University of Alberta

Paramedian Palate Morphology in the Adolescent:
A Cone Beam CT Study

by

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fulfillment of the

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Abstract

Objective: The aims of this study were to 1) determine if a relationship exists between the available bone in the paramedian-palate (PP) and age, sex and palatal morphology in growing patients, 2) identify the most appropriate locations for paramedian palatal implantation, considering available bone and interference of adjacent tooth roots.

Methods: Cone-beam CT scans were acquired in 183 orthodontic patients (10-19 years old). Reconstructed data was used to measure the PP.

Results: Significant variability in the bone thickness was found. Male subjects had greater bone thickness in 6 of 9 locations measured. Age and palatal measurements did not demonstrate a clinically useful relationship to bone thickness. Locations appropriate for implantation were identified.

Conclusions: The PP meets orthodontic implant placement criterion in growing patients. Age and palatal morphology are not valid predictors of bone height in the PP. Due to variability of bone thickness CBCT remains valuable prior to paramedian implant placement in growing individuals.

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Chapter 1 – Introduction and Literature Review

1-1 Introduction

The following pages will elaborate on the existing state of knowledge surrounding the use of osseointegrated implants as anchorage aids in orthodontics. The practice of orthodontics will always require a large measure of patient cooperation and tolerance. As all clinicians strive to improve aspects of their craft, orthodontists have tried various schemes and methods to reduce or even eliminate the requirement of patient compliance. If that attempt produces improved treatment results or decreased treatment times as a corollary, then it would be a worthwhile pursuit indeed.

Orthodontic anchorage requirements present sufficient clinical challenges without factoring in dependence on patient compliance.[1] As the use of titanium implants became more widespread in dentistry, orthodontists were quick to recognize the potential for absolute, compliance independent anchorage; clinical use of implants in orthodontics has been less than common however. Challenges to this potential include the fact that once placed, implants osseointegrate, and therefore cannot be placed in a critical growth center in growing patients. [2] Growing patients make up the majority of orthodontic patients. [3] Furthermore, the placement of dental implants is a surgical procedure that requires adequate diagnostic and treatment planning methods to ensure success. [4]

Current research has lead to the suggestion that growing patients can be treated with dental implants for non compliance dependent orthodontic anchorage, and that diagnostic imaging modalities appropriate for the task exist and are improving at a rapid rate.[5] The paramedian region of the anterior hard palate has been the subject of recent research as a potential host site for implants in growing patients, and low dose dental computerized tomography has been used to explore it.[6]

Many questions remain to be answered however. In particular, is there an area or the palate which is most suitable for implant placement? Is there any relationship between the age and/or sex of the adolescent patient and their ability to be considered a candidate for orthodontic implant placement? Are there easily recognizable physical attributes of the patient, such as the form of the palate that would indicate to the orthodontist or the oral surgeon that a patient may or may not be a suitable subject?

This paper will discuss the possibilities in detail, and attempt to provide information that improves the prospects for this treatment, using emerging imaging techniques.

1-2 Literature Review

1-2-1 Orthodontic anchorage

The term anchorage, as it relates to orthodontic treatment, may be defined as 'resistance to unwanted tooth movement'. [7] Anchorage requirements must be considered in orthodontic treatment planning as unique for each specific situation. Clinicians routinely depend on pitting groups of teeth or stabilizing devices against the teeth requiring movement in an attempt to limit unwanted tooth movement. Various fixed tooth borne appliances have been used with limited effect, and the results obtained with removable anchorage aids are dependent on patient compliance.[8] To date, no device exists which provides perfect anchorage. Clinicians can only strive to minimize the inescapable result of Newton's third law 'for every action there is an equal and opposite reaction' which often results in compromised orthodontic outcomes. [4]

1-2-2 Implants in orthodontics

The search for ideal anchorage is far from complete; however, the use of endosseous implants as anchorage in orthodontics shows great promise. Animal studies, material selection, surgical technique and eventual use of implants in humans, followed by diversification of the uses of implants have been the subject of early research.

Improved implant design, diagnostic and surgical protocol, and host site selection have been the focus of more recent research. An early realization in the field of orthodontics was that the ankylotic nature of implants could be beneficial in treatment mechanics.[9]

1-2-3 Background history

Historically, the use of implants to augment orthodontic anchorage began in 1945 with an animal study. The results of that study and those over the next nineteen years consistently demonstrated poor results, presumably due to a lack of osseointegration with the various implant materials used, resulting in consistent early implant failure. [10]

This changed with the esteemed work of P.I. Branemark, reported in 1969, in which titanium implants were shown to osseointegrate and remain stable in the jaws of dogs for periods of greater than five years, under considerable forces. [11]

Further studies by Branemark and coworkers have demonstrated even greater success with human subjects in the field of restorative dentistry. The successes have been attributed to the use of titanium implants and specific surgical techniques. [10]

1-2-4 Case studies and research

In 1984, Roberts et al implanted acid etched titanium implants in the femurs of rabbits. After 6 – 12 weeks of healing, forces of orthodontic magnitude (100 grams) were applied with springs between the implants. Out of twenty implants, only one failed. These results demonstrated that titanium implants osseointegrate in a short time period and can withstand constant loading. More importantly, it was stated that 'endosseous implants have the potential as a source of firm osseous anchorage for orthodontic and dentofacial orthopedics'. [12] Turley et al (1988) came to a similar conclusion in a study using implants for orthodontic traction in dogs.[13]

Roberts et al (1989) [14] used the retro molar region for implantation to mesialize a molar into an atrophic alveolar site. It was noted that peri-implant tissue conditions were less than ideal due to the location of the implant and the fact that it was surrounded by unattached mucosa. Despite this, Higuchi and Slack (1991) presented a prospective study in which seven adults were orthodontically treated using titanium implants in the mandibular ramus. Forces of 150 to 400 grams were used without complication and all treatment goals were met.[15]

Kanomi (1997) used a mini bone screw as an implant for orthodontic anchorage. It had a 1.2mm diameter and a 6mm length. The purpose of this was to ease the surgical requirements for patients and to provide more anatomical placement options. The small diameter of the implant allows vestibular placement, even between the roots of teeth. This technique still requires a two stage surgery however, and concern for hygiene and mucosal problems exist when it is placed in the unattached mucosa of the vestibular region[16] Ohmae et al achieved premolar intrusion successfully in dogs with the use of mini implants. [17]

1-2-5 The Palate as an Implantation Site

Various locations for implantation have been discussed, including alveolar bone and the retromolar region. Other locations such as the anterior nasal spine and the chin symphysis have been suggested, but will not be discussed here due to their obvious disadvantages.[8]

Some orthodontic applications of implant use can be coupled with restorative goals, allowing continued use of the implant as a tooth replacement following the completion of its use as an orthodontic anchorage aid. This scenario assumes that an appropriate edentulous area of alveolus exists at the outset of treatment [10].

The majority of orthodontic situations that could benefit from implant assisted anchorage do not present alveolar implant sites as they have a full dentition, or require extraction sites to be closed. As a result, alternative sites for implants have to be explored [4]. Implants to be used solely as orthodontic aids have a temporary duty and are placed with retrieval in mind.

Triaca et al (1992) recognized the potential of the median sagittal region of the anterior hard palate as an implant host site. Obvious disadvantages to using this area are the limited bone height available for implantation, the presence of the midpalatal suture and incisive foramen, and the potential interference of the roots of adjacent teeth.[18]

Block and Hoffman, (1995) described the use of a textured hydroxyapatite coated titanium disk known as the 'onplant' to circumvent the disadvantages of using the palate as an anchorage site. In their animal study, the onplant resisted continuous forces of up to 11 ounces (312 grams) and successfully moved teeth without anchorage loss. [19] A case study by Janssens et al (2002) used the onplant to successfully extrude molars in a 12 year old girl. The disadvantages to working with this device include the two stage surgical procedure to utilize it for orthodontic anchorage. Furthermore, the midpalatal suture must not be covered by the disk in growing individuals as this may interfere with inter-maxillary growth once it osseointegrates.[20]

To address the lack of bone height available in the median sagittal region of the anterior hard palate, Wehrbein et al (1996) collaborated with implant manufacturer Straumann to develop the 'orthosystem'. The resulting implants are of smaller dimensions (4 or 6 mm length, 3.3 mm diameter) than those typically used for dental replacement. Immediate stability was enhanced by a self tapping design, and surface texturing. A further advantage is the single stage surgical procedure whereby the implant is equipped with a transmucosal neck, and a healing cap is placed at the initial surgery. Explantation is achieved using a trephine with a diameter of 4.2 mm that is precisely guided by the implant.[4] The authors tested this system with great success in dogs [21] before performing case studies on humans.

A case study by the same authors demonstrated that successful implantation and orthodontic treatment reduced the over jet in their patient by 8 mm with only 0.5 mm anchorage loss, presumably due to deformation of the orthodontic appliance.

The ability to implant in the midpalatal suture with short small diameter implants was further described by Wehrbein et al in 1999. Twelve patients between the ages of 15 and 39 had 4 or 6 mm long, 3.3 mm diameter implants placed at the level of the first premolars in the midsaggital region of the hard palate. Lack of perforation into the nasal cavity was proven by probing at the time of surgery. The implants were inserted perpendicular to the curvature of the palate. Post operative cephalograms were shown to underestimate the vertical bone support by an average of 2 mm, as the implants appeared to project into the nasal cavity on the film. This contradicted the surgical findings, where probing verified that there was no perforation. The use of lateral cephalograms to direct implant placement may be inadequate, suggesting that other imaging modalities such as computerized tomography (CT) may be required.[22]

Glatzmaier et al (1995) described the use of a resorbable implant in the mid sagittal palate.[23] A lack of osseointegration gave rise to disappointing results. Schiel et al (1996) also favored the mid sagittal palate.[24]

Persson and Thilander (1977), while studying palatal suture closure in humans ranging from 15 to 35 years age, found that great variation exists among individuals with regards to the start of closure, as well as to the advancement of closure with age. They concluded that a marked degree of closure rarely exists until the third decade of life.[25] The fibrous components of the suture increases with age, and bundles of fibers can be seen running transversally across the suture and further increasing the mechanical strength of the joint. When cranial growth ceases, most sutures ossify. An orthopedic force or pathologic fusion of sutures may prevent normal growth through displacement but may not necessarily prevent drift from continuing or even prevent an increase in compensation due to this absence of displacement.[26,27] The potential degree of alteration of maxillary growth due to disruption of the suture by placement of an implant is unknown. Furthermore, the quality of the suture area in adolescents would not be ideal for implant osseointegration. [25]

Efforts to assess the degree of suture closure have resulted in poor correlation to the gold standard, which is use of histological specimens. Studies by Melsen, and Persson and Thilander on autopsy material can allow the clinician to assess the degree of closure through biopsy. Obviously, less invasive methods are required. Anterior occlusal radiographs are subject to artifacts and obscuring from the nose or vomer and correlation to age is unpredictable as well.[25,28,29]

It becomes apparent that the palate has many advantages as an implantation site. Surgically, it is easily accessible, with the attached mucosa providing exceptional peri-implant conditions. Even in areas where the mucosa was more than 4mm in thickness, the soft tissue conditions of the palatal implants in the study by Wehrbein et al (1996) were considered normal at recall. [4] The main disadvantages to using the palate remain the lack of vertical bone thickness, and the recommendation to avoid the midpalatal suture in growing patients.[6,30]

In general, practitioners perceive other factors as reasons to avoid treatment planning implants for orthodontic anchorage as well. Favero et al (2002) explored the psychological reasons that prevent orthodontists from treatment planning implants. The fact that current methods focus on adult patients (not growing patients) and that most involve two stage surgery are among the reasons. Perceived increase in treatment time while waiting for osseointegration was also a factor.[31] It is well known that the majority of orthodontic patients are growing adolescents. Huang investigated the age distribution of over 100 000 patients receiving orthodontic treatment in Washington state. Fully 86% of the patients were under 20 years old, with the majority being in their early teens.[3] It would follow that an implant orthodontic anchorage system suitable for treating the growing patients of this age group would be a major development.

The modification in size and length coupled with the single stage surgical technique and an eight week healing period of the Straumann orthosystem has gone a long way towards addressing these concerns. Traditional dental implants of shorter length have also proven to be effective in addressing concerns about limited bone height, but they still require two stage surgical technique.

The temporary nature of the implant for orthodontic use is also considered to be a positive when considering the growing patient. Temporary placement and subsequent removal can address the concern regarding implant exposure due to bone remodeling during growth, and the ankylotic behavior of implants. Site selection however, is the critical factor to address the condition of the growing patient.[31]

Thus it becomes apparent that before an implant system for orthodontic anchorage is to have a major impact on the practice of orthodontics, an alternative to the median palatal region of the anterior hard palate must be found.

1-2-6 The Paramedian Palate as an Implantation Site

The paramedian region of the anterior hard palate has the advantage of avoiding the uncertainty of the midpalatal suture, and it is considered relatively stable from a growth point of view. [26]

Bernhart et al (2000) examined the paramedian region of the palate as a host site for implant placement. 22 patients ranging in age from 12.7 to 48.1 years, requiring maximum anchorage orthodontics in the maxilla, but refusing headgear or other anchorage aids were found. Each was examined with CT for pre-operative planning of implant placement. Multiplanar reconstructions of the resulting CT scans were used to identify sites with the appropriate vertical bone volume to support the proposed implants. A distinction was made between the vertical bone volume in the median sagittal and paramedian regions. The authors stated that the indication for implant treatment in the median sagittal plane should be limited to adults and fully grown juveniles due to the possibility of developmental disturbances of the palatal suture.[6]

Four planes were designated at 3, 6, 9 and 12 mm from the incisal foramen in the mid sagittal view (fig. 1). A coronal cut, or multiplanar reconstruction was made at each of these four planes, perpendicular to the curvature of the hard palate (figs. 2-5)

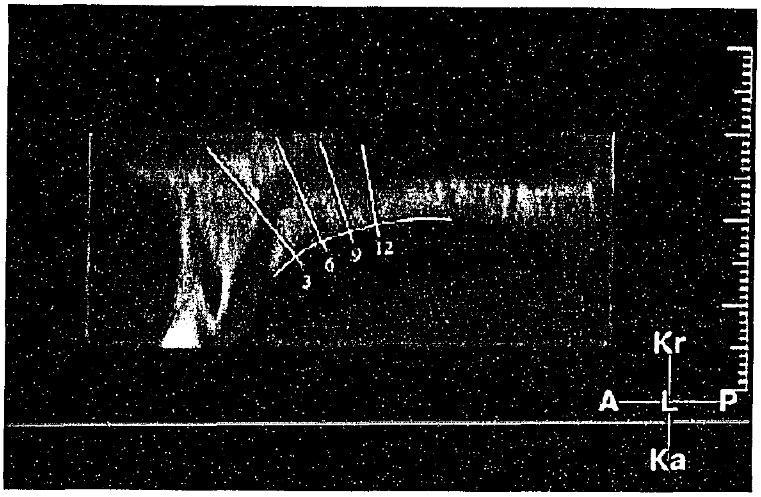


Figure 1-1: Multiplanar Reconstruction of the Hard Palate, Planes 3-12.[6]

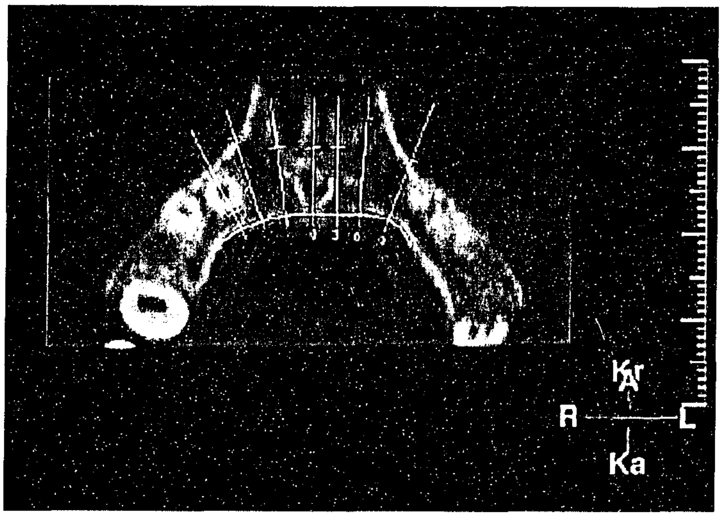


Figure 1-2: Multiplanar Reconstruction of Plane 3
(with visualization of the measuring distance of 0mm, 3mm, 6mm and 9mm from the midline suture).[6]

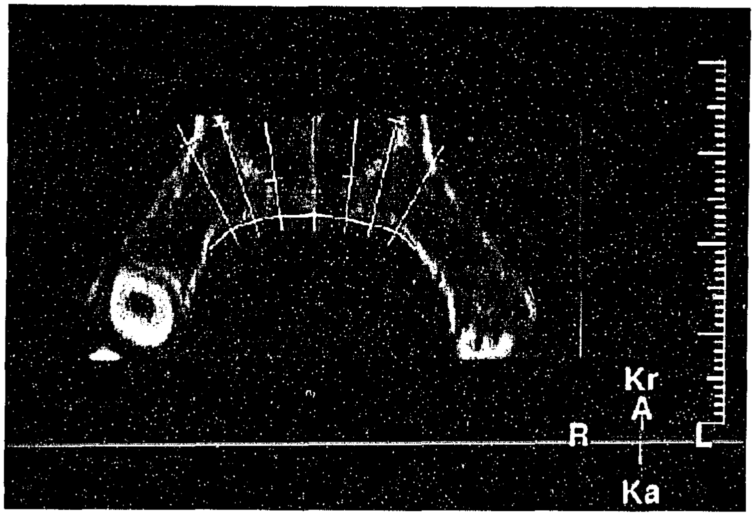


Figure 1-3: Multiplanar Reconstruction of Plane 6
(with visualization of the measuring distance of 0mm, 3mm, 6mm and 9mm from the midline suture).[6]

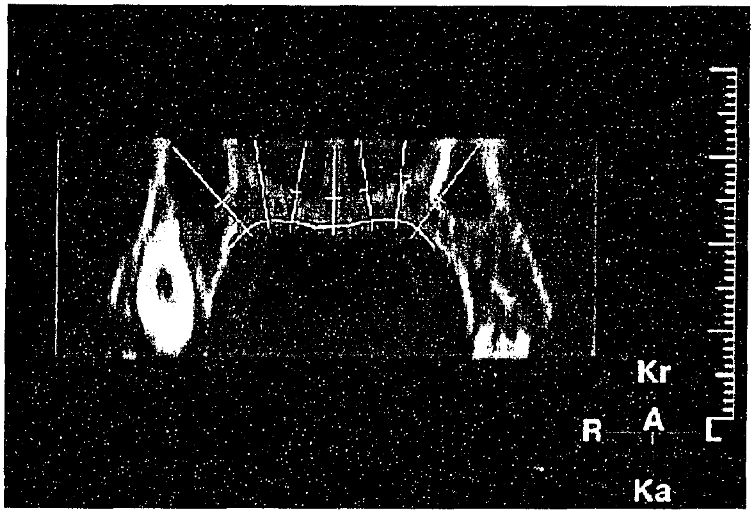


Figure 1-4: Multiplanar Reconstruction of Plane 9
(with visualization of the measuring distance of 0mm, 3mm, 6mm and 9mm from the midline suture).[6]

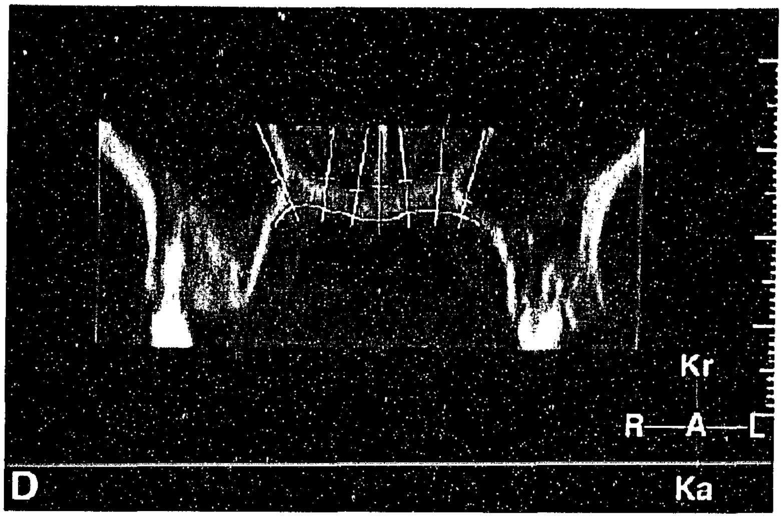


Figure 1-5: Multiplanar Reconstruction of Plane 12
(with visualization of the measuring distance of 0mm, 3mm, 6mm and 9mm from the midline suture).[6]

Measuring distances of 0 mm (the midpalatal suture), 3 mm, 6 mm, and 9 mm were drawn on each of the reconstructions for each subject. In the mid-sagittal plane, the cranial limit of the measurements was the bony floor of the nose excluding the nasal septum, while in the laterally adjoining measurements it was the opposing cortical bone of the nasal floor, the opposing cortical bone of the alveolar process and the root of the adjacent tooth, respectively. If the limit was formed by unerupted teeth, the measurement was excluded from further analysis.

Suitable vertical bone volume for insertion of palatal implants was defined in the study as 4 mm or more (vertically), which correlates well with the work of Schiel et al (1996).[24] The authors of that study reported implant failures in the mid-sagittal palate at the level of the second premolars due to thin cortical bone lamellae approximately 12mm posterior to the incisive foramen. Re- insertion of the implants at the level of the first premolars, approximately 6 mm posterior to the incisive foramen, resulted in success.

The authors concluded that as far as available bone volume is concerned, placement of implants in the paramedian region was most statistically possible, in this sample, at the planes 6 and 9 mm posterior from the incisive foramen at a distance 3 and 6 mm respectively, laterally from the median line while avoiding the palatal suture. [6] No association was found between the age of the subjects and bone volume available in the paramedian region. The relative risk of a dental root limiting the vertical bone volume was found to decrease the further the measurement was taken posteriorly. The highest risk was found 3 mm posterior and 9 mm lateral to the incisive canal.[6] Although the study is very promising in establishing the paramedian palate as a potential host site for orthodontic implants, certain shortcomings of the design limit the ability to make broad conclusions regarding the growing patient.

The 22 patients in the Bernhart et al [6] study ranged in age from 13 to 48 years, and no specific listing of ages was provided. The reader does not know how many of the subjects are non –growing. This lessens the impact of the finding that there was no association between age and vertical bone volume found, as the distribution of age in the subjects cannot be appreciated. It also decreases the ability to apply the results to the general orthodontic population (86% of whom were under the age of 20, and 36% of whom were male in the study by Huang et al (2004)[3], as does the fact that only 4 of the 22 subjects were male.

Perhaps the greatest shortcoming of the Bernhart et al [6]study was the measuring method. A slice thickness of 1.5 mm was used to produce the CT images upon which the bone volume measurements were made. Great care has been taken to measure bone height in these images with no apparent consideration being given to the diameter of the implant fixture. These images are only three dimensional to the extent that the image depth was 1.5 mm (figs. 1-5). The implants used in the study had a diameter of 3.75 mm. With a minimal 1 mm margin of error for surgical placement on either side of the implant, an appreciation for the actual dimensions of the implant site can only be derived by examining a cumulative slice depth of at least 5.75 mm. This would result in more appropriate bone height measurements and give a full appreciation for the possibility of interference with the roots of adjacent teeth, nasal cavity and sinuses. Examination of the images in the study reveals that if an implant were placed at each measuring line, sinus and nasal floor perforations would occur, and damage to adjacent teeth would result. The use of an isolated two dimensional image can be quite inaccurate as anyone who has 'scrolled' through a series of such images can attest.

Most recently, computed tomography (CT) has been used to measure mid-sagittal and paramedian bone height in 32 patients with an age range of 12 to 49 years. A similar measuring technique to the previous study was used, with the same attendant disadvantages regarding the three dimensions of the zone of implantation.[32]

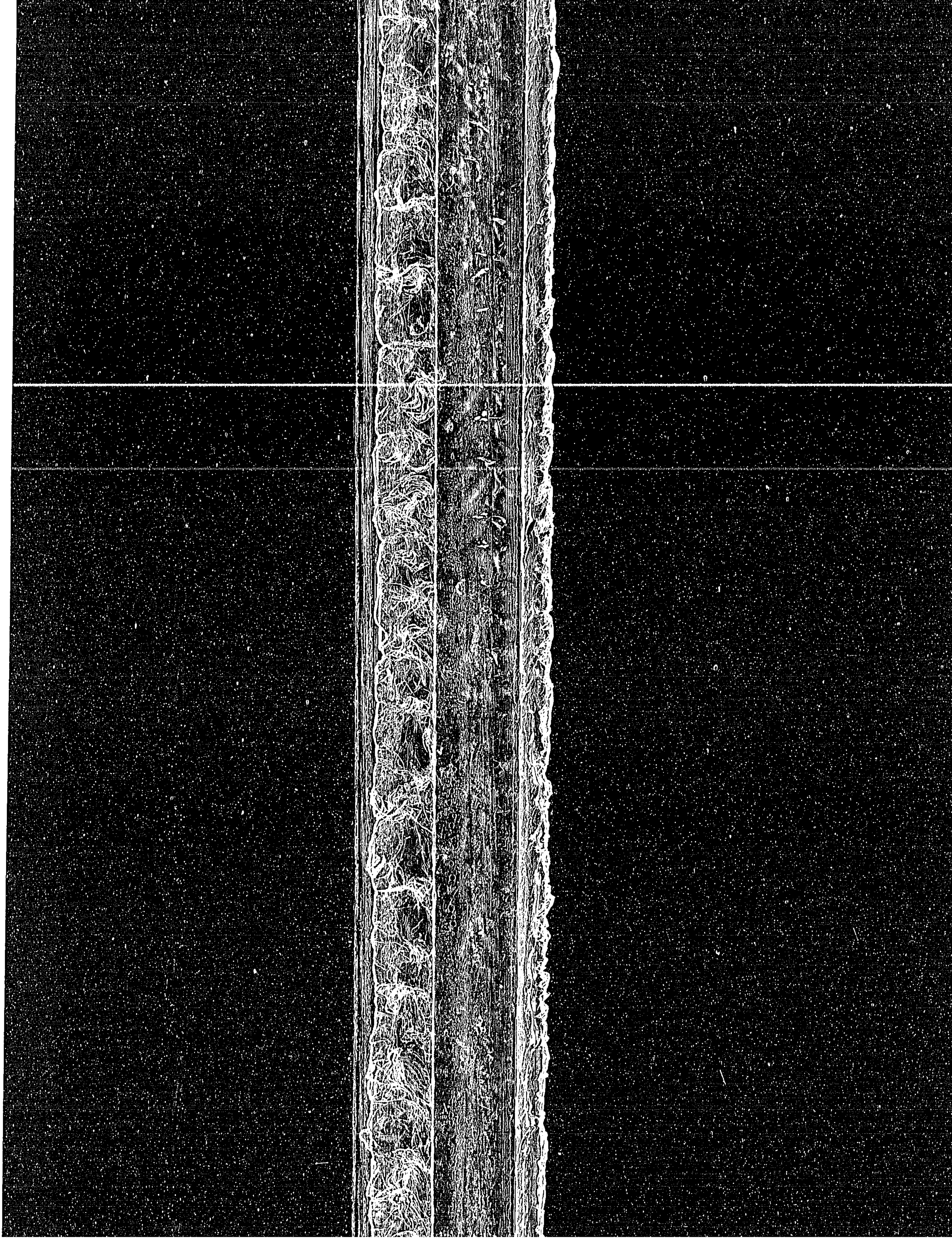
In this study by Gahleitner et al[32], para-coronal planes were established at 3, 6, 9 and 12 mm posterior to the incisive foramen, but only one measurement was taken in the paramedian region for each of these planes, in the area with the most bone height. Overall, a large variability in palatal bone height was found, with the most bone height in the paramedian, 6 mm posterior from the incisive foramen.

Despite the shortcomings of these studies, the use of CT to obtain the measurements offers great improvements over previous pre-operative diagnostic records. Wehrbein et al (1999), demonstrated that lateral cephalograms routinely underestimated the bone volume in the mid sagittal palate by at least 2 mm.[22] Mah et al (2003) pointed out that two dimensional radiographs suffer from lack of perspective, effects of projection and superimposition, imaging artifacts and information voids. Lateral cephalograms then, can be considered as a preliminary diagnostic tool; only CT data can accurately measure the true vertical bone volume at this time. [33] [34] [6]

1-2-7 Palatal Form in Diagnosis and Treatment Planning

Palatal dimensions have been used in the study of many types of craniofacial conditions, such as cleft lip and palate, the relationship of premature birth and intubation to palatal form and to assess changes due to treatments and growth. Plaster dental casts are usually the basis of the measurements, and contribute various types of error that are associated with combining hard and soft tissue measurements. Early methods, such as simple caliper type measurements of intermolar width, though accurate, are confusing due to the variety of landmarks used in different studies. For this one measurement alone, suggested landmarks have been mesio-lingual cusp tips, most palatal point of the cemento enamel junctions and most palatal point of the gingival margins of the first permanent molars. The measurement of palatal height, though easier to define, requires complicated methods such as Moiré photography, the accuracy of which has been questioned [35,36]. Most of the studies in a systematic review by Paulsson et al. included palatal measurements using fairly reliable methods and appliances for measurements of palatal alterations such as Olivetti inspector machine, optical gauging and the reflex microscope. However, there are hardly any normal standards to determine accurately whether a palate is deformed, and this can conceivably be a reason for the divergent results observed in the studies regarding palatal morphology [37].

CT scanning presents the ability to base measurements on easily defined hard tissue landmarks and the use of orthogonal measurement techniques, the result being reproducible, accurate measurements, allowing various assessments of palatal form. The ratio of palatal height over palatal width, expressed as a percentage to create a palatal index, may be used as a numerical value by which to compare the general palatal form.[38] The width of the palate may be represented as the palatal most distance between the maxillary first molars at the cemento- enamel junction. This is an easily recognizable landmark on CT scans, even if they are of poor definition. The palatal height may be measured as the distance from the inter-molar line to the bony cortex of the hard palate at the midline of the palate, perpendicular to the line measuring the width. The ratio between the height and width (PH / PW), expressed as a percentage, can serve as an easily understood index (Fig. 8).



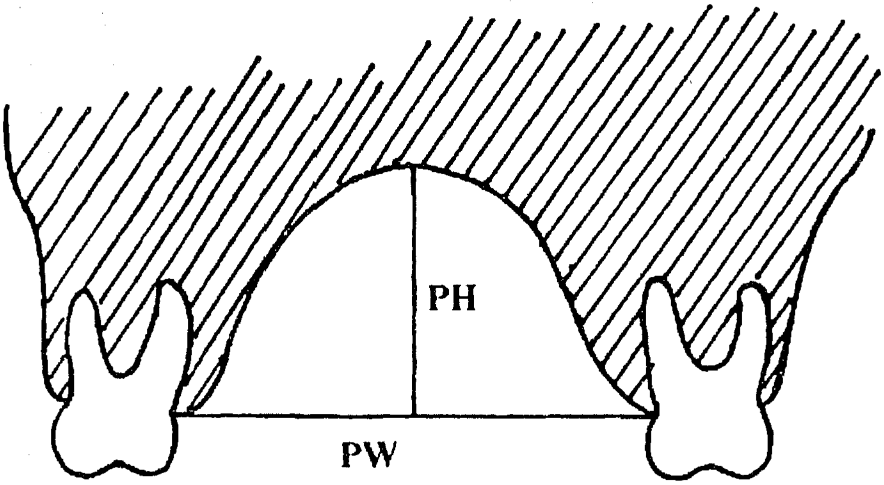


Figure 1-6: **Measurements of palatal height (PH) and width (PW)**

Previous research has attempted to match palatal index values to the subjective assessment of palatal form, with the idea that clinicians could then assess palatal form without complicated measuring techniques. Howell et al, (1981) and Younes (1995) both found good agreement between clinical assessment of palatal form and measured palatal indices.[39,40] Therefore, if palatal height, width or index is found to have a significant relationship with physical attributes of the patient, it is reasonable to assume that the relationship may be assessed by clinicians in a practical setting.

1-2-8 Digital Volumetric Imaging

The analysis of human craniofacial patterns was first initiated by anthropologists and anatomists who recorded various dimensions of ancient dry skulls. The first measurements obtained for craniofacial patterns were then based on osteological landmarks (craniometry). With time, measurements were made directly on living subjects using palpation or pressing the supra adjacent tissue, and finally, with the invention of radiographic techniques, measurements were made on cephalometric radiographs (cephalometry).[41,42]

Since the development of cephalometric radiology, several cephalometric analyses have been proposed. They have been useful in describing how individual patients vary from norms derived from other studies, and also for establishing descriptive communication between clinicians.[43]

Cephalometric analysis is a two dimensional type of diagnostic rendering of a three-dimensional structure, and resultant cephalometric measurements on radiographic images are subject to projection, landmark identification, and measurement errors. [42,44]

Magnification and distortion of the skeletal and dental structures present in the images play an important role in the creation of radiographic projection errors. Magnification occurs because the x-ray beam originates from a point source and do not parallel all the points of the object examined. Distortion occurs as a result of different magnifications occurring between different planes. Even though many landmarks used in cephalometric analysis are located in the mid-sagittal plane, some landmarks and many structures that are useful for the description of craniofacial form are affected by distortion due to their location at different depth fields. [42,44]

Landmark identification errors are considered as the major source of cephalometric error. This type of error is influenced by many factors such as the quality of the radiographic image, the precision of landmark definition, reproducibility of the landmark location, the operator and registration procedure. [42,44] Fortunately, the development of computerized equipment for electronic determination of landmarks has greatly improved data collection and processing which has reduced the potential for human measuring errors. Presently, the errors related to the recording procedure comprise the precision with which a marked point on the film or tracing can be identified by the cross-hair of the recording device, and the error of the digitizing system. The errors of the digitizers have been shown to suffer from varying degrees of scaling errors and fields of non-linearity.[42, 44] Despite the known and potential errors, cephalometric radiographs are still widely used and in many cases are essential in the diagnosis and treatment of the patient.

Since the mid 1970's, three dimensional analyses and related procedures in orthodontics have been attempted through several different approaches. The first step in this broad area was the fabrication of three-dimensional models that imitated oral structures. [45-47]

Three-dimensional craniofacial imaging requires application of various techniques from disciplines such as applied mathematics, computer science and statistics.[48] Although several computer based three-dimensional methods have been developed to assist orthodontic diagnosis [49,50] and others to predict the results of treatment [51-54], the data which is usually obtained from various sources create potential problems in their analysis since few accepted standards or conventions for managing this computational data in the human jaws exist. [55] Clinical utilization of this data involves transformation of the information from three- to two-dimensional format. Once analyzed, these are then reconstructed mentally by the clinician who could potentially contribute error to the process. Other shortcomings are lack of perspective, superimposition effects, imaging artifacts, information voids, and lack of functional analysis. [33]

Widespread use of CT for dental implant imaging has made it a mainstream diagnostic technique in the field of dental surgery and restorative dentistry. In the medical field, its use has risen from roughly 5 million examinations in 1983 to more than 20 million in 1995 in the United States alone.[5] If this trend in medicine is followed in dentistry, the demand for 3-dimensional dental imaging devices can be expected to follow. Currently, several machines are either commercially available or FDA approval pending.

Since the first clinical use of CT scans in 1972, technological development has been rapid. Work is progressing on a fifth generation of conventional or medical CT, and the second generation of low dose dental CT, or cone beam computed tomography (CBCT) is approaching.

1-2-9 CBCT vs. Traditional CT

There are two principle differences that distinguish CBCT from traditional CT: the type of imaging source – detector complex and the method of data acquisition. The x- ray source for traditional CT is a high output rotating anode generator while that for CBCT can be a low energy fixed anode tube similar to that used in dental panoramic machines. CT employs a fan-shaped x-ray beam from its source for imaging and records the data on solid state image detectors arranged in a 360 degree array around the patient. CBCT technology uses a cone-shaped x-ray beam with a special image intensifier and a solid state sensor or an amorphous silicon plate for capturing the image (Fig. 1-7).

Conventional CT devices image the patient in a series of slices captured as the patient is moved through the source and sensor array, resulting in a spiral type acquisition. The resulting multiple "slices" must then be stacked to obtain a complete image. CBCT machines currently use a one rotation sweep of the stationary patient similar to the technique seen in panoramic radiography which allows for a single rotation of the gantry to generate a scan of the entire head. Scan times vary from 70 seconds (NewTom 9000) to 10 seconds (CB MurcuRay) for the complete cranio-facial complex.

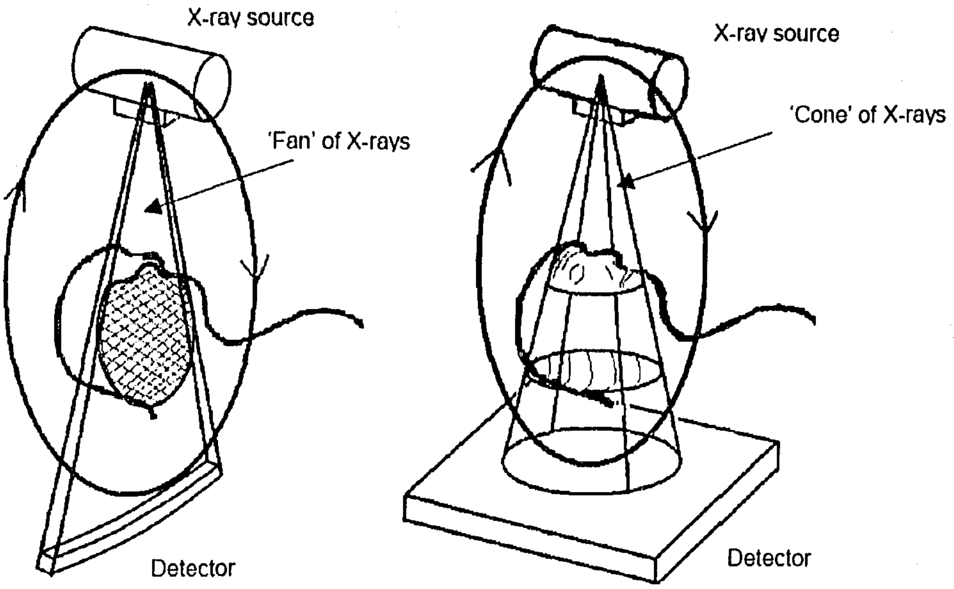


Figure 1-7: Image acquisition of the traditional fan beam tomographer vs. Image acquisition of the cone beam computed tomographer[56]

Cone-beam technology utilizes x-rays much more efficiently, requires far less electrical energy, and allows for the use of smaller and less expensive x-ray components than fan-beam technology. In addition, the fan-beam technology used in conventional CT scanners does not lend itself to miniaturization because it requires significant space to spiral around the entire body. The decrease in resolution from the images of the latest models of medical CT to CBCT images is great, but has limited effect on the visualization or measurement of hard tissues such as bones and teeth.[56,57]

As with all types of CT imaging, CBCT relies on interpolation of the data set which is acquired. Interpolation into units called voxels allows data points to be represented as cubes, representing the 3D volume. Mathematically, voxels are located by coordinates of their vertices. When the original data set is sampled, it is mathematically reconstructed via complex algorithms, and is re-sampled to allow the user to investigate the data set. This re-sampling is subject to errors such as post-aliasing and smoothing, in which frequency components of the original data are presented in the reconstruction at different frequencies or are attenuated. Mathematically, this is known as the Nyquist sampling theorem. The voxel is a 3D representation of a pixel and is based on the nearest neighbor interpolation of spatial samples. Therefore, the interior of whole voxel has the same value. In visualization, we would prefer continuous data, but reconstruction provides discrete data points. This allows inadvertent selection of the 'nearest neighbor' point which can lead to error. In practicality, it can result in measuring errors approximately equal to twice the voxel size. [58]

1-2-10 The Future of CBCT

Advances in the use of three-dimensional imaging software have permitted important changes in the perception of three-dimensional craniofacial structures. An example is their use to evaluate the temporomandibular joint under the influence of functional appliances[59,60]. CBCT imparts less radiation dose than spiral CT (a CBCT scan can be as low as 36uSv or similar in absorbed dose to a dental periapical full mouth series; as new models are developed, this value is expected to decrease further). It also allows secondary reconstructions, such as sagittal, coronal and para-axial cuts and 3D reconstructions of different craniofacial structures [61] which are not magnified nor distorted in size or shape. [5,62]

Compared to the traditional cephalometric radiographs, CBCT produces images which are anatomically true, 3D representations with 1 to 1 correlation, from which slices can be displayed from any angle in any part of the skull and output digitally on paper or film, even allowing the printing of images of anatomical structures at their true size. 3D volumetric imaging provides useful information for clinicians in identifying teeth and other structures for diagnostic and descriptive purposes.[63]

For these reasons a trend from traditional two-dimensional analog films to three-dimensional digital imaging systems is underway. Currently, three dimensional imaging modalities such as CT and magnetic resonance imaging are used only in the most complex clinical situations. More routine situations such as dental treatments (including some implant placement and many types of maxillofacial surgery) rely completely on two dimensional imaging such as plain film, panoramic and periapical radiographs and photographs. Even when three-dimensional imaging is included in the diagnostic process, it is typically reduced to a series of two dimensional slices, which are then mentally integrated by the clinician(s) involved. It is expected that more complete, integrated and accurate patient information would allow the construction of patient-specific models upon which treatments can be simulated or appliances fabricated. Establishing a three level platform that can achieve this would include a first level with imaging and other patient data (photographs and examination) giving qualitative information. The second level would include patient models synthesized from the information in the first level that will provide qualitative and semi-quantitative information on the patient's features (information from level one plus quantitative measurements of the subject). Finally, the third level of modeling would provide qualitative and dimensionally accurate quantitative information that can be used for therapeutics, research and education (information from the previous levels combined with three dimensional imaging and functional analysis). The movement from one level to another is expected to be significantly more demanding on the imaging source and in the model construction.[33]

Maki et al (2003) predict that with the extension of the field of view, images of facial profile as seen in a facial photograph, panoramic and cephalometric views as well as accurate representations of dental cast models will be derived from a single scan. Other information such as virtual set up modeling of the digital dentition including the actual position and inclination of roots may lead to laser lithograph modeling to produce an individualized orthodontic appliance. The authors are currently working on surgical prediction modeling and the use of automated finite element modeling to visualize jaw movement.[49]

The technological advances described have not come without drawbacks. Since this technology became commercially available in North America in 2001, the current challenge for the clinicians is to understand and interpret 3D imaging and also to decide on a particular imaging modality as a function of the information/diagnostic yield vs. patient risk and cost benefit analysis.[33] Currently, there is no specific way to analyze this type of three dimensional imaging as it relates to traditional radiographic analyses, and interpretation limitations still exist. New standards are required and clinicians need special training when dealing with these types of images.[5]

1-3 Conclusion

The use of implants for orthodontic anchorage in humans has been a valid treatment option for over 20 years. This technique is becoming more widespread in its use and will likely enjoy increased acceptance as an alternative to conventional anchorage techniques by patients and practitioners alike.

There has been considerable advancement in the materials and techniques associated with temporary implant placement specifically for orthodontics. The use of this anchorage technique in the largest segment of the population seeking orthodontic treatment, the growing patient, has been recognized as the next logical step in improving treatment time and results in cases where anchorage requirements are greater than achievable by traditional means, or patient acceptance of anchorage aids is an issue. The identification of the paramedian hard palate as a site for temporary implant placement is an important development towards this goal. However, the data supporting the use of the paramedian palate (in growing patients) for the placement of temporary implants has not kept pace with the advances in materials and techniques.

Technological improvements in diagnostic imaging, such as the use of CT scanning, allow accurate assessment of the suitability of implant host sites in the growing population. The development of low radiation dose cone beam CT units that are commercially available at a lower cost has made superior diagnostic information available to large orthodontic clinics and teaching institutions at an improved risk/benefit ratio to the patient. Until this technology is widely available to the average clinician, research to clarify the suitability of the paramedian hard palate for orthodontic implant placement is required, and, is the purpose of this paper.

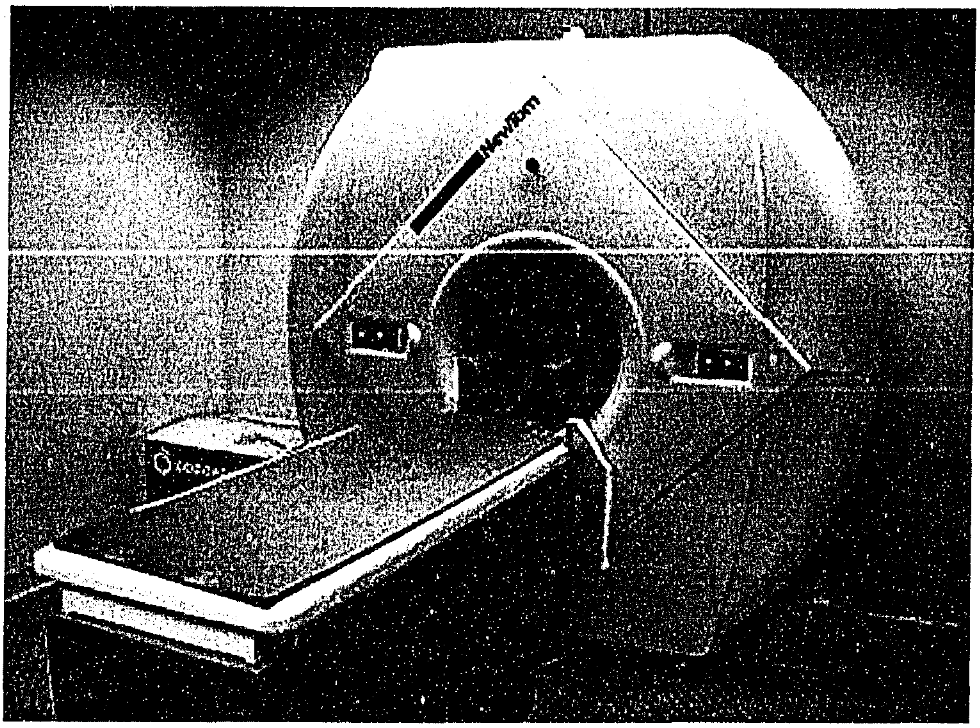


Figure 1-8: NewTom 9000 CBCT

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1-5 Research Objectives

The primary objective of this study is to examine the relationship between the age and sex of the subject, and vertical bone depth in the paramedian region of the anterior hard palate. Palatal dimensions will be explored to determine if any relationship to age, sex or vertical bone volume of the paramedian region of the anterior hard palate exists. It is hoped that with a large enough sample, a relationship between easily recognizable palatal forms and vertical bone volume can be made that will aid orthodontists in the treatment planning of anchorage with implants, and surgeons in their approach to implant placement for orthodontic use, and that appropriate vertical bone volume will exist to host implant placement for orthodontic anchorage in a predictable relationship with the age, sex or palatal form of the subject. (Appropriate vertical bone volume is defined as the presence of at least four millimeters of bone height, and a bone width of at least six millimeters for the requirements of implant placement.)

The secondary objective of the study is to interpret the findings of the first objective and make recommendations regarding the most appropriate location for orthodontic implants based on the vertical bone volumes found.

1-6 Research Hypotheses and Questions

The aim of this thesis is to determine if associations exist between certain attributes of the adolescent patient, vertical bone volume in the anterior hard palate, and the ability of the palate to host palatal implants for orthodontic anchorage. Bone measurements made with CBCT will be utilized to test the following hypotheses:

1. No relationship exists between the age of the adolescent orthodontic patient and the vertical bone volume of the paramedian region of the anterior hard palate.

2. No relationship exists between the gender of the adolescent orthodontic patient and the vertical bone volume of the paramedian region of the anterior hard palate.

3. No relationship exists between the palatal form of the adolescent orthodontic patient and the vertical bone volume of the paramedian region of the anterior hard palate.

4. No area of the paramedian region of the adolescent anterior hard palate contains adequate vertical bone volume to predictably host implants for orthodontic anchorage.

5. The presence of teeth in the anterior hard palate will not significantly limit the availability of vertical bone volume, and will not vary between male and female subjects in the sample, at the chosen measuring locations.

From the hypotheses the following research questions arise:

1. Are there certain attributes of the adolescent patient that may be considered predictive of the vertical bone volume in the anterior hard palate?

2. Are there regions of the paramedian hard palate of the adolescent population that can predictably host implants for orthodontic anchorage?

3. Which regions of the paramedian hard palate have vertical bone volume availability limited by the presence of erupted and unerupted teeth?

Existing knowledge of the paramedian palate has resulted in the current standard of care for placement of palatal implants, which requires CT imaging in addition to traditional diagnostic records (panoramic and cephalometric radiographs as well as models) resulting in increased cost and radiation to the orthodontic patient. Limited vertical bone volume, great variability within and among patients, and the risk of interference of adjacent vital structures during implantation, in combination with limited availability of the technology may prevent orthodontists from recommending implant anchorage for this group of patients. It is hoped that CBCT examination of the bone volume in the anterior hard palate will reveal relationships with age, gender and/or palatal form of the adolescent patient, and that these relationships may aid orthodontists in the treatment planning of anchorage with implants, and surgeons in their approach to implant placement for orthodontic use. It is further hoped that an area(s) of the paramedian hard palate may exist that can predictably host orthodontic implants (adequate vertical bone volume with minimal interference of teeth and other vital structures) as identified by easily determined patient attributes, decreasing the need for increased diagnostic imaging.

Chapter 2 – A Pilot Study

Variability of Adolescent Paramedian Palatal Morphology

2-1 Introduction

Recent studies of the paramedian palate, as a common element, have concluded that the bone thickness available for implantation is highly variable.[1-3] Closer scrutiny of the past research leading to this conclusion revealed that they were clinical trials, with few subjects and large age ranges, resulting in limited applicability to the adolescent population.

A pilot study was deemed necessary for three purposes.

1) To estimate the variance of bone thickness in the paramedian palate for the adolescent population, in an effort to determine a sample size that would allow investigation of the research questions with reasonable power.

2) To develop measurement methods for assessing the vertical bone volume in the anterior paramedian hard palate of the adolescent, and test the intra-rater reliability for this method.

3) To determine if the right and left sides of the paramedian palate are symmetrical, allowing for measurement of one side only, in the main study.

2-2 Subjects and Methods

Ten subjects were randomly chosen from the available pool of scans. In order to represent the range of ages in which most orthodontic patients fall, three scans were of 10 year old subjects, 4 were 15 years old, and 3 were 20 years old.

Measurements of vertical bone volume were made at 18 locations in the paramedian region of the hard palate for each subject, consisting of 9 measurements on the right side and 9 measurements on the left. These measurements were repeated 3 times on three separate days for each of the patients, in random order by the same operator (KK), with at least a week between each group of measurements. This data was used to assess symmetry between the sides of the anterior hard palate. The measurements of vertical bone volume were tested for reliability by the Intra-Class Coefficient (ICC) test, for each of the nine locations. The measurements were repeated 5 times on 5 separate days by the same operator (KK), in random order, on all nine locations for all ten patients.

Following guidelines by Currier, we determined an ICC of .90 to be high reliability, an ICC of between .80 and .90 to be good reliability, and an ICC between .70 and .80 to represent moderate and acceptable reliability. [4] A higher proportion implies more reliable rating.

$$\text{intra-class correlation coefficient} = \frac{\text{True variance}}{\text{True variance} + \text{error variance}}.$$

The values attained demonstrate that error variance or 'noise' associated with the measuring technique is separated from the true variance the study seeks to determine.

An ICC value of .90 means that 90% of the observed variance is due to the true variance in the variable studied.[5]

2-3 Statistical Analysis

A paired t test was conducted to determine if symmetry existed for the right and left sides. Intra-class correlation coefficient tests were used to determine intra-rater reliability.

2-4 Results

The differences between the sides in each of the subjects were found to be not significantly different from zero, p=0.05 (table 2-1). Since the right and left sides of the palate were found to be symmetrical, the intra-rater reliability testing was carried out on one side, or nine measurements per patient.

The ICC values ranged from 0.98 to 0.85 (table 2-2).

Table 2-1: Paired Samples Test to show symmetry

TRIAL		Mean	Std. Deviation	P value
1	Pair 1	-.50000	.707107	.052
	Pair 2	.00000	.816497	1.000
	Pair 3	.20000	.421637	.168
	Pair 4	.10000	.875595	.726
	Pair 5	.20000	.918937	.509
	Pair 6	-.30000	.483046	.081
	Pair 7	.00000	1.247219	1.000
	Pair 8	-.60000	1.429841	.217
	Pair 9	-.20000	.632456	.343
2	Pair 1	.20000	.421637	.168
	Pair 2	.00000	.471405	1.000
	Pair 3	.10000	.567646	.591
	Pair 4	.20000	.788811	.443
	Pair 5	-.50000	1.080123	.177
	Pair 6	-.10000	.737865	.678
	Pair 7	.10000	.994429	.758
	Pair 8	-.40000	1.264911	.343
	Pair 9	-.20000	.632456	.343
3	Pair 1	.30000	.483046	.081
	Pair 2	-.10000	.316228	.343
	Pair 3	.00000	.471405	1.000
	Pair 4	-.10000	.567646	.591
	Pair 5	-.30000	1.159502	.434
	Pair 6	-.10000	.737865	.678
	Pair 7	.20000	.632456	.343
	Pair 8	-.20000	.788811	.443
	Pair 9	-.20000	.632456	.343

Table 2-2: Intra rater reliability Tests

Measuring Location	N (subjects)	N (trials)	ICC value	95% C.I.
1	10	5	.9198	.8201 - .9760
2	10	5	.9351	.8519 - .9808
3	10	5	.9755	.9416 - .9929
4	10	5	.9762	.9432 - .9931
5	10	5	.9417	.8661 - .9828
6	10	5	.8888	.7586 - .9661
7	10	5	.9826	.9581 - .9950
8	10	5	.8553	.6963 - .9550
9	10	5	.8666	.7168 - .9588

2-5 Discussion

The method developed for assessing the vertical bone volume in the paramedian hard palate, using cone beam CT is described in great detail in the research papers of this thesis. The method was first used in this pilot study to determine if the rater (KK) could use the measuring technique to produce consistent results. This was determined by the ICC test.

The results of the paired samples test demonstrated that the differences seen between the right and left sides of the palate were not significantly different from zero. This result allowed the use of one side of the palate in gathering measurements for the main study, and was expected from findings of previous researchers.[1-3]

As expected from various reports in the literature, great variation existed in the vertical bone volume at all of the locations in the paramedian region of the hard palate of the pilot patients. A range as large as 1- 15 mm was found at a single measuring point. The sample size required to investigate the research questions was to be calculated with this variability in mind. However, calculation of the sample size for detecting differences between female and male was not achievable in practice. As a result, it was decided that all available scans at the time of data collection would be analyzed, and a post hoc power analysis would be performed.

In the research papers, it was decided that the vertical bone volumes would be expressed as the mean amount available at each location, for males and females separately, along with the 95% confidence interval. Confidence intervals are most appropriately used to express the uncertainty attached to research findings when it is practically necessary to use a sample of limited size.[6] The mean bone volumes found are a point estimate for age and gender being studied. The advantage of the confidence interval is that it expresses a range of values which will contain the mean of the entire population 95% of the time. There is a 2.5% chance that the population mean will be higher than our confidence interval, and a 2.5% chance that it will be lower. The confidence interval expresses the degree of precision within which we can claim the sample mean estimates the population means. Furthermore, not all values within the confidence interval are equally likely to represent the population mean. Values around our point estimate are much more likely to be representative of the population mean than the values at either extreme of the confidence interval. Thus, if the vertical bone volume required to support palatal implantation is exceeded by the lower value of the confidence interval, that particular measuring point can be identified as a valid location for implantation with a high degree of confidence. This appraisal of the data depends, of course, on our sample being representative of the general population seeking orthodontic treatment. Some care has been taken to show how our sample relates to the general population seeking orthodontic treatment,[7,8] but the reader must reconcile the demographics of the sample to his or her own practice demographics to decide on the ultimate interpretation of the results.

The 95% confidence interval is also used to better describe the difference in bone volumes found between males and females. For example, in chapter 3, in six of nine locations males were found to have significantly greater vertical bone volume. The confidence intervals are narrow, and consistently show that females have less bone volume than males at those locations, adding validity to the results. This is also corroborated by the observed power of the results.[9]

2-6 Conclusions

Variability in bone depth between different locations in the hard palate was large. Considering that an objective of the thesis was to determine differences in bone depth between genders, the pilot sample was inadequate for this determination. Instead, all available data at the time of data collection was collected. Reporting of the results with confidence intervals and post hoc power analysis wherever possible will demonstrate the validity of the results.

The developed measuring method was used by the co-investigator (KK) to obtain the pilot study data with good to high reliability. The left and right sides of the anterior hard palate were found to be symmetrical in the pilot subjects, allowing for subsequent measurements to be done on one side only.

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Chapter 3 –Predictive Factors of Vertical Bone Depth in the Paramedian Palate of Adolescents

3-1 Abstract

Background: Palatal Implant placement for orthodontic anchorage in adolescent patients depends on vertical bone depth in the paramedian palate (PP). The aim of this study was to determine if a relationship exists between the vertical bone depth in the PP of growing patients and age, gender and palatal morphology. Clinically detectible traits may decrease the need for further imaging prior to implant placement for orthodontic anchorage. **Methods:** Cone-beam CT (CBCT) scans (Newtom-9000, Verona, Italy) were acquired in 183 orthodontic patients (10-19 years old). Vertical bone depth was measured at nine unilateral locations in the PP of each subject. Univariate and multivariate statistical tests were used. **Results:** Significant variability in the bone thickness was found between locations and subjects. Male subjects had significantly greater mean bone thickness in 6 of 9 locations measured. Age and palatal measurements did not demonstrate a clinically useful relationship to bone depth. **Conclusions:** Males demonstrated 1.22 mm more vertical bone on average than females at six of the nine locations measured. Age and palatal morphology are not valid predictors of bone height in the PP. Due to large variability of bone thickness in this region, CT imaging remains valuable prior to paramedian implant placement in growing individuals. The paramedian palate presents a promising region for palatal implant placements in view of the fact that implant placement in the midpalatal suture is contraindicated in growing individuals.

3-2 Introduction

The paramedian palate (PP) of adolescents has become an area of interest to orthodontists desiring absolute, non-compliance dependent anchorage. The use of titanium implants for orthodontic anchorage has become more accepted as a viable treatment alternative in recent years. Most research to date has focused on their use in adults, with the mid palatal suture as the implantation site of choice. In adolescents, it has been recommended to avoid the midpalatal suture owing to its nature as a growth center.[1] The potential degree of alteration of maxillary growth due to disruption of the suture by placement of an implant is unknown. Other studies have suggested that the placement of implants in the midpalatal suture of growing patients is contraindicated due to questionable quality of bone and the uncertain effect of an ankylotic fixture in a growth site [2].

Since growing patients make up the majority of orthodontic patients, recent research has focused on the PP as a potential implantation site. Bernhart et al (2000) and Gahleitner (2004), using dental CT, demonstrated regions of adequate vertical bone volume for implant placement in the PP of man.[1],[3]

Published research has shown a clinical focus, with sample sizes in the range of twenty to thirty patients, and fewer growing patients.[2-4] To obtain an understanding of the anatomy of the PP that applies to the population requiring PP implantation, a study of a large number of adolescent subjects is required. It is hoped that the identification of predictors of vertical bone depth in the PP of adolescents may be possible with a large sample, examined by CT. Such predictors could be used by orthodontists and surgeons alike to aid treatment planning decisions. The aim of this study is to determine if age, sex or palatal form of the adolescent patient can serve as predictors of vertical bone depth available for orthodontic implant placement in the PP.

3-3 Materials and Methods

The population tested consisted of individuals between the ages of 10 and 19 years seeking orthodontic treatment, which had their pre-orthodontic records taken at Edmonton Diagnostic Imaging Inc. Cone beam CT (CBCT) scans (Newtom-9000, Verona, Italy) of 183 adolescents obtained for the purposes of pre-orthodontic treatment planning were available.

The range of age groups was designed to encompass the ages that make up the majority of orthodontic patients. Males made up 32% of the sample, which is in line with the results of Huang (2004) who found that males made up 36% of patients seeking orthodontic care in a study of the demographics of demand for orthodontic care.[5]
The lower age limit was set by the earliest age at which comprehensive orthodontic treatment is generally undertaken,[6] and the upper limit by the age at which palatal growth is considered complete enough to have little consequence on treatment options. [7] In order to provide a wide range of ages for analysis, those ages were considered to be 10 and 19 years of age respectively. These subjects were divided into three age groups strictly defined by year, month and day so that age group 10-13 started on the tenth birthday, and ended on the day before the thirteenth birthday. Similarly, the age group 13-16 began on the thirteenth birthday and ended the day before the sixteenth birthday.
Only subjects that demonstrated normal development were included. Those that exhibited conditions such as supernumerary teeth in the area of interest or cleft palate were excluded from the study. Those that had previous orthodontic treatment, or were in

the process of orthodontic treatment, were also excluded. Out of the 189 data sets available within the age groups selected, 6 were omitted due such concerns. Distribution of the sample by age and gender is provided in Table 3-1.

Table 3-1: Distribution of Sample by Age and Gender

Age Groups	*Female (%)*	*Male (%)*	*Total/Group (%)*
10 – 13	43 (23.5)	15 (8.2)	58 (31.7)
13 - 16	45 (24.6)	32 (17.5)	77 (42.1)
16 – 19	36 (19.7)	12 (6.6)	48 (26.2)
Total	124 (67.7)	59 (32.2)	183 (100)

Multiplanar reformatting of the obtained CBCT data was performed with eFilm workstation software (Milwaukee, WI). The volume of data is initially visible as a two dimensional image in the axial orientation. The mid-sagittal plane was located by creating a line bisecting the incisive foramen and the odontoid process of the second cervical vertebrae. The odontoid process was chosen due to its midline position and distance from the incisive foramen, to reduce the influence of local asymmetry on the ability to choose a reproducible midline. (Fig.3-1)

Multiplanar reformatting was performed along this line to create a mid-sagittal view. Reference lines in the software were used to coordinate this view precisely with the selected line in the axial view. In this sagittal view, measuring lines were placed along the hard palate on the oral side. Using the distal margin of the incisive foramen as the starting point of the measurements, multiplanar reconstructions of para coronal sections were made at intervals of 4, 8, and 12 mm distal from the foramen. The resulting para coronal reconstructions were made perpendicular to the curvature of the palate to simulate the best possible path of insertion of an orthodontic implant[2,8,9] and these reconstructions are referred to as Planes 4, 8 and 12 (fig.3-2).

In each of the three reconstructed para coronal planes, measuring lines were established on the subject's left side at intervals of 3, 6 and 9 mm, starting from the median-sagittal plane on the oral side of the hard palate. These measuring lines were also made perpendicular to the curvature of the palate to simulate the best possible path of insertion of an orthodontic implant in all three planes of space[2,8,9]. They are referred to as Distances 3, 6 and 9 (fig.3-3). An earlier pilot study confirmed that the subjects were symmetrical and therefore only one side of the palate was measured in each para coronal reconstruction. The resulting intersections of Plane and Distance are nine locations in the paramedian palate of each subject. The name of the location is a description of its orientation to the distal margin of the incisive foramen, in millimeters. The locations then, are P4D3, P4D6, P4D9, P8D3-9 and P12D3-9. The least available vertical bone depths were measured at these nine locations (fig. 3-4).

Any measurement that was in the path of an erupting tooth was not included in the analysis. Measurements that encountered fully erupted teeth were recorded at that level.

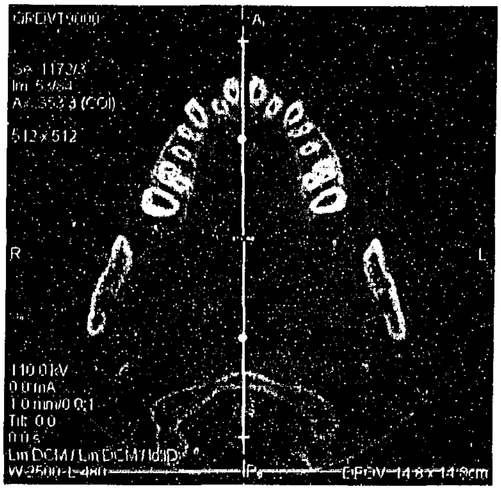

Figure 3-1: Multiplanar reformatting of the axial data as illustrated results in the sagittal view seen in Fig. 3-2.

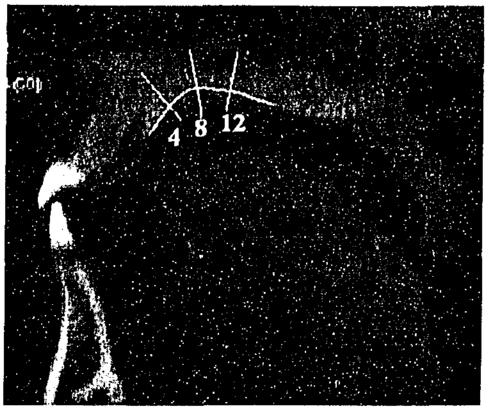

Figure 3-2: Sagittal View Showing Planes 4, 8 and 12, described by their distance in mm. from the posterior margin of the incisive canal.

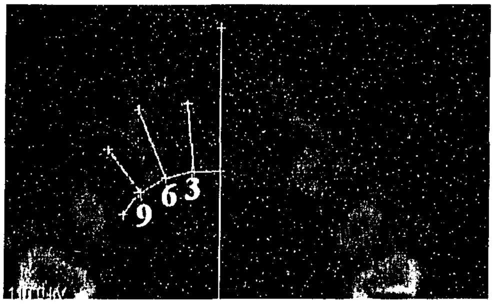

Figure 3-3: Paracoronal view at Plane 4, in which Distances 3, 6 and 9 were established at 3, 6 and 9 mm. from the midline. The intersection of Plane and Distance results in the measuring locations P4D3, P4D6, and P4D9.

Measuring location	Relationship to the incisive foramen (mm distal, mm lateral)
P4D3	4, 3
P4D6	4,6
P4D9	4,9
P8D3	8,3
P8D6	8,6
P8D9	8,9
P12D3	12,3
P12D6	12,6
P12D9	12,9

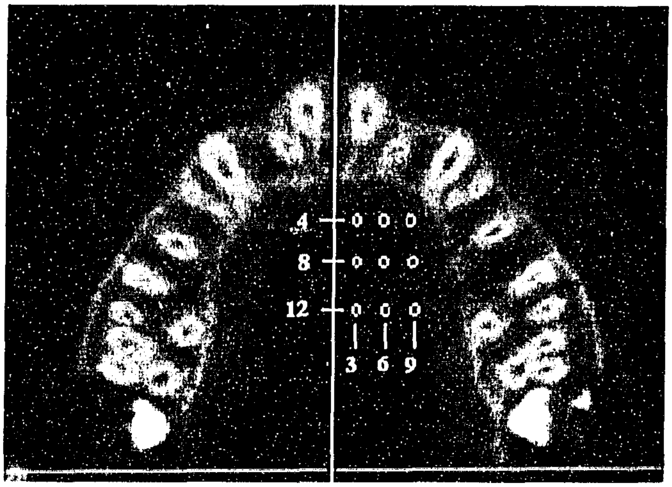

Figure 3-4: Map of the location of each vertical bone depth measurement as they relate to the distal margin of the incisive foramen, in millimeters.

The form of the hard palate demonstrates great variability. In clinical terms, palatal vaults are often described as 'high and narrow' or 'low and broad'. Describing various palatal forms in terms of an easily understood index allows clinicians to make treatment planning decisions without relying on such subjective descriptors.[10] Attempts to categorize palatal forms mathematically have met with little success. There are hardly any normal standards to determine accurately whether a palate is deformed, and this can conceivably be a reason for the divergent results observed in previous studies regarding palatal morphology.[11]

CT scanning presents the ability to base measurements on easily defined hard tissue landmarks and the use of orthogonal measurement techniques, the result being reproducible, accurate measurements.[12] In this paper, the width of the palate was measured as the palatal most distance between the maxillary first molars at the cemento-enamel junction, and the palatal height was measured as the distance from the bony cortex of the hard palate at the midline of the palate, perpendicular to the line measuring the width (Fig.3-5). The ratio between the height and width (PH / PW), expressed as a percentage, can serve as an easily understood palatal index (PI). [10].

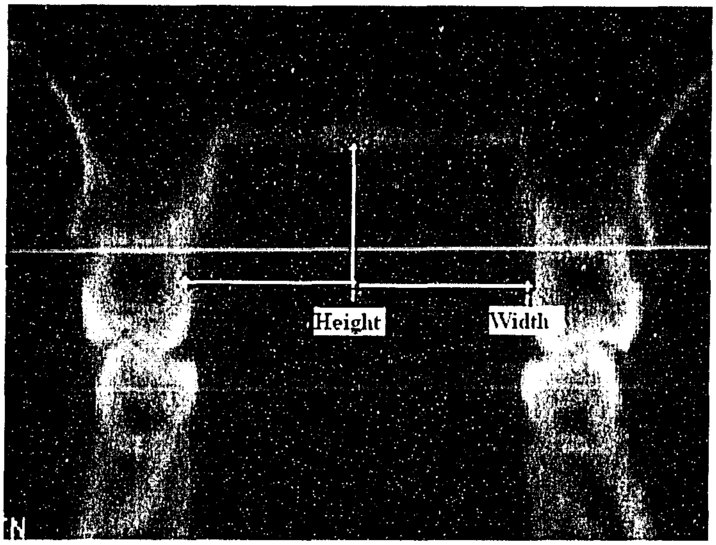

Figure 3-5: Palatal Index

The palatal dimensions of height and width were taken at the most lingual point of the first permanent molars from CEJ to CEJ. Palatal index = palatal height / palatal width.

The same investigator (KK) completed the multiplanar reformatting and bone depth measurements for the 183 subjects.

A pilot study was conducted to determine measurement reliability, palatal symmetry and sample size requirement. Measurements of vertical bone depth were tested for reliability by the Intra-Class Coefficient test, and values ranged from 0.98 to 0.85 in a pilot study. The subjects were examined for symmetry in the same pilot study, which also demonstrated no significant difference between the right and left sides of the palate, allowing the use of 9 vertical bone depth measurements for each subject in addition to palatal height, width and index measurements. A recent study by Gahleitner et al. confirmed that the same symmetry existed.[3]

Repeated measures MANOVA of the associations of age category, sex and palatal measurements on the mean vertical bone depth at the 9 measured locations was carried out. Post hoc power analysis of the results of the MANOVA was done. The association between palatal factors and age and gender were analyzed using linear regression analysis, and an independent samples t-test was used to further elucidate the relationship between gender and palatal factors (SPSS 12.0, Chicago Ill.).

3-4 Results

The combination of 3 planes with 3 measurements per plane resulted in 9 measurements for each of 183 patients, totaling 1647 measurements of palatal bone depth. 28 measurements were removed from the analysis due to contact with unerupted teeth (all of which were found in age category 1) resulting in 1619 measurements for further analysis. Measurements that encountered erupted teeth were taken at that level.

The association of gender with mean vertical bone depth at each of the nine locations is provided in Table 3-2 and illustrated in Figure 3-6. At six of the nine locations, males had significantly more vertical bone depth than females (range of 0.98 to 1.46 mm more, $p<0.05$). The locations P4D6, P4D9 and P8D9 did not demonstrate significant differences in vertical bone depth between genders.

At eight of the nine locations, no significant relationship between the age of the subjects and vertical bone depth in the paramedian palate existed. A statistically significant relationship existed at location P12D9 only, where age categories one and two had 1.20 and 0.85 mm more vertical bone depth on average than age category three (fig.3-7).

Bone depth was found to be associated with palatal height, palatal width, and palatal index as described in table 3-3.

Regression analysis of the association between palatal height with gender and age revealed an R^2 value of 0.194. Age was statistically significant ($p=0.000$), gender was not statistically significant ($p=0.095$). Regression analysis of the association between palatal width with gender and age revealed an R^2 value of 0.038. Age was not statistically significant (p=0.331), but gender was (p=0.013). Regression analysis of the association between palatal index with gender and age revealed an R^2 value of 0.131. Age was statistically significant (p=0.000), and gender was not statistically significant (p=0.908) (table 3-4).

An independent sample t-test of the association between palatal width and gender revealed that male widths were 1.18mm wider on average than female palatal widths (p=0.014) (table 3-5).

Table 3-2: Measurements of mean vertical bone depth at each of the nine paramedian locations

location	Male Mean (S.D.)	n	Female Mean (S.D.)	n	difference	P value	Power
P4D3	7.48 (3.10)	59	6.43 (2.53)	123	1.05	.016	.676
P4D6	5.07 (3.41)	55	4.49 (2.79)	120	0.58	.226	.227
P4D9	2.09 (1.42)	55	2.06 (1.21)	120	0.03	.889	.052
P8D3	5.56 (2.03)	59	4.10 (1.65)	124	1.46	.000	.999
P8D6	5.95 (2.95)	58	4.52 (2.13)	124	1.43	.000	.961
P8D9	4.75 (2.83)	55	4.58 (2.99)	121	0.17	.723	.064
P12D3	4.03 (1.48)	59	2.96 (1.16)	124	1.07	.000	1.000
P12D6	4.32 (2.02)	59	3.35 (1.89)	124	0.98	.002	.887
P12D9	5.90 (2.80)	58	4.60 (2.48)	122	1.30	.002	.886

Mean vertical bone depth (male mean, female mean), the difference between genders (difference), and standard deviation (S.D.) measurements given in millimeters. Measurements excluded were in the path of erupting teeth (28 total).

Table 3-3: Locations in which bone depth was associated with palatal factors.

Factor	Location	Rate of change	P value
Palatal	P12D3	-0.12	.008
Palatal	P4D9	0.07	.04
	P12D3	-0.06	.045
	P12D6	-0.14	.002
Palatal	P4D6	-0.06	.034
	P8D9	-0.08	.009
	P12D6	-0.04	.04

The association is described by rate of change. A one millimeter increase in the palatal factor (Factor) corresponds to an increase or decrease in a millimeter amount equal to the rate of change (Rate of change) at the locations (Location) listed.

Table 3-4: Regression analysis. The association between palatal factors and age and gender.

	Age and gender in model		Age	Gender
	R^2	P value	P value	P value
Palatal Height	0.194	.000	.000	.095
Palatal Width	0.038	.031	.331	.013
Palatal Index	0.131	.000	.000	.908

Table 3-5: Independent T test of the relationship between palatal factors and gender

	Mean difference between genders (mm)	P value	95% confidence interval of the difference	
			lower	upper
Palatal Height	.50	.174	-.22	1.23
Palatal Width	1.18	.014	.24	2.13
Palatal Index	.02	.984	-2.48	2.43

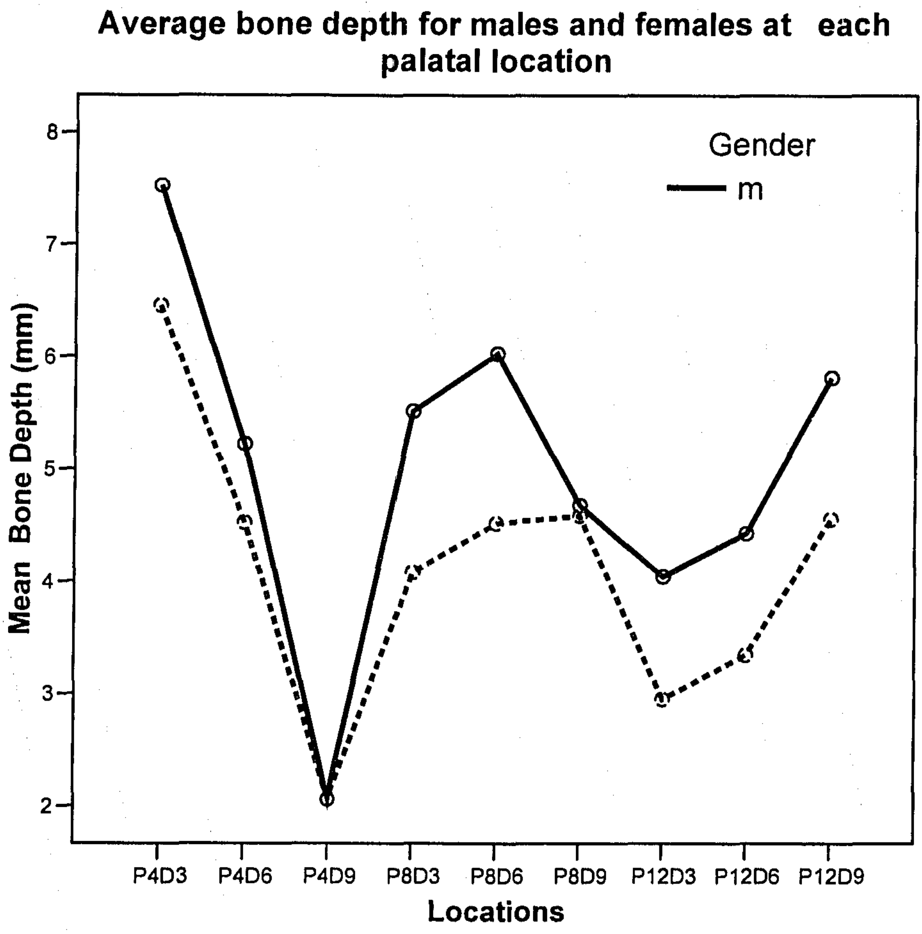

Figure 3-6: Average bone depth for males and females at each palatal location

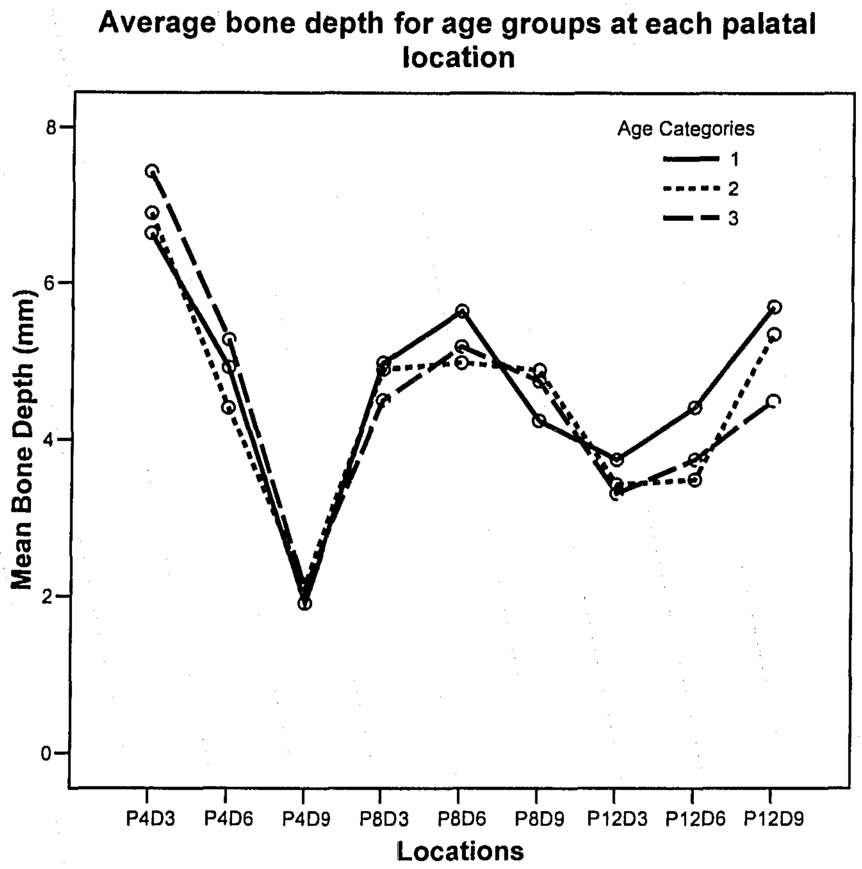

Figure 3-7: Average bone depth for age groups at each palatal location

3-5 Discussion

Clinical trials using implants of varying length have demonstrated that the paramedian palate is a suitable host site for implants in orthodontic treatment. Previous investigators have utilized both conventional radiographic examinations and CT methods to determine which subjects had appropriate vertical bone depth for implant placement, and the best location for implantation. [1,2 4,7-9,13] A common finding has been great variability in the vertical bone depth among patients, and the use of conventional radiographs for pre-surgical planning has provided results that were consistently different from surgical findings.[8]

To date, the literature has not explored factors that may be predictive of vertical bone depth availability in addition to conventional radiographs and diagnostic records. As a result, the need for diagnostic imaging tools such as CBCT has intensified. Identification of predictive factors might decrease imaging requirements and/or aid in treatment planning palatal implants.

CBCT produces images which are anatomically true, 3D representations with 1 to 1 correlation, from which slices can be displayed from any angle in any part of the imaged region and archived digitally; anatomical structures can even be printed at their true size. The radiation dose of a dental CT scan can be as low as 36uSv or similar in absorbed dose to a dental periapical full mouth series. [12,14] It also allows secondary reconstructions, such as sagittal, coronal and para-axial cuts and 3D reconstructions of different craniofacial structures which are not magnified nor distorted in size or shape. [12]

Using CBCT and appropriate software for data reconstruction, our results demonstrate that males consistently have more vertical bone depth in the PP than do females. Six of nine locations studied had on average 1.22 mm more mean vertical bone depth. Three of the locations, did not demonstrate significant gender difference, likely due to the large number of measurements that were limited by the presence of teeth in these locations, as described in chapter 4 of this thesis. Post hoc power analysis was done due to impractical apriori sample size calculations. The results demonstrate adequate power to determine the differences in bone depth seen between genders at the six locations. The measurements at P4D6, P4D9 and P8D9 did not demonstrate adequate power, again possibly due to the large number of measurements limited by the presence of teeth in these locations.

Eight of the nine locations examined did not demonstrate a relationship between vertical bone depth and age. One location, P12D9, demonstrated increased bone depth in the 10-13 and 13-16 year old category, with those ages having 1.20 and 0.85 mm more bone depth than the same area in the 16-19 year old group. These findings complement those of Howell et al[16], who reported an increase in palatal index from the mixed to the permanent dentition, measured distal to the second premolar, while the area between the first and second premolars remained stable as children aged. An increased palatal index resulted primarily due to increased palatal height (at the level of the first permanent molars in this study), which might be expected as palatal remodeling with age expresses most of its effect in this area.[15-17] Bone quality in the posterior hard palate has been identified as generally poorer quality than in the anterior; thus age related changes in bone depth at this location may have limited practical usefulness.[18]

The association between the palatal factors (palatal height, width and index) with bone depth, although statistically significant, demonstrates that large changes in these factors correspond to minimal change at the measured location. For example, a 10mm change in palatal height corresponds to 1.2mm less bone depth at P12D3. The clinical usefulness of these observations is questionable.

Palatal width did not increase with age. Regression analysis of the association between palatal factors and age and gender, although statistically significant, was a poor fit, describing only 19.4% of the variance in palatal height, 3.8% of the variance in palatal width and 13.1% of the variance in palatal index. Gender was related to palatal width, with male widths 1.18mm wider on average than female palatal widths.

3-6 Conclusions

The results of this study suggest that the orthodontist and surgeon, when considering implants for orthodontic anchorage, can expect to find similar vertical bone depth availability in the paramedian hard palate over the age range of 10 to 19 years. Palatal form, aside from surgical access considerations, has no relationship to the vertical bone depth present. Males have on average, 1.22 mm more vertical bone depth compared to females, at the locations P4D3, P8D3, P8D6, P12D3, P12D6 and P12D9. Due to the lack of readily identifiable predictors of vertical bone depth in the palate, thorough pre-operative imaging remains essential in treatment planning palatal implants for orthodontic anchorage.

3-7 References

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Chapter 4 - Vertical Bone Volume in the Paramedian Palate of Adolescents: A CT Study

4-1 Abstract

Background: The paramedian palate (PP) has been used as a host site for orthodontic implant anchorage in adolescents. The aim of this study was to identify the most appropriate location(s) for PP implantation, considering available bone and interference of adjacent tooth roots in a group of growing patients. **Methods:** Cone-beam CT (CBCT) scans (Newtom-9000, Verona, Italy) were acquired in 183 orthodontic patients (10-19 years old). Paracoronal views of the PP region were reconstructed (eFilm workstation, Milwaukee, WI) at 4, 8 and 12mm posterior from the incisive foramen, and measurements of bone height made in each reconstruction at 3, 6 and 9mm increments laterally from the midline to describe the PP. **Results:** At the location 4mm posterior to the incisive foramen and 3mm lateral to the midline, 93% of male and 91% of female subjects met criterion for implantation. At 8mm posterior to the incisive foramen and 3mm lateral to the midline, 86% of male and 58% of female subjects met criterion for implantation. **Conclusions:** The PP contains a number of valid implant host sites in adolescent males and females. The best location was 4mm distal and 3mm lateral to the incisive foramen at which 93.2% of males and 91.9% of females had a minimum amount of vertical bone depth sufficient to host a 3mm implant with very little practical tooth interference. CBCT provides an opportunity to accurately assess the entire volume of a proposed implant site.

4-2 Introduction

The palatal implant has demonstrated effectiveness in patients requiring enhanced orthodontic anchorage when it is not deemed possible to rely on conventional techniques. The palate has many advantages as an implantation site. Surgical placement can be done in a single stage, with the attached mucosa providing exceptional peri-implant conditions. Even in areas where the thickness of the mucosa is more than 4mm, the soft tissue conditions of the palatal implants in a study by Wehrbein et al (1996) were considered normal at recall.[1] Implants designed specifically with shorter length that are considered temporary in nature have supported the orthodontic application.[2]

The main disadvantages to using the palate remain the relative lack of vertical bone thickness and its great variability between patients. The possibilities of sinus perforation, interference with the incisive canal or roots of adjacent teeth as well as the recommendation to avoid the midpalatal suture in growing patients remain a concern.[1,3]

The majority of orthodontic patients are growing children and adolescents[4] in whom the midpalatal suture must be avoided during palatal implant placement due to its nature as a growth center. [1,3,5,6] To address this issue, the paramedian palate (PP) has been identified through various CT, radiographic and case studies as a suitable location for implantation.

PP implants have been used in clinical situations for orthodontic anchorage with considerable success. Bernhart et al (2001) reported a time related success probability of

84.8% during 22.9 months of orthodontic treatment with PP implants, while Gahleitner et al (2004) achieved successful anchorage with PP implants in 93% of their patient sample.[2,5] Bernhart et al (2000) concluded that placement of implants in the paramedian region was most statistically possible at 6 and 9 mm posterior from the incisive foramen at a distance 3 and 6 mm laterally from the median line while avoiding the palatal suture, in 22 subjects aged 13 to 48.[3] Gahleitner et al (2004) found the most bone in the PP region at 3 and 6 mm distal from the incisive foramen, in 32 subjects aged 12 to 49.[5] Although promising for the PP as an implant host site, there remains a gap in the literature when it comes to describing the most suitable location for PP implantation in a group of growing children and adolescent patients.

Recent work has established CT as a useful technology to identify the best location for implant placement in the PP of an individual patient.[3,5] The familiar advantages of CT for visualizing proposed implant sites in the alveolar ridge apply to its use in the PP.[7] The CT data set is subjected to multiplanar reconstruction, allowing measurement of any area desired within the scanned volume with increased accuracy, and lack of projection or superimposition errors when compared to two dimensional techniques. Recent introduction of cone beam CT (CBCT) allows 3D imaging of the maxillary complex with total absorbed radiation doses comparable to a series of conventional intra-oral diagnostic radiographs.[8]

Measurements of bone made with CT can be described as bone volumes when the thickness of the slice being examined is considered. The most commonly used implants in the palate are cylindrical in form and have diameters of 3.3 and 3.75 mm, and lengths of 3, 4 and 6 mm. To accurately determine the bone volume available for this group of implants (accounting for a 1 mm surgical margin on either side of the implant, and for the length) a cumulative slice thickness of at least 5.3 mm must be explored (for implants of 3.3 mm diameter), and there must be at least 4mm present in the vertical dimension to support a 3mm implant, and 7mm to support a 6mm implant. Recent studies have explored a slice thickness of 1 to 1.5 mm (much less than the diameter of the implant being contemplated) while evaluating whether 4 or 7mm of bone height is present. When measurements of bone height are taken within such a thin slice it results in incomplete information as to whether or not the reported bone volumes are in fact available for implantation, or if interference with vital structures will take place. Using CT to generate such nearly two dimensional images does not utilize the full benefit of this technology, and negates the added value of volumetric scanning. The systematic location of a region of interest, followed by examination of the total volume of that region is known as hierarchical data mining.[9]

CBCT imaging of a large group of adolescent patients presents an opportunity to explore the PP with the criterion of implantation in mind. The goal of this study therefore is to analyze the CBCT data of such a group. The anatomy of the PP will be described, with particular emphasis on measuring vertical bone volume and defining regions that are most likely to support implantation through hierarchical data mining.

4-3 Materials and Methods

Newtom-9000® (Verona, Italy) CBCT scans of 183 adolescents (124 females, 59 males, mean age 14 years 7 months, age range 10 -19 years) which were collected for pre-orthodontic records at Edmonton Diagnostic Imaging Inc. were used as the study sample. The range of age was designed to encompass the ages that make up the majority of orthodontic patients [4], as well as to encompass those considered to be growing. The growth criterion is the most important for the study, as it is those patients in whom the placement of implants in the midpalatal suture is contraindicated due to its' nature as a growth site,[10] [3,11] in turn necessitating the use of the PP. Cases with supernumerary teeth in the area of interest, cleft palate or previous orthodontic treatment were excluded from the study. From the 189 data sets available within the defined age range, 6 were excluded.

Multiplanar reformatting of the obtained data and location of the measuring sites was performed with eFilm workstation software (Milwaukee, WI), and is described in detail in a previous study. A pilot study determined that the right and left sides of the palate were not significantly different; therefore, the measuring locations were recorded on the left side only, resulting in nine locations in the left side of the anterior paramedian hard palate. The measuring locations are described by the intersection of planes and distances. The planes are located 4, 8 and 12 mm from the distal margin of the incisal foramen, and are identified by P4, P8 and P12. The distances are located 3, 6 or 9 mm from the midline, and are identified by D3, D6 and D9. In this way, the names of the nine locations are descriptions of their orientation in the paramedian palate. (Figure 4-1)

Measuring location	Relationship to the incisive foramen (mm distal, mm lateral)
P4D3	4, 3
P4D6	4,6
P4D9	4,9
P8D3	8,3
P8D6	8,6
P8D9	8,9
P12D3	12,3
P12D6	12,6
P12D9	12,9

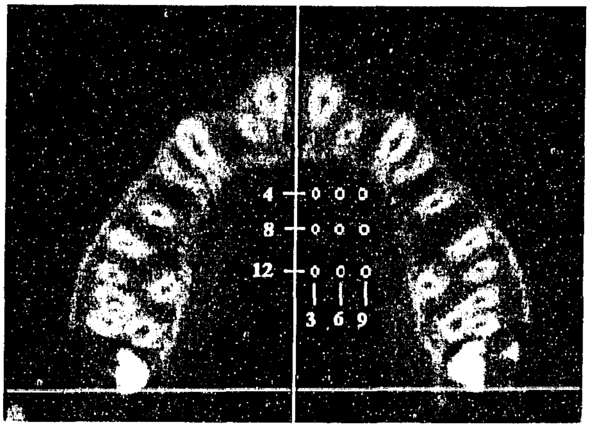

Figure 4-1: Map of the location of each vertical bone depth measurement as they relate to the distal margin of the incisive foramen, in millimeters.

The most commonly used implants in the palate have diameters of 3.3 and 3.75 mm, and lengths of 3, 4 and 6 mm. To account for surgical placement, a 1mm buffer must exist beyond these measurements.[12] For this study, the minimal bone volume required for implantation was defined as 4mm in length and 6mm in diameter (1mm buffer on length, and 1mm on either side of the diameter gives 5.75mm, rounded to 6mm for ease of measurement, and to compensate for future explantation).

A region of interest (ROI) was explored at each measuring location extending 3 mm anterior and 3mm posterior to the center as well as 3mm laterally on either side of the center. The ROI measures 6mm by 6mm, and thus accounts for the diameter of the implant plus a buffer for surgical placement (fig 4-2). Within each ROI, the lowest vertical measurement was recorded as the bone height available for implantation. The boundaries of the measurements were the cortical bone of the nasal/sinus floor, the exterior cortex of the alveolar process or the root of an adjacent tooth. If an unerupted tooth was found in the ROI, the location was excluded from further analysis. If an erupted tooth root was encountered, the vertical measurement was recorded at that level.

In this manner, the vertical bone volumes at the measuring locations of the anterior paramedian hard palate are mapped out as they relate to the ability of that location to host an implant.

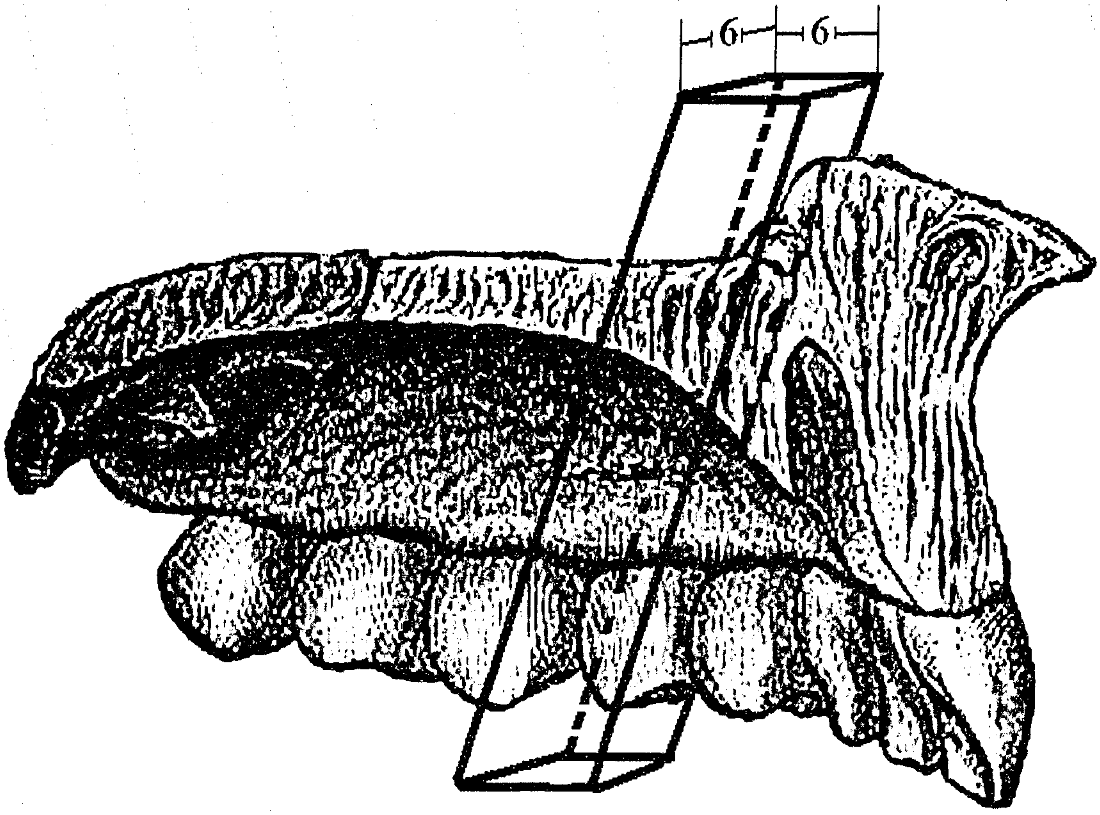

Figure 4-2: Representation of the Region of Interest (ROI)

Representation of the Region of Interest (ROI) that must be explored at each measuring location to gain an appreciation of that site as an implant host site (hierarchical data mining). A measurement at the mesial edge of the ROI would give much larger values than a measurement at the distal edge. The same observations can be made laterally from the center of the measuring location.

Descriptive statistics (mean bone heights with 95% confidence intervals) were calculated to describe the minimum vertical bone volume available in the ROI at each measuring location. The number of measurements having teeth as a border, by gender for each location, the number of measurements held to less than 4mm by teeth, and the percentage of measurements that could support no implant, 3mm implants and 6mm implants were calculated using a chi square analysis (SPSS 12.0 (Chicago Ill.).

4-4 Results

Minimum mean bone heights for the ROI for male and females are provided in Table 4-1.

Table 4-1: Mean minimum bone height measurements within each ROI.

Measuring location (ROI)	Male		Female		difference	P value
	Mean (S.D.)	95% C.I.	Mean (S.D.)	95% C.I.		
P4D3	7.48 (3.10)	6.78 - 8.18	6.43 (2.53)	5.94 - 6.91	1.05	.016
P4D6	5.07 (3.41)	4.30 - 5.84	4.49 (2.79)	3.96 - 5.02	0.58	.226
P4D9	2.09 (1.42)	1.76 - 2.41	2.06 (1.21)	1.83 - 2.28	0.03	.889
P8D3	5.56 (2.03)	5.10 - 6.02	4.10 (1.65)	3.78 - 4.41	1.46	.000
P8D6	5.95 (2.95)	5.33 - 6.57	4.52 (2.13)	4.09 - 4.95	1.43	.000
P8D9	4.75 (2.83)	4.00 - 5.50	4.58 (2.99)	4.06 - 5.10	0.17	.723
P12D3	4.03 (1.49)	3.711 -	2.96 (1.16)	2.73 - 3.18	1.07	.000
P12D6	4.32 (2.02)	3.83 - 4.82	3.35 (1.89)	3.00 - 3.69	0.97	.002
P12D9	5.90 (2.80)	5.23 - 6.56	4.60 (2.48)	4.14 - 5.06	1.30	.002

Mean, standard deviation (S.D.), confidence interval (C.I.) and the difference between genders (difference) are measured in millimeters.

In males, 5 of the 9 measuring locations yielded mean bone heights greater than the minimum 4mm required for implantation and had a 95% C.I. in which the lower value of the interval was still greater than 4mm. Females had 4 such locations. In both sexes, the best location was P4D3, followed by P8D6 and closely by P12D9 in males and followed by P12D9 and closely by P8D9 and P8D6 in females. P4D6 and P8D9 were last for males.

The number of ROI where a tooth formed a boundary is shown in Table 4-2. Three locations (P4D6, P4D9 and P8D9, Figure 4-3) had the highest percentage of measurements in which a tooth formed the boundary of that measurement (73.8%, 98.4% and 51.9% overall). At P8D6 and P8D9, males had a significantly higher percentage of measurements limited by teeth than females.

All of the locations were secondarily examined to determine the percentage of measurements that were limited by teeth *and* resulted in that measurement being less than the minimum 4mm required. (Table 4-3) Again, the same three locations (P4D6, P4D9 and P8D9) demonstrated the highest percentages (41.5%, 86.3% and 33.9%). For this practical criterion, males and females were not significantly different.

The percentage and number of subjects that had less than 4mm, greater than or equal to 4mm and greater than or equal to 7mm at each location, separated by gender, is provided in Table 4-4. This chart can be used to gain an appreciation of the percentage of subjects who could host no implants, or implants of 3mm and 6mm lengths at the various locations.

The single best site was P4D3, with 93.2% of males and 91.9% of females demonstrating enough vertical bone volume to host a 3mm implant with very little practical tooth interference.

Table 4-2: Number of measurements at each Region of Interest in which a tooth formed the boundary, determined by Chi Square test.

Measuring location	Overall	Male	Female	P value
	# (%)	# (%)	# (%)	
P4D3	39 (21.3)	17 (28.8)	22 (17.7)	.087
P4D6	135 (73.8)	46 (78.0)	89 (71.8)	.373
P4D9	180 (98.4)	58 (98.3)	122 (98.4)	.967
P8D3	0 (0)	0 (0)	0 (0)	1
P8D6	33 (18.0)	16 (27.1)	17 (13.7)	.027
P8D9	95 (51.9)	38 (64.4)	57 (46.0)	.02
P12D3	0 (0)	0 (0)	0 (0)	1
P12D6	1 (0.5)	0 (0)	1 (0.8)	.489
P12D9	25 (13.7)	10 (16.9)	15 (12.1)	.372

Table 4-3: Number of Regions of Interest in which a tooth formed the boundary, limiting any measurement within the ROI to less than 4mm, or in which an unerupted tooth was encountered. Chi-Square test.

Location of ROI	Overall	Male	Female	P value
	# (%)	# (%)	# (%)	
P4D3	8 (4.4)	3 (5.1)	5 (4.0)	.745
P4D6	76 (41.5)	23 (39.0)	53 (42.7)	.630
P4D9	158 (86.3)	50 (84.7)	108 (87.1)	.665
P8D3	0 (0)	0 (0)	0 (0)	1
P8D6	11 (6.0)	4 (6.8)	7 (5.6)	.763
P8D9	62 (33.9)	21 (35.6)	41 (33.1)	.736
P12D3	0 (0)	0 (0)	0 (0)	1
P12D6	1 (0.5)	0 (0)	1 (0.8)	.489
P12D9	11 (6.0)	3 (5.1)	8 (6.5)	.716

Table 4-4: Ability of Each Location to Host an Implant

The measurements at each ROI are classified into three categories: <4mm = no implant, ≥4mm = 3mm implant possible, ≥ 7mm = 6mm implant possible, Chi square test.

Location	Gender	< 4mm		≥ 4mm		≥ 7mm	
		n	(%)	n	(%)	n	(%)
P4D3	M	4	(6.8)	55	(93.2)	34	(57.6)
	F	11	(8.9)	113	(91.1)	53	(42.7)
P4D6	M	27	(45.8)	32	(54.2)	14	(23.7)
	F	54	(43.5)	70	(56.5)	25	(20.2)
P4D9	M	52	(88.1)	7	(11.9)	1	(1.7)
	F	110	(88.7)	14	(11.3)	1	(0.8)
P8D3	M	8	(13.6)	51	(86.4)	18	(30.5)
	F	52	(41.9)	72	(58.1)	13	(10.5)
P8D6	M	13	(22.0)	47	(79.7)	17	(28.8)
	F	45	(36.3)	80	(64.5)	19	(15.3)
P8D9	M	26	(44.1)	33	(55.9)	15	(25.4)
	F	58	(46.8)	66	(53.2)	33	(26.6)
P12D3	M	21	(35.6)	38	(64.4)	3	(5.1)
	F	89	(71.8)	35	(28.2)	0	(0)
P12D6	M	23	(39.0)	36	(61.0)	9	(15.3)
	F	75	(60.5)	49	(39.5)	8	(6.5)
P12D9	M	13	(22.0)	46	(78.0)	23	(39.0)
	F	45	(36.3)	79	(63.7)	28	(22.6)

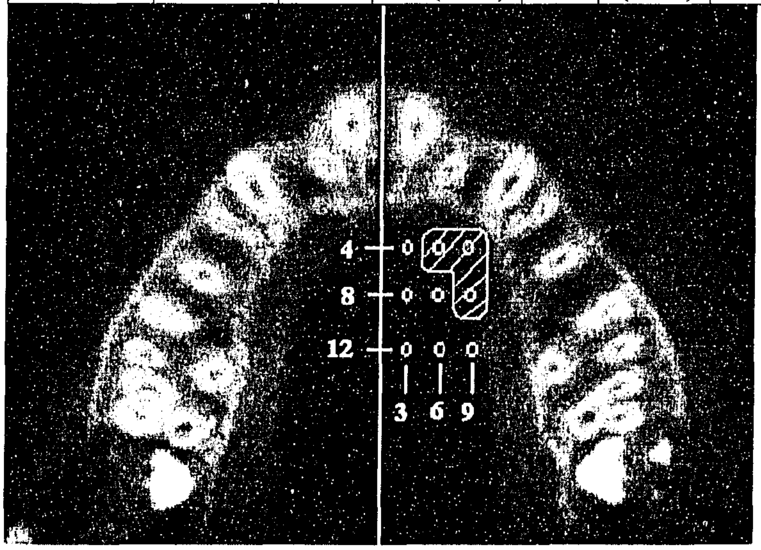

Figure 4-3: the locations with the most measurements with teeth as boundaries are outlined. Those locations are P4D6, P4D9 and P8D9 as described in tables 4-2 and 4-3.

4-5 Discussion

The paramedian palate (PP) has been identified as a viable alternative for the placement of temporary implants intended for orthodontic anchorage. This has been a critical development since reservation for using orthodontic implants in growing patients evolved from the lack of an obvious host site.[6] Implants designed specifically for orthodontic anchorage and the palatal area have also improved acceptance of this technique.

The versatility of CBCT to evaluate the bone availability in the PP is remarkable, allowing volumetric examination of the ROI. Existing literature has reported measurements of bone height in the PP using thin slice thicknesses.[3,5] Using a ROI to record bone height as a representation of volume, at a series of locations, provides a truly 3-D method for evaluating the ability of these sites to host an implant, and identify critical structures that might be encountered at those sites.

Using this technique, six locations in males and four locations in females were found to contain greater than the 4mm minimum vertical bone height with a 95% confidence interval. The locations P4D6, P4D9 and P8D9 should be regarded with caution as a large percentage of the measurements at these sites had teeth as a boundary (table 4-2, figure 4-3), with males having significantly more teeth as boundaries in these areas. A lesser but clinically significant number of measurements at these locations were limited to less than 4mm by teeth. There was no difference between males and females when evaluated in this fashion. All other locations demonstrated few measurements with teeth as boundaries.

The identification of P4D3 as the best site in growing patients corresponds well to the work of Bernhart and Gahleitner.[3,5] Location P12D9, while demonstrating significant bone volume, should also be regarded with caution as previous researchers have commented on the poor quality of bone for implantation in the posterior hard palate.[13]

Table 4-4 represents a summary of the locations with the number and percent of measurements at each location as they relate to implant placement. Those measurements that are less than 4mm cannot host even the shortest 3mm implant. Those greater than or equal to 4mm and greater than or equal to 7mm can host 3mm or 5 and 6mm implants respectively.

Presenting the data with 95% confidence intervals gives the reader the ability to appraise the uncertainty attached to these research findings. Thus, if the vertical bone depth required to support palatal implantation is exceeded by the lower value of the confidence interval, that particular measuring point can be identified as a valid location for implantation with a high degree of confidence. This appraisal of the data depends, of course, on the sample being representative of the general population seeking orthodontic treatment. Some care has been taken to show how the sample relates to the general population seeking orthodontic treatment,[4,14] but the reader must reconcile the demographics of the sample to his or her own practice demographics to decide on the ultimate interpretation of the results.

Despite being free of magnification and superimposition errors, CBCT relies on interpolation of the acquired data. Interpolation into units called voxels allows data points to be represented as cubes, comprising the 3D volume. The voxel is a 3D representation of a pixel and is based on the nearest neighbor interpolation of spatial samples. Therefore, the interior of the whole voxel has the same value. In visualization, we would prefer continuous data, but reconstruction provides discrete data points. This allows inadvertent selection of the 'nearest neighbor' point which can lead to error (as described by the Nyquist Sampling Theorem). In practicality, it can result in measuring errors approximately equal to twice the voxel size.[15]

Although not statistically evaluated, large variation in maxillary sinus size and form seemed to be the primary reason for the wide variation seen in the bone volume between individuals. Further studies with CBCT aimed at exploring this observation are needed.

4-6 Conclusions

The results of this study further validate the PP region in adolescents as a host site for orthodontic implants. There are a number of valid host sites in adolescent males and females, with P4D3 (4mm distal and 3mm lateral to the incisive foramen) identified as the best location. 93.2% of males and 91.9% of females had a minimum amount of vertical bone depth at this location sufficient to host a 3mm implant with very little practical tooth interference. CBCT provides an opportunity to assess the entire volume of a proposed implant site through hierarchical data mining.

4-7 References

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Chapter 5 General Discussion

5-1 Introduction

This thesis has several objectives. The first objective is to examine the manner in which orthodontists interpret three dimensional data gathered by CT scan, and to highlight the differences between traditional 2D radiographs and emerging 3D technology. Concepts required to utilize 3D images appropriately, such as hierarchical data mining are introduced. The second objective is to cast a critical eye on the allure of cone beam CT units that can easily be placed in an orthodontic office, and soon may be promoted as the standard of care for orthodontic records. Is it necessary to use this technology when treatment planning a procedure such as a palatal implant for orthodontic anchorage? Are there any predictive factors in the adolescent patient that may allow the clinician to reduce the need for further imaging as opposed to promoting it during the treatment planning exercise? The third objective is to analyze the 3D data gathered in the manner developed in the first objective, to attempt to answer the questions:

- 'Where is the best possible location for a palatal implant in an adolescent when absolute orthodontic anchorage is required?'
- 'What lengths of implants are practical in the palate of the adolescent (what percentage of the sample could tolerate 3 mm and/or 6mm implants)?'
- 'In which locations is there a practical risk of the implant interfering with erupted or unerupted teeth?'

The fourth objective is to make recommendations on future research projects to further the science of 3D imaging and treatment planning in orthodontics using the perspective gained through immersion in the current literature.

5-2 3D Imaging in Orthodontics

Traditional orthodontic radiographs are two dimensional images. Properly diagnosing the orthodontic patient requires assimilation of these images into the mind's eye in order to deliver optimal treatment to each patient. Certain aspects of this process are anything but scientific, and attempts to analyze the process can result in cookbook like treatment recommendations that ignore the individuality of the patient. Technologies that provide more information to the diagnostic process are typically accepted by orthodontists. This has resulted in the evolution of orthodontic treatment planning towards a greater appreciation of the effects of orthodontic treatments on the 'whole face' (i.e. facial esthetics, the underlying skeletal structures and function as well as how the teeth fit together). In this way, the availability of 3D imaging in orthodontics promises to benefit the profession and the patients we treat. It is also our responsibility as scientists to critically evaluate technological advances and how they benefit us. In particular, it is important to avoid cavalier usage and interpretation of the technology to suit preconceived notions that may be based on years of experience, however effectively or ineffectively that experience has served.[1] Description of a systematic and thorough approach to the data follows.

5-3 Hierarchical Data Mining

3D data sets derived from CT scanning are commonly mishandled in two ways. Firstly, clinicians can pour over the hundreds of thin slice axial images, resulting in data overload. Alternately, they may interpret select images as independent 2D images in the manner they are accustomed to, missing the benefits of the technology. Both approaches are unsound, and result in improper use of the data. A systematic approach to the 3D data set has been referred to as hierarchical data mining. The concept of hierarchal data mining is important to gaining the appropriate perspective of a large volume of data using a combination of axial and off-axial 2D thick-slice reconstructions, targeted thin-slice reconstructions, and interactive 3D manipulation. Thick-slice axial and multiplanar reconstructions are used to make most interpretations in a time efficient and accurate fashion. In specific cases where higher resolution data is needed, areas of interest are evaluated further to improve specificity in a focused review of thin-section data. The number of images to review remains manageable, while the in-plane resolution of the reconstructions maintains the same high quality expected from the axial images. This review is supplemented in select cases by the review of 3D volume data and additional rendering tools on a 3D workstation.[2-4]

A considerable difficulty in developing the measuring technique came from the software available to manipulate the CT data. Software is being developed at a rapid rate, but very few packages contain all of the functions necessary for making simple measurements of complex areas like the palate. Only one package in the literature (Easy Vision R4, Philips, Eindhoven, The Netherlands) was able to generate multiplanar reconstructions perpendicular to a curved, user defined line, such as the oral surface of the hard palate, and this software is proprietary, supplied with Philips CT equipment only.

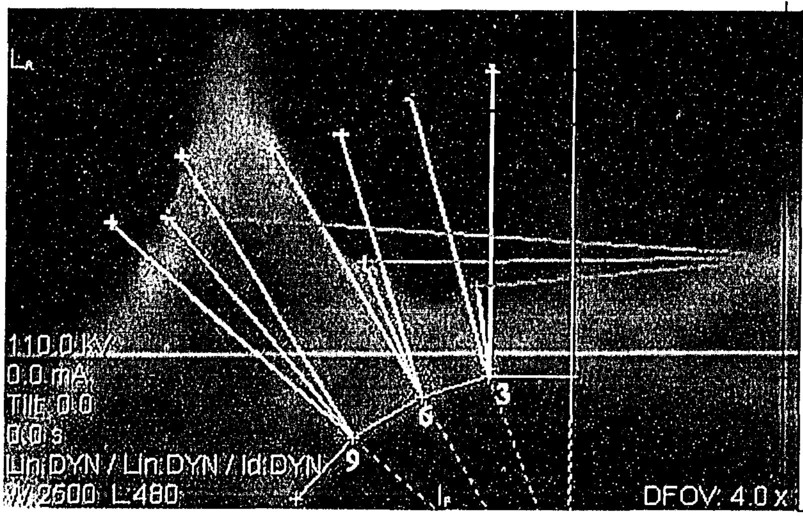
In this work, the following technique was developed to simulate tangents to a curved surface.

5-4 Selecting Planes and Directing Measuring Lines

The eFilm workstation software (Milwaukee, WI) was selected because of its ability to create multiplanar reconstructions based on the views created by previous reconstructions. This is required to precisely locate the para-coronal planes (Planes 4, 8 and 12) in which the distance measurements were made, and to select the measuring lines in those para-coronal planes (Distances 3, 6 and 9). At the time the data was collected, the software provided with the NewTom could not perform this function.

It is desirable that the measuring lines be as perpendicular to the curvature of the oral surface of the hard palate as possible, since surgical implant placement will follow the same principle to allow the best seating of the implant [5,6].

An example of the procedure for measuring bone depth at the distances in the para-coronal planes follows. The distances measured on the oral surface of the curved palate were made up of straight line segments, of the desired 3 mm length. Each segment was positioned as a 'best fit' to the curvature of the palate. For the measuring lines to approximate a perpendicular to the curve, guide lines were established at 90° to each 3 mm segment at its junction with the next segment. Bisection of these guide lines by the measuring line resulted in an approximation of a line that is perpendicular to the curvature at that point (fig. 5-1). The same method was used to select Planes 4-12 in the mid sagittal view, except that the straight line segments were 4 mm long, with the para coronal planes resulting between the guidelines instead of measuring lines. This technique proved to be reliable in the hands of the co-investigator (KK) as demonstrated by reliability testing found in the pilot study chapter.



Guideline 90 degrees to first 3 mm segment

Guideline 90 degrees to second 3 mm segment

Measuring lines bisecting guidelines to approximate 'perpendicular to the curvature of the palate'

Figure 5-1: Measuring perpendicular to the curvature of the palate

In the research papers of this work, despite the fact that the plane of the measurements was difficult to locate, the actual measuring points were placed in similar locations as in recent publications.[7,8] Most significantly, the measuring points were not treated as 2D, but rather as a region of interest (ROI), in which the hierarchical process of examining the bone volume and vital structures of the ROI was carried out. No other work in the field of orthodontics found by the authors to date has used this approach to measurement, and it is hoped that diagnostic sensitivity is improved by the increased information found by exploring the ROI.

5-5 Measuring Tool and Software

As described in the literature review, the accuracy of volumetric scanning is subject to the principles of the Nyquist sampling theorem.[9] In order to avoid compounding measuring errors, it has been recommended that primary reconstructions of the data set produced by the CBCT machine (NewTom 9000 in this work) be completed such that secondary reconstructions are perpendicular to the primary. For example, if measurements of alveolar bone height of the mandible were planned, the primary reconstruction of the data set should be done parallel to the inferior border of the mandible. In this way, when the secondary reconstructions are made, the measurements of alveolar bone height are basically perpendicular to the primary reconstruction. Mozzo et al demonstrated high geometric accuracy of measurements in this manner.[10]

In this thesis, many secondary reconstructions were required to be made perpendicular to a curved surface, which is the oral surface of the hard palate. To fulfill the relationship recommended by Mozzo et al, several primary reconstructions per data set would be required. The magnitude of this task was deemed outside of the scope of this project and may not be necessary to achieve highly accurate measurements. The same CBCT machine was used test the accuracy of surgical templates for implant placement. In that study, the reconstructed images were not always perpendicular to the primary reconstruction, and the measurement accuracy was considered excellent (0.2mm in translation and 1.1mm in rotation).[11] Therefore, with true three dimensional software capability, this concern may be unfounded. The eFilm software package was chosen for its ability to create secondary reconstructions that are not perpendicular to the primary reconstruction. This was a great advantage in examining the ROI along the axis of insertion of the contemplated implant. Further research in this area would be beneficial to dental implant planning.

5-6 Factors Predictive of the Vertical Bone Volume

What current research recommends and how it relates to the results of this thesis. Is 3D imaging the Answer?

When considering palatal implants for orthodontic anchorage in adolescents, the results of the first research paper are unambiguous, and not unexpected if compared the results of Bernhardt and Gahleitner.[7,8] These researchers recommend pre-operative diagnostic imaging due to the limited vertical bone volume of the area and the great variability that exists between individuals. CT scanning was recommended as the tool of choice for various reasons cited in their papers, and the same was found in this research. Although mean vertical bone volumes were found to vary by gender, other easily identifiable patient characteristics such as age and palatal form were non contributory, leading to this conclusion.

Some comment on the variability of bone volumes in the past research and in our sample, as it relates to the design of this research is warranted at this time. The degree of variability in vertical bone volume in the paramedian palate of adolescents was impossible to assess from existing research, as there were not enough subjects measured in the age groups we were interested in. As a result, sample size calculations would need to be based on estimated variance. Calculation of sample size with estimated variance from these papers, combined with estimated effect size (1mm) and desired power (80%)

resulted in numbers beyond those available in the data pool (at Edmonton Diagnostic Imaging Inc.). Sample size calculations from the pilot study were also not practical, since the wide age range studied did not allow enough subjects of each gender per age group without making the pilot study too large. As a result, it was determined that all available scans within the desired age range would be included in the study, and a post hoc power analysis would be carried out. To further compensate for this lack of a-priori sample determination, the results were reported as confidence intervals. Fortunately, the confidence intervals were narrow for the areas which we reported as significant, and the results demonstrated effect sizes that hold clinical significance.

So, although the factor (gender) that demonstrated statistical significance in assessing bone volumes in the PP of adolescents can be described in clinically significant terms, the large variability in PP bone volumes in adolescents prevent the identification of age and palatal form as predictors. Again, this underscores the conclusion that careful pre-operative imaging is essential. The use of conventional radiographs for pre-surgical planning of palatal implants by Wehrbein et al provided results that were consistently different from surgical findings,[12] while CT scanning demonstrates improved accuracy and is the current method of choice for pre-surgical planning of implants.[4,8,13]

5-7 Where is the best possible location for a palatal implant in an adolescent when absolute orthodontic anchorage is required?

The results provided in Chapter 4 were consistent with the work of Bernhardt and Gahleitner[7,8] in identifying a location closely distal and lateral to the incisive foramen as the most predictable in terms of bone volume, and free from interference by teeth. In our work, the location was 4mm distal and 3mm lateral to the foramen, and for Bernhardt, it was 3mm distal and 3mm lateral to the foramen, and for Gahleitner it was 6mm distal to the foramen and 'in the paramedian'. Other locations were also identified as suitable for implantation.

5-8 What lengths of implants are practical in the palate of the adolescent (what percentage of the sample could tolerate 3 mm and/or 6mm implants)?

In Chapter 4, five locations in males and 4 locations in females were found to contain greater than the 4mm minimum vertical bone height with a 95% confidence interval. Table 4-4 of Chapter 4 demonstrates through simple percentages, the proportion of the sample that could support 3mm and 6mm implants at each location. For both males and females, P4D3 was the best location. 93.2% of males and 91.9% of females had enough vertical bone volume at this location to host a 3mm implant with very little practical tooth interference. 57.6% of males and 42.7% of females could host a 6mm implant at this location.

5-9 In which locations is there a practical risk of the implant interfering with erupted or unerupted teeth?

For discussion of teeth in the ROI, a distinction between teeth forming the boundary of a measurement vs. teeth forming the boundary of the measurement and limiting that measurement to less than 4mm must be made. Six locations (P4D3, P8D3, P8D6, P12D3, P12D6 and P12D9) demonstrated a range of measurements with teeth as boundaries from 0 to 28.8%. The same locations demonstrated a range of measurements that were limited to less than 4mm by teeth, or where an unerupted tooth was in the ROI, of only 0 to 6.8%. The three remaining locations (P4D6, P4D9 and P8D9) demonstrated a range of measurements with teeth as boundaries from 46.0 to 98.4%. The same locations demonstrated a range of measurements that were limited to less than 4mm by teeth, or where an unerupted tooth was in the ROI, of 33.1 to 87.1%. Thus it becomes apparent that only these three locations have substantial practical interference of teeth when it comes to placing 3mm implants.

5-10 Clinical Implications

The best location for PP implantation, in both males and females was P4D3, which demonstrated mean bone volumes suitable for implantation of 3 and 6 mm implants for both sexes. The only other location common to both sexes that had minimal tooth interference and satisfactory bone levels was P8D6. Although other locations were also identified as favorable for implantation (P4D6 in males and P8D9 in females) they should be regarded with caution due to the high number of measurements where teeth formed the boundary and where teeth limited the length of the measurement to less than four millimeters. Location P12D9, in both sexes, although demonstrating mean bone volumes suitable for implantation, has been identified as an area with poor bone quality.[14] These results serve as evidence towards promoting the PP as a host site for implantation, and towards eliminating some of the reasons why orthodontists are unlikely to treatment plan implants for absolute anchorage. Due to the great variability between individuals however, 3D imaging remains necessary for appropriate implant planning.

5-11 Recommendations on future research

Two main areas that can be expanded on became apparent during this thesis. Firstly, the effect of changing the plane of the primary reconstruction on measurements made within secondary reconstructions which are not perpendicular to the primary reconstruction needs further exploration. As previously discussed, there is research suggesting that accuracy will suffer if subsequent reconstructions are not made perpendicular to the primary,[10] and research showing good accuracy when the opposite is true.[11] The palate is an ideal site for such an assessment since there is no single best place to perform a primary reconstruction.

Secondly, regarding the variability of vertical bone volume between individuals that has been mentioned throughout this thesis, sinus size also demonstrated great variability in size and extent within the naso-maxillary complex. It would be possible to measure sinus parameters with volume rendering techniques common to software packages for CBCT data. The association between sinus parameters and available bone volume in the anterior hard palate could then be analyzed.

5-12 References

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Appendices

Appendix 1 - Sample of Data Collection Form

I.D #	Sex	Scan date	Birth date	Palatal h/w	Plane 4	Dist. 3
						6
						9
					Plane 8	3
						6
						9
					Plane 12	3
						6
						9

I.D #	Sex	Scan date	Birth date	Palatal h/w	Plane 4	Dist. 3
						6
						9
					Plane 8	3
						6
						9
					Plane 12	3
						6
						9

I.D #	Sex	Scan date	Birth date	Palatal h/w	Plane 4	Dist. 3
						6
						9
					Plane 8	3
						6
						9
					Plane 12	3
						6
						9

Appendix 2 - Pilot study data

	Bone depth at Locations in Plane A, right and left sides, trial 1					
patient	pad1	pad2	pad3	pad4	pad5	pad6
1	9	10	7	6	8	11
2	2	5	11	11	5	2
3	1	6	7	7	6	2
4	2	10	11	10	11	3
5	3	3	5	5	3	3
6	1	1	6	6	1	1
7	2	3	13	13	3	2
8	1	1	3	3	1	2
9	2	2	4	4	3	2
10	1	1	2	2	1	1

Bone depth at Locations in Plane A, right and left sides, trial 2

patient	pad1	pad2	pad3	pad4	pad5	pad6
1	15	6	6	5	6	14
2	3	4	13	13	3	2
3	1	6	7	7	6	1
4	3	11	9	10	11	3
5	2	3	5	5	3	2
6	1	1	6	5	1	1
7	2	3	14	14	3	2
8	1	1	3	3	1	1
9	2	2	4	4	3	2
10	1	1	2	2	1	1

Bone depth at Locations in Plane A, right and left sides, trial 3

patient	pad1	pad2	pad3	pad4	pad5	pad6
1	14	6	6	6	6	14
2	2	4	13	13	4	2
3	2	6	7	7	6	1
4	3	10	9	10	11	2
5	2	3	5	5	3	2
6	1	1	6	6	1	1
7	2	3	14	14	3	1
8	1	1	3	3	1	1
9	1	2	5	5	2	1
10	1	1	2	1	1	1

Bone depth at Locations in Plane A, left side, trial 4

patient	pad1	pad2	pad3
1	9	10	7
2	2	4	13
3	1	6	7
4	3	11	9
5	2	3	5
6	1	1	6
7	2	3	13

8	1	2	3
9	2	2	5
10	1	1	2

Bone depth at Locations in Plane A, left side, trial 5

patient	pad1	pad2	pad3
1	13	6	6
2	3	5	12
3	2	5	6
4	3	10	10
5	3	3	6
6	1	2	5
7	2	4	13
8	1	2	4
9	1	2	4
10	1	2	3

Bone depth at Locations in Plane B, right and left sides, trial 1

patient	pbd1	pbd2	pbd3	pbd4	pbd5	pbd6
1	9	6	6	6	5	7
2	6	9	6	6	8	7
3	5	10	9	9	11	6
4	6	9	7	7	9	5
5	4	7	5	6	7	4
6	2	5	5	6	3	2
7	2	5	7	8	6	2
8	1	2	4	4	2	1
9	7	2	3	3	2	7
10	2	4	5	5	4	2

Bone depth at Locations in Plane B, right and left sides, trial 2

patient	pbd1	pbd2	pbd3	pbd4	pbd5	pbd6
1	9	4	5	5	4	7
2	6	8	5	6	8	6
3	4	9	8	9	12	4
4	6	7	6	6	9	5
5	4	8	6	6	8	4
6	2	4	5	4	4	2
7	1	5	7	8	5	2
8	1	2	4	4	2	1
9	8	2	3	3	2	8
10	2	4	6	5	4	2

Bone depth at Locations in Plane B, right and left sides, trial 3

patient	pbd1	pbd2	pbd3	pbd4	pbd5	pbd6
1	8	4	5	5	4	8
2	6	8	6	5	8	7
3	4	9	8	9	11	4
4	6	7	6	6	9	5
5	4	7	5	6	7	4

6	2	5	6	5	3	2
7	2	5	7	8	6	3
8	1	2	5	5	2	1
9	8	2	3	3	2	8
10	2	4	5	5	4	2

Bone depth at Locations in Plane B, left side, trial 4

patient	pbd1	pbd2	pbd3
1	9	4	5
2	6	8	5
3	5	10	9
4	6	7	6
5	4	7	5
6	2	4	5
7	3	5	7
8	1	2	4
9	8	2	3
10	2	4	5

Bone depth at Locations in Plane B, left side, trial 5

patient	pbd1	pbd2	pbd3
1	8	6	5
2	6	9	5
3	4	10	8
4	7	7	7
5	4	7	6
6	2	4	6
7	2	4	6
8	1	3	5
9	8	3	3
10	3	5	6

	Bone depth at Locations in Plane C, right and left sides, trial 1					
patient	pcd1	pcd2	pcd3	pcd4	pcd5	pcd6
1	6	3	4	4	3	4
2	4	3	3	4	5	5
3	9	5	5	6	8	7
4	9	6	5	5	6	9
5	8	5	5	5	5	10
6	3	5	3	3	6	3
7	3	6	6	7	8	3
8	13	5	3	2	3	13
9	5	2	3	3	2	6
10	3	4	3	3	4	3

Bone depth at Locations in Plane C, right and left sides, trial 2

patient	pcd1	pcd2	pcd3	pcd4	pcd5	pcd6
1	5	3	4	4	3	5
2	5	3	3	4	5	5
3	9	5	5	6	7	7
4	10	4	4	4	4	10
5	7	4	4	4	4	9

6	3	4	2	2	4	3
7	2	7	6	7	9	2
8	14	6	3	2	4	13
9	4	2	2	2	2	4
10	3	4	4	4	4	3

Bone depth at Locations in Plane C, right and left sides, trial 3

patient	pcd1	pcd2	pcd3	pcd4	pcd5	pcd6
1	5	3	4	4	3	5
2	5	3	3	4	5	5
3	8	6	5	6	6	7
4	9	4	4	4	4	9
5	7	4	4	4	4	8
6	2	5	3	3	5	2
7	2	7	6	7	8	2
8	13	5	3	2	4	12
9	4	1	2	2	1	4
10	3	4	4	4	4	2

Bone depth at Locations in Plane C, left side, trial 4

patient	pcd1	pcd2	pcd3
1	5	3	4
2	5	4	3
3	9	5	5
4	10	4	4
5	7	4	4
6	2	5	3
7	3	6	6
8	13	5	3
9	4	1	2
10	3	4	4

Bone depth at Locations in Plane C, left side, trial 5

patient	pcd1	pcd2	pcd3
1	5	4	4
2	5	3	3
3	9	6	5
4	9	5	4
5	8	5	4
6	3	5	4
7	2	6	6
8	13	5	4
9	4	2	3
10	3	5	3

Appendix 3 – Main Data Set

3-1 Bone depth measurements at each location, by patient

patient	pad1	pad2	pad3	pbd1	pbd2	pbd3	pcd1	pcd2	pcd3
f4	5	4	2	3	3	4	2	3	7
55	4	5	2	3	6	6	2	3	6
33d	8	4	2	4	8	3	3	6	4
34c	5	6	3	3	3	6	2	2	7
3aa	12	7	6	6	10	7	5	7	12
50	8	2	1	3	4	5	3	4	3
1db	6	12	3	4	4	8	5	3	7
84	12	2	1	5	2	3	4	6	2
75e	8	9	3	3	8	3	2	3	3
45b	4	1	1	7	2	2	4	8	13
a6	6	4	2	5	7	1	4	9	2
3d2	4	3	2	4	5	6	3	4	8
6cb	6	12	4	5	4	2	4	3	2
22c	4	2	1	3	2	7	3	3	7
24a	3	5	3	2	2	7	2	1	3
3c6	5	1	1	4	2	1	3	4	5
db	6	5	1	1	7	5	2	2	5
316	5	2	1	5	8	4	4	4	2
212	7	10	3	4	3	9	3	2	5
ca	4	2	1	7	6	2	5	5	7
cb	4	2	1	6	5	2	4	6	6
10	4	6	1	7	9	3	6	8	4
39d	11	2	1	5	3	2	4	5	2
36	6	2	1	3	4	1	2	2	6
68	4	2	2	13	14	4	5	7	3
234	9	6	1	6	5	9	4	3	7
e3	7	6	2	4	9	3	4	5	6
bf	12	3	1	7	7	4	4	5	9
2c2	7	4	3	6	7	7	6	4	6
73d	10	4	3	6	4	4	4	2	13
628	8	3	1	5	4	3	3	4	10
577	4	3	2	2	3	4	2	1	3
5bb	11	4	2	6	6	5	4	5	4
319	5	4	2	4	5	1	4	3	1
dd	5	2	1	5	6	1	3	3	6
464	7	4	2	3	5	4	3	3	2
e6	7	2	1	5	5	2	3	5	5
9f	5	1	1	4	4	5	3	3	4
11d	11	2	1	6	7	2	5	6	1
13b	4	4	3	3	3	3	2	3	5
ff	5	3	1	10	2	1	6	7	8

45e	6	6	2	3	5	7	2	6	7
383	3	1	1	4	4	5	3	2	5
5f4	5	11	1	4	4	11	3	4	8
2ac	5	2	1	2	3	2	2	3	5
216	2	1	1	4	2	1	3	4	5
65b	13	2	1	4	6	2	3	3	7
3be	9	13	3	7	9	3	5	6	5
466	5	6	2	3	3	9	3	2	3
461	6	10	6	5	9	9	4	5	7
533	11	8	3	6	8	9	5	4	8
576	4	3	1	3	5	4	3	5	9
6f6	5	12	1	5	4	1	4	4	2
697	3	3	2	2	4	2	2	2	1
465	6	15	5	3	5	6	3	4	7
488	3	2	1	7	5	3	5	7	9
4ce	6	9	2	3	5	6	2	3	2
5ba	10	5	2	7	12	4	4	5	2
72e	15	3	2	6	12	7	5	6	7
77c	10	5	4	4	6	12	3	4	9
780	15	14	4	7	2	3	5	3	1
1d	4	3	2	7	5	2	7	10	6
86	6	5	1	3	2	9	3	2	3
c9	4	2	2	8	5	2	5	5	10
e7	6	3	1	4	3	2	2	4	2
1d0	7	8	1	3	2	6	1	1	4
1be	8	3	2	3	4	1	2	2	1
83	5	6	1	2	2	8	2	1	2
3b	8	7	1	6	6	5	4	3	7
98	3	1	1	4	2	3	3	4	8
2d0	9	3	2	6	5	2	5	3	1
73	5	3	2	5	5	1	4	1	1
381	8	1	1	5	7	2	3	4	11
791	10	1	1	6	4	3	4	5	8
53	6	4	4	4	5	3	4	4	8
bc	4	3	3	3	3	7	1	1	4
1e 4	6	8	3	2	3	9	2	2	3
79f	4	3	3	2	3	6	2	1	6
72	6	6	2	4	4	9	3	2	7
2dd	8	4	1	5	4	2	2	1	4
2a8	8	2	2	6	7	1	4	6	4
46a	6	4	4	3	4	6	3	2	3
458	7	3	3	3	3	1	2	2	1
7bf	5	2	2	4	7	1	3	6	3
51	8	2	2	4	4	12	3	4	7
2be	12	3	2	7	14	7	6	7	10
343	7	6	1	6	7	2	4	3	6
315	10	4	1	4	5	6	2	3	6
163	3	2	1	7	6	4	5	4	7
9e	7	4	2	8	9	4	6	7	8
143	10	2	1	5	11	8	2	4	7

1c7	12	3	2	9	3	2	8	9	10
1c6	8	10	1	7	5	6	5	3	8
109	3	2	1	6	6	3	2	2	4
1d9	6	4	2	5	5	8	5	4	8
27c	10	2	1	4	5	9	2	4	7
75c	5	8	4	3	4	1	3	2	2
139	6	6	2	4	5	5	4	4	6
96	6	5	2	6	8	4	5	4	9
4f7	4	6	3	2	1	3	2	1	3
222	9	2	1	4	3	3	1	2	5
7e	6	4	1	6	6	4	5	4	9
191	4	3	1	7	4	1	2	2	4
2fa	4	8	4	3	4	3	3	5	1
382	4	6	1	3	4	6	3	3	6
4f4	5	6	3	3	4	7	2	1	5
6ce	7	3	3	6	5	7	3	2	6
77b	10	5	2	7	9	3	5	6	6
85	8	7	3	4	4	9	3	2	5
e5	5	3	1	4	5	6	3	4	7
167	4	3	4	3	2	2	2	1	2
336	4	5	4	3	3	9	3	3	5
46d	4	3	3	4	5	3	1	2	6
7ae	10	5	4	4	4	3	2	1	2
13d	9	11	4	4	5	2	3	2	4
9b	5	9	6	3	4	8	3	3	6
246	4	4	2	7	4	3	3	5	5
340	11	1	1	7	3	2	4	4	6
28c	8	3	2	5	6	9	4	5	3
487	6	7	2	4	3	9	3	2	4
190	4	2	1	8	4	1	4	5	7
3c	10	7	2	8	6	6	5	3	6
16c	10	4	3	4	10	9	4	5	6
325	10	3	3	3	4	3	2	2	7
47d	7	4	1	5	10	1	4	6	6
77	7	2	2	4	5	10	3	3	6
1e	2	2	1	8	3	1	4	8	4
165	4	5	3	3	2	7	2	1	4
3ea	7	9	7	5	4	8	3	2	4
70	6	4	2	10	10	6	8	7	4
8e	3	4	2	3	3	6	2	2	3
11e	7	4	1	4	5	10	4	3	4
3fc	4	4	1	4	1	4	2	1	4
46f	11	1	1	5	6	6	3	4	8
170	5	6	1	1	1	2	1	1	2
15b	12	6	3	5	9	6	4	6	12
731	10	1	1	7	12	2	2	3	6
1d6	5	2	1	3	4	3	3	5	6
1b0	4	5	1	3	2	4	2	1	4
6b8	5	2	2	3	7	3	3	4	8
1c4	8	5	1	3	1	3	1	1	1

2b0	4	11	3	4	6	5	3	4	5
75f	4	5	1	4	3	2	4	2	4
2fe	4	3	1	2	2	3	1	1	6
407	9	7	3	5	7	1	4	5	7
3f6	7	3	2	3	4	6	3	3	5
6de	8	11	3	3	3	8	2	3	6
474	3	4	7	2	3	2	1	2	3
4ab	7	8	4	6	6	7	5	5	8
12	4	5	5	3	3	6	3	3	5
69e	8	7	2	4	4	7	4	3	5
553	3	3	1	2	2	4	1	2	3
732	13	2	1	8	5	1	6	11	2
6b5	7	4	4	2	4	4	2	4	3
18a	5	7	2	4	6	2	3	4	1
50	9	1	1	3	3	8	3	3	1
67a	6	5	2	6	2	3	6	1	1
14	3	5	4	2	2	4	1	1	2
3fe	9	5	3	6	8	6	5	5	3
2f7	10	15	1	6	6	6	5	6	8
749	10	2	1	4	6	12	3	3	6
73b	4	2	1	8	5	1	4	8	1
a7	10	5	4	5	6	11	4	4	5
7b9	9	4	1	4	5	3	2	2	4
7a1	10	4	3	3	3	6	3	2	3
745	13	2	1	7	8	3	4	3	5
8f	7	10	1	4	4	8	5	3	5
2a	3	1	1	5	6	1	2	3	4
119	7	3	1	3	3	5	3	2	4
281	7	10	1	4	5	10	3	2	4
306	4	3	2	4	6	2	2	3	10
6a	8	4	1	4	6	2	3	4	1
2d7	10	7	3	8	8	11	3	3	6
24	11	4	2	7	10	4	5	7	4
38e	4	8	1	2	4	8	2	3	6
54b	7	8	1	4	5	1	3	3	1
54e	6	5	3	3	7	3	2	4	2
56c	6	4	3	2	1	4	2	1	2
61b	5	7	5	3	4	11	2	2	3
328	10	1	1	4	2	1	4	5	3
566	9	2	1	4	6	1	2	3	1
13e	8	10	3	6	6	11	5	8	4
7cf	9	7	1	2	1	2	1	1	2
276	7	8	2	3	4	3	2	3	2
330	3	7	2	3	5	6	2	5	3
6a7	7	4	1	7	7	13	4	4	8
656	8	11	5	6	10	8	4	6	5
26c	4	7	4	4	3	7	4	3	5
430	3	3	2	3	3	2	1	2	4
764	5	3	3	2	2	6	1	1	2
53c	10	6	1	7	12	7	5	7	4

300	7	5	4	6	8	4	6	6	8
28f	7	10	2	4	7	6	3	4	7
5c0	5	3	2	10	9	5	7	8	8
596	6	12	2	4	5	2	3	3	1
5d3	4	2	1	3	4	8	2	2	8
748	9	15	3	5	5	11	4	5	9
740	12	3	2	5	6	14	4	3	6
497	3	1	1	4	1	1	2	3	1
58d	6	7	4	5	4	14	3	2	7
55c	4	3	2	5	10	4	4	4	6
568	5	7	5	2	3	5	2	1	3
7b7	5	9	3	2	1	5	2	1	3
788	12	7	3	9	9	7	4	4	5
68b	6	2	1	7	5	2	3	4	1
660	12	6	1	8	10	2	4	5	1
7a7	4	2	1	4	6	2	4	1	4
65f	11	9	3	7	11	2	4	6	7

3-2 Tooth Interference for Each Location, by Patient (0=no tooth interference, 1= border of measurement formed by a tooth, 2= unerupted tooth formed border of measurement)

patient	sex	pad1	pad2	pad3	pbd1	pbd2	pbd3	pcd1	pcd2	pcd3
f4	f	0	1	1	0	0	1	0	0	0
55	m	0	2	2	0	0	2	0	0	0
33d	f	0	1	1	0	0	1	0	0	1
34c	f	0	0	1	0	0	0	0	0	0
3aa	m	0	2	2	0	0	2	0	0	0
50	f	0	1	1	0	0	1	0	0	1
1db	m	0	0	1	0	0	1	0	0	0
84	m	0	2	2	0	2	2	0	0	2
75e	f	0	0	1	0	0	1	0	0	1
45b	f	1	1	1	0	1	1	0	0	0
a6	f	1	2	2	0	0	2	0	0	2
3d2	f	2	2	1	0	0	2	0	0	0
6cb	f	0	0	1	0	0	0	0	0	0
22c	f	0	1	1	0	0	0	0	0	0
24a	f	0	0	1	0	0	0	0	0	0
3c6	f	0	1	1	0	1	1	0	0	1
db	f	0	1	1	0	0	0	0	0	0
316	f	0	2	2	0	0	0	0	0	0
212	f	0	0	2	0	0	0	0	0	0
ca	m	1	1	1	0	1	1	0	0	1

cb	m	1	1	1	0	1	1	0	0	1
10	f	1	1	1	0	1	1	0	0	2
39d	f	0	1	1	0	1	1	0	0	1
36	f	0	1	1	0	0	1	0	0	0
68	m	1	1	1	0	0	1	0	0	1
234	f	0	1	1	0	0	0	0	0	0
e3	m	0	1	1	0	0	1	0	0	0
bf	m	0	1	1	0	1	1	0	0	0
2c2	m	0	1	1	0	0	0	0	0	0
73d	f	0	1	1	0	0	1	0	0	0
628	m	0	1	1	0	1	1	0	0	1
577	f	1	1	1	0	0	0	0	0	0
5bb	m	0	2	2	0	0	2	0	0	1
319	f	1	1	1	0	1	1	0	1	1
dd	f	1	1	1	0	1	1	0	0	1
464	f	0	1	1	0	0	1	0	0	0
e6	f	1	1	1	0	1	1	0	0	0
9f	f	0	1	1	0	0	0	0	0	0
11d	f	0	1	1	0	1	1	0	0	1
13b	f	0	1	1	0	0	1	0	0	0
ff	f	1	1	1	0	1	1	0	0	0
45e	f	0	1	1	0	0	1	0	0	1
383	f	1	1	1	0	0	1	0	0	0
5f4	f	0	0	1	0	0	0	0	0	0
2ac	f	0	1	1	0	0	1	0	0	0
216	f	1	1	1	0	1	1	0	0	0
65b	f	0	2	2	0	0	2	0	0	0
3be	m	0	0	1	0	0	1	0	0	1
466	f	0	0	1	0	0	0	0	0	0
461	m	0	0	1	0	0	0	0	0	0
533	f	0	1	1	0	0	1	0	0	0
576	f	0	1	1	0	0	1	0	0	0
6f6	f	0	0	1	0	0	0	0	0	0
697	f	0	1	1	0	0	1	0	0	1
465	f	0	0	1	0	0	0	0	0	0
488	m	1	1	1	0	1	1	0	0	0
4ce	f	0	0	1	0	0	0	0	0	0
5ba	f	0	0	1	0	0	0	0	0	0
72e	m	0	1	1	0	0	0	0	0	0
77c	m	0	1	1	0	0	0	0	0	0
780	m	0	0	1	0	0	0	0	0	0
1d	m	1	1	1	0	1	1	0	0	1
86	m	0	1	1	0	0	0	0	0	0
c9	m	1	1	1	0	1	1	0	0	0
e7	m	0	0	1	0	0	0	0	0	0
1d0	f	0	0	1	0	0	0	0	0	0
1be	m	0	1	1	0	0	0	0	0	0
83	f	0	1	1	0	0	0	0	0	0
3b	f	1	1	1	0	0	1	0	0	0
98	m	1	1	1	0	1	1	0	0	1

2d0	f	0	1	1	0	0	1	0	0	0
73	m	1	1	1	0	1	1	0	0	0
381	f	0	1	1	0	0	1	0	0	0
791	m	0	1	1	0	1	1	0	0	0
53	f	0	1	1	0	0	1	0	0	0
bc	f	0	1	1	0	0	0	0	0	0
1 e4	f	0	0	1	0	0	0	0	0	0
79f	f	0	1	1	0	0	0	0	0	0
72	f	0	1	1	0	0	0	0	0	0
2dd	f	0	1	1	0	0	1	0	0	0
2a8	f	0	1	1	0	0	1	0	0	1
46a	f	1	1	1	0	0	0	0	0	0
458	f	0	1	1	0	0	0	0	0	0
7bf	f	0	1	1	0	0	0	0	0	0
51	f	0	1	1	0	0	0	0	0	0
2be	m	0	1	1	0	0	1	0	0	0
343	m	1	1	1	0	0	1	0	0	0
315	m	0	1	1	0	0	1	0	0	0
163	f	1	1	1	0	1	1	0	0	0
9e	m	1	1	1	0	0	1	0	0	0
143	f	0	1	1	0	0	0	0	0	0
1c7	m	0	1	1	0	1	1	0	0	0
1c6	m	0	0	1	0	0	0	0	0	0
109	m	1	1	1	0	0	1	0	0	0
1d9	m	1	1	1	0	0	1	0	0	0
27c	f	0	1	1	0	0	0	0	0	0
75c	f	0	0	1	0	0	0	0	0	0
139	f	0	1	1	0	0	1	0	0	0
96	m	1	1	1	0	1	1	0	0	0
4f7	f	0	0	1	0	0	0	0	0	0
222	f	0	1	1	0	0	1	0	0	0
7e	m	1	1	1	0	0	1	0	0	0
191	f	1	1	1	0	1	1	0	0	0
2fa	f	0	1	1	0	0	0	0	0	0
382	m	0	1	1	0	0	0	0	0	0
4f4	f	0	0	1	0	0	0	0	0	0
6ce	f	1	1	1	0	0	1	0	0	0
77b	f	0	1	0	0	0	1	0	0	0
85	m	0	1	1	0	0	0	0	0	0
e5	m	0	1	1	0	0	0	0	0	0
167	f	0	0	1	0	0	0	0	0	0
336	f	0	0	1	0	0	0	0	0	0
46d	f	1	1	1	0	0	1	0	0	0
7ae	f	0	1	1	0	0	1	0	0	0
13d	m	0	0	1	0	0	0	0	0	0
9b	f	0	1	1	0	0	0	0	0	0
246	f	1	1	1	0	1	1	0	0	1
340	m	0	1	1	0	1	1	0	0	0
28e	f	0	1	1	0	0	0	0	0	0
487	f	0	1	1	0	0	0	0	0	0

190	m	1	1	1	0	1	1	0	0	0
3c	m	0	1	1	0	0	1	0	0	0
16c	m	0	1	1	0	0	0	0	0	0
325	f	0	1	1	0	1	1	0	0	0
47d	m	0	1	1	0	0	1	0	0	0
77	f	0	1	1	0	0	0	0	0	0
1e	f	1	1	1	0	1	1	0	0	0
165	f	0	0	1	0	0	0	0	0	0
3ea	m	0	0	1	0	0	0	0	0	0
70	m	1	1	1	0	0	1	0	0	0
8e	f	0	0	1	0	0	0	0	0	0
11e	f	0	1	1	0	0	0	0	0	0
3fc	f	0	0	1	0	0	0	0	0	0
46f	f	0	1	1	0	0	1	0	0	0
170	f	0	0	1	0	0	0	0	0	0
15b	m	0	1	1	0	0	1	0	0	0
731	m	0	1	1	0	0	1	0	0	0
1d6	f	0	1	1	0	0	1	0	0	0
1b0	f	0	1	1	0	0	0	0	0	0
6b8	f	1	1	1	0	0	1	0	0	0
1c4	f	0	0	1	0	0	0	0	0	0
2b0	f	0	0	1	0	0	1	0	0	0
75f	f	0	0	1	0	0	0	0	0	0
2fe	m	0	1	1	0	0	1	0	0	0
407	f	0	1	1	0	0	1	0	0	0
3f6	f	0	1	1	0	0	0	0	0	0
6de	f	0	0	1	0	0	0	0	0	0
474	f	0	0	0	0	0	0	0	0	0
4ab	f	0	0	1	0	0	0	0	0	0
12	f	0	0	1	0	0	0	0	0	0
69e	f	0	0	1	0	0	0	0	0	0
553	f	0	1	1	0	0	0	0	0	0
732	f	0	1	1	0	1	1	0	0	1
6b5	f	0	1	1	0	0	0	0	0	0
18a	f	0	0	1	0	0	0	0	0	0
50	f	0	1	1	0	0	1	0	0	0
67a	f	0	1	1	0	0	0	0	0	0
14	m	0	0	1	0	0	0	0	0	0
3fe	m	0	1	1	0	0	1	0	0	0
2f7	m	0	0	1	0	0	1	0	0	0
749	f	0	1	1	0	0	0	0	0	0
73b	m	1	1	1	0	1	1	0	0	1
a7	f	0	1	1	0	0	0	0	0	0
7b9	f	0	1	1	0	0	1	0	0	0
7a1	m	0	1	1	0	0	0	0	0	0
745	f	0	1	1	0	0	1	0	0	0
8f	m	0	0	1	0	0	0	0	0	0
2a	f	1	1	1	0	0	1	0	0	0
119	f	0	1	1	0	0	0	0	0	0
281	m	0	0	1	0	0	0	0	0	0

306	f	1	1	1	0	0	1	0	0	0
6a	f	0	1	1	0	0	0	0	0	0
2d7	f	0	0	1	0	0	0	0	0	0
24	f	0	1	1	0	0	0	0	0	0
38e	f	0	0	1	0	0	0	0	0	0
54b	m	0	1	0	0	0	0	0	0	0
54e	f	0	1	1	0	0	0	0	0	0
56c	f	0	1	1	0	0	0	0	0	0
61b	m	0	0	1	0	0	0	0	0	0
328	f	0	1	1	0	1	1	0	0	0
566	f	0	1	1	0	0	1	0	0	0
13e	f	0	0	1	0	0	0	0	0	0
7cf	f	0	0	1	0	0	0	0	0	0

Appendix 4 - Pilot Study Statistics

4-1 Reliability Tests
(10 subjects, nine locations, five trials assessed at each location)

Location PAD1

```
                Intraclass Correlation Coefficients
        One-way random effects model (People Effect Random)

                         ICC     95% Confidence Interval
Measure                 Value   Lower Bound   Upper Bound   F-Value    Sig.

Single Rater            .9198      .8201         .9760       2.7779   .0126
Average of Raters       .9829      .9580         .9951      11.6671   .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                    N of Items = 5

Alpha =     .9832
```

Location PAD2

```
                 Intraclass Correlation Coefficients
          One-way random effects model (People Effect Random)

                      ICC      95% Confidence Interval
Measure              Value    Lower Bound   Upper Bound   F-Value    Sig.

Single Rater         .9351       .8519         .9808       3.4756   .0030
Average of Raters    .9863       .9664         .9961      14.5976   .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                    N of Items = 5

Alpha =    .9863
```

Location PAD3

```
                 Intraclass Correlation Coefficients
          One-way random effects model (People Effect Random)

                      ICC      95% Confidence Interval
Measure              Value    Lower Bound   Upper Bound   F-Value    Sig.

Single Rater         .9755       .9416         .9929       9.5362   .0000
Average of Raters    .9950       .9878         .9986      40.0521   .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                    N of Items = 5

Alpha =    .9945
```

Location PBD1

```
                 Intraclass Correlation Coefficients
          One-way random effects model (People Effect Random)

                      ICC      95% Confidence Interval
Measure              Value    Lower Bound   Upper Bound   F-Value    Sig.
```

```
Single Rater          .9762      .9432         .9931        9.8157   .0000
Average of Raters     .9951      .9881         .9986       41.2261   .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                   N of Items = 5

Alpha =     .9951
```

Location PBD2

```
                     Intraclass Correlation Coefficients
               One-way random effects model (People Effect Random)

                     ICC      95% Confidence Interval
Measure              Value   Lower Bound   Upper Bound    F-Value     Sig.

Single Rater         .9417      .8661         .9828        3.8920   .0013
Average of Raters    .9878      .9700         .9965       16.3464   .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                   N of Items = 5

Alpha =     .9896
```

Location PBD3

```
                     Intraclass Correlation Coefficients
               One-way random effects model (People Effect Random)

                     ICC      95% Confidence Interval
Measure              Value   Lower Bound   Upper Bound    F-Value     Sig.

Single Rater         .8888      .7586         .9661        1.9509   .0720
Average of Raters    .9756      .9402         .9930        8.1938   .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                   N of Items = 5

Alpha =     .9747
```

Location PCD1

```
                     Intraclass Correlation Coefficients
```

```
             One-way random effects model (People Effect Random)

                              ICC      95% Confidence Interval
Measure                      Value   Lower Bound   Upper Bound    F-Value     Sig.

Single Rater                 .9826      .9581         .9950      13.4608    .0000
Average of Raters            .9965      .9913         .9990      56.5354    .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                        N of Items = 5

Alpha =    .9967
```

Location PCD2

```
                   Intraclass Correlation Coefficients
             One-way random effects model (People Effect Random)

                              ICC      95% Confidence Interval
Measure                      Value   Lower Bound   Upper Bound    F-Value     Sig.

Single Rater                 .8553      .6963         .9550       1.4550    .1982
Average of Raters            .9673      .9198         .9907       6.1111    .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.

Reliability Coefficients

N of Cases =     10.0                        N of Items = 5

Alpha =    .9685
```

Location PCD3

```
                   Intraclass Correlation Coefficients
             One-way random effects model (People Effect Random)

                              ICC      95% Confidence Interval
Measure                      Value   Lower Bound   Upper Bound    F-Value     Sig.

Single Rater                 .8666      .7168         .9588       1.5941    .1502
Average of Raters            .9701      .9268         .9915       6.6954    .0000

Degrees of freedom for F-tests are 9 and 40. Test Value = .8.
```

```
Reliability Coefficients

N of Cases =      10.0                    N of Items = 5

Alpha =    .9703
```

4-2 Paired Samples Test of mean bone depths, demonstrating symmetry between left and right sides of the palate

					Mean	95% C.I				
Trial			Mean	Std. Deviation	Std. Error	Lower	Upper	t	df	Sig. (2-
1	Pair 1	PAD1 - PAD6	-.50000	.707107	.223607	-1.00583	.00583	-2.236	9	.052
	Pair 2	PAD2 - PAD5	.00000	.816497	.258199	-.58409	.58409	.000	9	1.000
	Pair 3	PAD3 - PAD4	.20000	.421637	.133333	-.10162	.50162	1.500	9	.168
	Pair 4	PBD1 - PBD6	.10000	.875595	.276887	-.52636	.72636	.361	9	.726
	Pair 5	PBD2 - PBD5	.20000	.918937	.290593	-.45737	.85737	.688	9	.509
	Pair 6	PBD3 - PBD4	-.30000	.483046	.152753	-.64555	.04555	-1.964	9	.081
	Pair 7	PCD1 -	.00000	1.247219	.394405	-.89221	.89221	.000	9	1.000
	Pair 8	PCD2 -	-.60000	1.429841	.452155	-1.62285	.42285	-1.327	9	.217
	Pair 9	PCD3 -	-.20000	.632456	.200000	-.65243	.25243	-1.000	9	.343
2	Pair 1	PAD1 - PAD6	.20000	.421637	.133333	-.10162	.50162	1.500	9	.168
	Pair 2	PAD2 - PAD5	.00000	.471405	.149071	-.33722	.33722	.000	9	1.000
	Pair 3	PAD3 - PAD4	.10000	.567646	.179505	-.30607	.50607	.557	9	.591
	Pair 4	PBD1 - PBD6	.20000	.788811	.249444	-.36428	.76428	.802	9	.443
	Pair 5	PBD2 - PBD5	-.50000	1.080123	.341565	-1.27267	.27267	-1.464	9	.177

	Pair 6	PBD3 - PBD4	-.10000	.737865	.233333	-.62784	.42784	-.429	9	.678
	Pair 7	PCD1 -	.10000	.994429	.314466	-.61137	.81137	.318	9	.758
	Pair 8	PCD2 -	-.40000	1.264911	.400000	-1.30486	.50486	-1.000	9	.343
	Pair 9	PCD3 -	-.20000	.632456	.200000	-.65243	.25243	-1.000	9	.343
3	Pair 1	PAD1 - PAD6	.30000	.483046	.152753	-.04555	.64555	1.964	9	.081
	Pair 2	PAD2 - PAD5	-.10000	.316228	.100000	-.32622	.12622	-1.000	9	.343
	Pair 3	PAD3 - PAD4	.00000	.471405	.149071	-.33722	.33722	.000	9	1.000
	Pair 4	PBD1 - PBD6	-.10000	.567646	.179505	-.50607	.30607	-.557	9	.591
	Pair 5	PBD2 - PBD5	-.30000	1.159502	.366667	-1.12946	.52946	-.818	9	.434
	Pair 6	PBD3 - PBD4	-.10000	.737865	.233333	-.62784	.42784	-.429	9	.678
	Pair 7	PCD1 -	.20000	.632456	.200000	-.25243	.65243	1.000	9	.343
	Pair 8	PCD2 -	-.20000	.788811	.249444	-.76428	.36428	-.802	9	.443
	Pair 9	PCD3 -	-.20000	.632456	.200000	-.65243	.25243	-1.000	9	.343

Appendix 5 - Statistics for Chapter 3

5-1 Repeated Measures MANOVA

Within-Subjects Factors

factor1	Dependent Variable
1	pad1
2	pad2
3	pad3
4	pbd1
5	pbd2
6	pbd3
7	pcd1
8	pcd2
9	pcd3

Between-Subjects Factors

		N
sex	f	124
	m	59
ageCAT	1	58
	2	77
	3	48

Repeated Measures MANOVA: Sex and Age appear Significant

Effect		Value	F	Hypothesis df	Error df	Sig.
factor1	Pillai's Trace	.816	95.368(a)	8.000	172.000	.000
	Wilks' Lambda	.184	95.368(a)	8.000	172.000	.000
	Hotelling's Trace	4.436	95.368(a)	8.000	172.000	.000
	Roy's Largest Root	4.436	95.368(a)	8.000	172.000	.000

factor1 * sex	Pillai's Trace	.115	2.801(a)	8.000	172.000	.006
	Wilks' Lambda	.885	2.801(a)	8.000	172.000	.006
	Hotelling's Trace	.130	2.801(a)	8.000	172.000	.006
	Roy's Largest Root	.130	2.801(a)	8.000	172.000	.006
factor1 * ageCAT	Pillai's Trace	.168	1.985	16.000	346.000	.013
	Wilks' Lambda	.838	1.981(a)	16.000	344.000	.014
	Hotelling's Trace	.185	1.977	16.000	342.000	.014
	Roy's Largest Root	.120	2.585(b)	8.000	173.000	.011

Bone depth does not vary with age at 8 of 9 locations

Dependent Variable	Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
pad1	Intercept	7.969	.512	15.568	.000	6.959	8.979
	[sex=f]	-1.070	.437	-2.448	.015	-1.933	-.207
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.797	.531	-1.499	.136	-1.845	.252
	[ageCAT=2]	-.539	.506	-1.064	.289	-1.537	.460
	[ageCAT=3]	0(a)	.	.	.	.	.
pad2	Intercept	5.629	.563	10.000	.000	4.518	6.739
	[sex=f]	-.699	.481	-1.455	.147	-1.648	.249
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.352	.584	-.602	.548	-1.505	.802
	[ageCAT=2]	-.869	.557	-1.562	.120	-1.967	.229
	[ageCAT=3]	0(a)	.	.	.	.	.
pad3	Intercept	2.105	.241	8.723	.000	1.629	2.582
	[sex=f]	-.001	.206	-.007	.994	-.408	.405
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.190	.251	-.760	.448	-.685	.304
	[ageCAT=2]	.051	.239	.216	.830	-.419	.522
	[ageCAT=3]	0(a)	.	.	.	.	.
pbd1	Intercept	5.223	.334	15.647	.000	4.564	5.881
	[sex=f]	-1.436	.285	-5.038	.000	-1.998	-.873
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.480	.347	1.384	.168	-.204	1.164
	[ageCAT=2]	.396	.330	1.199	.232	-.256	1.047
	[ageCAT=3]	0(a)	.	.	.	.	.
pbd2	Intercept	5.946	.455	13.065	.000	5.048	6.844
	[sex=f]	-1.512	.389	-3.889	.000	-2.279	-.745
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.450	.473	.953	.342	-.482	1.383
	[ageCAT=2]	-.206	.450	-.457	.648	-1.094	.682
	[ageCAT=3]	0(a)	.	.	.	.	.

pbd3	Intercept	4.799	.553	8.674	.000	3.708	5.891
	[sex=f]	-.093	.472	-.198	.843	-1.026	.839
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.506	.574	-.881	.380	-1.639	.628
	[ageCAT=2]	.138	.547	.253	.800	-.941	1.218
	[ageCAT=3]	0(a)	.	.	.	.	.
pcd1	Intercept	3.862	.238	16.222	.000	3.392	4.332
	[sex=f]	-1.094	.203	-5.379	.000	-1.495	-.692
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.432	.247	1.746	.082	-.056	.919
	[ageCAT=2]	.115	.235	.488	.626	-.350	.579
	[ageCAT=3]	0(a)	.	.	.	.	.
pcd2	Intercept	4.291	.358	11.995	.000	3.585	4.997
	[sex=f]	-1.083	.306	-3.545	.001	-1.686	-.480
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.667	.371	1.795	.074	-.066	1.400
	[ageCAT=2]	-.256	.354	-.723	.470	-.954	.442
	[ageCAT=3]	0(a)	.	.	.	.	.
pcd3	Intercept	5.132	.481	10.673	.000	4.183	6.081
	[sex=f]	-1.260	.411	-3.068	.002	-2.070	-.449
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	1.198	.499	2.400	.017	.213	2.183
	[ageCAT=2]	.851	.475	1.789	.075	-.088	1.789
	[ageCAT=3]	0(a)	.	.	.	.	.

There is a significant difference in vertical bone depth between genders at 6 of 9 Locations

Dependent Variable	Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Observed Power(a)
						Lower Bound	Upper Bound	
pad1	Intercept	7.475	.355	21.061	.000	6.774	8.175	1.000
	[sex=f]	-1.047	.431	-2.429	.016	-1.898	-.196	.676
	[sex=m]	0(b)	.	.	.	.	.	.
pad2	Intercept	5.068	.391	12.977	.000	4.297	5.838	1.000
	[sex=f]	-.576	.474	-1.214	.226	-1.512	.360	.227
	[sex=m]	0(b)	.	.	.	.	.	.
pad3	Intercept	2.085	.167	12.497	.000	1.756	2.414	1.000
	[sex=f]	-.028	.203	-.140	.889	-.428	.372	.052

	[sex=m]	0(b)	.	.	.	.	.	.
pbd1	Intercept	5.559	.231	24.034	.000	5.103	6.016	1.000
	[sex=f]	-1.463	.281	-5.205	.000	-2.017	-.908	.999
	[sex=m]	0(b)	.	.	.	.	.	.
pbd2	Intercept	5.949	.316	18.849	.000	5.326	6.572	1.000
	[sex=f]	-1.433	.383	-3.737	.000	-2.190	-.676	.961
	[sex=m]	0(b)	.	.	.	.	.	.
pbd3	Intercept	4.746	.383	12.395	.000	3.990	5.501	1.000
	[sex=f]	-.165	.465	-.355	.723	-1.083	.753	.064
	[sex=m]	0(b)	.	.	.	.	.	.
pcd1	Intercept	4.034	.166	24.364	.000	3.707	4.361	1.000
	[sex=f]	-1.074	.201	-5.341	.000	-1.471	-.677	1.000
	[sex=m]	0(b)	.	.	.	.	.	.
pcd2	Intercept	4.322	.252	17.166	.000	3.825	4.819	1.000
	[sex=f]	-.975	.306	-3.188	.002	-1.579	-.372	.887
	[sex=m]	0(b)	.	.	.	.	.	.
pcd3	Intercept	5.898	.337	17.514	.000	5.234	6.563	1.000
	[sex=f]	-1.302	.409	-3.181	.002	-2.109	-.494	.886
	[sex=m]	0(b)	.	.	.	.	.	.

Bone depth does not vary with palatal height

Dependent Variable	Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
pad1	Intercept	8.922	1.496	5.964	.000	5.970	11.875
	[sex=f]	-1.095	.439	-2.492	.014	-1.962	-.228
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.945	.575	-1.642	.102	-2.080	.191
	[ageCAT=2]	-.570	.509	-1.120	.264	-1.575	.434
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	-.065	.095	-.678	.499	-.252	.123
pad2	Intercept	7.759	1.638	4.735	.000	4.525	10.992
	[sex=f]	-.754	.481	-1.568	.119	-1.704	.195
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.682	.630	-1.083	.280	-1.926	.561
	[ageCAT=2]	-.940	.557	-1.686	.093	-2.040	.160
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	-.144	.104	-1.384	.168	-.350	.061
pad3	Intercept	2.341	.706	3.315	.001	.947	3.734
	[sex=f]	-.008	.207	-.036	.971	-.417	.402
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.227	.271	-.836	.404	-.763	.309
	[ageCAT=2]	.044	.240	.182	.856	-.430	.518
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	-.016	.045	-.355	.723	-.105	.073
pbd1	Intercept	5.325	.977	5.451	.000	3.397	7.252
	[sex=f]	-1.439	.287	-5.016	.000	-2.005	-.873

	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.464	.376	1.235	.218	-.277	1.205
	[ageCAT=2]	.392	.332	1.180	.239	-.264	1.048
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	-.007	.062	-.111	.912	-.130	.116
pbd2	Intercept	4.066	1.323	3.073	.002	1.455	6.677
	[sex=f]	-1.463	.389	-3.766	.000	-2.230	-.696
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.742	.509	1.459	.146	-.262	1.747
	[ageCAT=2]	-.143	.450	-.318	.751	-1.032	.745
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	.127	.084	1.512	.132	-.039	.294
pbd3	Intercept	7.463	1.605	4.650	.000	4.296	10.630
	[sex=f]	-.162	.471	-.344	.731	-1.092	.768
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.920	.617	-1.490	.138	-2.137	.298
	[ageCAT=2]	.050	.546	.092	.927	-1.028	1.128
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	-.180	.102	-1.767	.079	-.382	.021
pcd1	Intercept	5.583	.683	8.175	.000	4.236	6.931
	[sex=f]	-1.138	.201	-5.674	.000	-1.534	-.742
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.164	.263	.626	.532	-.354	.683
	[ageCAT=2]	.058	.232	.249	.804	-.401	.516
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	-.117	.043	-2.683	.008	-.202	-.031
pcd2	Intercept	3.955	1.047	3.779	.000	1.890	6.020
	[sex=f]	-1.074	.307	-3.496	.001	-1.681	-.468
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.719	.402	1.786	.076	-.075	1.513
	[ageCAT=2]	-.245	.356	-.687	.493	-.947	.458
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	.023	.067	.342	.733	-.109	.154
pcd3	Intercept	4.633	1.407	3.294	.001	1.857	7.409
	[sex=f]	-1.247	.413	-3.019	.003	-2.062	-.432
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	1.276	.541	2.358	.019	.208	2.343
	[ageCAT=2]	.867	.479	1.812	.072	-.077	1.812
	[ageCAT=3]	0(a)	.	.	.	.	.
	pheight	.034	.090	.378	.706	-.143	.210

Bone depth does not vary with palatal width

Dependent Variable	Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
pad1	Intercept	8.603	2.333	3.687	.000	3.999	13.207
	[sex=f]	-1.091	.444	-2.454	.015	-1.968	-.214
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.801	.533	-1.503	.135	-1.853	.251
	[ageCAT=2]	-.532	.508	-1.047	.296	-1.534	.471
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	-.019	.067	-.278	.781	-.152	.114
pad2	Intercept	1.689	2.548	.663	.508	-3.340	6.717
	[sex=f]	-.572	.485	-1.178	.240	-1.530	.386
	[sex=m]	0(a)	.	.	.	.	.

	[ageCAT=1]	-.323	.582	-.554	.580	-1.472	.826
	[ageCAT=2]	-.911	.555	-1.642	.102	-2.006	.184
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	.117	.074	1.585	.115	-.029	.262
pad3	Intercept	-.084	1.087	-.077	.939	-2.229	2.062
	[sex=f]	.069	.207	.335	.738	-.339	.478
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.174	.248	-.702	.484	-.665	.316
	[ageCAT=2]	.028	.237	.119	.905	-.439	.495
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	.065	.031	2.064	.040	.003	.127
pbd1	Intercept	6.630	1.518	4.369	.000	3.635	9.625
	[sex=f]	-1.482	.289	-5.124	.000	-2.052	-.911
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.469	.347	1.354	.178	-.215	1.154
	[ageCAT=2]	.411	.330	1.242	.216	-.242	1.063
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	-.042	.044	-.951	.343	-.128	.045
pbd2	Intercept	3.657	2.067	1.769	.079	-.423	7.736
	[sex=f]	-1.437	.394	-3.650	.000	-2.215	-.660
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.467	.472	.989	.324	-.465	1.399
	[ageCAT=2]	-.230	.450	-.511	.610	-1.118	.658
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	.068	.060	1.135	.258	-.050	.185
pbd3	Intercept	.077	2.496	.031	.975	-4.848	5.002
	[sex=f]	.060	.475	.125	.901	-.879	.998
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.471	.570	-.826	.410	-1.597	.654
	[ageCAT=2]	.088	.543	.163	.871	-.984	1.161
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	.140	.072	1.940	.054	-.002	.282
pcd1	Intercept	5.972	1.073	5.566	.000	3.855	8.090
	[sex=f]	-1.162	.204	-5.684	.000	-1.565	-.759
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.416	.245	1.698	.091	-.068	.900
	[ageCAT=2]	.137	.234	.588	.557	-.324	.598
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	-.062	.031	-2.016	.045	-.124	-.001
pcd2	Intercept	9.066	1.589	5.705	.000	5.930	12.201
	[sex=f]	-1.238	.303	-4.088	.000	-1.835	-.640
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.632	.363	1.740	.084	-.085	1.348
	[ageCAT=2]	-.205	.346	-.593	.554	-.888	.478
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	-.141	.046	-3.080	.002	-.232	-.051
pcd3	Intercept	3.556	2.189	1.624	.106	-.764	7.875
	[sex=f]	-1.209	.417	-2.899	.004	-2.031	-.386
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	1.210	.500	2.419	.017	.223	2.197
	[ageCAT=2]	.834	.477	1.750	.082	-.107	1.774
	[ageCAT=3]	0(a)	.	.	.	.	.
	pwidth	.047	.063	.738	.461	-.078	.171

Bone depth does not vary with palatal index

Dependent Variable	Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
pad1	Intercept	8.476	1.313	6.453	.000	5.884	11.068
	[sex=f]	-1.067	.438	-2.435	.016	-1.932	-.202
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.874	.564	-1.550	.123	-1.986	.239
	[ageCAT=2]	-.563	.511	-1.103	.271	-1.571	.444
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	-.011	.027	-.419	.676	-.066	.043
pad2	Intercept	8.438	1.427	5.914	.000	5.623	11.254
	[sex=f]	-.683	.476	-1.434	.153	-1.622	.257
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.780	.612	-1.274	.204	-1.989	.428
	[ageCAT=2]	-1.006	.555	-1.813	.071	-2.101	.089
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	-.064	.030	-2.139	.034	-.122	-.005
pad3	Intercept	2.925	.616	4.748	.000	1.709	4.140
	[sex=f]	.003	.206	.017	.987	-.402	.409
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-.315	.264	-1.193	.234	-.837	.206
	[ageCAT=2]	.012	.239	.048	.961	-.461	.484
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	-.019	.013	-1.445	.150	-.044	.007
pbd1	Intercept	4.837	.856	5.649	.000	3.147	6.527
	[sex=f]	-1.438	.286	-5.034	.000	-2.002	-.874
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.539	.368	1.465	.145	-.187	1.264
	[ageCAT=2]	.414	.333	1.245	.215	-.243	1.071
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	.009	.018	.489	.625	-.027	.044
pbd2	Intercept	5.209	1.167	4.464	.000	2.906	7.511
	[sex=f]	-1.516	.389	-3.894	.000	-2.284	-.748
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.563	.501	1.124	.263	-.425	1.551
	[ageCAT=2]	-.170	.454	-.374	.709	-1.065	.725
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	.017	.024	.687	.493	-.031	.065
pbd3	Intercept	8.183	1.393	5.873	.000	5.434	10.933
	[sex=f]	-.073	.465	-.158	.875	-.991	.844
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	-1.022	.598	-1.709	.089	-2.202	.158
	[ageCAT=2]	-.026	.542	-.048	.962	-1.095	1.043
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	-.077	.029	-2.638	.009	-.134	-.019
pcd1	Intercept	4.525	.609	7.433	.000	3.323	5.726
	[sex=f]	-1.090	.203	-5.365	.000	-1.490	-.689
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.331	.261	1.265	.207	-.185	.846
	[ageCAT=2]	.083	.237	.349	.727	-.384	.550
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	-.015	.013	-1.183	.238	-.040	.010
pcd2	Intercept	2.567	.908	2.828	.005	.776	4.358
	[sex=f]	-1.093	.303	-3.610	.000	-1.691	-.496
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	.930	.390	2.387	.018	.161	1.698
	[ageCAT=2]	-.172	.353	-.487	.627	-.868	.524

	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	.039	.019	2.064	.040	.002	.076
pcd3	Intercept	5.080	1.234	4.115	.000	2.643	7.516
	[sex=f]	-1.260	.412	-3.059	.003	-2.073	-.447
	[sex=m]	0(a)	.	.	.	.	.
	[ageCAT=1]	1.206	.530	2.277	.024	.161	2.252
	[ageCAT=2]	.853	.480	1.778	.077	-.094	1.800
	[ageCAT=3]	0(a)	.	.	.	.	.
	pindex	.001	.026	.046	.963	-.050	.052

5-2 Descriptive Statistics of bone depth at each location for males and females

	sex			Statistic	Std. Error	sex	Statistic	Std. Error
pad1	f		Mean	6.43	.227	M	7.47	.404
		95% C.I.	Lower Bound	5.98			6.67	
			Upper Bound	6.88			8.28	
			5% Trimmed Mean	6.33			7.36	
			Median	6.00			7.00	
			Variance	6.393			9.633	
			Std. Deviation	2.528			3.104	
			Minimum	2			3	
			Maximum	13			15	
			Range	11			12	
			Interquartile Range	4			5	
			Skewness	.574	.217		.469	.311
			Kurtosis	-.400	.431		-.525	.613
pad2	f		Mean	4.49	.250	M	5.07	.444
		95% C.I.	Lower Bound	4.00			4.18	
			Upper Bound	4.99			5.96	
			5% Trimmed Mean	4.27			4.80	
			Median	4.00			4.00	
			Variance	7.764			11.616	
			Std. Deviation	2.786			3.408	
			Minimum	1			1	
			Maximum	15			15	
			Range	14			14	
			Interquartile Range	4			4	
			Skewness	1.152	.217		1.214	.311
			Kurtosis	1.308	.431		.870	.613
pad3	f		Mean	2.06	.109	M	2.08	.185
		95% C.I.	Lower Bound	1.84			1.72	
			Upper Bound	2.27			2.45	
			5% Trimmed Mean	1.94			1.91	

			Median	2.00			2.00	
			Variance	1.468			2.010	
			Std. Deviation	1.212			1.418	
			Minimum	1			1	
			Maximum	7			7	
			Range	6			6	
			Interquartile Range	2			2	
			Skewness	1.256	.217		1.649	.311
			Kurtosis	1.805	.431		2.626	.613
pbd1	f		Mean	4.10	.148	M	5.56	.264
		95% C.I.	Lower Bound	3.80			5.03	
			Upper Bound	4.39			6.09	
			5% Trimmed Mean	4.02			5.45	
			Median	4.00			6.00	
			Variance	2.706			4.113	
			Std. Deviation	1.645			2.028	
			Minimum	1			2	
			Maximum	10			13	
			Range	9			11	
			Interquartile Range	2			3	
			Skewness	.845	.217		.861	.311
			Kurtosis	.669	.431		1.893	.613
pbd2	f		Mean	4.52	.191	M	5.95	.384
		95% C.I.	Lower Bound	4.14			5.18	
			Upper Bound	4.90			6.72	
			5% Trimmed Mean	4.42			5.76	
			Median	4.00			5.00	
			Variance	4.544			8.704	
			Std. Deviation	2.132			2.950	
			Minimum	1			2	
			Maximum	12			14	
			Range	11			12	
			Interquartile Range	3			4	
			Skewness	.781	.217		.944	.311
			Kurtosis	.862	.431		.510	.613
pbd3	f		Mean	4.58	.269	M	4.75	.369
		95% C.I.	Lower Bound	4.05			4.01	
			Upper Bound	5.11			5.48	
			5% Trimmed Mean	4.41			4.61	
			Median	4.00			4.00	
			Variance	8.945			8.020	
			Std. Deviation	2.991			2.832	
			Minimum	1			1	
			Maximum	12			12	
			Range	11			11	
			Interquartile Range	5			5	
			Skewness	.672	.217		.555	.311
			Kurtosis	-.550	.431		-.547	.613
pcd1	f		Mean	2.96	.104	M	4.03	.193
		95% C.I.	Lower Bound	2.75			3.65	
			Upper Bound	3.17			4.42	
			5% Trimmed Mean	2.92			3.98	
			Median	3.00			4.00	
			Variance	1.340			2.206	
			Std. Deviation	1.158			1.485	
			Minimum	1			1	

			Maximum	6			8	
			Range	5			7	
			Interquartile Range	2			2	
			Skewness	.559	.217		.332	.311
			Kurtosis	.123	.431		.512	.613
pcd2	f		Mean	3.35	.170	M	4.32	.263
		95% C.I.	Lower Bound	3.01			3.80	
			Upper Bound	3.68			4.85	
			5% Trimmed Mean	3.18			4.25	
			Median	3.00			4.00	
			Variance	3.578			4.084	
			Std. Deviation	1.892			2.021	
			Minimum	1			1	
			Maximum	11			10	
			Range	10			9	
			Interquartile Range	2			3	
			Skewness	1.209	.217		.515	.311
			Kurtosis	2.078	.431		-.034	.613
pcd3	f		Mean	4.60	.223	M	5.90	.365
		95% C.I.	Lower Bound	4.16			5.17	
			Upper Bound	5.04			6.63	
			5% Trimmed Mean	4.46			5.87	
			Median	4.00			6.00	
			Variance	6.145			7.852	
			Std. Deviation	2.479			2.802	
			Minimum	1			1	
			Maximum	13			12	
			Range	12			11	
			Interquartile Range	3			4	
			Skewness	.724	.217		.011	.311
			Kurtosis	.857	.431		-.526	.613

5-3 Regression Analyses

5-3-1 The Association between Palatal Factors and Age and Gender

Palatal Height with Age and Gender

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	gender, age[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: pheight

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.440[a]	.194	.185	2.111103

a. Predictors: (Constant), gender, age

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	192.538	2	96.269	21.601	.000[a]
	Residual	802.216	180	4.457		
	Total	994.754	182			

a. Predictors: (Constant), gender, age

b. Dependent Variable: pheight

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.990	1.022		6.842	.000
	age	.037	.006	.428	6.397	.000
	gender	.560	.334	.112	1.678	.095

a. Dependent Variable: pheight

5-3-2 Palatal Width with Age and Gender

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	gender, age[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: pwidth

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.194[a]	.038	.027	3.026057

a. Predictors: (Constant), gender, age

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	64.588	2	32.294	3.527	.031[a]
	Residual	1648.264	180	9.157		
	Total	1712.852	182			

a. Predictors: (Constant), gender, age

b. Dependent Variable: pwidth

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.346	1.464		21.407	.000
	age	.008	.008	.071	.976	.331
	gender	1.195	.479	.182	2.495	.013

a. Dependent Variable: pwidth

5-3-3 Palatal Index with Age and Gender

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	age, gender[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: pindex

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.361[a]	.131	.121	7.3604

a. Predictors: (Constant), age, gender

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1463.945	2	731.973	13.511	.000[a]
	Residual	9751.510	180	54.175		
	Total	11215.456	182			

a. Predictors: (Constant), age, gender

b. Dependent Variable: pindex

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	23.075	3.562		6.479	.000
	gender	.134	1.164	.008	.115	.908
	age	.104	.020	.361	5.198	.000

[a] Dependent Variable: pindex

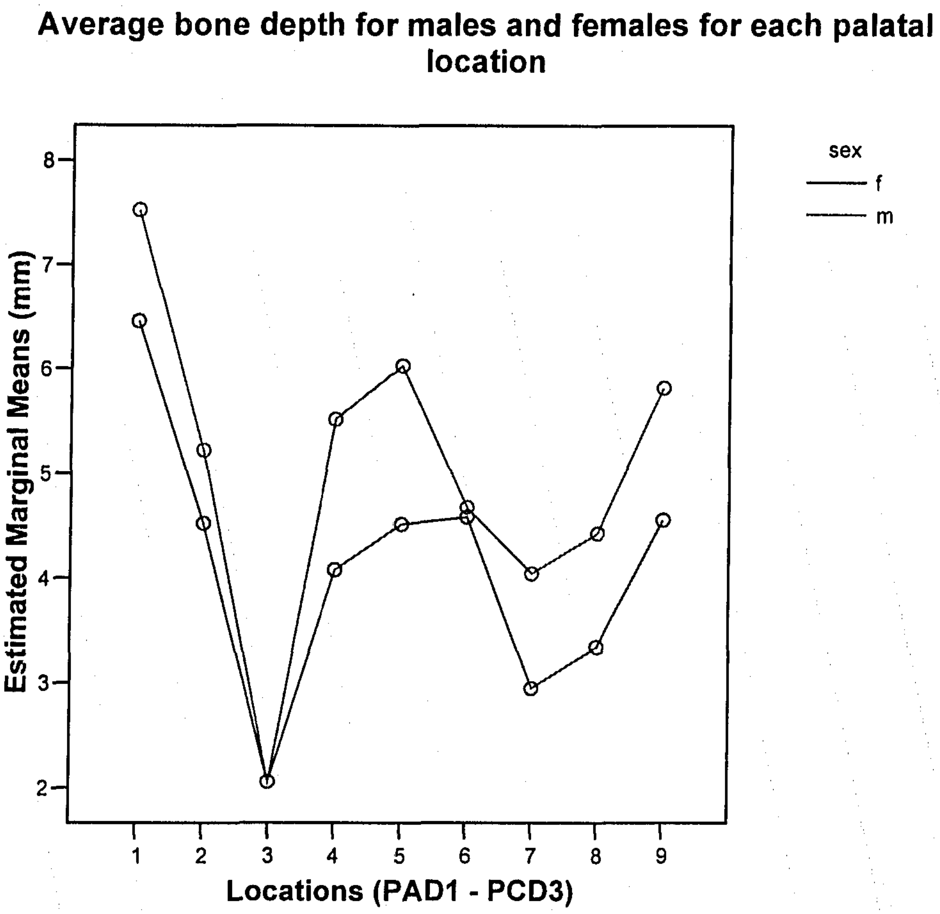
5-4 T-Test of Mean Palatal Widths between Genders

Group Statistics

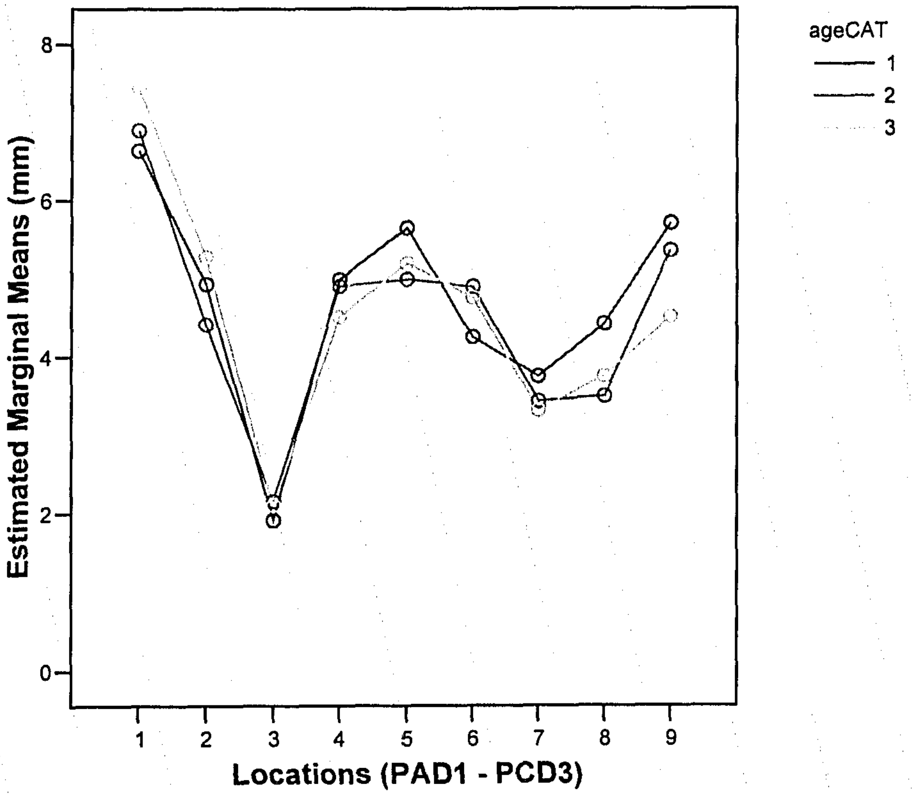
	1:F 0:M	N	Mean	Std. Deviation	Std. Error Mean
pheight	0	59	13.92	2.402	.313
	1	124	13.41	2.299	.206
pwidth	0	59	33.93	3.189	.415
	1	124	32.75	2.946	.265
pindex	0	59	41.243	7.4686	.9723
	1	124	41.268	8.0548	.7233

Independent Samples Test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
pheight	Equal variances assumed	1.366	181	.174	.504	.369	-.224	1.232
	Equal variances not assumed	1.345	109.8	.181	.504	.375	-.239	1.247
pwidth	Equal variances assumed	2.470	181	.014	1.182	.479	.238	2.126
	Equal variances not assumed	2.402	106.4	.018	1.182	.492	.206	2.158
pindex	Equal variances assumed	-.020	181	.984	-.0254	1.2450	-2.4820	2.4311
	Equal variances not assumed	-.021	122.3	.983	-.0254	1.2119	-2.4244	2.3735


Average bone depth for males and females for each palatal location
Estimated Marginal Means (mm)
8
7
6
5
4
3
2
1
2
3
4
5
6
7
8
9
Locations (PAD1 - PCD3)
sex
f
m

Average bone depth for each age group for each palatal location



Appendix 6 - Statistics for chapter 4

6-1 Percentile Representation of Bone Volume Availability for Females and Males

		sex	Percentiles						
			5	10	25	50	75	90	95
Weighted Average (Definition 1)	pad1	f	3.00	4.00	4.00	6.00	8.00	10.00	11.00
	pad2	f	1.00	2.00	2.00	4.00	6.00	8.00	10.75
	pad3	f	1.00	1.00	1.00	2.00	3.00	4.00	4.00
	pbd1	f	2.00	2.00	3.00	4.00	5.00	7.00	7.00
	pbd2	f	1.25	2.00	3.00	4.00	6.00	7.00	8.00
	pbd3	f	1.00	1.00	2.00	4.00	7.00	9.00	10.75
	pcd1	f	1.00	2.00	2.00	3.00	4.00	4.50	5.00
	pcd2	f	1.00	1.00	2.00	3.00	4.00	6.00	7.75
	pcd3	f	1.00	1.50	3.00	4.00	6.00	8.00	8.00
	pad1	M	3.00	4.00	5.00	7.00	10.00	12.00	12.00
	pad2	M	1.00	2.00	3.00	4.00	7.00	10.00	13.00
	pad3	M	1.00	1.00	1.00	2.00	3.00	4.00	6.00
	pbd1	M	3.00	3.00	4.00	6.00	7.00	8.00	9.00
	pbd2	M	2.00	2.00	4.00	5.00	8.00	10.00	12.00
	pbd3	M	1.00	1.00	2.00	4.00	7.00	9.00	10.00
	pcd1	M	2.00	2.00	3.00	4.00	5.00	6.00	7.00
	pcd2	M	1.00	2.00	3.00	4.00	6.00	7.00	8.00
	pcd3	M	1.00	2.00	4.00	6.00	8.00	10.00	10.00

6-2 Chi Square Tests for Chapter 4

Chi Square: Number of Measurements in Which a Tooth is encountered at PAD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pad1ch4	183	100.0%	0	.0%	183	100.0%

sex * pad1ch4 Crosstabulation

			pad1ch4		Total
			.00	1.00	
sex	f	Count	102	22	124
		% within sex	82.3%	17.7%	100.0%
		% within pad1ch4	70.8%	56.4%	67.8%
	m	Count	42	17	59
		% within sex	71.2%	28.8%	100.0%
		% within pad1ch4	29.2%	43.6%	32.2%
Total		Count	144	39	183
		% within sex	78.7%	21.3%	100.0%
		% within pad1ch4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.922[b]	1	.087		
Continuity Correction[a]	2.299	1	.129		
Likelihood Ratio	2.822	1	.093		
Fisher's Exact Test				.121	.066
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.57.

Chi Square: Number of Measurements in Which a Tooth is encountered at PAD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pad2ch4	183	100.0%	0	.0%	183	100.0%

sex * pad2ch4 Crosstabulation

			pad2ch4		Total
			.00	1.00	
sex	f	Count	35	89	124
		% within sex	28.2%	71.8%	100.0%
		% within pad2ch4	72.9%	65.9%	67.8%
	m	Count	13	46	59
		% within sex	22.0%	78.0%	100.0%
		% within pad2ch4	27.1%	34.1%	32.2%
Total		Count	48	135	183
		% within sex	26.2%	73.8%	100.0%
		% within pad2ch4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.792[b]	1	.373		
Continuity Correction[a]	.504	1	.478		
Likelihood Ratio	.809	1	.369		
Fisher's Exact Test				.472	.241
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.48.

Chi Square: Number of measurements in which a tooth is encountered at PAD3, by gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pad3ch4	183	100.0%	0	.0%	183	100.0%

sex * pad3ch4 Crosstabulation

			pad3ch4		Total
			.00	1.00	
sex	f	Count	2	122	124
		% within sex	1.6%	98.4%	100.0%
		% within pad3ch4	66.7%	67.8%	67.8%
	m	Count	1	58	59
		% within sex	1.7%	98.3%	100.0%
		% within pad3ch4	33.3%	32.2%	32.2%
Total		Count	3	180	183
		% within sex	1.6%	98.4%	100.0%
		% within pad3ch4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.002[b]	1	.967		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.002	1	.968		
Fisher's Exact Test				1.000	.691
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 2 cells (50.0%) have expected count less than 5. The minimum expected count is .97.

Chi Square: Number of measurements in which a tooth is encountered at PBD1, by gender

Warnings

No measures of association are computed for the crosstabulation of sex * pbd1ch4. At least one variable in each 2-way table upon which measures of association are computed is a constant.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd1ch4	183	100.0%	0	.0%	183	100.0%

sex * pbd1ch4 Crosstabulation

			pbd1ch4	
			.00	Total
sex	f	Count	124	124
		% within sex	100.0%	100.0%
		% within pbd1ch4	67.8%	67.8%
	m	Count	59	59
		% within sex	100.0%	100.0%
		% within pbd1ch4	32.2%	32.2%
Total		Count	183	183
		% within sex	100.0%	100.0%
		% within pbd1ch4	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	183

a. No statistics are computed because pbd1ch4 is a constant.

Chi Square: Number of measurements in which a tooth is encountered at PBD2, by gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd2ch4	183	100.0%	0	.0%	183	100.0%

sex * pbd2ch4 Crosstabulation

			pbd2ch4		
			.00	1.00	Total
sex	f	Count	107	17	124
		% within sex	86.3%	13.7%	100.0%
		% within pbd2ch4	71.3%	51.5%	67.8%
	m	Count	43	16	59
		% within sex	72.9%	27.1%	100.0%
		% within pbd2ch4	28.7%	48.5%	32.2%
Total		Count	150	33	183
		% within sex	82.0%	18.0%	100.0%
		% within pbd2ch4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.863[b]	1	.027		
Continuity Correction[a]	3.998	1	.046		
Likelihood Ratio	4.633	1	.031		
Fisher's Exact Test				.039	.025
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 10. 64.

Chi Square: Number of measurements in which a tooth is encountered at PBD3, by gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd3ch4	183	100.0%	0	.0%	183	100.0%

sex * pbd3ch4 Crosstabulation

			pbd3ch4		Total
			.00	1.00	
sex	f	Count	67	57	124
		% within sex	54.0%	46.0%	100.0%
		% within pbd3ch4	76.1%	60.0%	67.8%
	m	Count	21	38	59
		% within sex	35.6%	64.4%	100.0%
		% within pbd3ch4	23.9%	40.0%	32.2%
Total		Count	88	95	183
		% within sex	48.1%	51.9%	100.0%
		% within pbd3ch4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.445[b]	1	.020		
Continuity Correction[a]	4.731	1	.030		
Likelihood Ratio	5.508	1	.019		
Fisher's Exact Test				.026	.014
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 28.37.

Chi Square: Number of Measurements in Which a Tooth is encountered at PCD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd1ch4	183	100.0%	0	.0%	183	100.0%

sex * pcd1ch4 Crosstabulation

			pcd1ch4	Total
			.00	
sex	f	Count	124	124
		% within sex	100.0%	100.0%
		% within pcd1ch4	67.8%	67.8%
	m	Count	59	59
		% within sex	100.0%	100.0%
		% within pcd1ch4	32.2%	32.2%
Total		Count	183	183
		% within sex	100.0%	100.0%
		% within pcd1ch4	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	183

[a] No statistics are computed because pcd1ch4 is a constant.

Chi Square: Number of Measurements in Which a Tooth is encountered at PCD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd2ch4	183	100.0%	0	.0%	183	100.0%

sex * pcd2ch4 Crosstabulation

			pcd2ch4		Total
			.00	1.00	
sex	f	Count	123	1	124
		% within sex	99.2%	.8%	100.0%
		% within pcd2ch4	67.6%	100.0%	67.8%
	m	Count	59	0	59
		% within sex	100.0%	.0%	100.0%
		% within pcd2ch4	32.4%	.0%	32.2%
Total		Count	182	1	183
		% within sex	99.5%	.5%	100.0%
		% within pcd2ch4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.478[b]	1	.489		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.781	1	.377		
Fisher's Exact Test				1.000	.678
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .32.

Chi Square: Number of Measurements in Which a Tooth is encountered at PCD3, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd3ch4	183	100.0%	0	.0%	183	100.0%

sex * pcd3ch4 Crosstabulation

			pcd3ch4		Total
			.00	1.00	
sex	f	Count	109	15	124
		% within sex	87.9%	12.1%	100.0%
		% within pcd3ch4	69.0%	60.0%	67.8%
	m	Count	49	10	59
		% within sex	83.1%	16.9%	100.0%
		% within pcd3ch4	31.0%	40.0%	32.2%
Total		Count	158	25	183
		% within sex	86.3%	13.7%	100.0%
		% within pcd3ch4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.798[b]	1	.372		
Continuity Correction[a]	.440	1	.507		
Likelihood Ratio	.774	1	.379		
Fisher's Exact Test				.368	.250
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.06.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PAD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * 1:<4 2:>=4	183	100.0%	0	.0%	183	100.0%

sex * 1:<4 2:>=4 Crosstabulation

			1:<4 2:>=4		Total
			0	1	
sex	f	Count	10	114	124
		% within sex	8.1%	91.9%	100.0%
		% within 1:<4 2:>=4	71.4%	67.5%	67.8%
	m	Count	4	55	59
		% within sex	6.8%	93.2%	100.0%
		% within 1:<4 2:>=4	28.6%	32.5%	32.2%
Total		Count	14	169	183
		% within sex	7.7%	92.3%	100.0%
		% within 1:<4 2:>=4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.093[b]	1	.760		
Continuity Correction[a]	.000	1	.994		
Likelihood Ratio	.095	1	.758		
Fisher's Exact Test				1.000	.509
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 1 cells (25.0%) have expected count less than 5. The minimum expected count is 4.51.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PAD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pad2L4	183	100.0%	0	.0%	183	100.0%

sex * pad2L4 Crosstabulation

			pad2L4		Total
			1	2	
sex	f	Count	54	70	124
		% within sex	43.5%	56.5%	100.0%
		% within pad2L4	69.2%	66.7%	67.8%
	m	Count	24	35	59
		% within sex	40.7%	59.3%	100.0%
		% within pad2L4	30.8%	33.3%	32.2%
Total		Count	78	105	183
		% within sex	42.6%	57.4%	100.0%
		% within pad2L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.135[b]	1	.714		
Continuity Correction[a]	.043	1	.836		
Likelihood Ratio	.135	1	.713		
Fisher's Exact Test				.751	.419
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 25. 15.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PAD3, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pad3L4	183	100.0%	0	.0%	183	100.0%

sex * pad3L4 Crosstabulation

			pad3L4		Total
			1	2	
sex	f	Count	109	15	124
		% within sex	87.9%	12.1%	100.0%
		% within pad3L4	68.1%	65.2%	67.8%
	m	Count	51	8	59
		% within sex	86.4%	13.6%	100.0%
		% within pad3L4	31.9%	34.8%	32.2%
Total		Count	160	23	183
		% within sex	87.4%	12.6%	100.0%
		% within pad3L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.078[b]	1	.780		
Continuity Correction[a]	.002	1	.968		
Likelihood Ratio	.077	1	.781		
Fisher's Exact Test				.813	.475
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.
42.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PBD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd1L4	183	100.0%	0	.0%	183	100.0%

sex * pbd1L4 Crosstabulation

			pbd1L4		Total
			1	2	
sex	f	Count	52	72	124
		% within sex	41.9%	58.1%	100.0%
		% within pbd1L4	86.7%	58.5%	67.8%
	m	Count	8	51	59
		% within sex	13.6%	86.4%	100.0%
		% within pbd1L4	13.3%	41.5%	32.2%
Total		Count	60	123	183
		% within sex	32.8%	67.2%	100.0%
		% within pbd1L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	14.607[b]	1	.000		
Continuity Correction[a]	13.348	1	.000		
Likelihood Ratio	16.061	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 19.34.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PBD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd2L4	183	100.0%	0	.0%	183	100.0%

sex * pbd2L4 Crosstabulation

			pbd2L4		Total
			1	2	
sex	f	Count	43	81	124
		% within sex	34.7%	65.3%	100.0%
		% within pbd2L4	81.1%	62.3%	67.8%
	m	Count	10	49	59
		% within sex	16.9%	83.1%	100.0%
		% within pbd2L4	18.9%	37.7%	32.2%
Total		Count	53	130	183
		% within sex	29.0%	71.0%	100.0%
		% within pbd2L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.107[b]	1	.013		
Continuity Correction[a]	5.276	1	.022		
Likelihood Ratio	6.497	1	.011		
Fisher's Exact Test				.015	.009
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 17.09.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PBD3, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd3L4	183	100.0%	0	.0%	183	100.0%

sex * pbd3L4 Crosstabulation

			pbd3L4		Total
			1	2	
sex	f	Count	58	66	124
		% within sex	46.8%	53.2%	100.0%
		% within pbd3L4	69.0%	66.7%	67.8%
	m	Count	26	33	59
		% within sex	44.1%	55.9%	100.0%
		% within pbd3L4	31.0%	33.3%	32.2%
Total		Count	84	99	183
		% within sex	45.9%	54.1%	100.0%
		% within pbd3L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.118[b]	1	.731		
Continuity Correction[a]	.034	1	.853		
Likelihood Ratio	.118	1	.731		
Fisher's Exact Test				.753	.427
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 27.08.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PCD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd1L4	183	100.0%	0	.0%	183	100.0%

sex * pcd1L4 Crosstabulation

			pcd1L4		Total
			1	2	
sex	f	Count	89	35	124
		% within sex	71.8%	28.2%	100.0%
		% within pcd1L4	80.9%	47.9%	67.8%
	m	Count	21	38	59
		% within sex	35.6%	64.4%	100.0%
		% within pcd1L4	19.1%	52.1%	32.2%
Total		Count	110	73	183
		% within sex	60.1%	39.9%	100.0%
		% within pcd1L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	21.826[b]	1	.000		
Continuity Correction[a]	20.343	1	.000		
Likelihood Ratio	21.758	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 23.54.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PCD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd2L4	183	100.0%	0	.0%	183	100.0%

sex * pcd2L4 Crosstabulation

			pcd2L4		Total
			1	2	
sex	f	Count	75	49	124
		% within sex	60.5%	39.5%	100.0%
		% within pcd2L4	76.5%	57.6%	67.8%
	m	Count	23	36	59
		% within sex	39.0%	61.0%	100.0%
		% within pcd2L4	23.5%	42.4%	32.2%
Total		Count	98	85	183
		% within sex	53.6%	46.4%	100.0%
		% within pcd2L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	7.430[b]	1	.006		
Continuity Correction[a]	6.591	1	.010		
Likelihood Ratio	7.456	1	.006		
Fisher's Exact Test				.007	.005
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 27.
40.

Chi Square: Number of Measurements Less Than 4mm and ≥ 4mm at PCD3, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd3L4	183	100.0%	0	.0%	183	100.0%

sex * pcd3L4 Crosstabulation

			pcd3L4		Total
			1	2	
sex	f	Count	44	80	124
		% within sex	35.5%	64.5%	100.0%
		% within pcd3L4	77.2%	63.5%	67.8%
	m	Count	13	46	59
		% within sex	22.0%	78.0%	100.0%
		% within pcd3L4	22.8%	36.5%	32.2%
Total		Count	57	126	183
		% within sex	31.1%	68.9%	100.0%
		% within pcd3L4	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.372[b]	1	.066		
Continuity Correction[a]	2.774	1	.096		
Likelihood Ratio	3.498	1	.061		
Fisher's Exact Test				.087	.046
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 18. 38.

Chi Square: Number of Measurements ≥ 7mm at PAD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * 1:<7 2:>=7	183	100.0%	0	.0%	183	100.0%

sex * 1:<7 2:>=7 Crosstabulation

			1:<7 2:>=7		Total
			1	2	
sex	f	Count	71	53	124
		% within sex	57.3%	42.7%	100.0%
		% within 1:<7 2:>=7	74.0%	60.9%	67.8%
	m	Count	25	34	59
		% within sex	42.4%	57.6%	100.0%
		% within 1:<7 2:>=7	26.0%	39.1%	32.2%
Total		Count	96	87	183
		% within sex	52.5%	47.5%	100.0%
		% within 1:<7 2:>=7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.552^b	1	.059		
Continuity Correction^a	2.980	1	.084		
Likelihood Ratio	3.558	1	.059		
Fisher's Exact Test				.081	.042
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 28.05.

Chi Square: Number of Measurements ≥ 7mm at PAD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pad2L7	183	100.0%	0	.0%	183	100.0%

sex * pad2L7 Crosstabulation

			pad2L7		Total
			1	2	
sex	f	Count	99	25	124
		% within sex	79.8%	20.2%	100.0%
		% within pad2L7	69.2%	62.5%	67.8%
	m	Count	44	15	59
		% within sex	74.6%	25.4%	100.0%
		% within pad2L7	30.8%	37.5%	32.2%
Total		Count	143	40	183
		% within sex	78.1%	21.9%	100.0%
		% within pad2L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.648[b]	1	.421		
Continuity Correction[a]	.377	1	.539		
Likelihood Ratio	.636	1	.425		
Fisher's Exact Test				.447	.267
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 12. 90.

Chi Square: Number of Measurements ≥ 7mm at PAD3, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pad3L7	183	100.0%	0	.0%	183	100.0%

sex * pad3L7 Crosstabulation

			pad3L7		Total
			1	2	
sex	f	Count	123	1	124
		% within sex	99.2%	.8%	100.0%
		% within pad3L7	68.0%	50.0%	67.8%
	m	Count	58	1	59
		% within sex	98.3%	1.7%	100.0%
		% within pad3L7	32.0%	50.0%	32.2%
Total		Count	181	2	183
		% within sex	98.9%	1.1%	100.0%
		% within pad3L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.292[b]	1	.589		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.273	1	.601		
Fisher's Exact Test				.542	.542
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is . 64.

Chi Square: Number of Measurements ≥ 7mm at PBD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd1L7	183	100.0%	0	.0%	183	100.0%

sex * pbd1L7 Crosstabulation

			pbd1L7		
			1	2	Total
sex	f	Count	111	13	124
		% within sex	89.5%	10.5%	100.0%
		% within pbd1L7	73.0%	41.9%	67.8%
	m	Count	41	18	59
		% within sex	69.5%	30.5%	100.0%
		% within pbd1L7	27.0%	58.1%	32.2%
Total		Count	152	31	183
		% within sex	83.1%	16.9%	100.0%
		% within pbd1L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	11.393[b]	1	.001		
Continuity Correction[a]	10.015	1	.002		
Likelihood Ratio	10.696	1	.001		
Fisher's Exact Test				.001	.001
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 9. 99.

Chi Square: Number of Measurements ≥ 7mm at PBD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd2L7	183	100.0%	0	.0%	183	100.0%

sex * pbd2L7 Crosstabulation

			pbd2L7		Total
			1	2	
sex	f	Count	104	20	124
		% within sex	83.9%	16.1%	100.0%
		% within pbd2L7	71.7%	52.6%	67.8%
	m	Count	41	18	59
		% within sex	69.5%	30.5%	100.0%
		% within pbd2L7	28.3%	47.4%	32.2%
Total		Count	145	38	183
		% within sex	79.2%	20.8%	100.0%
		% within pbd2L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.024[b]	1	.025		
Continuity Correction[a]	4.188	1	.041		
Likelihood Ratio	4.812	1	.028		
Fisher's Exact Test				.032	.022
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 12.25.

Chi Square: Number of Measurements ≥ 7mm at PBD3, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pbd3L7	183	100.0%	0	.0%	183	100.0%

sex * pbd3L7 Crosstabulation

			pbd3L7		Total
			1	2	
sex	f	Count	91	33	124
		% within sex	73.4%	26.6%	100.0%
		% within pbd3L7	67.4%	68.8%	67.8%
	m	Count	44	15	59
		% within sex	74.6%	25.4%	100.0%
		% within pbd3L7	32.6%	31.3%	32.2%
Total		Count	135	48	183
		% within sex	73.8%	26.2%	100.0%
		% within pbd3L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	$.029^b$	1	.864		
Continuity Correction^a	.000	1	1.000		
Likelihood Ratio	.029	1	.864		
Fisher's Exact Test				1.000	.508
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.48.

Chi Square: Number of Measurements ≥ 7mm at PCD1, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd1L7	183	100.0%	0	.0%	183	100.0%

sex * pcd1L7 Crosstabulation

			pcd1L7		Total
			1	2	
sex	f	Count	124	0	124
		% within sex	100.0%	.0%	100.0%
		% within pcd1L7	68.9%	.0%	67.8%
	m	Count	56	3	59
		% within sex	94.9%	5.1%	100.0%
		% within pcd1L7	31.1%	100.0%	32.2%
Total		Count	180	3	183
		% within sex	98.4%	1.6%	100.0%
		% within pcd1L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.410^b	1	.011		
Continuity Correction^a	3.645	1	.056		
Likelihood Ratio	6.897	1	.009		
Fisher's Exact Test				.032	.032
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is .97.

Chi Square: Number of Measurements ≥ 7mm at PCD2, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd2L7	183	100.0%	0	.0%	183	100.0%

sex * pcd2L7 Crosstabulation

			pcd2L7		Total
			1	2	
sex	f	Count	116	8	124
		% within sex	93.5%	6.5%	100.0%
		% within pcd2L7	69.9%	47.1%	67.8%
	m	Count	50	9	59
		% within sex	84.7%	15.3%	100.0%
		% within pcd2L7	30.1%	52.9%	32.2%
Total		Count	166	17	183
		% within sex	90.7%	9.3%	100.0%
		% within pcd2L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	3.676[b]	1	.055		
Continuity Correction[a]	2.706	1	.100		
Likelihood Ratio	3.440	1	.064		
Fisher's Exact Test				.099	.053
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 5. 48.

Chi Square: Number of Measurements ≥ 7mm at PCD3, by Gender

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
sex * pcd3L7	183	100.0%	0	.0%	183	100.0%

sex * pcd3L7 Crosstabulation

			pcd3L7		
			1	2	Total
sex	f	Count	96	28	124
		% within sex	77.4%	22.6%	100.0%
		% within pcd3L7	72.7%	54.9%	67.8%
	m	Count	36	23	59
		% within sex	61.0%	39.0%	100.0%
		% within pcd3L7	27.3%	45.1%	32.2%
Total		Count	132	51	183
		% within sex	72.1%	27.9%	100.0%
		% within pcd3L7	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.351[b]	1	.021		
Continuity Correction[a]	4.566	1	.033		
Likelihood Ratio	5.191	1	.023		
Fisher's Exact Test				.033	.017
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 16.44.

Chi Square: Number of measurements limited to <4mm by teeth, or an unerupted tooth was encountered, at each location, by gender

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PAD1, by Gender

Crosstab

			try1		
			.00	1.00	Total
sex	f	Count	119	5	124
		% within sex	96.0%	4.0%	100.0%
		% within try1	68.0%	62.5%	67.8%
	m	Count	56	3	59
		% within sex	94.9%	5.1%	100.0%
		% within try1	32.0%	37.5%	32.2%
Total		Count	175	8	183
		% within sex	95.6%	4.4%	100.0%
		% within try1	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.106[b]	1	.745		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.103	1	.748		
Fisher's Exact Test				.714	.506
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 1 cells (25.0%) have expected count less than 5. The minimum expected count is 2.58.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PAD2, by Gender

Crosstab

			try2		Total
			.00	1.00	
sex	f	Count	71	53	124
		% within sex	57.3%	42.7%	100.0%
		% within try2	66.4%	69.7%	67.8%
	m	Count	36	23	59
		% within sex	61.0%	39.0%	100.0%
		% within try2	33.6%	30.3%	32.2%
Total		Count	107	76	183
		% within sex	58.5%	41.5%	100.0%
		% within try2	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.233[b]	1	.630		
Continuity Correction[a]	.104	1	.748		
Likelihood Ratio	.233	1	.629		
Fisher's Exact Test				.748	.375
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 24.50.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PAD3, by Gender

Crosstab

			try3		Total
			.00	1.00	
sex	f	Count	16	108	124
		% within sex	12.9%	87.1%	100.0%
		% within try3	64.0%	68.4%	67.8%
	m	Count	9	50	59
		% within sex	15.3%	84.7%	100.0%
		% within try3	36.0%	31.6%	32.2%
Total		Count	25	158	183
		% within sex	13.7%	86.3%	100.0%
		% within try3	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.187[b]	1	.665		
Continuity Correction[a]	.041	1	.839		
Likelihood Ratio	.184	1	.668		
Fisher's Exact Test				.652	.412
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.06.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PBD1, by Gender

Crosstab

			try4	Total
			.00	
sex	f	Count	124	124
		% within sex	100.0%	100.0%
		% within try4	67.8%	67.8%
	m	Count	59	59
		% within sex	100.0%	100.0%
		% within try4	32.2%	32.2%
Total		Count	183	183
		% within sex	100.0%	100.0%
		% within try4	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	183

a. No statistics are computed because try4 is a constant.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PBD2, by Gender

Crosstab

			try5		
			.00	1.00	Total
sex	f	Count	117	7	124
		% within sex	94.4%	5.6%	100.0%
		% within try5	68.0%	63.6%	67.8%
	m	Count	55	4	59
		% within sex	93.2%	6.8%	100.0%
		% within try5	32.0%	36.4%	32.2%
Total		Count	172	11	183
		% within sex	94.0%	6.0%	100.0%
		% within try5	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.091[b]	1	.763		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.089	1	.765		
Fisher's Exact Test				.748	.498
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 1 cells (25.0%) have expected count less than 5. The minimum expected count is 3.55.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PBD3, by Gender

Crosstab

			try6		
			.00	1.00	Total
sex	f	Count	83	41	124
		% within sex	66.9%	33.1%	100.0%
		% within try6	68.6%	66.1%	67.8%
	m	Count	38	21	59
		% within sex	64.4%	35.6%	100.0%
		% within try6	31.4%	33.9%	32.2%
Total		Count	121	62	183
		% within sex	66.1%	33.9%	100.0%
		% within try6	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.114[b]	1	.736		
Continuity Correction[a]	.029	1	.864		
Likelihood Ratio	.114	1	.736		
Fisher's Exact Test				.741	.430
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 0 cells (.0%) have expected count less than 5. The minimum expected count is 19.99.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PCD1, by Gender

Crosstab

			try7	
			.00	Total
sex	f	Count	124	124
		% within sex	100.0%	100.0%
		% within try7	67.8%	67.8%
	m	Count	59	59
		% within sex	100.0%	100.0%
		% within try7	32.2%	32.2%
Total		Count	183	183
		% within sex	100.0%	100.0%
		% within try7	100.0%	100.0%

Chi-Square Tests

	Value
Pearson Chi-Square	.[a]
N of Valid Cases	183

a. No statistics are computed because try7 is a constant.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PCD2, by Gender

Crosstab

			try8		Total
			.00	1.00	
sex	f	Count	123	1	124
		% within sex	99.2%	.8%	100.0%
		% within try8	67.6%	100.0%	67.8%
	m	Count	59	0	59
		% within sex	100.0%	.0%	100.0%
		% within try8	32.4%	.0%	32.2%
Total		Count	182	1	183
		% within sex	99.5%	.5%	100.0%
		% within try8	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.478[b]	1	.489		
Continuity Correction[a]	.000	1	1.000		
Likelihood Ratio	.781	1	.377		
Fisher's Exact Test				1.000	.678
N of Valid Cases	183				

a. Computed only for a 2x2 table

b. 2 cells (50.0%) have expected count less than 5. The minimum expected count is . 32.

Chi Square: Number of Measurements limited to <4mm or an unerupted tooth was encountered at PCD3, by Gender

Crosstab

			try9		Total
			.00	1.00	
sex	f	Count	116	8	124
		% within sex	93.5%	6.5%	100.0%
		% within try9	67.4%	72.7%	67.8%
	m	Count	56	3	59
		% within sex	94.9%	5.1%	100.0%
		% within try9	32.6%	27.3%	32.2%
Total		Count	172	11	183
		% within sex	94.0%	6.0%	100.0%
		% within try9	100.0%	100.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.132[b]	1	.716		
Continuity Correction[a]	.001	1	.975		
Likelihood Ratio	.136	1	.712		
Fisher's Exact Test				1.000	.502
N of Valid Cases	183				

[a] Computed only for a 2x2 table

[b] 1 cells (25.0%) have expected count less than 5. The minimum expected count is 3.55.