less susceptible teeth may be indicative of a more severe physiological disruption, and are therefore more diagnostic.

The nature of the sample does not permit an analysis of the incidence of enamel defects by sex and it makes it impossible to determine if the number of defects per tooth reflects variability in the susceptibility to hypomineralization in certain tooth sectors or if it reflects the fact that the sample is extremely biased and the different tooth types belong to different individuals. The sample from Tojal de Vila Chã shows a higher frequency of hypoplasias on the mandibular and maxillary canines, with respectively 20.1% and 16.9% of the teeth affected. The type of hypoplastic defect is predominantly linear.

The presence of hypoplastic defects is not used directly as a means of diet assessment, but it can provide information on the nutritional conditions of the weaning infants and children, since they are associated with a deficiency in Vitamin D or extreme fever (Lukacs,1989:267). Anthropologists have reported different rates of incidence of hypoplasias and associated them with specific dietary strategies.

While for the American precontact transition from preagricultural to an agricultural subsistence strategy it has become clear that there was a decrease in general health conditions which is reflected in the presence or absence of hypoplastic defects on the tooth enamel of precontact populations (see Hutchinson & Larsen, 1990 for review of the literature), the health conditions in the Mesolithic/Neolithic transition in Europe are not yet clear. Y'Edynak (1989:27) reported 95% hypoplastic teeth in a Mesolithic sample from Vlasac, Yugoslavia. Hillson (1979) emphasized that a cereal based diet consumed during pregnancy or lactation - for example, oats, which is deficient in Vitamin D - can cause hypoplasias in the infant. Neiburger (1990) stated that hypoplasias are more often reported in agriculturalist populations. However, he emphasized that hypoplasias can be caused by many factors and cannot be taken as indicative of lack of nutritional success. In the sample from Caldeirão (Neolithic Portugal), Jackes & Lubell (n/d) reported the presence of slight hypoplasias in 20% of the canines. These figures suggest a marked increase of canine hypoplasia over that found in Moita and Arruda, two Mesolithic sites (Meiklejohn, pers. comm. in Jackes & Lubell, 1987:16). From the total number of canines analyzed in Tojal de Vila Chã, 20.1% of the mandibular and 16.9% of the maxillary teeth exhibited hypoplastic defects which is consistent with those results. Alexandersen (1988) reported the presence of hypoplastic defects in a Mesolithic population from Southern Scandinavia but the results are given per individual skeleton (66%) and therefore comparison cannot be established with the present sample. Lower values are given by the same researcher for the Neolithic of Danemark (45% of the individuals being affected): the pattern seems to be reversed from the American data. In the Mesolithic samples from Estremadura Lubell et al., (1989) reported the presence of hypoplastic defects in 48.2% of the permanent teeth, which is a significantly higher value than that obtained for the Neolithic. For the Mesolithic of Italy, however, Silvana and coworkers reported a "... very low degree of severity in all the dentitions of the Sicilian mesolithic samples..." (Silvana et al., 1985:251). The pattern that has been so perfectly identified for the American precontact history does not seem to apply to the European samples.

CHAPTER SIX

CONCLUSIONS

The transition from hunting-gathering to agriculture in prehistoric Europe is defined as the Mesolithic-Neolithic period. In Portugal it is archaeologically associated with the appearance of a specific type of ceramic called 'Cardial', supposedly decorated with incisions made with shells of Cardium edule, a bivalve very common in Mesolithic shell middens in the area. This transition must have occurred between 6,500 and 5,500 years before present in the Estremadura area (central coastal Portugal) (Zilhão, n/d).

The Mesolithic is archaeologically defined as a period of adaptation to a Holocene environment, with reduction of the number of members in individual hunting groups and a specialization on more varied sources of game, due to the extinction and/or migration of the large herbivores, at the end of the Pleistocene (Butzer, 1971:535/536). In Portugal, as in other parts of Europe, mesolithic people very commonly settled in estuary areas and explored the riverine and marine resources; their habitation sites are commonly refered to as 'shell middens' given the high concentration of molluscs recovered from those areas. Their lithic technology was characterized by the presence of microliths, bladelet components of composite tools, with varied geometrical forms. Although for the Estremadura region there is no direct evidence of plant foods consumed by these coastal populations (given the lack of paleobotanical data) it is assumed that they ate the available nuts, berries and fruits and they obtained their protein from the consumption of fish and shellfish available on the coast and river estuaries (Arnaud, 1982, 1985; Lello, 1990). What motivated these people to change their subsistence pattern and initiate cultivation has been the object of curiosity in extensive archaeological research since the 19th century.

Neolithic communities are characterized by archaeologists as the first 'farmers' and 'herders'. While the beginning of this mode of production did not happen simultaneously all over the world, the Near Eastern model for the appearance of the first farmers was generalized to the European prehistory until the second half of the 20th century. Models for the appearance of agriculture in all areas of Europe oscillated between migrationist explanations or local development alternatives (Dennell, 1983). Although not independent of their socio-economic environment and of the historical conditions of Europe itself, prehistorians have used the available data to support their models, sometimes with very little information on the actual environment and population distribution at the time. Presently, it is accepted by most archaeologists that there was no replacement of populations in the Mesolithic-Neolithic transition in Western Europe and that populations with both subsistence strategies coexisted and must have been in contact with each other (Lubell & Jackes, 1988). For the Estremadura, the most recent models developed for the introduction of agriculture view it as a result of the contact between coastal populations (or sailors), who knew agriculture, and the native hunter-gatherer groups of the estuarine areas and the interior (Arnaud, 1982; Zilhão, n/d).

The beginning of cereal cultivation and the advancing sedentism are traditionally seen as indication of the appearance of the Chalcolithic period, in which villages and fortified settlement sites were supposed to be the dominant settlement strategies. The dates for this latter period of prehistory are usually set at between 5,500 and 4,500 years before present in the Estremadura region (Jorge, 1986).

The differences between Mesolithic and Neolithic subsistence systems are established as a transition from hunting/fishing/gathering to an agricultural mode of production. Although these changes are not yet proven by direct archaeological evidence, stable isotopic analysis of human skeletons from both archeological contexts revealed for Mesolithic people, a higher consumption of marine resources and a generally more varied diet than that of Neolithic people, who seemed to have a more terrestrial and more homogeneous diet (Lubell et al., 1992). Analysis of dental wear patterns reveals a much higher level of occlusal attrition for Mesolithic teeth than in teeth from Neolithic sites. This trend suggests a change in the amount of grit in the diet (maybe the large amounts of shellfish consumed by the estuary populations). The real changes that occurred between the Neolithic and the Chalcolithic have not been fully understood and although the settlement strategies seem to be different between the two periods there is no hard evidence for any change in economic systems between Neolithic and Chalcolithic. Analysis of human skeletal data may provide useful information for this question.

With data available from the dental wear patterns and lesions from Mesolithic and Neolithic teeth of the Portuguese Estremadura it is possible to evaluate how wear patterns and pathological lesions of the dentition from people buried in Tojal de Vila Chã differ from those visible in earlier and contemporaneous populations; similarities and differences between their subsistence patterns can therefore be verified. It was hypothesized that the wear of the occlusal surfaces of the anterior and posterior teeth as well as the pathological lesions in teeth from Tojal de Vila Chã should exhibit the same patterns as teeth from Neolithic sites of the same geographical area and they should show a contrast with the teeth from Mesolithic cemeteries.

In order to test this hypothesis a sample of 2,500 loose teeth recovered from Tojal de Vila Chã were analyzed. The development of techniques for the analysis of loose teeth is important for this geographical area since most of the dentitions found in Neolithic burial sites of the Estremadura are disassociated from the jaws. The problems encountered in the use of a sample of this nature are numerous; there is no control for sex or age of the individuals and consequently accounting for patterns that might be dependent on those variables cannot be accomplished. However, general patterns of attrition and of pathological lesions were possible to analyze.

The wear patterns of the teeth from Tojal de Vila Chã were analyzed in order to identify their general distribution within the dentition, the rate of attrition (amount of wear on adjacent teeth), the differences between the wear patterns of anterior and posterior teeth, and features that might be indicative of the use of teeth as tools.

Occlusal attrition was recorded qualitatively for the anterior and posterior teeth and quantitatively for the maxillary and mandibular molars. The incisors and canines analyzed were exclusively all loose and the results demonstrated that the maxillary central incisors and canines exhibited pronounced wear on the incisal surface, which is related to the development of a labio-incisal erosion of the tooth surface and often exhibits the shape of chipping, possibly due to pressure on the tooth surface. Chipping was visible at very early stages of occlusal erosion of the tooth, which suggests that it is related to activities that are shared by juveniles, adolescents, and adults and is possibly not related to diet.

The use of the anterior teeth as tools is also supported by the observation of lingual wear in the maxillary and mandibular incisors and canines. The high degree of erosion of the lingual surface in some of the teeth is comparable to the type of wear reported for the Tagus Mesolithic sites and referred to in the literature as the 'signe du cordonnier'. With this type of wear the lingual surface is totally polished, very smooth, and sometimes dentine is exposed. This erosion has been explained by the use of the involved teeth in basket production or in the chewing and stretching of strips of leather. This activity might be related to the production of artifacts such as knife handles, which would occur in the Mesolithic and Neolithic, independently of the subsistence strategy adopted in each period.

The analysis of occlusal wear of the posterior teeth revealed a clear association of the patterns observed with the Neolithic sites of Estremadura. The amount of wear of the occlusal surface is in general less severe than the Mesolithic pattern of occlusal attrition. For this sector, and for the lower jaw, both <u>in situ</u> and loose teeth were analyzed. The results revealed that at the time the second molar has fully erupted and shows no evidence of polishing of the occlusal surface, the first molar exhibits level 1 or 2 of attrition. These results contrast with the observations on the Mesolithic teeth, in which a score 3 was consistently found in the first molar when the second molar was at eruption. Similarly, the rate of attrition between the occlusion of the second molar and the occlusion of the third is at level

2, which is also lower than the Mesolithic values. These results suggest that the diet of Neolithic populations had less grit and provoked a slower rate of attrition. Therefore, lower percentages of higher wear scores cannot be justified by a lower life expectancy but they should be interpreted as the result of differences in the consistency of the foods consumed.

The results obtained from the qualitative analysis of molars were confirmed by the measurement of the occlusal slope as the amount of wear increased. The crowns of the loose molar teeth were measured at three locations: the buccal crown height, the lingual crown height and the buccolingual diametre. From these, a trigonometrical principle was applied in order to define the value of the angle formed by the slope of the occlusal surface. Comparison of these values with the specific wear score observed in the quantitative analysis for each tooth revealed a dependency of the slope variation with the amount of wear on the tooth surface. Comparison with values obtained by several other researchers on samples of pre-agricultural and agricultural skeletal populations (Smith, 1984; Lubell & Jackes, 1988) suggests that the sample from Tojal de Vila Chã exhibits the same distribution of occlusal angles as other Neolithic samples from Estremadura, and it differs from the flatter surfaces observed on Mesolithic teeth. Comparison with values obtained from the measurement of the functional angles of the occlusal surfaces of hunter-gatherers and agriculturalists dentitions revealed that the range of values observed in Tojal de Vila Chã is smaller than some of the agriculturalist samples but the surfaces are more heavily sloped than the hunter-gatherers' teeth.

From the analysis of the wear patterns of the dentition from Tojal de Vila Chã, the site seems to be comparable to other Neolithic samples from the same region and clearly shows a difference from the the patterns of wear exhibited by Mesolithic populations. However, the fact that the anterior dentition shows heavier wear than the posterior teeth and chipping of the incisal surface suggests that some of the generalizations accepted about the differences between hunter-gatherers' and agriculturalists' dental use might not be as clear as has been proposed. Similarly, comparison of the slopes of the occlusal surface observed in Tojal de Vila Chã with other samples reported in the literature suggests that the transition to agriculture and to a cereal based diet might not be the pattern in this geographical region. A mixed economy is more likely to have been present for a longer period of time than previously thought.

The presence of carious lesions and enamel hypoplastic defects was evaluated for Tojal de Vila Chã in order to establish a comparison with other skeletal samples from early agricultural populations. Different frequencies of pathological lesions have been consistently reported for pre-agricultural and agricultural populations. It is accepted that the consumption of carbohydrates (in conjunction with other factors) is likely to provoke more severe bacterial demineralization than a diet where carbohydrates are absent. The differences in carious teeth between pre-contact and post-contact North American native populations have demonstrated the role of diet and the presence of sugars (sucrose or fructose) in the introduction of caries to populations in which the disease was unknown before. Since cereals are a part of the carbohydrate component of human diet, they have been identified as responsible for higher caries frequency observed in American precontact agriculturalists' teeth than in pre-agricultural teeth. For European prehistory, however, this pattern does not seem to be valid. If the caries frequencies observed in American skeletal samples are similar to those observed in the Northern part of Europe, the Southern portion of the continent appears to [illegible] an opposite trend; teeth are more carious in the Mesolithic than in the Neolithic. This pattern has been confirmed by recent research and the difference appears to be at the Mesolithic level, for which the caries frequency is much higher in Italy and Portugal than in more northern samples. This has been explained by the consumption of dried fruits and nuts, cariogenic food items possibly eaten by Mesolithic peoples.

In the sample from Tojal de Vila Chã, the overall percentage of carious teeth (5.5%) can be identified as consistent with some values obtained for populations with mixed economies in American precontact history and for some Neolithic European samples. When compared to the values obtained for the Mesolithic of the same region (within a 50 km range), Tojal de Vila Chã exhibits a lower frequency of carious lesions, which is in conformity with the latest results obtained by physical anthropologists working in the area. However, the reason for this change in the pattern of distribution of carious lesions has not yet been explained. If it is due to the consumption of sucrose (dried fruits and nuts) by the Mesolithic people, why did the Neolithic people not explore this food source when they were living in the same areas sharing the same climate conditions ?

The dietary reasons for the differences in caries frequency between Mesolithic and Neolithic will hopefully be explained by future research on paleobotany and further archaeological and physical anthropology work. Meanwhile, it is clear that using low frequencies of the disease as a valid indicator of the presence of a hunting-gathering subsistence strategy in a given skeletal sample has to be reassessed and regional differences have to be considered.

Similar inconsistencies and regional variations are apparent through the quantification of linear enamel hypoplastic defects in the teeth from Tojal de Vila Chã. The numbers reported for the precontact American populations generally reveal a higher frequency of defects in agriculturalists than in hunter-gatherers; this has been interpreted as the result of a decrese in the quality of subsistence conditions with the transition. In prehistoric Europe, however, the trend appears to be different. In Yugoslavia, very high percentages of hypoplastic teeth have been reported for the Mesolithic samples; in Italy, very low frequenies have been reported for the same archaeological context (but no quantification was reported). More specifically, in the Estremadura the frequencies observed in other Neolithic sites are similar to the results obtained for the present sample. Also similar is the incidence per tooth: the canines are undoubtedly more sensitive to hypomineralization. The Mesolithic sites of the Tagus area exhibited higher percentages than the Neolithic groups. Once again, the application of models created for the transition from hunting and gathering to agriculture in America to European prehistory does not seem to be valid and regional differences have to be considered.

Overall, dentition from Tojal de Vila Chã does not differ in wear patterns and lesions from the Neolithic patterns found elsewhere in the Estremadura region. This suggests that the Chalcolithic people did not adopt significantly different diets and that the transitional period may have been longer than previously portrayed.

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