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Variation in Orthodontic Treatment Planning Decisions of Class II Cases between Virtual 3D Models and Traditional Plaster Study Models

by

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Dedication

To my wife Megan, my best friend, for giving your all these last six years. May your dedication in time, talent, and love be returned tenfold. To Makall, Bryn, and ???, for providing me with a real education in life. Thank you! I love you!

Forza Azzuri!

Abstract

The purpose of this study was to evaluate the use of digital models in treatment decisions compared to traditional plaster models. Pretreatment records of 10 class II patients were assessed by 20 orthodontists serving as the experimental group. The records were viewed at two time points at least one month apart, with the model format changed at the second session. A control group of 11 orthodontists evaluated the same 10 cases, with the plaster model used on both occasions. Orthodontists were scored on consistency of treatment decisions based on: surgery, extraction, and auxiliary appliance. As the data consisted of matched pairs and was nominal, the McNemar test and Kappa statistic were used to test and measure Intrarater reliability. A proportion of agreement was calculated for each group. Neither group showed statistically significant differences in decisions made. Digital models are a valid tool for treatment planning even difficult orthodontic cases.

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Chapter One

Introduction
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1.1 General Introduction:

Over the past twenty years computers have become a mainstay in every workplace. What was once accomplished by hand is now checked by, if not performed by a computer. There is no aspect of life that has not been altered (usually positively) by these advancements. In the 1960's computers were introduced to the dental field for storage of patient data which had been kept on paper [1]. Later, companies began introducing ways to manufacture dental lab products without ever sending them to a lab. Eventually, the trend became "going paperless". In the 1990's digital radiographs, photographs, and electronic charts were introduced. Computers were being used to transfer patient information from practitioner to insurance companies or other doctors via the World Wide Web. Although the transition has been a slow one, the trend has caught on and offices around North America have begun trying to eliminate the need for patient chart files, traditional photographs, and x-rays, at least at the chair.

Orthodontic diagnosis and treatment planning is multifaceted data interpretation involving the use of a doctor's clinical impression, radiographs, photographs, and study models. The question came to be, when will *all* of the diagnostic materials used in orthodontics be available on computer? That query was answered in 1999 when OrthoCAD (Cadent, Carlstadt, NJ, www.orthocad.com) was brought to market at the annual session of the American Association of Orthodontists. Two years later, in 2001, rival emodels were introduced to offer another representation of the virtual model (Geodigm Corporation, Chanhassen, MN, www.geodigmcorp.com.). This past year (2003) another version of the digital study model was offered as Orthographics was introduced (Ortho Cast, Inc., High Bridge, NJ, www.orthocast.com). These services allow an orthodontist to receive a 3-D computer image of the patient's teeth within a matter of a few days simply by sending in an existing model or an alginate impression. The image may then be downloaded and viewed using free software available from the aforementioned websites.

The reasons for incorporating or ignoring the change in technology are varied, and many orthodontists are comfortable using the traditional records that they have relied on for years. Others are more at ease using plaster models while integrating digital photographs and radiographs in their offices. In doing so, these orthodontists are already using current software which utilizes digital photographs and radiographs to treatment plan, write referral letters, predict growth, etc., leaving models as the last element to a true digital treatment record yet to be fully embraced by the profession. Thus, it stands to reason that there would be a need to examine why this is the case. Is the new tool more cumbersome while treatment planning? Will it cause doctors to make/omit treatment recommendations which they may not have made with traditional models?

Despite the tendency for the orthodontic community to move toward a digital office, not all orthodontists are convinced that there can be an effective transition. The definitive effectiveness of digital decision making has not been elucidated. In particular, there is a need to examine the consistency in orthodontic decision making between traditional plaster models and the virtual format. Logically, if there is consistency between the two (especially when compared to similar trials with controls), then the technology of digital models could seemingly replace its traditional counterpart.

The primary objective of this study is to examine if orthodontists can use digital study models as a substitute for plaster study models in a clinical setting without altering decision making in treatment plans, noting intra-rater variation.

1.2 Literature Review

1.2.1 Introduction

Plaster models have been a part of dental, and more importantly orthodontic, diagnosis and treatment planning for generations. While other aspects of patient records have progressed with technology, the plaster model has remained as the default "gold standard." However, plaster models may not necessarily be the *right* way to approach treatment planning; rather, to this point they may have been the *only* way to go about it. A thorough review of the literature reveals that scientist and clinician alike have been experimenting with technologies to register another form of model[2-13]. This ranges from using photocopiers to various means of computer scanning an image. These scanning technologies have been used in other disciplines for years, yet there exist comparatively few studies in orthodontics on this subject. Additionally, a physical model has other potential inherent limitations. Storage, retrieval, potential breakage, and lab diagnostics are examples of areas where the traditional model has offered difficulties over the years to practitioners. Over time, the orthodontist becomes weary of handling plaster models

Furthermore, reliability in an orthodontist's clinical and diagnostic judgments has been an area of concern. Studies looking at various aspects of clinical decision making have shown that orthodontists are mediocre in reliably reproducing information thought to be basic to patient care.

1.2.2 A Gold Standard

When judging a gold standard or assessing a method of accomplishing a task, much care should be given as to why the change is being explored. Is there a flaw in the current method? Has a variable entered into the work that is immeasurable by the current customary procedure? According to Scholz [14], in today's fast paced society, the more direct questions are:

- Is it better?
- Is it faster?
- Is it more efficient?
- Is it cost effective (often times phrased as less expensive)?

To add to his list, is it reproducible? If the answer is no to any or all of these questions, then the investigation may cease before it ever commences. Assuming all the previous criteria are met, there should be familiar components of current practices which will facilitate transition to the new standard or method.

The first thing that must be examined when considering orthodontic models is their use in the clinical record. High quality records in orthodontics are essential to treatment planning, in an academic environment as well as in a private practice. Study models have been referred to as the one component of patient records consistently taken worldwide, although their quality varies dramatically [15]. In fact, plaster models have been deemed the most essential piece of the patient record for treatment planning [16] [17] [18]. Han et al[19] state that study models "alone provided adequate information for treatment planning," adding that other types of diagnostic records made only "small differences" when added incrementally.

Not surprisingly, plaster models are the most desired piece of information to evaluate a case. "Professionally-prepared study casts provide the *only* three-dimensional record" of the teeth and ridge [20] [21]. The question one might ask is, are plaster models a "gold standard?" Han[19], in studying treatment decisions related to orthodontic records, is bold enough to make this statement in relating her study to a gold standard of orthodontic records; that is, the author calls the records used in every day orthodontics (panograph, cephalogram, cephalogram tracing, photos, and plaster models) a gold standard.

Whether or not orthodontic plaster models are a "gold standard" is questionable. A "gold standard" is difficult to describe in a biological science. A static image of a dynamic environment cannot always offer a definite representation of what is to be found. Wilks[22], a veterinarian, described this phenomenon best by stating that those who use the term "gold standard" must be aware that this represents only the best available test or detection method available at that time. At no point does this represent an absolute value, but a tool against which others can be measured. One must then evaluate whether the new tests are as sensitive, or perhaps more sensitive, than those traditionally used. It is precisely this argument that the current investigation debates. Are digital models as clinically sensitive a tool as that which has been used to this point in orthodontics as the default tool in treatment planning?

1.2.3 Storage of Study Models

1.2.3.a Physical Storage of Orthodontic Models:

The storage of study models has long been a topic of discussion in the orthodontic community. To this end, there have been some orthodontists who have asked for a two-dimensional medium to give three-dimensional representation of the study model. There have been attempts to store models with microfilm, although this is an expensive endeavor [23].

The primary issues related to model storage have to do with office space allocation, off-site storage, and duration of model retention. Typically, an orthodontic office will dedicate space for the models of patients who are in active (current) treatment and those who have recently completed treatment. Other models are stored at off-site centers at home or in commercial buildings at a cost to the orthodontist. For the traditional orthodontic practice with paper records and plaster models, it has been found that 100 models take up three linear feet of shelving when stored in boxes holding four sets[24]. In this scenario, if records were put into storage at the rate of 250 patients per year for 36 years (a total of 8960 patients), an orthodontist would need 448 linear feet of shelving. This is a reasonable example as the current median case starts (patients beginning treatment) in the United States for an orthodontist in practice for 6-10 years is 256 per year, with an average of 500 active patients [25].

One study in the U.K. discussed the physical limitations of plaster model storage. Due to the large number of patients seen in this clinic, the authors estimated that nearly 200 sets of models were brought in to the clinic some days. Because of the weight and size of these models, it is easy to see how the casts might be damaged easily. This is especially true if space is at a premium and the models are kept outside the clinic. The authors noted that when space becomes an issue it may be necessary to discard some of the materials. In fact, of the 124 orthodontists who responded to the questionnaire in the study, nearly 80% stated that they were experiencing problems with storage, with fully 25% of the orthodontists committing completed cases to an off-site storage facility [26].

1.2.3.b Medico-Legal Storage of Study Models

Assuming an orthodontist finds space, either in office or off-site, the question of how long to store plaster models must be considered. Several different opinions on the matter have been offered, both in N. America and throughout the world. One author, from the state of Utah, recommended that *all* records be maintained 7 to 10 years from the date of last service *or* past the age of accountability [27]. In the United Kingdom model storage is more clearly defined. All models must be kept for 11 years, or for 7 years after the age of majority (25 years) . The record must be kept for whichever is longer [28-30]. McGuinness found that the mean storage time in the U.K. was 6.44 years (SD 3.01 years) with only two of 124 respondents keeping study models for 11 years [26]. One may wonder why such recommendations are made when less than 2% of surveyed orthodontists keep the models the full time counseled.

The single largest body of orthodontists, the American Association of Orthodontists (AAO), offers advice to its members on the AAO website. It is recommended that patient records be kept for the appropriate statute of limitations period, yet this period is state-dependent. Generally speaking this period is from five to fifteen years, and each state has its own law as to when the statutes begin to run. In some states this the time is delayed from starting until the patient reaches the age of majority. Additionally, there are individual interpretations as to whether the statute applies at the time when the patient discovers the act or when the act was committed. Considering this, the AAO states that the best manner in handling this dilemma is "simply to retain the records indefinitely" [31]. This sentiment is echoed in other papers as well [24,26,32], which may lead some to believe that this is the wisest course of action.

1.2.4 Digital Models

1.2.4.a Advantages of Digital Models

While plaster models have their many uses clinically, the manufacturers of digital models have developed reasons to switch model formats. The two more established companies, Geodigm (emodels) and Cadent (OrthoCAD), both list ten advantages on their respective websites [33,34].

- *Storage*-the models are stored on a computer, freeing up space. In addition, there is 24-hour access online
- *Multiple Site Access*-the digital models may be accessed from any computer via the Internet, provided the computer has the free software loaded on it
- *Retrieval*-digital models may be viewed instantly, saving staff time
- *Backup*-copies of the digital model are backed up at a service center for 10 years (Cadent) or indefinitely (Geodigm). This ensures that any glitch on the orthodontist's computer is covered.
- *Communication*-digital models may be printed or sent via e-mail to other dentists and dental specialists, allowing for improved interdisciplinary treatment planning
- *Speed*-digital models can be downloaded automatically or manually on a secure connection. As this can be done at night, it saves employee time

- *Convenience*-the same materials needed for traditional impressions and bite registration are required for digital model fabrication
- *Diagnostics*-both companies offer diagnostic tools such as extractions, placing brackets, moving jaws, etc, allowing quicker evaluation of possible treatments.
- *Cost Effective*-the models may be reproduced on an as needed basis. Also, as treatment efficiency increases and retrieval/storage time decreases, the staff will have more time for patient care
- *Enhanced Revenue*-due to the state-of-the-art digital model patient satisfaction, adoption, and revenues may be increased.

Again, these "advantages" or reasons to use digital models are offered by the manufacturers of the product. Orthodontists currently using plaster in their offices may not agree with these, but it is interesting to explore the possibility that many facets of traditional modus operandi in orthodontics may be either inefficient or worth changing.

In addition to the manufacturers of the digital models, others in the orthodontic community see advantages to the digital model. Ackerman and Proffit[35] state that all elements of the craniofacial complex will be able to be analyzed in either a static or an animated format. They also mentioned the ease of rearranging teeth on a computer screen rather than resetting them in wax. Eventually, these authors see the digital model replacing not only the plaster model, but also the articulator used to analyze the bite, saying that the articulator will be" relegated to a historical curiosity" [35].

Industry as a whole has been changed by the use of computers. As stated before, orthodontists have used computers for many years, but have only begun to understand their potential uses in the past few years. Once of the greatest advantages to using a computer is when dealing with measurements. Several studies have shown that computer models can be used to measure to the hundredth or thousandth of a millimeter [5,12,36-39]. Redmond [40] states that OrthoCAD can be measured to within 100 microns (0.1mm), whereas emodels is said to be accurate to 0.01mm [41]. While measurements this precise are not needed clinically, they support the argument that digital models are in fact a viable tool for evaluating several aspects of the dentition, especially when considering that plaster models have been shown to have shortcomings [42,43].

Plaster models are commonly used in treatment planning. Using a hand caliper and plaster models, many important measurements may be gathered. While the computer allows one to attain a level of accuracy that is clinically irrelevant, it has been shown to be somewhat less exact when used by the orthodontist to make true measurements. These differences have again and again been deemed statistically insignificant [44-47]. Zilberman et al [48] reiterated the fact that plaster may be more accurate, but added that OrthoCAD's accuracy is clinically acceptable. He anticipated that, considering the advantages offered, the digital procedure would become the standard for future orthodontic clinical use.

1.2.4.b Digital Models and Treatment

Harrell et al [49] were bold enough to predict the future of digital models. Along with improving the clinician's ability to determine treatment alternatives, the authors suggested that the 3-D model could be used to evaluate a fourth dimension, time. It was suggested that this new technology could allow an orthodontist to better examine final treatment outcomes. Citing work done in British Columbia [50], Harrell describes the use of digital models to predict muscular, occlusal, and articular movements in a simulated computer session. This dynamic model allows all parts (teeth, soft tissue, muscles, etc.) to move individually. It is conceivable that orthodontists and surgeons could use this technology to improve treatment presentation, determine options, and more exactly forecast final treatment outcomes with greater confidence. Surely, the dynamic model could offer greater interdisciplinary treatment planning.

Often times a patient will present with crowding that may be due to a myriad of variables. It is not uncommon for an orthodontist to ask a lab technician to take plaster models, section the teeth, and reset them in wax in varying patterns to determine how/if the teeth can be incorporated into the arch; that is, it may be necessary to remove teeth to accommodate a solid occlusion. OrthoCAD and emodels [33,34,41,51] both offer technology allowing for simulated extraction of teeth and subsequent closure of spaces to permit the orthodontist to determine if the extraction pattern is correct (Figure1.1). This is advantageous in that it can be done in much less time than with plaster models. Included in this feature is a color coded bite registration which shows not only where the patient is biting, but also a force load comparison.

Furthermore, both companies are working on or have brought to market a tool which will allow for orthodontic bracket placement on a virtual model. When sending in a digital model impression the orthodontist may select which prescription and manufacturer of bracket he uses. The model companies will place the brackets on a digital model for the orthodontist to view and will allow him to simulate treatment by adding archwires. The orthodontist has the ability to change where the brackets sit on the teeth and, with the click of a mouse, the treatment will reoccur with the new bracket positions (Figure 1.2). For an added cost, Cadent will send the doctor a tray with brackets ready to be placed in the patient's mouth (Figure 1.3). This technology is fascinating, and it has been used in similar applications with the Invisalign orthodontic appliances. As seen with the other companies, Invisalign is "like doing a setup on a computer" [52]. The doctor "treats" the case on a computer before the appliances are made. Once approval is granted from the doctor, fabrication and shipment commence, and a digital model is all that is needed to produce the clear plastic trays the patient wears.

A newer technology that is being explored is the SureSmile[38] process. The orthodontist uses a direct 3-D scanner to pass over the teeth in all directions, capturing every aspect of the teeth. Using a grid which the scanner places on the teeth, the images are recorded on a camera in the scanner's handle (Figure 1.4). Each arch is scanned in about 90 seconds. A virtual setup can then be performed, for each tooth can be moved independently in all three dimensions. The basic features of the setup and treatment planning are similar to other digital model companies, but with the SureSmile process once the bracket placement has been checked, a robot will produce archwires in sizes and shapes selected by the orthodontist. The accuracy level is reported at less than 1 degree (or 50 microns)[53] of error in bends and twists. It is hoped that wire bending can be kept to a minimum this way, and that undesirable tooth movements can also be reduced. No further research to support this advance has been published.

Storage and portability are issues that cannot be rivaled with a plaster model. While the plaster model has been shown to be cumbersome, a digital model takes as little as 800kB (emodels) and no more than 3MB (OrthodCAD) (Figure 1.5). So, for less than

$1 a 650-700MB disk can hold between 200 OrthoCAD models and 850 emodels [21]. Likewise, a standard 40GB hard drive could hold more cases than any single orthodontist could treat (between 13,000 OrthoCAD and 50,000 emodels patients). Once these images are registered in a database, they can be viewed wirelessly at a meeting or on the road. Or, with special software, they can even be viewed on a handheld Pocket PC [54,55] (Figure 1.6).

1.2.5 Reliability and Dental Decision Making

Stevens [44] noted that for a paradigm shift to occur in the way models are used three conditions must be satisfied, namely that information must be accurate, available, and decipherable. These statements applied to the tool being tested, as changing a gold standard is an involved process. But what of the raters using the tool? Really, the *accuracy* is a two-tiered question. On the one hand the tool must display precision, yet on the other hand the rater must also demonstrate *accuracy* (or reproducibility) with the tool.

1.2.5.a Decisions Related to Sequential Records

Standard orthodontic records consist of a panograph, a cephalogram (and tracing), photos, and a set of plaster models [27,31,56]. Although this study deals with the effectiveness of only one component in this set of clinical information, to remain consistent with other studies that have been carried out the full patient record as described above was provided in this study.

The most cited work dealing with consistency and records was carried out by Han et al [19]. The purpose of the study was to examine how information obtained from incrementally supplied records contributes to treatment decisions. In this study five orthodontists evaluated the pretreatment records of 57 Class II, Division I patients. These patients were chosen to reduce the number of variables that could be introduced, keeping patients in one major diagnostic group. Once a month for five months the records were presented to the orthodontists. Each time the records varied and they were given in the following order:

- Study models only (S)
- S + Facial photographs (F)
- S + F + Panoramic radiograph (P)
- S + F + P + Lateral cephalogram (C)
- S + F + P + C + Tracing (T)

At each session the raters were asked to suggest treatment from a "decision tree." A complicated formula was used to eliminate certain decisions and errors, and it was determined that the "diagnostic standard" was the record set 4 (S + F + P + C).

Over the course of the study, the intrarater consistency of treatment plan decisions ranged from 53% to 73%, averaging 65% for the group. According to the authors, these numbers were lower than expected. Decisions made for adult patients had the highest reliability (76%), and those made for patients in the late mixed dentition were the least constant (56%). Han concluded that by and large (55%) *study models alone provided treatment plans that were "equivalent to the diagnostic standard" or full record set.* However, no mention was made by Han regarding the possibility that introducing photos first could have yielded the same results. For this reason, it cannot be conclusively shown that models are the *most important* component of the patient record.

Previous to Han et al's research, Greenhill and Basford [16] conducted a similar study where they asked four orthodontists, four general dentists, a periodontist, and two non-dental staff to rate severity of treatment need for 30 cases. The records were given in three sequential groupings one month apart, and again study models alone were given first. As before, adding more extensive diagnostic records were not shown to affect the priority assessments. Orthodontists were described as being more consistent in appraising treatment need than other raters, yet neither the orthodontists nor the dentists changed priority scores significantly between the first and the third evaluations.

A major flaw to the scientific process in this paper seemed to revolve around the fact that the groups weren't balanced well: four specialists who routinely relieve malocclusion, four general dentists, *one* periodontist, and *two non-dental* staff members. Involving an untrained observer and then comparing how he/she rates cases over time and with differing records seems less valid than asking a Ford salesman to give an opinion on a new Chevy truck. The dental professionals should be more consistent than the staff members, and any other report would cast a dim light on the care the public should expect.

1.2.5.b Perception of Malocclusion

Patients often seek multiple opinions regarding orthodontic care. In doing so they are often surprised to find that there are many answers to the same question: what is required to straighten the teeth? This depends on many factors, yet arguably the most important is the degree of malocclusion as determined by the clinician. Many methods have been developed to gauge treatment need: treatment priority index (TPI), occlusal index (OI), peer assessment rating (PAR) index, handicapping labio-lingual deviations (HLD) index, handicapping malocclusion index, the index of orthodontic treatment need (IOTN), and the index of complexity, outcome, and need (ICON) [44,57,58]. Of these, there is no "truth" or "gold standard" that exists to determine the need for orthodontic care [57].

Keeling[57] looked at seven orthodontists who examined and rated the malocclusion on 52 elementary schoolchildren (6281 children were screened). The children had a mean age of 9.38 years and were 48% male and 75% white. Generally, the median Kappa statistics (*Table 1.1[59] is provided at the end of this chapter for interpretation of previous research results found in the orthodontic literature)* showed that the interrater reliability was poor for maxillary and mandibular AP positions (.22 & .25, respectively), incisor exposure (.24), interlabial gap (.26), and maxillary crowding (.36). Moderate reliability was demonstrated for mandibular crowding (.45), facial convexity (.48), overbite (.59), overjet (.67), and molar classification (.68-right, .72-left). The Kappa statistics for untrained dentists were much lower (.37) when examining molar relationship as cited in this study. Only for posterior crossbite was the Kappa score deemed excellent (.79).

Experience in determining need for treatment has been placed in question. Berk et al [60] asked three groups of dental practitioners to review 137 casts and give their opinion as to whether the patients required orthodontic treatment. The groupings consisted of 10 general dentists, 18 orthodontists, and 15 pediatric dentists. The basic question to be answered was "to what extent does this occlusion need orthodontic treatment?" Responses were merely scored 1-7, 1=none/minimal and 7=great. Results from this study showed that intragroup (dentists scored against dentists, etc.) reliability was extremely high for each group, with the following mean Kappa values: general dentists 0.865, orthodontists 0.896, and pediatric dentists 0.951. Between group reliability testing showed values that were lower: general dentists 0.733, orthodontists 0.835, and pediatric dentists 0.808. Thus we see that all groups of dental practitioners scored well for determining need for treatment, but orthodontists were slightly more reliable when compared to the other doctors.

Lewis [61] also found that degree of malocclusion and need for treatment were consistently well measured between raters. In his study impact on facial-attractiveness was the most reliable score reported.

1.2.5.c Extraction Decisions

The need to extract teeth has been a topic of controversy for many years in orthodontics. Debating such an issue is not productive as every clinician can justify his decisions by demonstrating good treatment results on past cases where a similar decision is made. Weintraub et al [62] states that no controlled clinical trials have established relative value of either strategy, and orthodontists tend to adopt a protocol with some degree of aversion to or bias toward extractions. Ribarevski et al [63] echoed these sentiments, adding that there is a lack of scientific substantiation behind extraction decisions. Therefore, extraction decisions may direct orthodontic treatment planning decisions toward inconsistency.

Having acknowledged this division of opinion, it is not expected that orthodontists would agree *between* themselves as to the need for extraction. Conversely, it would be expected that *within* them there would be a good correlation. Ribarevski et al [63] looked more closely at this by soliciting ten orthodontists to twice examine 60 pretreatment records (full set as described previously) of Class II, Division I patients with a full range of malocclusion severity. The only factor considered was whether the proposed treatment would entail extractions. Intrarater reliability was ranged from 0.54 to 0.96, or moderate to nearly total agreement, with percentage agreement ranging from 80% to 98%. The multi-examiner Kappa statistic was figured by looking at all possible pairwise comparisons, showing the degree of agreement between any two raters chosen randomly. The Kappa value range was 0.11 to 0.73, with a mean value of 0.38. In only 13 of the 60 cases (21.7%) was there complete agreement as to extraction/nonextraction between the ten orthodontists.

Baumrind et al [64] asked five orthodontists to assess 148 cases for extraction decisions. In contrast to the previous study, he found complete agreement for extraction/nonextraction 66% of the time. This was, by the authors' admissions, higher than expected. A more exact breakdown shows that there was total accord 40% for extraction therapy and 26% of the time for nonextraction therapy. The patient pool was not limited to Class II, Division 1 individuals as in previous studies; rather, it included patients of each molar classification.

Baumrind established a protocol for defining a *borderline patient*, but it seems to lack any concrete parameters. A patient for whom different orthodontists disagreed on extraction/nonextraction therapy as the "optimum" treatment was classified as "borderline." By this standard it would stand to reason that the subjective view of the orthodontist leaves too much leeway for interpretation. A better method of determining what a "borderline patient" is might include such variables as: set minimum and maximum arch perimeter deficiencies, arch curves, molar relationship, and overjet/overbite.

A study[17] evaluating whether articulation of study casts would affect treatment planning decisions, based on a wide range of malocclusions. Raters were asked to make decisions by holding models in their hands (H1) at the first visit. At the second session raters examined the models on an articulator (A1). A third session was done by hand (H2) and the decisions were compared based on H1 v H2 and H1 v A1. There was excellent agreement for all treatment planning decisions except extractions. Here, there was greater reliability for extraction decisions between H1 & H2 (0.73) than for the articulated group H1 & A1 (0.55). In fact, all H1 & H2 Kappa values were higher for all decisions except one (need for removable appliance). The results of this study show that articulation of study models did not affect the treatment planning decisions in a meaningful manner. Hand articulated models had equally high agreement over the wide range of cases, yet the author indicated more research could be undertaken to determine if articulation of study casts is case specific.

1.2.5.d Treatment Planning Decisions

A common experience in a graduate orthodontic residency is for a resident to ask for an opinion about a case from whichever instructor is in the clinic that day. If the same case was shown to each instructor in the program, then invariably there would be multiple treatment plans for the same patient. The adage stating that if you ask ten orthodontists about a patient, then you'll get back 11 opinions seems true.

Lee et al [65] looked at the factors which influence consistency in treatment planning decisions. Ten orthodontists looked at 60 pretreatment case vignettes on two occasions and were asked to answer the following questions:

- Is treatment necessary?
- Are extractions needed?
- Is orthodontics alone enough? Or is surgery required?
- Is growth modification treatment required?

The Kappa statistic level of intrarater agreement within raters was 0.66 (range 0.24-0.90) for treatment need, 0.63 (range 0.53-0.80) for extractions, 0.61 (range 0.14-0.81) for functional appliance, and 0.58 (range -0.02 to 1.00) for surgical need. Between orthodontist levels of agreement, they had mean kappa values of 0.54 for treatment need, 0.40 for extractions, 0.46 for functional appliance, and 0.36 for surgical treatment. These values illustrate once again that orthodontists don't always agree with each other or with themselves for that matter. Levels of agreement were lowest when the contrasts between variables were small. Put another way, more cases classified as severe elicited more congruity. In the author's opinion, the orthodontists appeared to be using cephalometric data to make decisions rather than clinical (study cast/photo) observations in patients where growth modification was considered. This was based on the fact that increased skeletal discrepancy led to increased agreement. Surgical decision agreement was thought to be based on amount of skeletal discrepancy for the same reason. Age and amount of overjet were also considered major influences in the decision to recommend surgery, yet no statistical analysis of these opinions was provided.

Luke et al [66] described the unique nature of orthodontics in dentistry as less concerned with diagnosis and treatment of a specific disease and more concerned with norms for growth and development of the face and occlusion. All too often interpretation of a norm or application of an established norm dictates to what extent a patient will be treated. Improved definitions of diagnostic criteria along with research to redefine the classification of orthodontic problems may be needed to assist orthodontists in communicating their treatment planning decisions.

Pair et al [43] studied the diagnostic assessment of study casts by providing rigid, clear definitions of diagnostic subcategories. The hypothesis was that orthodontists could improve on scores from past studies by using these objective guidelines. Ten pretreatment sets of study casts were evaluated by 30 orthodontists in the Los Angeles area and scored for seven diagnostic subcategories. All groups returned what the authors termed "acceptable" reliability with the intraclass correlation ranging between 0.87 and 0.98. The authors implore the orthodontic community to standardize the definitions of commonly used subcategories. This would facilitate communication between colleagues and allow investigators a format to compare research more readily. Although the orthodontists who participated in this study were trained before the data collection, some of the definitions were different from those the raters might have been using in practice. For this reason even the standardized, clear guidelines may introduce error and bias. Unless all orthodontists are trained in the same terminology this will continue to be a problem.

1.2.5.e Digital Models and Reliability Measures

Although the digital model technology is new, attempts have been made to test their reliability in reproducing basic measurements used in orthodontics to assist in diagnosis and treatment planning. Often in a clinical setting a clinician will measure teeth with a caliper to determine tooth size and relationship to opposing/adjacent teeth.

Santoro[47] assessed tooth size, overbite, and overjet by asking two examiners to measure plaster models with a Boley gauge and periodontal probe independently of each other to test the interrater reliability. The values were recorded to the nearest 0.1mm and 0.5mm, respectively. The same efforts were made with the digital model, using the OrthoCAD software to measure to the nearest 0.1mm. For the ease of the evaluators, each tooth measured was enlarged 2-3 times using the built in magnifying tool. At this point the examiners' measurements from the two model formats were compared via Pearson correlation (P<.0001), indicating good interexaminer relability. There was a statistically significant difference (P<.05) between tooth width ("tooth size") and overbite measurements between the two model methods, with the digital measurements reading lower than the corresponding plaster measurements. The range in mean differences was from 0.16mm (Upper R 1st Molar) to 0.49mm (overbite). However, the author does not report this difference as being clinically significant, claiming this was most likely due to alginate shrinkage during the transportation to OrthoCAD. Overjet measurements were not found to be statistically different. The mean difference for overjet was found to be .0098mm.

Intraoperator reliability was discussed by Garino and Garino[45], wherein repeated landmark positions and digitization of the same points on stone and digital casts was examined. Sixteen different measurements were identified by the first examiner, and each was repeated for accuracy by a second examiner. This was done two times by both examiners using a digital caliper with the stone casts and the OrthoCAD 3D software's virtual caliper. The difference between the two means of measurement obtained by the same operator (at two sessions) was used to compare the means of the stone and digital casts. For *all sixteen* points and landmarks the digital model was more precise. Additionally, an evaluation of variance did show a lesser dispersion for the digital casts.

The fact that the digital casts were more precise was explained by the authors to be related to resolution. The OrthoCAD caliper has a resolution of 0.1mm (100 microns), while the manual caliper has a resolution of 0.5mm (500 microns). According to the authors this leads to the conclusion that same value measurements on traditional plaster models will not be as precise as their virtual counterparts.

More recently Stevens[67] conducted research at the University of Alberta using the Geodigm software to test the same general hypothesis that was tested in the previous two studies: that rater reliability with common measurements is similar between plaster and digital models. Three examiners working independently recorded measurements on 24 plaster casts and emodels (tooth size, overbite, overjet) to the accuracy of 0.01mm from the direct occlusal view. The Concordance Correlation Coefficients for intra examiner reliability were 0.923 for plaster and 0.882 for emodels. As for inter examiner comparisons, they were 0.851 for plaster and 0.835 for emodels. According to the author these values all rank as "excellent" because they were above 0.75.

In his study Stevens did not identify a statistically significant difference in intrarater and interrater reliability with regards to tooth size measurements and Bolton 6 (upper and lower anterior tooth size relationships). However, there were statistically significant differences with respect to overbite and anterior crowding. The digital models indicated more anterior crowding than the plaster models (P=0.003), although this was not deemed clinically relevant. Plaster, on the other hand, led the examiners to predict larger overbite measurements (P=0.001).

Each of these authors[45,47,67] found slight differences in the measurements between the plaster and the digital models. However, none reported that the differences would affect the clinical measurements of a person using the new digital tool. But in the private office these measurements are often not made. Having established both the OrthoCAD and emodels as reliable measurement tools, it would seem obvious that a more commonly used application would need to be tested.

1.2.6 Summary

Plaster models have been shown to be the most critical component of the orthodontic record as relates to treatment planning. Whether those models are held in the hand or are mounted on an articulator, they still provide valuable information needed to make clinical decisions. Their place as a gold standard has not been successfully challenged to this point. However, current technology has opened the door for a possible paradigm shift in the way models are used in the orthodontic office.

With all of their potential advantages over their plaster counterparts, digital models appear to be the future of orthodontics. Many studies have been performed to evaluate the reliability of plaster models when used as a tool, measuring the reliability of the orthodontists using the models. While results varied, they did not discredit the tool.

In light of the research that has been done to test and prove the reproducibility of digital model measurements, it would now stand to reason that their use as a treatment planning tool should be tested. If they can be used as reliably as plaster models, then the gold standard may soon be changing.

1.3 Figures and Tables

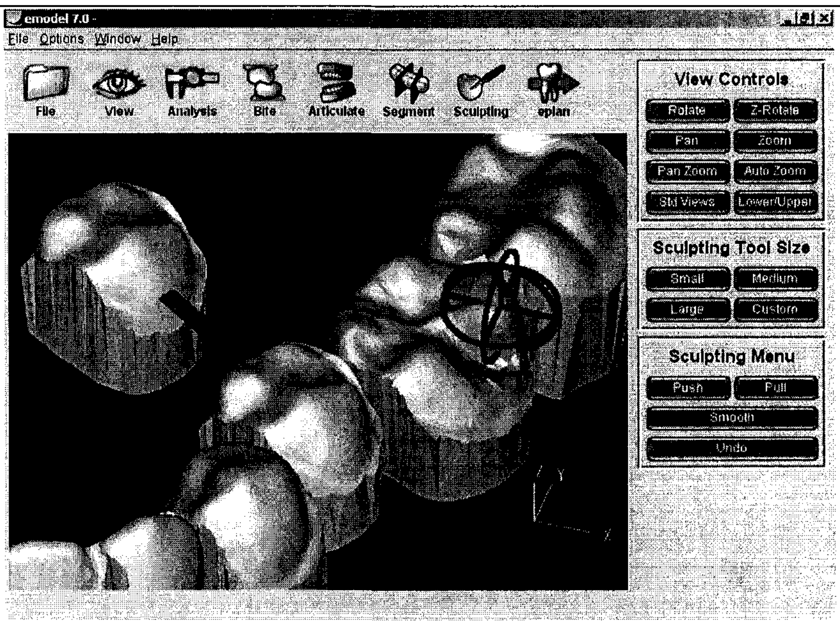

Figure 1.1-Sculpting a Digital Tooth
In preparation to extracting teeth or doing a surgical setup, each tooth must be sculpted individually to assure proper fit. Once this step is complete the orthodontist may take teeth out, isolate and rotate teeth, and put them back in as desired.
(Still image taken from www.dentalemodels.com)

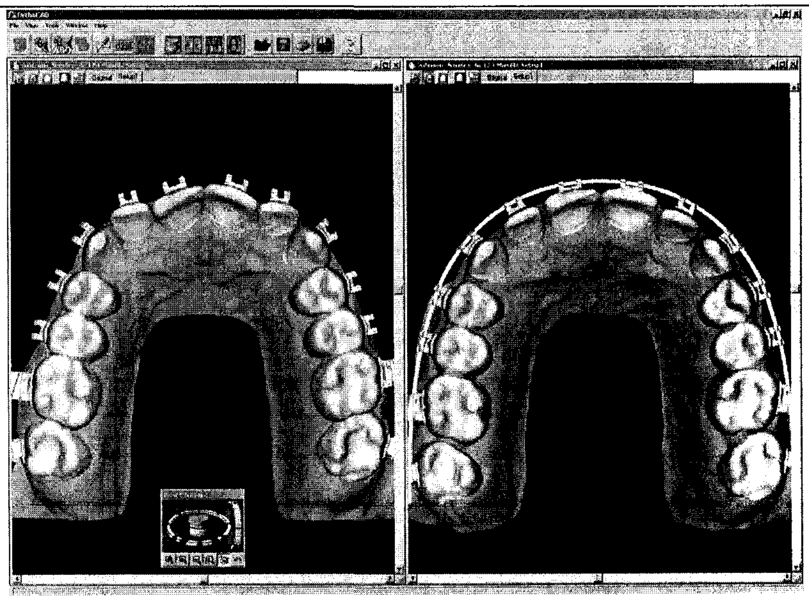

Figure 1.2-Virtual Bracket Placement Tool
The doctor selects the particular manufacturer and prescription of brackets to be used. Treatment is simulated as though the patient had gone through a rectangular NiTi wire to see the how the rotations will be worked out.
(Still image taken from www.orthocad.com)

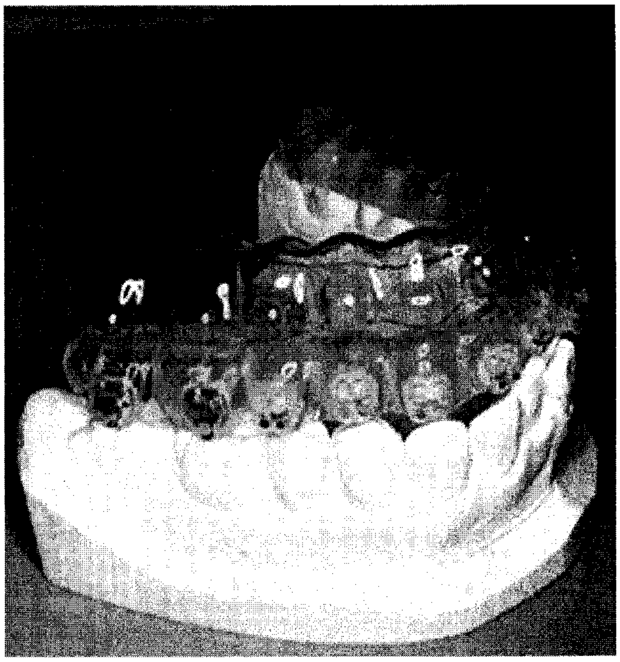

Figure 1.3 Indirect Bonding Tray Made from Digital Model/Impression
Once a digital model is made and the orthodontist has chosen the bracket system, a virtual setup of the case is made. The orthodontists may alter the placement of the brackets as desired. Once final approval has been granted, OrthoCAD fabricates a bracket placement tray for the initial appointment.
(Still image taken from www.orthocad.com)

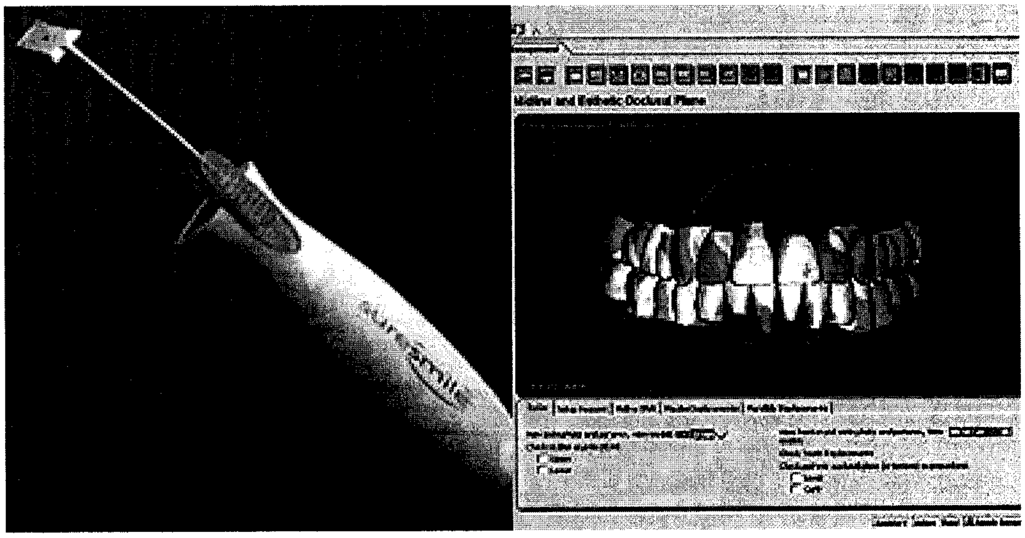

Figure 1.4 –The SureSmile Process
The oral scanner seen above is passed over the teeth in each arch for 90 sec/arch. The image seen at the right is created in real time as the teeth are scanned. From here a robotic arm bends wire to match the treatment plan set forth by the orthodontist.
(Still images taken from www.suresmile.com)

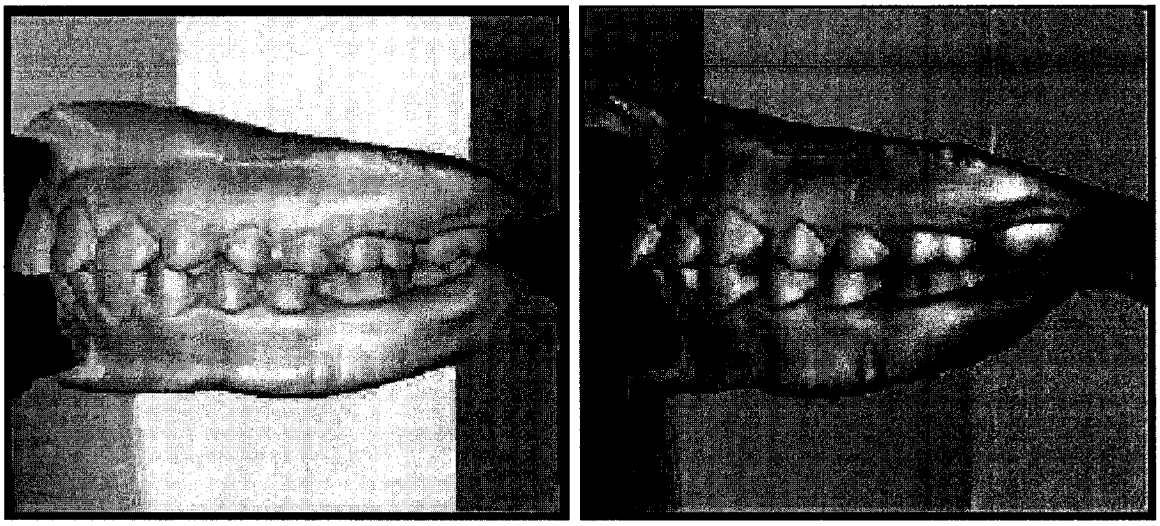

Figure 1.5--emodel Molar Relationship Rotated on Z-axis
The digital image seen is the left buccal view from two different orientations. Note the slight difference in molar and canine appearance. Digital models require only 600kB to 3MB or space, making them ideally suited for storage.
(Still images taken from www.dentalemodels.com)

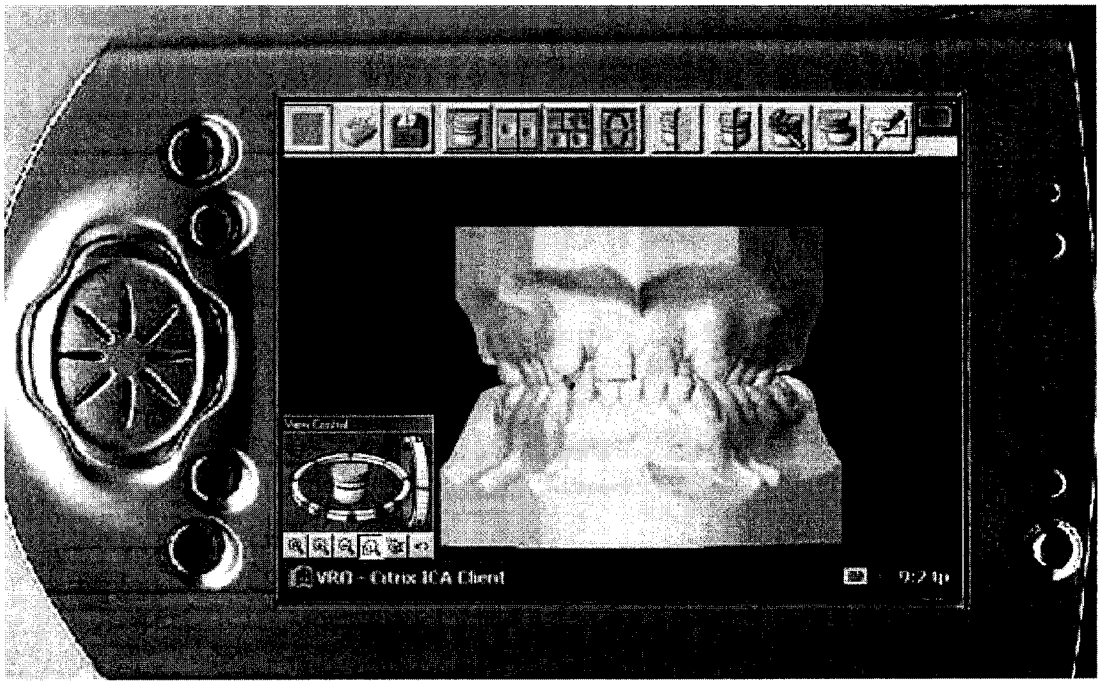

Figure 1.6-Digital Model Portability
OrthoCAD digital model on a Pocket PC handheld device. The small size of digital files makes portability manageable and communication more effective.
(Redmond WR, AJODO 2001, 120 (3):325-327)[54]

Table 1.1--Kappa Statistic in Orthodontic Literature

Kappa Statistic	Strength of Agreement
<0	Poor
0-0.2	Slight
0.21-0.4	Fair
0.41-0.6	Moderate
0.61-0.8	Substantial
0.81-1.00	Almost Perfect

(Richmond S, et al, Br J Orthod 1994;21:65-68)[59]

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1.5 Research Questions

This study aims to determine whether there is a difference in treatment planning decisions based on the type of model the practitioner uses as part of the pretreatment record. The following research questions specifically address this objective:

1.5.1 Primary Research Questions:

1. Is there a difference in treatment planning decisions made by orthodontists based on study model format?
2. Is there any difference in intrarater reliability measurements for surgery, extractions or auxiliary appliances based on study model format?
3. Does one type of model format lend itself to more extensive or aggressive treatment decisions? That is, will either format bias orthodontists to do more surgery, extractions, or auxiliary appliances?

1.5.2 Secondary Research Questions:

4. What are the attitudes of the participating orthodontists regarding digital models?

1.6 Null Hypotheses

1. There is no difference in orthodontic treatment planning decisions between utilization of plaster study models and virtual 3D models in Class II subjects.

2. One type of model format does not lend itself to more extensive or aggressive treatment decisions. That is, neither format biases orthodontists to do more surgery, extractions, or auxiliary appliances.

Chapter Two

Research Paper

Variation in Orthodontic Treatment Planning Decisions Of Class II Cases between Virtual 3D Models And Traditional Plaster Study Models

2.1 Introduction

Over the past twenty years computers have become a mainstay in almost every workplace. In the 1990's digital radiographs, photographs, and electronic charts were introduced to the orthodontic practice. In 1999, OrthoCAD (Cadent, Carlstadt, NJ, www.orthocad.com) was brought to market at the annual session of the American Association of Orthodontists. In 2001, emodels was introduced to offer another representation of the virtual model (Geodigm Corporation, Chanhassen, MN, www.geodigmcorp.com.). In 2003, a third version of the digital study model was offered when Orthographics was introduced (Ortho Cast, Inc., High Bridge, NJ, www.orthocast.com). These services allow an orthodontist to receive a 3-D computer image of the patient's teeth within a matter of a few days simply by sending in an existing model or a dental alginate impression. The image may then be downloaded and viewed using free software available from the supplier website.

The reasons for incorporating or ignoring digital technology are varied. Many orthodontists are comfortable using the traditional records they have relied on for years. Others integrate plaster models with digital photographs and radiographs in their offices. In doing so, these orthodontists are already using software which utilizes digital photographs and radiographs to treatment plan, write referral letters, predict growth, etc., leaving models as the last element missing from a fully digital treatment record.

As with all technologically related fields, digital orthodontics changes rapidly. The research literature yielded several articles dealing with the degree of dimensional precision associated with digital model fabrication and laser surface scanning[1-4]. Other research considered the accuracy of the digital model versus plaster in measurements.[5-8]

To date, all published articles have dealt with the OrthoCAD version. The digital model format to this point has not been used in a clinical trial to test reliability of decision making.

Orthodontists' reliability in patient classification and treatment planning decisions using traditional tools has been previously reported.

Lee[9] evaluated intrarater and interrater reliability of treatment planning decisions, specifically noting treatment need, extractions, functional appliance, and surgical need. He found that orthodontists' reliability was generally substantial[10] when compared to themselves, but was only fair when compared to one another. Others have examined extraction decisions[11,12] between orthodontists, but their results were conflicting, with one study showing substantial agreement and the other fair. This inconsistency is possibly due to the way orthodontists define terms that are seen as commonplace. It has been suggested that unless all orthodontists are trained in the same verbiage this will continue to be a problem[13].

Malocclusion[14,15], study cast mounting[16], and determination of treatment need[10] were all looked at in separate studies. Each study showed varying degrees of concurrence. Whenever the orthodontists were scored against one another they had considerably lower level of agreement than when scored against themselves. Study models were found to be the most important component on treatment decision making[17,18].

Luke[19]suggested that orthodontics is not concerned with diagnosis and treatment of a specific disease. The use of population "norms" to contrast with a particular individual introduced the need for clinical judgement.

The effectiveness of digital decision making has not been elucidated. In particular, there is a need to examine the consistency in orthodontic decision making between traditional plaster models and the virtual format. If there is consistency between the two (especially when compared to similar trials with controls), then the technology of digital models could seemingly replace its traditional counterpart.

The primary objective of the present study was to see if there is a difference in intrarater agreement measurements for surgery, extractions or auxiliary appliances based on study model format; that is, if discordant pairs in treatment decisions are statistically attributable to model format. A second objective was to evaluate whether one type of model format lends itself to more extensive or aggressive treatment decisions. That is, does one format bias orthodontists to do more surgery, extractions, or use auxiliary appliances?

2.2 Methods and Materials

******This study was approved by the Human Research Ethics Board at the University of Alberta. (Appendix H)*

2.2.1 Selection of Cases

The principal investigator obtained names for 107 patients who exhibited at least an end to end relationship on one side. All patients were in treatment at the University of Alberta during the Spring of 2003. All cases were evaluated for the following criteria:

- ANB angle between 4°and 9°
- positive overjet of at least 4 mm
- at least 13 years old at the time of records
- at least 1/2 step class II molar relation, at least on one side (Figure 2.1)

Twenty-four patients remained and fifteen were randomly chosen from these to be evaluated by a focus group.

A focus group consisting of three University of Alberta orthodontic instructors, all with a minimum of 3 years clinical experience evaluated the 15 sets of pretreatment records. The cases were then ranked by the focus group according to treatment difficulty. Ten cases were selected by the group to make up the patient record pool. Two records from the more extreme ends were selected as "almost surely surgery" and "almost surely not surgery". Six more cases were taken as "truly borderline" cases. The pretreatment records, including study models, extraoral photographs, panoramic radiographs, lateral cephalograms (and tracing), were duplicated[17] and constituted the patient information given to the orthodontist sample.

For the digital model, a duplicate set of plaster models and a wax bite wafer for each patient were sent to Geodigm Corporation (Chanhassen, MN) for registration and model fabrication. The duplicate model was sent for scanning to digital format so that the plaster and digital models were more closely comparable (both duplicates of the original). Additionally, an eleventh case (class I malocclusion) was selected to serve as a test case to familiarize practitioners with the model technology the day of treatment planning.

The examiners and records were each assigned a code number for blinding, to maintain doctor anonymity, and protect patient confidentiality. Both the orthodontists and the patients gave consent for use of their information in this study.

2.2.2 Selection of Orthodontists

Lists of practicing orthodontists were obtained from the Alberta Society of Orthodontists and the Nevada Orthodontic Society, randomized, and orthodontists were contacted to participate. For the variable group, 10 orthodontists from Las Vegas and 10 from Edmonton was the goal, so 13 from each city were contacted to allow for dropout. If a selected orthodontist was practicing with a partner(s), then all practitioners in that office were asked to participate. Twenty three of the 26 contacted orthodontists agreed to participate in the study, and 20 of the 23 who agreed to participate completed both study sessions. Of the 3 orthodontists who did not complete both trials, one had the information get lost in international mail, one was relocating to a different office, and one was renovating his office. The three orthodontists who were contacted and did not participate at all did so because there was no articulator use (two) or declined due to time commitment (one).

To be included in the variable group, the orthodontists could not have used a digital model in treatment planning prior to this study. A list of orthodontists in N. America using Geodigm emodels technology was obtained from 3M Unitek (who was partnered with Geodigm in the technology at the time of data collection). Additionally, each orthodontist contacted was questioned regarding familiarity of digital models before being included in this study. Those who had used digital models were taken into consideration for inclusion only for the control group.

For the control group, letters were sent to 13 orthodontists in Edmonton, Alberta, and Calgary, Alberta. Eleven orthodontists responded positively, with all eleven treatment planning the cases twice. Two did not respond when contacted by phone to confirm that the letter arrived. This group was provided as a control group regarding the digital model tool.

2.2.3 Decision Flow Chart

A decision tree (Figure 2.2) was adopted from Han et al[17] and modified to fit the particular cases in this study. The same tree was given to both the variable and control groups. "No treatment" was not an option on the chart as the study was looking for treatment consistencies, and for the surgical cases fixed banding was assumed. Three major categories were targeted in this study for agreement:

- surgery/no surgery
- extract/do not extract
- auxiliary appliance/no auxiliary appliance.
  (RPE, Headgear/Facebow, Frankel, Herbst, Bionator, other)

2.2.4 Data Collection

For the variable group, two treatment planning sessions were scheduled, with at least a one month interval between sessions. Orthodontists were given either the digital model or the plaster model version of the records at the first meeting, with the alternate format given at the second session. For the digital model sessions, the models were brought to a location chosen by each orthodontist and shown on a laptop. The trail model was used to familiarize the orthodontists with the software and model manipulation. The principal investigator was present to answer technical questions relating to software use. No auxiliary help was needed for the plaster session. At each session the orthodontists marked the treatment(s) of choice that they would recommend to the patient, assuming no precluding factors to treatment. Each orthodontist was asked to arrive at a final treatment plan based on what he or she felt was the treatment of choice in his or her office, with patient options not affected by financial restraints. There was no "correct" treatment plan, as each orthodontist's treatment plans were tested only against themselves. There were no time limits to eliminate an individual orthodontist's variance in methods of deriving a treatment plan.

For the control group, two treatment planning sessions were also scheduled at least one month apart. Both of the sessions were done using the plaster record format, with the cases presented in random order. No one provided technical support, as the records given are considered standard. Each orthodontist's selected treatment was based on the same assumptions as previously described and the scoring was handled in the same manner.

2.2.5 Analytical Methods

**All data was examined using SPSS 11.5 (SPSS, inc., Chicago, IL, USA) statistical analysis software.*

2.2.5.a. Variable Group

The traditional set of plaster models, in conjunction with the other materials, was considered the "gold standard" by which diagnostic and treatment decisions made with the digital model should be compared. McNemar's test provided a method of evaluating where discrepancies arose.

McNemar's test is a non-parametric method using match pair labels (A,B). It is used to determine whether the occurrence of (A,B) is as likely as (B,A) in situations where the data consists of paired observations/outcomes A and B. As a result, the hypothesis being tested can be stated, "are AB pairs as likely as BA pairs[20]." Thus, the McNemar test is used to measure *discordant pairs,* regardless of concordant pairs. It is used with nominal scale data, assuming that the pairs are matched. All calculations are expressed in terms of a p-value based on the following 2x2 table[21]:

	No	Yes	Total
No	AA (a)	AB (b)	AA+AB (p_1)
Yes	BA (c)	BB (d)	BA+BB (q_1)
Total	AA+BA (p_2)	AB+BB (q_2)	AA+AB+BA+BB

The McNemar calculation is based on the following formula, df = 1:

$$\chi^2 = \frac{(|b-c|-1)^2}{b+c}$$

The data was examined both group and by case in this manner. The total number of observations in this group was 400 (200 digital/200 plaster), leading to 200 comparisons of the new tool versus the standard.

A simple Kappa statistic was also generated for surgery, extractions, and auxiliary appliance need for comparison to previous studies. The Kappa statistic was used to measure reliability, taking into account both the *discordant and concordant* pairs, as it is affected by both sets. The Kappa statistic was generated using the following formula:

$$\kappa = \frac{2(ad-bc)}{p_1q_2 + p_2q_1}$$

A proportion of agreement was calculated for each of the main treatment decisions (surgery, extraction, auxiliary appliance) as a whole, as well as by case. The proportion of agreement looks specifically at the 2x2 table to see what the observed proportion of overall agreement is. The proportions of specific agreement for negative ratings (P_{No}) and positive ratings (P_{Yes}) were also calculated. The proportions can be defined by the following formulas:

$$P_{Overall} = \frac{AA+BB}{AA+AB+BA+BB} \qquad P_{No} = \frac{2AA}{2AA+AB+BA} \qquad P_{Yes} = \frac{2BB}{2BB+AB+BA}$$

The proportions of agreement P_{No} and P_{Yes} are estimated conditional probabilities. For example, P_{No} estimates the conditional probability, given that one of the raters (randomly selected) makes a negative rating, that other raters will do likewise. A higher value for both P_{No} and P_{Yes} would imply that the observed level of agreement is higher than would occur by chance.

2.2.5.b. Control Group

To allow for comparison with other orthodontic reliability studies[9-12,19,22], the Kappa statistic was used in this group. The McNemar and Proportion tests were also used. The data was examined both by doctor and by case. The target number of observations was 200 for this group, and a total of 220 observations were obtained (110 plaster-session one and 110 plaster-session two). Thus, 110 treatment planning session comparisons were made.

2.2.5.c. Between Groups

A two independent sample t-test with equal variances assumed was used to study the percent agreement between the two groups for the following decisions: surgery, extractions, auxiliary appliance use. The percentage of time the raters agreed with themselves overall in the variable (plaster + digital models) was compared to the control (plaster + plaster). Also, the Kappa coefficients for the two groups were noted alongside the McNemar p-values to compare the variable and control groups.

2.2.5.d. Power Analysis

Previous publications did not provide suitable data for sample size prediction. To evaluate for a possible Type II statistical error a post hoc power analysis[23] was performed.

2.3 Results

**Complete data output is provided in Appendices E and F*

**A description of the cases used in this study is provided in Table 2.1.*

**A description of the orthodontist study sample by age and years of practice is provided in Table 2.2.*

**Descriptive statistics regarding the breakdown of treatment frequencies and type of surgery chosen for each set of observations are provided in Tables 2.3 and 2.4.*

2.3.1 Intrarater Agreement-Variable Group

Changes in treatment recommendation based on use of plaster and digital models are provided in Table 2.5 and statistical measures are provided in Table 2.6. There was an overall proportion of agreement for surgery/no surgery of 0.775, with matching decisions made 155/200 times. When the discrepancies arose, 22 times the digital model session gave a positive response for surgery. The other 23 positives for surgery were found with the plaster model. There was as close to an exact split in the discrepancies as possible (22/45 v 23/45). Neither the digital model nor the plaster model skewed the orthodontists to make treatment decisions regarding surgery leaning one way versus the other (McNemar p-value 1.00).

There was an overall proportion of agreement for extraction decisions of 0.785, with the same outcome 157/200 times. Differences were seen in 43 instances. Positives for extractions with the digital model only occurred 18 times whereas 25 positives for plaster only were noted. This shows that the orthodontists were slightly more likely to suggest extractions with the plaster model than the digital (25/43 v 18/43). However, this is not a statistically significant discrepancy (McNemar p-value 0.36).

There was an overall proportion of agreement regarding need for auxiliary appliance of 0.870, and total agreement was seen 174/200 times. There was an exact split between the digital and plaster positives. Thirteen positives were reported with digital only and 13 positives with plaster only. Orthodontists were not influenced to recommend auxiliary appliances more by either model format (McNemar p-value 1.00).

The Kappa statistics for the three scored decisions ranged from 0.539-0.570 (Tables 2.6 and 2.7) and are provided for comparison to the control group's outcomes. The variable groups' Kappa scores are deemed moderate by Richmond[10] (Table 2.8).

Case 8 was the most discordant case as 7 out of the 23 total positive responses for the plaster model came from this case (Table 2.9). It also turned out to be the least predictable case for surgery (McNemar p-value 0.18). The discordant pairs appeared 7 times for plaster positive only, while they appeared only twice for digital model only. There was an overall proportion of agreement of 0.55 for surgery for this case. Case 10 skewed the data for emodels somewhat as 5 out of 22 positives for surgery for the digital model arose from this case and had a McNemar p-value of .727. The overall surgical proportion of agreement for Case 10 was 0.60 (Table 2.9).

There were 104 total surgeries recommended for the digital model format and 105 surgeries for the plaster. In each case a maxilla only was suggested 4 times; a mandible only 88 (plaster) and 84 (emodels) times; a combination of maxilla and mandible 13 (plaster) and 15 (emodels) times; other surgeries were recommended 0 (plaster) and 1 (emodels) time (Table 2.4).

When extractions were indicated with emodels (98 times) there was a mean of 2.77 teeth. There was a mean of 2.70 teeth when extractions were recommended plaster models (106 times) (Table 2.10).

2.3.2 Intrarater Agreement -Control Group

The three treatment decision groups all reported non-significant p-values with McNemar's test. Surgery and extraction had the highest (1.000), whereas auxiliary appliance listed a p-value of 0.791. The overall proportions of agreement were 0.836 for surgery, 0.818 for extractions, and 0.873 for auxiliary appliance need (Table 2.11)

The Kappa statistic values for the orthodontists as a group ranged from 0.626-0.672 (Table 2.7 and 2.12). These values are found to be in the "substantial" category according to Richmond[10] (Table 2.8)

The control group also showed consistency in the frequency and type of surgery recommended (Table 2.4). With the first plaster session there were 59 total surgeries: 1 maxilla only; 48 mandible only; 10 combination maxilla and mandible; 0 other. For the second plaster session there were 58 total surgeries: 0 maxilla only; 49 mandible only; 8 combination maxilla and mandible; 1 other surgery.

2.3.3 Intrarater Agreement -Between Groups

A power analysis was performed on the t-tests which compared the variable and control groups. However, power was too low to report the findings due to the small sample size.

2.4 Discussion

The digital model tool did not have a statistically significant effect on treatment planning decisions in Class II malocclusions. In fact, when there was a discrepancy between whether to recommend surgery or not, the discrepancies were split almost evenly (22:23) as to model format used to make that decision. The same may be said for the need for auxiliary appliances. In this instance there was an exact split between the model format used when treatment modality changed (13:13). The area of greatest deviation was that of extraction decisions, where the distribution seen was greater (18:25). Use of the plaster model tended to result in recommend extractions when the digital model did not. However, this was not a statistically significant difference.

When the cases were evaluated individually it was evident that the focus group did an excellent job in choosing the cases to be examined for this study. The focus group's choice of cases of "almost surely surgery" and "almost surely not surgery" were similarly treatment planned by the study orthodontist sample. However, even cases judged to be "borderline" were not influenced in a systematic way by model type for the variable group. In the same fashion the control group's agreement when looked at on a case by case basis solidified the recommendations of the focus group in choosing cases.

For both groups the cases which reported the lowest proportions of agreement for all major decisions were deemed "borderline" in the focus group's initial case selection.

Initially, the focus group had selected cases 1, 2, 4, 5, 8, and 10 for the "borderline" cases. Analysis shows that the lowest overall proportions of agreement seen were for cases 2, 4, 8, and 10. These cases had variables in common as seen in Table 2.1. These patients were all female between the ages of 13y2m and 16y1m. All cases had an ANB° greater than 6° with a low mandibular plane (mean 24.1°). Crowding was mild (0-2mm) in each arch, yet overjet was moderate (5-7mm). All of the patients had a discrepancy between bilateral molar and cuspid relationships, with a Class II on one side and a Class I or End on relation on the other.

Model format did not seem to alter the number of extractions per extraction treatment suggested. Neither did model format affect the frequency of treatment recommendations for any of the observations.

It is also interesting to point out that surgical type did not vary drastically depending on model type for the variable group. The control group also showed no significant difference in the types and numbers of surgeries between the first and second surgeries. This is further evidence that the model format is inconsequential as to the major treatment decisions being made.

The McNemar and Kappa test values given could be misinterpreted if not considered in context with the nature of the test. There were instances in which the McNemar p-values were non-significant (near 1.0), yet the Kappa statistic was only moderate (Table 2.6). This is due to the fact that the McNemar test considers only discordant pairs in obtaining a value, whereas the Kappa takes into account both the concordant and the discordant pairs. Thus, any change in the difference of concordant pair numbers would affect only Kappa. A change in the *difference between* discordant pairs would affect both statistics.

In the study there were ten orthodontists practicing in Las Vegas and ten practicing in Edmonton who were participants in the digital group. Both groups were very consistent in the total number and type of treatments planned, with almost no variation was shown when the model format changed.

Although a power analysis showed low power for any geographic statistical comparisons (small sample size), some trends were noticed. The Canadian group recommended more extractions in both the emodel and the plaster sessions (149 & 162) than did their American counterparts (122 & 124). There appeared to be more extraction of upper bicuspids for Class II camouflage treatment in the US. As for surgery, the Canadian orthodontists were almost twice as likely to recommend surgery when compared to their US colleagues. A total of 71 surgeries (35 emodel and 36 plaster) were recommended by the Americans; a total of 138 surgeries (69 emodel and 69 plaster) were treatment planned by Canadian orthodontists. For the auxiliary appliance, there was little difference in the number of recommended appliances. The US group recommended a total of 36 appliances (19 emodel and 17 plaster) whereas the Canadian group offered 32 total (15 emodel and 17 plaster).

According to Thomas[24], postpubertal patients presenting with a Class II malocclusion often only have two options in correcting the problem: mandibular surgery or camouflage. He also added that there is little disagreement in considering the patients who are at the extreme ends of the scale (as seen with our focus group's decisions). The problems arise when the patient is somewhere in the middle and could benefit from either option. He estimated that 15-20% of the teenage population in the United States has an overjet of 6mm or more. Proffit[25] puts that number of Class II individuals who might benefit from surgical intervention at around 10% of the population in general.

The actual choice of treatment is likely more a function of which orthodontist the patient happens to contact. Beyond the bias each orthodontist has based on characteristics such as risk aversion etc, there is very little hard evidence to justify one treatment as superior to another[26]. Orthodontics requires subjective judgment based on patient values, practitioner values and experiences, as well as many other factors.

Weaver[26] studied decisions in borderline surgery cases in Canadian orthodontists. She noted that risk-aversion was the most common attitude held, which would lend toward more extraction camouflage treatment than surgery. Perception of the cost of surgery as a burden was not a biasing factor in her findings. She alluded to the fact that there is a lack of knowledge in the orthodontic community regarding the actual fees associated with orthognathic surgery. Availability of an oral surgeon was surveyed, finding that whether the patient lived in an area with high or low surgeon availability, the recommendations were similar.

The number of years in practice, when the orthodontist attended a residency program and experience with borderline surgical cases are all important considerations as to what treatment is recommended. So, too, is the availability of surgery in a particular area due to the potential financial constraint placed on a patient. Orthodontists also have different perceptions as to the value of surgical treatments and what is truly beneficial to the patient.

One orthodontist in the study was concerned about the introduction of confounding variables by including the entire record set (photos, radiographs, models) in a study which looked at the reliability of models. The full record set was employed by as the study aimed to achieve a real life clinical situation which was justified by previous studies. Limiting the study to models only would not allow for orthodontists to adequately evaluate the patient pool selected for this study as surgery/no surgery was one of the three treatment decisions studied.

Although more results were obtained than were reported in the "Results" section, the small sample size involved in this study limited the power of these results. Geographical comparisons and between group comparisons were affected by the amount of data collected, yet would be of great interest if the power was higher (sample size larger).

2.6 Conclusions

1-There was no statistical difference in Intrarater treatment planning agreement (surgery, extraction and use of auxiliary appliances) in Class II malocclusion, based on the use of digital models in place of traditional plaster models. That is, discordant pairs in treatment decisions are not statistically attributable to model format.

2-There was no appreciable difference pertaining to recommendations of more aggressive (surgery, extractions) treatment based on model type.

3-Plaster models demonstrated a slightly higher percentage of treatment planning agreement in all three of the categories, however this is clinically insignificant.

2.7 Figures and Tables

FIGURE 2.1
ILLUSTRATION OF CLASS II
MALOCCLUSION

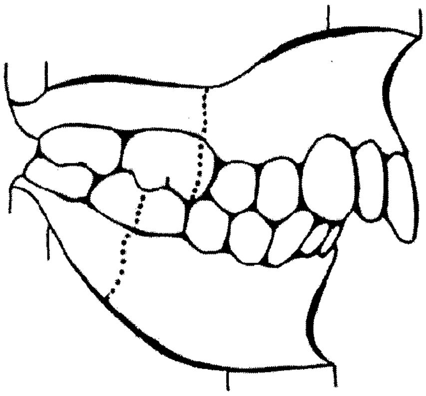

Fig.2.2 Decision flow chart for treatment planning

- Treatment Options
    - Surgery
        - Maxilla Only
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Mandible Only
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Maxilla + Mandible
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Other (i.e., SARPE)
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
    - Non-Surgical
        - Fixed Banding
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Functional Appliances (Frankel, Herbst, Bionator, Other) or Facebow or Headgear ____________(please specify appliance)
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Other (RPE etc.) ________________(please specify appliance)

Extractions: Right 8 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 Left

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

Table 2.1—Description of Cases Evaluated

	Gender	Age (years)	ANB°	MP-SN°	Crowding (mm) Max/Mand	Overjet (mm)	Molar L/R	Canine L/R
Case 1	F	13.6	5.3°	28.7°	2/0	5	End on/II	II/II
Case 2	F	16.1	6.2°	22.4°	1/0	6	II/End on	II/End on
Case 3	M	15.6	4.7°	22.3°	0/3	9	II/II	II/II
Case 4	F	15.0	6.6°	24.6°	0/0	7	End on/II	End on/ II
Case 5	F	33.6	7.3°	38.1°	0/0	4	II/I	II/II
Case 6	F	19.0	4.1°	33°	12/8	4	II/End on	II/End on
Case 7	F	14.7	9.2°	38.1°	3/7	8	II/II	II/II
Case 8	F	15.2	8°	22.5°	0/0	7	II/End on	II/End on
Case 9	F	13.1	5.2°	22.6°	7/1	4	II/II	II/II
Case 10	F	13.2	9.8°	26.9°	2/2	5	II/I	II/I

Table 2.2—Examiner comparison: age and practice in years

	Variable Group (years)	Control Group (years)	SD Variable	SD Control	p-value
Orthodontist's avg. age	40.3 (27-63)	46.55 (32-72)	11.59	14.96	.206
Orthodontist's avg. yrs in practice	11.91 (1-32)	14.57 (1-42)	10.85	14.06	. 556

Table 2.3—Frequency of Treatment Recommendations for Each Observation.

	emodel (variable)	Plaster (variable)	Plaster 1(Control)	Plaster 2 (Control)
Total surgeries	104	105	59	58
Avg Surgeries/Dr.	5.2	5.25	5.36	5.27
Total extractions	271	286	198	195
Avg Extractions/Dr.	13.55	14.3	18.0	17.73
Total aux appl	34	34	30	28
Avg Aux Appl/Dr.	1.7	1.7	2.72	2.54

Table 2.4--Frequency of Surgery Types Suggested for Each Observation

	emodel (variable)	Plaster (variable)	Plaster 1(Control)	Plaster 2 (Control)
Total surgeries	104	105	59	58
Maxilla only.	4	4	1	0
Mandible only	84	88	48	49
Maxilla + Mandible.	15	13	10	8
Other	1	0	0	1

Table 2.5--Changes in Treatment Recommendations Based on Session (Number of times a tool or session yielded a positive while the other tool or session yielded a negative for a given treatment)

		Plaster Surgery				Plaster 2 Surgery	
		No	Yes			No	Yes
Emodels Surgery	No	73	23	Plaster 1 Surgery	No	42	9
	Yes	22	82		Yes	9	50
		Plaster Extractions				Plaster 2 Extractions	
		No	Yes			No	Yes
Emodels Extractions	No	75	25	Plaster 1 Extractions	No	36	10
	Yes	18	82		Yes	10	54
		Plaster Aux. Appl				Plaster 2 Aux Appl	
		No	Yes			No	Yes
Emodels Aux. Appl	No	153	13	Plaster 1 Aux. Appl	No	74	6
	Yes	13	21		Yes	8	22

Table 2.6--Variable Group Treatment Decisions

Surgery		Extractions		Auxiliary Appliance	
$P_{overall}$	0.775	$P_{overall}$	0.785	$P_{overall}$	0.870
P_{Yes}	0.785	P_{Yes}	0.792	P_{Yes}	0.618
P_{No}	0.764	P_{No}	0.777	P_{No}	0.922
McNemar p-value (power)	1.000 (0.965)	McNemar p-value (power)	0.360 (0.815)	McNemar p-value (power)	1.000 (0.975)
Kappa Coefficient	0.549	Kappa Coefficient	0.570	Kappa Coefficient	0.539

The proportions of agreement were determined using the following formulas:

$$P_{Overall} = \frac{AA+BB}{AA+AB+BA+BB} \qquad P_{No} = \frac{2AA}{2AA+AB+BA} \qquad P_{Yes} = \frac{2BB}{2BB+AB+BA}$$

Table 2.7—Examination of Tool's Effect on Agreement

Procedure	McNemar p-value (variable)	Kappa (variable)	McNemar p-value (control)	Kappa (control)
Surgery	1.000	0.549	1.000	0.671
Extractions	0.36	0.570	1.000	0.626
Auxiliary Appliances	1.000	0.539	0.791	0.672

*Kappa statistics for variable group moderate, for control group substantial; Richmond [10]

Table 2.8--Guideline for Kappa Statistic Interpretation (Richmond [10])

Kappa Statistic	Strength of Agreement
<0	Poor
0-0.2	Slight
0.21-0.4	Fair
0.41-0.6	Moderate
0.61-0.8	Substantial
0.81-1.00	Almost Perfect

Figure 2.9—Surgery Cases Most Skewed by Model Format

Case 8	**Surgery Plaster**			***Case 10***	**Surgery Plaster**		
Surgery emodels	No	Yes	Total	**Surgery emodels**	No	Yes	Total
No	8	*7*	15	No	9	*3*	12
Yes	*2*	3	5	Yes	*5*	3	8
Total	10	10	20	Total	14	6	20

Table 2.10--Extraction Breakdown, Digital/Plaster Group

	Positive Decisions	Minimum # Teeth	Maximum # Teeth	Total # Teeth	Mean	SD
Emodel	98	1	4	271	2.77	1.092
Plaster	106	0	4	286	2.70	1.181

Table 2.11--Control Group Treatment Decisions

Surgery		Extractions		Auxiliary Appliance	
$P_{overall}$	0.836	$P_{overall}$	0.818	$P_{overall}$	0.873
P_{Yes}	0.847	P_{Yes}	0.844	P_{Yes}	0.759
P_{No}	0.824	P_{No}	0.783	P_{No}	0.913
McNemar p-value (power)	1.000 (.975)	McNemar p-value (power)	1.000 (.975)	McNemar p-value (power)	0.791 (.923)
Kappa Coefficient	0.671	Kappa Coefficient	0.626	Kappa Coefficient	0.672

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Chapter Three

General Discussion

3.1 The Digital Model as Part of the Electronic Oral Health Record

Information collected as part of the patient record has value only if and when it is available to the doctor and patient. In today's society there is a constant demand to have information more readily available. The ability to take a patient's record anywhere allows for information to be accessed and shared both rapidly and consistently with colleagues, patients, third party providers, labs, etc[1]. Transfer records could be sent and waiting before a patient arrives at a new location or consultation, even if it is the same day. However, little work has been done to examine the accuracy, confidentiality, and cost-effectiveness of teledentistry[2].

As the electronic patient record has become an integral part of the health community, it has become apparent that there is a need for standards. By striving for unity, information will be able to be transmitted more efficiently, with less time wasted deciphering what has been communicated and more time dedicated to patient care. The information must be decipherable to be useful. To this end the American Dental Association has established a Standards Committee for Dental Informatics. Its sole responsibility is to develop "standards, specifications, technical reports, and guidelines for components of a computerized dental clinical workstation[3]."

The issue of standardization comes to the forefront when dealing with privacy issues as well. In the United States the Health Insurance Portability & Accountability Act has sent a shiver throughout the health community. The goal of such a program is to maintain confidentiality of an individual's identifiable health information if transmitted by electronic means for administrative purposes. Targeted transactions consist of those which will generate income for the practice or other data needed for healthcare administration[4].

A digital model is part of the oral health record which can be utilized in a third party setting or in transmitting information to colleagues. The questions arise as to who is on the other end receiving the information. Securing sites and encoding data may not be enough to assure that confidentiality is maintained. However, hospitals throughout N. America have eliminated paper systems for transmission of viable health information. Although the issue of privacy is a concern, the sensitivity of orthodontic information pales in comparison to that of physicians. Each practitioner will need to evaluate his patient record management to ensure appropriate security.

The capabilities of the digital model are growing. Digital models are now used to set up teeth for treatment. They have been adapted (in rudimentary fashion) to be superimposed on a patient's lateral cephalometric x-ray, further enhancing the clinicians ability to make a complete diagnosis and treatment recommendations. Appliances are being made from digital models which may take the place of traditional braces[5]. While the present research focuses on traditional diagnostic utility, it appears likely that other applications of digital models will enhance treatment delivery.

Cost analysis has not been published related to the production of models. The "basic" digital model for Ortho Cast is the least expensive at $32 per set; OrthoCAD is in the middle at $36 per set; emodels is the most expensive at $39 per set. Granted, this is the price of the basic set up. While Geodigm does not charge for the use of their treatment tools, the OrthoCAD treatment tools take the price of their digital model to over $100 US. Plaster reproduction of the digital model from OrthoCAD costs approximately $350 US. Based on recent developments in other computer applications throughout society, it is reasonable to assume that the cost of digital model technology will decline and the capabilities to enhance treatment planning will increase.

Recently companies have begun to introduce in-office laser scanners that will eliminate the need to send models to offsite locations. One such company, Innovative Solutions, showed two scanners which range from $15,000 to $20,000 US at the 2004 Annual Session of the American Association of Orthodontists (AAO). In addition to purchasing hardware the orthodontist must purchase software from Innovative Solutions to manipulate these images. Also, there are not as many features provided with this "in house" method.

Also at the annual session of the AAO in May, 2004, the American Board of Orthodontics (ABO) agreed to accept models in digital format when cases are submitted by applicants seeking diplomat status. The AAO is the largest orthodontic specialty organization in the world and the ABO is the largest dental specialty examination body. Endorsement of the digital model format by these organizations signified the inclusions of this technology into mainstream practice. Previous studies have demonstrated the reliability and reproducibility of digital models[6-11] . The present study has demonstrated that digital models are clinically valid for treatment planning complex malocclusion. Digital study models can now be integrated into individual practices with confidence

3.2 Geographical Considerations-Canadian vs. US Orthodontists—Pilot Data

It has been demonstrated in the past that a practitioner's country of origin can affect assessments in orthodontics[12,13]. Specifically, payment methods, practice environment, country of origin (not of practice), and experience were all found to be influential factors.

In view of the limited sample size, geographic differences in overall treatment preferences was considered as a pilot study. Canada and the United States have economic differences when dealing with patients such as those in this study. Surgery in the United States is much more expensive, with little help from insurance companies. Whereas anesthesia and hospital stay are covered in Alberta by universal government funding, patients in the United States are required to cover these expenses out of pocket. A two-jaw surgery can cost a patient upwards of $25,000 US in Nevada when anesthesia and hospital stay are added to the surgeon's fee. That said, one would most likely observe a higher tendency toward surgery in Canada if money is the factor considered most important (in this study orthodontists were asked to treatment plan the cases as if there were no exclusionary factors toward the recommended treatment).

Although the orthodontists in this study were asked to treatment plan the cases irrespective of financial concerns, it is often difficult to remove oneself mentally from routine determining factors when making treatment decisions. An orthodontist who feels that a nonsurgical treatment provides adequate care for a patient who may benefit from surgery may be more conditioned to choose this treatment based on previous experience. Again, agreement within raters appears more relevant for this type of pilot study.

Training did not seem to be a biasing influence in this study. N. American programs teach the same basic principles in theory, with the didactics changing. Many of the participating orthodontists in this study were trained in Canada, however there were a number who received their training in the United States. Tables 3.1 and 3.2 provide data and descriptive statistics for decisions by geographic area.

3.3 Survey Responses as Pilot Data (Appendix A)

A survey was given to the orthodontists in the variable group after the second treatment session. The survey was not for statistical analysis, but qualitatively dealt with the attitudes the orthodontist had toward their experience with emodels.

The orthodontists who responded to the survey had a mean age of 40.3 years and had been in practice 11.9 years at the time of the survey. On average they started roughly 250 cases per year. There were two reasons given for taking study models: diagnosis and medico-legal concerns. Interestingly, the responses from Canadian orthodontists were biased toward diagnosis, while the American orthodontists were equally concerned with potential lawsuits.

Only three respondents claimed to have a paperless office. This is comparable to the work of Palmer[14] who suggested that 16% of Canadian orthodontists reported having paperless offices. Only two respondents did not use digital photography, and 8 claimed to use digital radiography in office. This idea may be misrepresented as some would deem a direct digital machine is not the same as a scanned image where no hard copy is saved. No respondent had a working knowledge of digital models at the time of the study.

The majority of the doctors stated that digital models were not cost prohibitive. At the same time, most indicated greater comfort with the plaster format. This may be misleading as many of the orthodontists agreed that familiarity with the digital format would allow them to work at the same pace as the plaster model. That said, 50% of respondents felt as though the time requirement for the digital model was no greater than for the plaster model—and that was having never used the emodel before the study.

The orthodontists were split as to whether the digital model format would be useful in treatment planning and case presentation, but most acknowledged that digital models are the future of orthodontics. Almost all respondents stated that they would both send and receive transfer cases using the digital model format. There was no clear indication who would benefit most from digital model applications; the patient, the doctor, the staff, or everyone.

Palmer[14] looked at computer and internet usage by orthodontists throughout Canada. While he briefly touched on digital models, a more in depth look at their use could prove useful. The survey given with this study asked raters which method they believed took more time. They were also asked who benefits the most (staff, doctor, patient, etc.) from the technology. Both of these questions could provide future research material. A much larger sample would be needed to draw any statistically valid findings from a similar survey.

Furthermore, a survey such as this could be compared in the future with answers provided by orthodontists who are currently using digital models in their offices. As it was the study was conducted to eliminate such doctors from participating. However, they may have answered questions such as trusting measurements and time required much differently than orthodontists who were just acquainting themselves with digital models.

3.4 Limitations of This Study

Cost was one of the primary limitations to this study. With the cost of a digital model from Geodigm at over $40 US when the study was begun, it was not feasible for Geodigm to donate more than eleven cases. Also, reproduction of records began to be a factor as each orthodontist was provided individual records. Geography prevented the use of one record set by multiple orthodontists in most cases. Shipping of the plaster models and records to the orthodontists in the study was donated by a member of the Graduate Orthodontic Department living in Calgary and an orthodontist in Las Vegas.

Time requirements were another limiting factor. Each orthodontist reported sessions lasting from 40 minutes to over two hours per session. Ideally, more cases would have been included in the study, but too much time may have been asked of the orthodontists. The orthodontists spent 1.5 to 4 hours treatment planning the cases. In general, orthodontists did not find that the digital model required more time than the plaster model.

Only one digital model company was represented in the study. Geodigm (emodels) provided the digital material needed for this study. However, Cadent (OrthoCAD) was solicited for help in this regard. They respectfully declined to offer services to this project. Perhaps this can be attributed to the fact that they have been the subject of many articles in the past[7-11,15-18] already and would not profit from another study using their services. The third company, Ortho Cast, was not publicly advertised when this study commenced.

The lack of familiarity with the digital model software did not appear to hinder the orthodontists from making treatment decisions based on feedback received from the survey. Measuring the amount of anterior overbite/overjet proved somewhat difficult. Comments were made that this relationship was easier to observe with the plaster model. The experience of the author is that the orientation of the model on the Z-axis is a factor which is critical when evaluating the models digitally. There is a cross-section function which allows the observer to electronically slice the model anywhere desired. At this point the model may be measured with the digital tool.

The occlusal indicator tool of the emodel was also difficult to read. At the time of this study the bite registration was only one color, blue. The intensity and size of the blue mark represented the force of the bite in that area. OrthoCAD was represented by a spectrum of colors much like would be found in a weather report to represent precipitation density. Familiarity with such a scheme may make the application easier. Since the time of the study Geodigm has introduced a multicolored occlusal registration.

An orthodontist who had taken part in this study (the control group) noted that as he was evaluating the cases for the study that he found there were some cases he could treatment plan, and indeed did treatment plan, without using the models. Then, realizing that he was participating in a study which deals with model reliability, he looked at the models for the cases which he had previously done without them. He did not mention whether his decisions changed based on this evaluation with the models from what it was previously.

It was proposed that there are cases in this study which do not require the use of models to arrive at a confident treatment plan. It was also suggested that there is no way to control whether or not the raters in this study were using models all, some, or none of the time. Furthermore, mention was made that the study contains too many confounding variables (although none were mentioned) to attribute the findings to the use of a particular format of model.

Addressing the fact that the use of models is arbitrary in treatment planning, studies in the past have used models sets to determine whether or not raters are reliable in their treatment planning. Two in particular[19,20] looked specifically at the components of an orthodontic record set to determine which of them gave the most information to assist the clinician in reaching a decision. It was determined that models are the most important piece of information used. But the studies were set up to introduce other elements of the record set in a manner of addition. Each time the rater evaluated a case there was a new factor to consider. For example, the first time a rater saw the case it was only models; the next time it was models and photos or models and x-rays. More information was added sequentially. The point at hand is that complete data sets were eventually given to the rater for them to make a decision. That is how the other studies looked at were set up, and for comparison's sake, it was decided that a complete representation of the patient should be given to each of the raters.

Furthermore, due to the nature of the cases (borderline surgery) and the fact that the raters were not privy to a clinical exam, there was a necessity to provide as much information to the orthodontists as possible. Much of the information which can be garnered in these cases comes from the auxiliary tools. Though they may be possible confounding variables, these things are also necessary to the complete diagnosis and treatment plan.

In light of the fact that the digital component of this study was supervised, there is no way to *assure* that the plaster models were used for any part of the study. It is hoped that the explanation of the goals would lead the rater to use the tools provided. However, as supported by the survey accompanying this study (see Appendix A) there is a large portion of the orthodontic community which uses the models for medico-legal reasons solely. These clinicians rarely look at a model to develop a treatment plan, and a change cannot be hoped for nor expected as to their habits with these ten cases. Just as they may never look at models, there are many orthodontists who don't routinely use a cephalometric x-ray in the traditional manner. They merely hold it up to a fluorescent light while chairside and proceed. Also, the geography involved in this study was a deterrent to supervision in this study. It was only possible to have a representative present for the digital component due to the educational demonstration requisite to the orthodontist's use of said models.

By limiting the study to class II patients there may have been a tendency for the orthodontists to find themselves in a predictable pattern where every patient was treated in the same way. It may have been wiser, or may be in the future, to broaden the scope of the study by including patients from all orthodontic classifications. It has been shown[21] that the Class II is the most prevalent subclassification, with 15-20% of the teenage population in the United States having an overjet of 6mm or more. Thomas[21] offers that the patients presenting with this malocclusion have two options if they are postpubertal: mandibular surgery or camouflage treatment. Much like the focus group who selected the criteria for this study, Thomas suggested that there is little disagreement about the patients who are at the extremes of classification. It is the patients lying in the grey zone who may lead to discrepancies in treatment planning.

Proffit[22] added that some 730,000 people in the US would benefit from Class II correction with surgical intervention. He also estimated that 10% of the US population has a Class II malocclusion. However, these may seem more socially acceptable because the patient can posture forward to achieve a somewhat normal relationship. Other subclassifications of malocclusion do not have this luxury. From the patient's perspective he states that a skeletal Class III is more likely to seek an orthodontic opinion.

3.5 Future Studies

The evolution of digital technologies in orthodontics has already been explored with radiology. This groundwork could be used as a model of future studies involving digital models

Record storage is much more accommodating with the digital model. Thousands of digital models can be stored on a standard computer hard drive, and hundreds may be filed on a disk. A detailed current cost analysis of plaster model fabrication and storage versus digital model and storage may be a helpful tool to consider. Such aspects as lab, staff, and storage costs could be evaluated. It must be kept in mind that this technology is likely to decrease in price in the future as it becomes more widely accepted and as competition drives the market. It must also noted that the current companies are piloting a new technology and may not be around for the duration of one's practice. Perhaps another study could explore the options available should the one of the companies go out of business.

Digital model companies are piloting the use of a simulated articulator for those orthodontists who feel the use of mounted models is necessary in treatment planning. Ellis[23] contends that hand articulation of study models will produce no less consistent results than will models mounted on an articulator. One study could either use orthodontists who mount models as a regular part of practice and have them duplicate this study (or that of Ellis) by alternating the mounting format with the digital model. Likewise, a range of orthodontists not restricted to the philosophy of mounting cases could be solicited to repeat either of the ideas proposed.

It appears that location did not significantly alter the consistency of treatment decisions, although there may have been a trend for the Canadian orthodontist to extract more with plaster, whereas the American extracted the same number of times whether using digital or plaster. This may be due in part to the fact that orthodontic training in N. America is accredited by the same standards. Also, the patient populations used represented those people who may present in any N. American office. However, it would be interesting to compare the treatment plans presented for this group of "borderline surgery" patients to practitioners in other cultures throughout the world. Perhaps these patients would not be deemed "borderline surgery" in the Middle East, the Orient, or other parts of the world. Even so, treatment modalities could be compared between examiners.

OrthoCAD allows the orthodontist to virtually treat a patient using the same braces that would be used in the office before there is any appliance in the patient's mouth. They then send a transfer tray to the orthodontist for placement of the appliances as prescribed in the virtual setup. One might be able to assess how much time is saved by this feature over the course of treatment, noting number of strategically repositioned brackets there are at the end of treatment. Is this function merely exciting to the orthodontist or does it truly save chair time over the course of treatment? Also, do the cases treat any more quickly due to the time taken prior to treatment to place brackets?

Three dimensional manipulations of digital models is an area of interest yet to be explored in the literature. With the bracket placement tools provided by OrthoCAD offering a virtual treatment before brackets are placed, it would be an interesting study to see just how accurate that computer prediction of treatment is. One could take the transfer bonding tray and place the brackets, let the wires work out, and then take impressions of where the teeth end up when the wires have worked out. At that point, the poured model could be scanned and compared to the predicted outcome to see how accurate the process is.

3.6 Conclusion

3.6.1 Main Conclusions

1- There is no statistically significant difference in Intrarater treatment planning agreement (surgery, extraction and use of auxiliary appliances) in Class II malocclusion, based on the use of digital models in place of traditional plaster models.

2- No one type of model format lends itself to more extensive or aggressive treatment decisions.

3- Plaster models demonstrate a slightly higher percentage of treatment planning agreement in all three of the categories, yet this is clinically insignificant.

3.6.2 Other Generalities (based on survey information)

- Orthodontists see digital models as the future when applied to the patient oral health record

- The digital model format did not require any more time to arrive at a treatment plan than the plaster model

- Orthodontists would accept and send transfer patients using the digital model format

- Orthodontists do not yet trust the measurements provided by the digital models

- Orthodontists are more comfortable with plaster models

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3.8 Figures and Tables

Table 3.1--Geographic Breakdown of Variable Group Decisions

emodel Data	**CDN Orthodontists**	**USA Orthodontists**
No. of Surgeries	69	35
Avg. No. Surgeries/Dr.	6.9	3.5
No. of Extractions	149	122
Avg. No. Extractions/Dr.	14.9	12.2
No. of Auxiliary Appl.	15	19
Avg. No. Auxiliary Appl.	1.5	1.9
Plaster Data	**CDN Orthodontists**	**USA Orthodontists**
No. of Surgeries	69	36
Avg. No. Surgeries/Dr.	6.9	3.6
No. of Extractions	162	124
Avg. No. Extractions/Dr.	16.2	12.4
No. of Auxiliary Appl.	17	17
Avg. No. Auxiliary Appl.	1.7	1.7

Table 3.2—t-tests for Geographic Agreement: USA vs. CDN

	Surgery	USA	CDN
Mean proportion		.77	.78
SD		.182	.103
Orthodontists		10	10
p-value (power)		*.88 (.052)*	
	Extractions	USA	CDN
Mean proportion		.74	.83
SD		.117	.095
Orthodontists		10	10
p-value (power)		*.076 (431)*	
	Auxiliary	USA	CDN
Mean proportion	**Appliance**	.88	.88
SD		.162	.140
Orthodontists		10	10
p-value (power)		*1.0 (.050)*	

APPENDICES

APPENDIX A
Exploratory Survey

(Frequency of Responses Given Next to Answer)

1) How long have you been practicing orthodontics (years)?
   - a) 1-5 *(9)*
   - b) 6-10 *(3)*
   - c) 11-15 *(1)*
   - d) 16-20 *(3)*
   - e) 21+ *(4)*

2) What is your age? _________

3) What is your **main** reason for taking study models in your practice today?
   - a) Diagnosis and treatment planning *(15)*
   - b) Case presentation *(0)*
   - c) Mid treatment progress *(0)*
   - d) Legal documentation *(5)*
   - e) Other (please specify) *(0)*
   - f) I don't routinely take study models in my practice *(0)*

4) For which of the following tasks do you, **the practitioner**, use a computer in your office? ***(Not enough responses given)***
   - a) Accounts receivable/payable
   - b) Scheduling
   - c) Digital imaging
   - d) Patient Education
   - e) Virtual models
   - f) Staff training
   - g) Diagnosis and treatment planning
   - h) Inventory
   - i) Charting
   - j) Consultations

5) Is your patient record "paperless"?
   - a) Yes *(3)*
   - b) No *(17)*

6) Does your practice use digital photography?
   - a) Yes *(18)*
   - b) No *(2)*

7) Does your practice use digital x-ray software?
   - a) Yes *(8)*
   - b) No *(12)*

8) Does your practice currently use digital model software?
   - a) Yes *(0)*
   - b) No *(20)*

9) At $50 US per set of digital models, is cost a prohibitive factor in determining whether you use plaster v. digital models? (Consider production + storage)

a) Yes, plaster more economical ***(8)***
b) Yes, Emodels more economical ***(1)***
c) No (reason unimportant) ***(11)***

10) Do you routinely include models (plaster or digital) when treatment planning?

a) All or most of the time (routinely) ***(16)***
b) About half of the time (occasionally) ***(1)***
c) But only for difficult or special cases (seldom) ***(3)***
d) Never ***(0)***

11) How would you rate the general comfort level/trust you place in digital models?

a) I am more comfortable with digital models ***(0)***
b) I am more comfortable with plaster models ***(14)***
c) I am at ease with either format ***(6)***

12) Do you trust the measurements provided by digital model software?

a) Yes ***(5)***
b) No ***(2)***
c) I am not familiar enough with digital models to judge adequately ***(13)***

13) Did the digital model software require more time to arrive at a treatment plan than did plaster models?

a) Yes, the digital model software required more of my attention ***(5)***
b) Yes, but software familiarity would remedy this ***(5)***
c) No, it took the same or less amount of time than plaster ***(10)***

14) Would digital models help you in patient consultation?

a) Yes ***(10)***
b) No ***(10)***

15) Do you consider digital models to be the present, the future, or a passing trend in orthodontics?

a) Present ***(1)***
b) Future ***(14)***
c) Passing trend ***(5)***

16) Prior to this study/survey had you used digital model software?

a) Yes, I currently use it in my practice ***(0)***
b) Yes, but only on a trial basis ***(5)***
c) No, this was my first experience ***(15)***

17) Do you feel the digital model software can enhance your abilities in treatment planning?
  a) Yes *(2)*
  b) No *(9)*
  c) Makes no difference either way *(9)*

18) Would you send transfer cases using digital models?
  a) Yes *(17)*
  b) No *(3)*

19) Would you accept transfer cases using digital models?
  a) Yes *(15)*
  b) No *(5)*

20) Who do you feel benefits the most from digital model technology?
  a) The orthodontist *(2)*
  b) The orthodontic staff *(4)*
  c) The patient *(2)*
  d) All of the above *(7)*
  e) None of the above *(5)*

21) How many full treatment cases (excluding phase I and transfer cases) did your practice start last year?
  a) Less than 150 *(5)*
  b) 151-250 *(7)*
  c) 251-350 *(2)*
  d) 351-450 *(2)*
  e) More than 450 *(4)*

Thank you for your participation in this survey as well as in the evaluation of the cases. I would appreciate any comments you have as to what could have been done better or what you found beneficial regarding this project. Please use the following lines and the back of the page, if necessary.

Appendix B
Treatment Decision Tree

Treatment Decision Tree (mark all that apply, specify teeth to extract, appliances, etc.)

- Treatment Options
    - Surgery
        - Maxilla Only
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Mandible Only
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Maxilla + Mandible
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Other (i.e., SARPE)
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
    - Non-Surgical
        - Fixed Banding
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Functional Appliances (Frankel, Herbst, Bionator, Other) or Facebow or Headgear ____________(please specify appliance)
            - Extract ______________(indicate teeth here or below)
            - Do Not Extract
        - Other (RPE etc.) ________________(please specify appliance)

Extractions:

Right 8 7 6 5 4 3 2 1 1 2 3 4 5 6 7 8 Left

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

Model Type: **Plaster**__________ **Emodel**_________

Doctor Code: _______________ **Case Code**: _______________

Appendix C

Raw Data Set

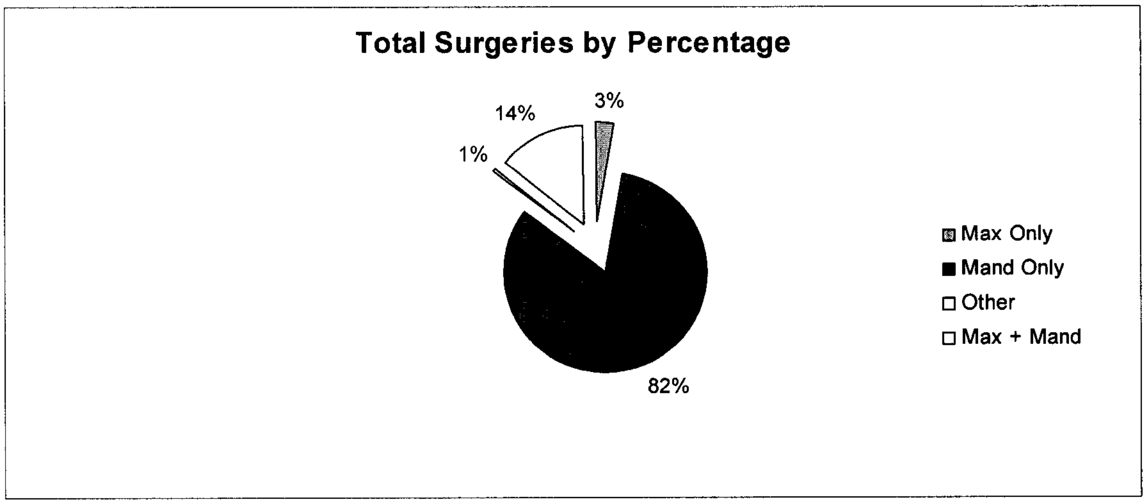
For all raw data numbers please refer to the Microsoft Excel spreadsheet CD kept with the Graduate Orthodontic Department Research Coordinator.

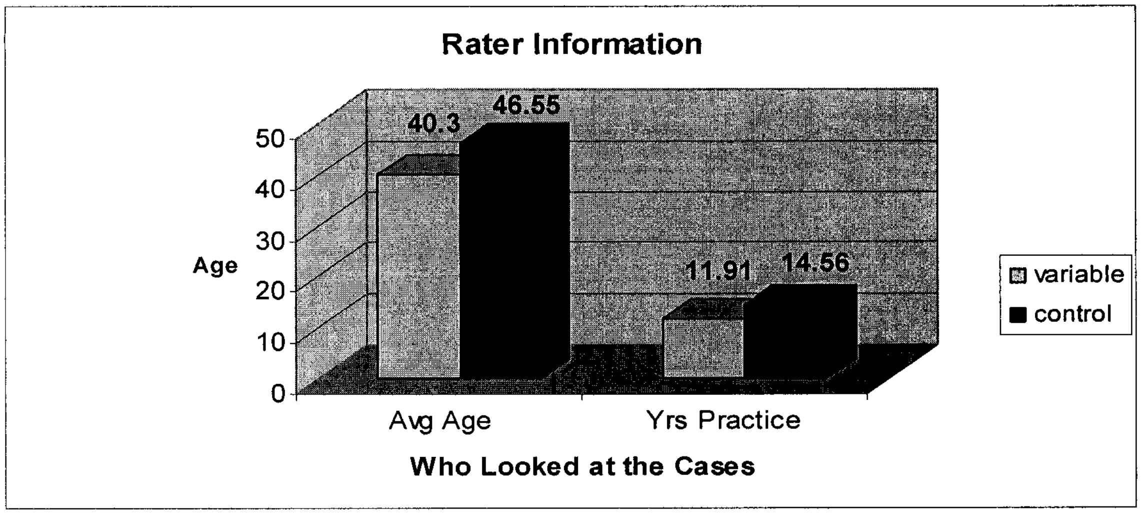
All SPSS data will be kept on the same CD in a Microsoft word format as well as in SPSS data and viewer document files.

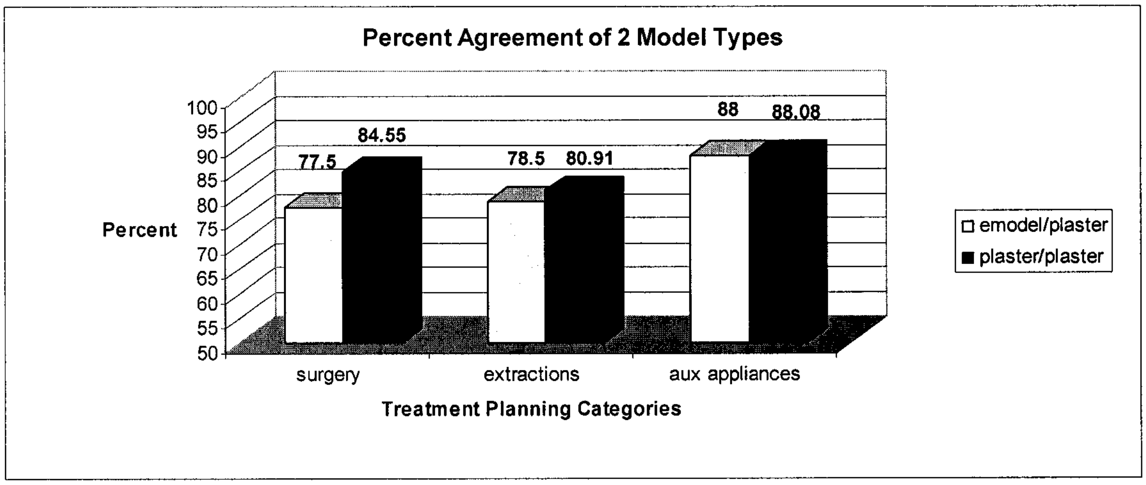
Appendix D: Supplemental Charts and Graphs

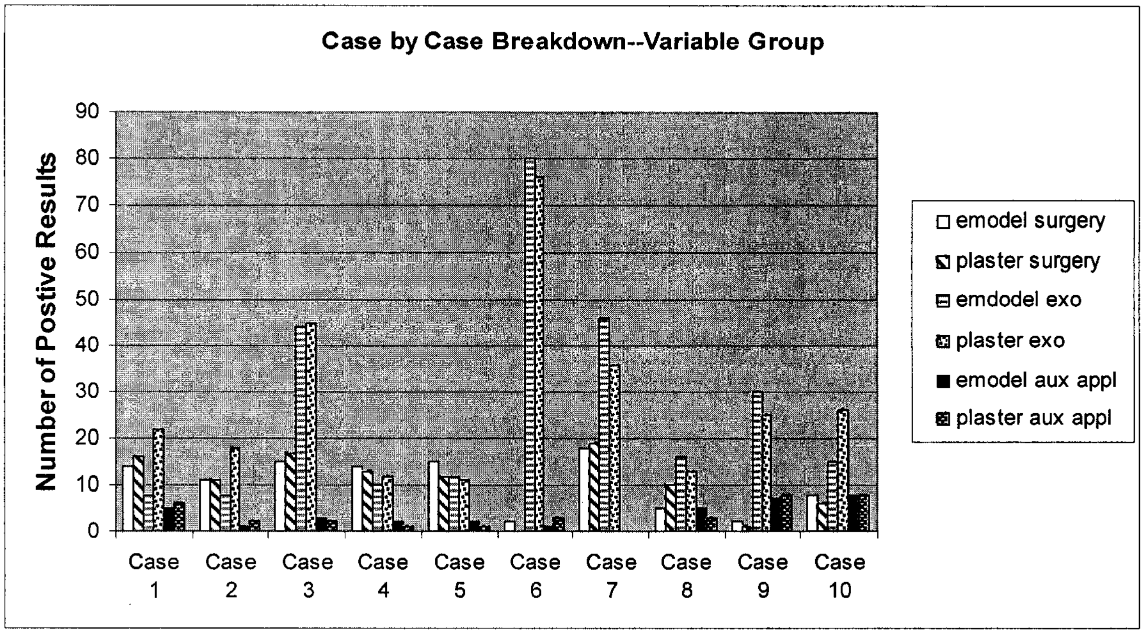
t-tests for Between Group Agreement: Variable v Control

	Surgery	Variable	Control
Mean proportion		.775	.836
SD		.145	.121
Orthodontists		20	11
p-value (power)		*.242 (.211)*	
	Extractions	Variable	Control
Mean proportion		.785	.818
Variance		.114	.14
Orthodontists		20	11
p-value (power)		*.48 (.107)*	
	Auxiliary Appliance	Variable	Control
Mean proportion		.88	.873
Variance		.148	.135
Orthodontists		20	11
p-value (power)		*.893 (.052)*	




Rater Information
50
40
30
20
10
0
Age
40.3
46.55
11.91
14.56
Avg Age
Yrs Practice
Who Looked at the Cases
▨ variable
■ control


Percent Agreement of 2 Model Types
100
95
90
85
80
75
70
65
60
55
50
Percent
77.5
84.55
78.5
80.91
88
88.08
surgery
extractions
aux appliances
Treatment Planning Categories
□ emodel/plaster
■ plaster/plaster


Case by Case Breakdown--Variable Group
Number of Postive Results
0
10
20
30
40
50
60
70
80
90
Case 1
Case 2
Case 3
Case 4
Case 5
Case 6
Case 7
Case 8
Case 9
Case 10
□ emodel surgery
▧ plaster surgery
⊟ emdodel exo
▨ plaster exo
■ emodel aux appl
▩ plaster aux appl

Appendix E: EMODELS/PLASTER Group Output Tables

Digital/Plaster Group Surgery Totals

		Plaster Surgery			$P_{overall}$	0.775
		No	Yes		P_{Yes}	0.785
Emodels Surgery	No	73	23		P_{No}	0.764
	Yes	22	82		McNemar p-value (power)	1.000 (0.965)
					Kappa Coefficient	0.549

Case by Case Surgery Totals, Digital/Plaster Group

CASE			Plaster Surgery						
			No	Yes		$P_{overall}$	P_{Yes}	P_{No}	McNemar p-value
Case 1	Emodels Surgery	No	2	4		0.70	0.800	0.400	0.687
		Yes	2	12					
Case 2	Emodels Surgery	No	6	3		0.70	0.727	0.667	1.000
		Yes	3	8					
Case 3	Emodels Surgery	No	3	2		0.90	0.938	0.750	0.500
		Yes	0	15					
Case 4	Emodels Surgery	No	4	2		0.75	0.815	0.615	1.000
		Yes	3	11					
Case 5	Emodels Surgery	No	5	0		0.85	0.889	0.769	0.250
		Yes	3	12					
Case 6	Emodels Surgery	No	18	0		0.90	N/A	0.947	≥0.5
		Yes	2	0					
Case 7	Emodels Surgery	No	1	1		0.95	0.973	0.667	1.000
		Yes	0	18					
Case 8	Emodels Surgery	No	8	7		0.55	0.400	0.640	0.180
		Yes	2	3					
Case 9	Emodels Surgery	No	17	1		0.85	N/A	0.919	1.000
		Yes	2	0					
Case 10	Emodels Surgery	No	9	3		0.60	0.429	0.692	0.727
		Yes	5	3					

**N/A for Proportions again is misleading because it merely reflects that a choice was not selected. A true calculation would give a value of "0" but would not be reflective of a measurable agreement.*

Digital/Plaster Group Extraction Totals

		Plaster Extractions				
		No	Yes		P_{Yes}	0.792
Emodels Extractions	No	75	25		P_{No}	0.777
	Yes	18	82		McNemar p-value (power)	0.360 (0.815)
					Kappa Coefficient	0.570
					$P_{overall}$	0.785

Case by Case Extraction Totals, Digital/Plaster Group

CASE			Plaster Extractions						
			No	Yes		$P_{overall}$	P_{Yes}	P_{No}	McNemar p-value
Case 1	Emodels Extractions	No	12	4		0.75	0.545	0.828	0.375
		Yes	1	3					
Case 2	Emodels Extractions	No	10	5		0.60	0.333	0.714	0.727
		Yes	3	2					
Case 3	Emodels Extractions	No	6	1		0.95	0.963	0.923	1.000
		Yes	0	13					
Case 4	Emodels Extractions	No	14	2		0.85	0.667	0.903	1.000
		Yes	1	3					
Case 5	Emodels Extractions	No	8	3		0.70	0.667	0.727	1.000
		Yes	3	6					
Case 6	Emodels Extractions	No	0	0		0.95	0.974	N/A	≥ 0.5
		Yes	1	19					
Case 7	Emodels Extractions	No	2	3		0.75	0.839	0.444	1.000
		Yes	2	13					
Case 8	Emodels Extractions	No	11	0		0.80	0.714	0.846	0.125
		Yes	4	5					
Case 9	Emodels Extractions	No	3	2		0.75	0.878	0.545	1.000
		Yes	3	12					
Case 10	Emodels Extractions	No	9	5		0.75	0.706	0.783	0.063
		Yes	0	6					

**N/A for Proportions again is misleading because it merely reflects that a choice was not selected. A true calculation would give a value of "0" but would not be reflective of a measurable agreement.*

Digital/Plaster Group Auxiliary Appliance Totals

		Plaster Aux. Appl			
		No	Yes	$P_{overall}$	0.870
				P_{Yes}	0.618
Emodels Aux. Appl	No	153	13	P_{No}	0.922
	Yes	13	21	McNemar p-value (power)	1.000 (0.975)
				Kappa Coefficient	0.539

Case by Case Auxiliary Appliance Totals, Digital/Plaster Group

CASE			Plaster Aux. Appl					
			No	Yes	$P_{overall}$	P_{Yes}	P_{No}	McNemar p-value
Case 1	Emodels Aux. Appl	No	12	3	0.90	0.545	0.823	1.000
		Yes	2	3				
Case 2	Emodels Aux. Appl	No	17	2	0.85	N/A	0.919	1.000
		Yes	1	0				
Case 3	Emodels Aux. Appl	No	17	0	0.95	0.800	0.971	1.000
		Yes	1	2				
Case 4	Emodels Aux. Appl	No	18	0	0.95	0.667	0.923	1.000
		Yes	1	1				
Case 5	Emodels Aux. Appl	No	17	1	0.85	N/A	0.919	1.000
		Yes	2	0				
Case 6	Emodels Aux. Appl	No	17	2	0.90	0.500	0.944	0.500
		Yes	0	1				
Case 7	Emodels Aux. Appl	No	20	0	1.00	N/A	1.000	N/A
		Yes	0	0				
Case 8	Emodels Aux. Appl	No	14	1	0.80	0.571	0.875	0.625
		Yes	3	2				
Case 9	Emodels Aux. Appl	No	11	2	0.85	0.800	0.880	1.000
		Yes	1	6				
Case 10	Emodels Aux. Appl	No	10	2	0.80	0.750	0.833	1.000
		Yes	2	6				

**N/A for Proportions again is misleading because it merely reflects that a choice was not selected. A true calculation would give a value of "0" but would not be reflective of a measurable agreement.*

Surgery Breakdown, Digital/Plaster Group

Surgery Type	emodels Surgeries	Plaster Surgeries
Maxilla Only	4	4
Mandible Only	84	88
Maxilla + Mandbile	15	13
Other	1	0

Extraction Breakdown, Digital/Plaster Group

	Positive Decisions	Minimum	Maximum	Total	Mean	SD
Emodel	98	1	4	271	2.77	1.092
Plaster	106	0	4	286	2.70	1.181

Appendix F: Plaster/Plaster Group Output Tables

Plaster/Plaster Group Surgery Totals

		Plaster 2 Surgery			$P_{overall}$	0.836
		No	Yes		P_{Yes}	0.847
Plaster 1 Surgery	No	42	9		P_{No}	0.824
	Yes	9	50		McNemar p-value (power)	1.000 (0.975)
					Kappa Coefficient	0.671

Case by Case Surgery Totals, Plaster/Plaster Group

CASE			Plaster 2 Surgery						
			No	Yes		$P_{overall}$	P_{Yes}	P_{No}	McNemar p-value
Case 1	Plaster 1 Surgery	No	0	0		0.818	0.900	N/A	≥0.5
		Yes	2	9					
Case 2	Plaster 1 Surgery	No	2	3		0.545	0.615	0.444	1.000
		Yes	2	4					
Case 3	Plaster 1 Surgery	No	0	0		0.909	0.952	N/A	≥0.5
		Yes	1	10					
Case 4	Plaster 1 Surgery	No	2	2		0.636	0.714	0.500	1.000
		Yes	2	5					
Case 5	Plaster 1 Surgery	No	2	0		0.909	0.914	0.800	1.000
		Yes	1	8					
Case 6	Plaster 1 Surgery	No	11	0		1.000	N/A	1.000	N/A
		Yes	0	0					
Case 7	Plaster 1 Surgery	No	0	0		1.000	1.000	1.000	N/A
		Yes	0	11					
Case 8	Plaster 1 Surgery	No	8	1		0.818	0.500	0.889	1.000
		Yes	1	1					
Case 9	Plaster 1 Surgery	No	10	1		0.909	N/A	0.952	≥0.5
		Yes	0	0					
Case 10	Plaster 1 Surgery	No	7	2		0.818	0.667	0.875	0.500
		Yes	0	2					

**N/A for Proportions again is misleading because it merely reflects that a choice was not selected. A true calculation would give a value of "0" but would not be reflective of a measurable agreement.*

Plaster/Plaster Group Extraction Totals

		Plaster 2 Extractions			
		No	Yes	$P_{overall}$	0.818
				P_{Yes}	0.844
Plaster 1 Extractions	No	36	10	P_{No}	0.783
	Yes	10	54	McNemar p-value (power)	1.000 (0.975)
				Kappa Coefficient	0.626

Case by Case Extraction Totals, Plaster/Plaster Group

CASE			Plaster 2 Extractions					
			No	Yes	$P_{overall}$	P_{Yes}	P_{No}	McNemar p-value
Case 1	Plaster 1 Extractions	No	4	1	0.727	0.727	0.727	1.000
		Yes	2	4				
Case 2	Plaster 1 Extractions	No	9	0	0.909	0.667	0.947	1.000
		Yes	1	1				
Case 3	Plaster 1 Extractions	No	6	2	0.818	0.750	0.857	0.500
		Yes	0	3				
Case 4	Plaster 1 Extractions	No	3	2	0.636	0.667	0.600	1.000
		Yes	2	4				
Case 5	Plaster 1 Extractions	No	7	1	0.818	0.667	0.875	1.000
		Yes	1	2				
Case 6	Plaster 1 Extractions	No	0	0	1.000	1.000	N/A	N/A
		Yes	0	11				
Case 7	Plaster 1 Extractions	No	2	0	1.000	1.000	1.000	N/A
		Yes	0	9				
Case 8	Plaster 1 Extractions	No	0	1	0.818	0.900	N/A	1.000
		Yes	1	9				
Case 9	Plaster 1 Extractions	No	1	1	0.818	0.889	0.500	1.000
		Yes	1	8				
Case 10	Plaster 1 Extractions	No	4	2	0.636	0.600	0.667	1.000
		Yes	2	3				

**N/A for Proportions again is misleading because it merely reflects that a choice was not selected. A true calculation would give a value of "0" but would not be reflective of a measurable agreement.*

Plaster/Plaster Group Auxiliary Appliance Totals

		Plaster 2 Aux Appl				
		No	Yes		$P_{overall}$	0.873
Plaster 1 Aux. Appl	No	74	6		P_{Yes}	0.759
	Yes	8	22		P_{No}	0.913
					McNemar p-value (power)	0.791 (0.923)
					Kappa Coefficient	0.672

Case by Case Auxiliary Appliance Totals, Plaster/Plaster Group

CASE			Plaster 2 Aux. Appl						
			No	Yes		$P_{overall}$	P_{Yes}	P_{No}	McNemar p-value
Case 1	Plaster 1 Aux. Appl	No	7	1		0.818	0.667	0.875	1.000
		Yes	1	2					
Case 2	Plaster 1 Aux. Appl	No	4	1		0.545	0.444	0.615	0.375
		Yes	4	2					
Case 3	Plaster 1 Aux. Appl	No	9	1		0.818	N/A	0.900	1.000
		Yes	1	0					
Case 4	Plaster 1 Aux. Appl	No	8	2		0.818	0.500	0.888	0.500
		Yes	0	1					
Case 5	Plaster 1 Aux. Appl	No	10	0		1.000	1.000	1.000	1.000
		Yes	0	1					
Case 6	Plaster 1 Aux. Appl	No	10	0		1.000	1.000	1.000	1.000
		Yes	0	1					
Case 7	Plaster 1 Aux. Appl	No	11	0		1.000	N/A	1.000	N/A
		Yes	0	0					
Case 8	Plaster 1 Aux. Appl	No	9	0		1.000	1.000	1.000	1.000
		Yes	0	2					
Case 9	Plaster 1 Aux. Appl	No	4	0		0.818	0.833	0.800	0.500
		Yes	2	5					
Case 10	Plaster 1 Aux. Appl	No	2	1		0.909	0.941	0.800	1.000
		Yes	0	8					

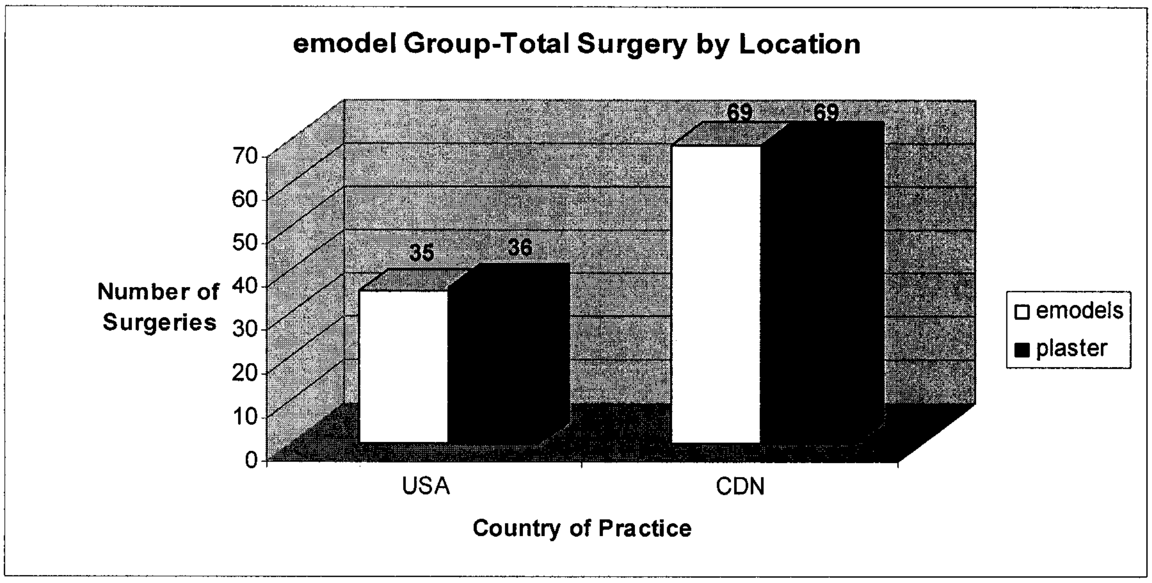
**N/A for Proportions again is misleading because it merely reflects that a choice was not selected. A true calculation would give a value of "0" but would not be reflective of a measurable agreement.*

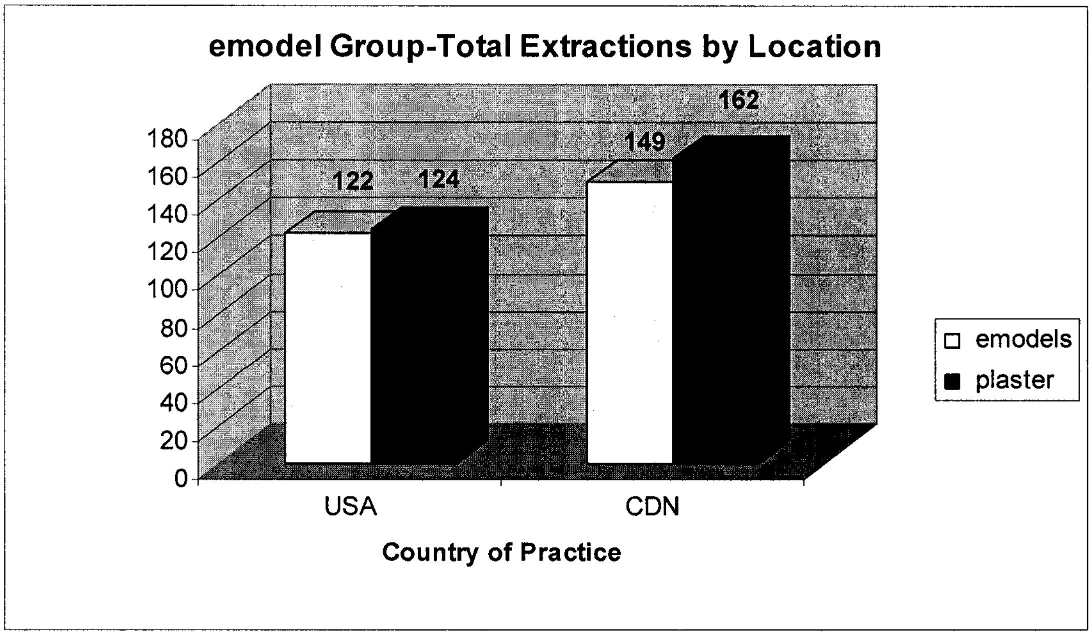
Surgery Breakdown, Plaster/Plaster Group

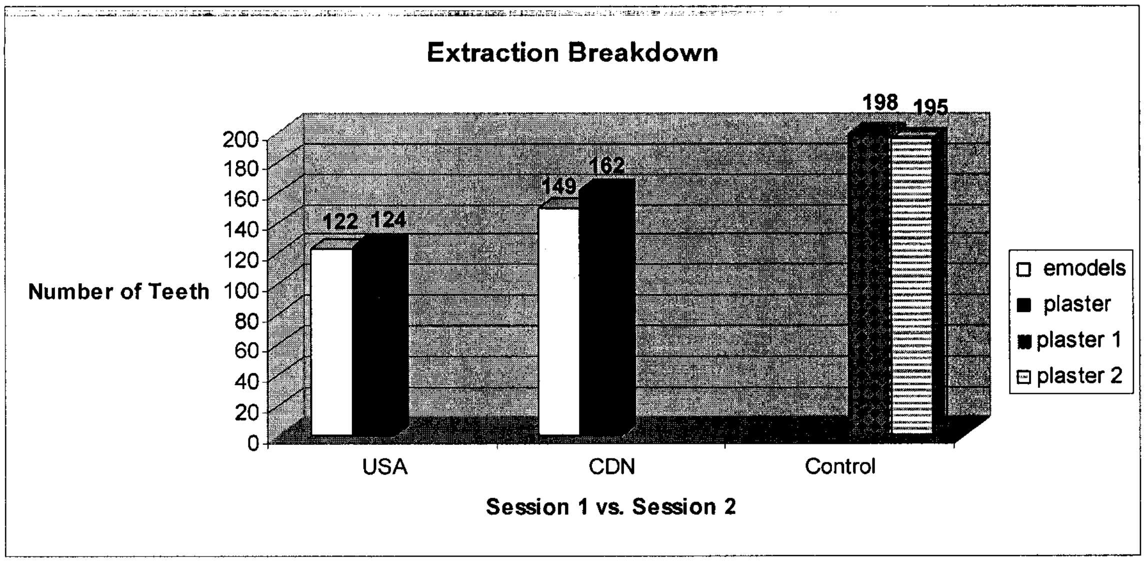
Surgery Type	Plaster 1 Surgeries	Plaster 2 Surgeries
Maxilla Only	1	0
Mandible Only	48	49
Maxilla + Mandbile	10	8
Other	0	1

Appendix G: Geographic Breakdown of Variable Group

emodel Data	**CDN Orthodontists**	**USA Orthodontists**
No. of Surgeries	69	35
Avg. No. Surgeries/Dr.	6.9	3.5
No. of Extractions	149	122
Avg. No. Extractions/Dr.	14.9	12.2
No. of Auxiliary Appl.	15	19
Avg. No. Auxiliary Appl.	1.5	1.9
Plaster Data	**CDN Orthodontists**	**USA Orthodontists**
No. of Surgeries	69	36
Avg. No. Surgeries/Dr.	6.9	3.6
No. of Extractions	162	124
Avg. No. Extractions/Dr.	16.2	12.4
No. of Auxiliary Appl.	17	17
Avg. No. Auxiliary Appl.	1.7	1.7


emodel Group-Total Surgery by Location
Number of Surgeries
0
10
20
30
40
50
60
70
35
36
69
69
USA
CDN
Country of Practice
□ emodels
■ plaster


emodel Group-Total Extractions by Location
0
20
40
60
80
100
120
140
160
180
122
124
149
162
USA
CDN
Country of Practice
□ emodels
■ plaster



Appendix H: Thesis Approval Letter