THE USE OF DIGITAL STUDY MODELS AND PERCEPTIONS

TOWARDS EXISTING DIGITAL MODEL SOFTWARE

IN ORTHODONTIC PRACTICE

A THESIS IN
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ABSTRACT

The purpose of this project was to determine what demographic factors, if any, lead to private practice orthodontists creating digital models and then taking the additional step of using these models in treatment planning. A 22-question survey, approved by the UMKC IRB, was constructed and distributed to 2,300 private practice orthodontists by email through the American Association of Orthodontists Partners in Research program. Orthodontic residency graduation year, gender, primary office location, and the use of other digital health records were just a few of the demographics examined in the survey. The survey was divided into two domains, orthodontist demographics and orthodontic office demographics. Additional questions addressed observational items such as the likes and dislikes of the software the orthodontist is currently using. Demographic factors were coded and one-way ANOVA testing was performed with a significance level of $\alpha = 0.05$. Overall, this study found a statistically significant association between orthodontist and orthodontic office demographics with the practitioner creating digital models and using of these models in treatment planning. In particular, recent orthodontic residents were more likely to create digital models. Orthodontists in certain geographic regions and that used digital dental records were also more likely to create digital models. No other statistically significant results were found and no factors showed a significant association with digital treatment planning; however, the majority of the respondents did create digital models. Observational questions revealed that cost and the preference for plaster models were the two main reasons orthodontists did not use digital models. Another interesting observation was that

several orthodontists felt that photographs eliminate the need for models. This survey revealed that the top four programs used for digital models and treatment planning were OrthoCAD®, OrthoTrac®, Invisalign® ClinCheck®, and SureSmile®.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Dentistry have examined a thesis titled “The Use of Digital Study Models and Perceptions Towards Existing Digital Model Software in Orthodontic Practice,” presented by Mark Greenburg, candidate for the Master of Oral and Craniofacial Sciences degree, and certify that in their opinion it is worthy of acceptance.

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CHAPTER 1

INTRODUCTION

Digital technology is an integral part of day-to-day life from phones to computers. This technology has permeated into every occupation including dentistry. Today, digital dentistry consists of electronic health records, digital radiographs, digital impressions, and digital photographs. All of these advances are relatively recent.

Digital Radiography

Digital radiography is now commonplace in dental offices. Early on, intraoral digital imaging sensors did not offer the resolution of conventional film radiographs which limited digital radiography use in dental offices (Dunn and Kantor 1993; Alder 1995). In addition, the cost of early intraoral digital radiography systems exceeded $20,000 (Farman et al. 1995). Many American dentists opted to use conventional film until the cost of these systems decreased (Farman et al. 1995).

Many different types of digital sensors exist to capture radiographic images. Charged-coupled devices (CCD) and complementary metal-oxide semiconductors (CMOS) are within digital sensors that connect directly to the computer and provide near instantaneous images (Alder 1995; Paurazas et al. 2000). Storage phosphor (SP) uses plates similar to conventional film radiographs that must be scanned into the computer after radiographs are taken (Alder 1995).

Digital radiographs offer many advantages over conventional film radiographs. First, the images produced are dynamic and therefore can be digitally enhanced to aid in diagnosis (Wenzel 1998). Second, they do not require any type of wet chemicals to render an image (Wenzel 1998). Third, direct digital systems reduce the radiation dose to patients by 5 to 50% over conventional radiographs (Wenzel 1998). Fourth, the working time needed to view a diagnostic radiographic image is greatly reduced (Wenzel 1998). Lastly, storing images and communicating those images is greatly improved with digital images (Alder 1995; Wenzel 1998).

In restorative dentistry, radiographs are used most often to diagnose interproximal carious lesions. SP digital radiography was found to be comparable to E-speed film in detecting interproximal caries both in terms of accuracy as well as between observers (Svanaes et al. 1996). CCD digital

radiography was also found to perform as well as E-speed film for detecting interproximal caries (White and Yoon 1997). Digital radiography also showed the same diagnostic ability of detecting periapical bony lesions (Paurazas et al. 2000). These studies show the diagnostic reliability of digital radiographs.

The technology used in dental digital radiography has greatly improved since the first digital intraoral radiograph was introduced in 1987 (Stelt et al. 2003). The improved technology and decreased costs have led to increased acceptance and use of digital radiographs among dentists. By 2000, the estimated use of digital radiography was only 5% by dental practitioners in North America (Miles and Razzano 2000). In a 2007 survey to dentists in Hawai'i, 36% reported using digital radiography (Brady 2007). On average these dentists had been using digital radiography for 3.4 years and 92% of them were happy with their digital equipment. The major reason that the dentists did not use digital radiography was the cost of equipment (Brady 2007). In comparison, 19.7% of dentists in Indiana used digital radiography in 2007 with the main reason for not using digital radiographs being initial cost (Brian and Williamson 2007). Within 3 years, a significant increase in digital radiography use was shown by a South Dakota survey of dentists. Fifty-five percent of these respondents utilized digital radiography (Pollard and Kennedy 2010). This percentage has further increased as a 2013 survey of general dental practitioners in the Netherlands showed that 90% of dentists used digital intraoral radiographs (Zande et al. 2015). These surveys show the rapid increase in acceptance and use of digital radiography among dentists.

Digital Photography in Dentistry

Photography is another important component of dentistry that has shifted from analog to digital. Photographs are used for patient instruction, treatment planning, medico-legal reasons, teaching, and communicating with laboratories (Haque et al. 2010). In 1999, 2.1 megapixel cameras were becoming commonplace and even 6 megapixel cameras were becoming available, but were very expensive. Six megapixel cameras still could not quite meet the image quality of film cameras (Abelson 1999). By 2011, digital cameras of 21.1 megapixels were offered (Shagam and Kleiman 2011). Continued advancements in digital cameras and decreasing cost has helped increase the use

of digital cameras by dentists. The main advantage of digital cameras is speed, as they can render a viewable image within seconds (Haque et al. 2010).

Acceptance and use of digital cameras by dentists has increased in the past decade by considerable amounts. In a 2004 survey of UK general dental practitioners, 30% used a digital camera (Sharland et al. 2004). By 2010, 59% of UK general dental practitioners used digital cameras (Haque et al. 2010). Within 6 years, the use of digital cameras almost doubled. Digital photography is becoming more common than conventional film photography.

Electronic Dental Records

Electronic (or digital) dental records (EDR) were first attempted by the Canadian Dental Association EDR project in the early 1970s. Unfortunately, this record system required computer systems too expensive for dental practitioners to purchase. By the late 1980s software existed that would prepare patient statements, process insurance claims, manage practice finances, aid in treatment planning, and schedule appointments (Snyder 1995). In the mid-1990s software began to address operatory procedures such as probing depths and dental findings. In 2000, the projected sales of software used for clinical procedures rose to almost the level of practice management software which demonstrated the use of EDRs by dentists (Delrose and Steinberg 2000). Digital records allowed for efficiency and convenience that was not possible with paper records (Rhodes 2014).

Surveys on using EDRs indicate an increased shift from paper charting to paperless. In a 2004 and 2005 survey of US general dentists, 25% utilized computers chairside, but only 1.8% were completely paperless (Schleyer et al. 2006). Two years later in a 2006 and 2007 survey conducted by the American Dental Association (ADA), 55% used computers chairside while 9.2% were paperless (American Dental Association. Survey 2007). This survey also found that new dentists were more likely to have a paperless office at 13.4% compared to 9.2 percent. In addition, 57.4% of the dentists said they were either very or somewhat likely to increase how much work completed and records maintained would be stored electronically over the next 12 to 24 months (American Dental Association. Survey 2007). In another survey conducted in 2007 by the ADA, 43.7% of US general

dentists worked with EDRs in their primary practice (American Dental Association. Survey 2008). These surveys indicate the increased acceptance and use of EDRs by general dentists.

Digital Impressions

Conventional impressions have long been used in dentistry to create study models or to allow fabrication of indirect restorations. These impressions are taken with materials such as polyether or vinyl polysiloxane (Christensen 2009). Conventional impressions offer many advantages over digital impressions, such as well-known techniques, simple equipment, low to moderate cost, high accuracy, repeatability and predictability (Christensen 2008a). Disadvantages include discomfort to patients, inaccuracies due to air bubbles or debris, messy materials, and need to stock necessary materials (Christensen 2008a). Conventional impression techniques can still be found in many general dentists practices (Christensen 2008b).

Digital impressions are an alternative to conventional impressions. In the 1980s, Dr.Werner Mormann desired to create tooth colored inlays to provide esthetic restorations without the polymerization shrinkage and microleakage found in direct composite restorations of that time (2006). Inlays could be milled to create a near perfect fit of the tooth preparation without the issues of direct composites. Dr. Mormann worked with Sirona Dental Systems to produce CEREC 1 which was the first computer-aided design and computer-aided manufacturing (CAD/CAM) system commercially available to dentists (2006). Such a system required an intraoral scanner that could accurately scan the teeth 3-dimensionally to produce a digital impression (Moörmann 2006). The invention of the CEREC 1 has led to multiple current options for intraoral scanners in order to obtain digital impressions (Ting-shu and Jian 2015). The advantages of digital impressions include simplicity, less messiness, increased patient comfort, decreased concerns about cross-contamination, quick transmission of impressions to laboratories, decreased inaccuracies, and no need to stock conventional trays or impression materials (Christensen 2008a, 2009). These are great advantages of digital impressions, but disadvantages also exist. Intraoral scanners are expensive, costing from approximately $12,000 to 30,000 dollars (Kravitz et al. 2014). These scanners also have associated

costs for upkeep and require repetition and practice to master (Christensen 2008a; Kravitz et al. 2014).

A topic of much research has been whether digital impressions are as accurate as conventional impressions and whether they allow the creation of restorations which are as accurate as those created using conventional impressions. Several studies have shown that all-ceramic crowns created from intraoral scans have better fitting margins than those made using silicone impressions (Syrek et al. 2010; Ng et al. 2014). A study also found that crowns fabricated using intraoral scans had better quality interproximal contact areas (Syrek et al. 2010). Better internal fit is another advantage of all-ceramic crowns made using intraoral scans over conventional silicone impressions (Pradíes et al. 2015). Cobalt-chromium fixed dental prostheses were also shown to have better internal and marginal fits when fabricated using an intraoral scan instead of a conventional silicone impression (Svanborg et al. 2014). These studies demonstrate the accuracy of digital impressions when creating indirect restorations.

The use of digital impressions for the fabrication of indirect restorations is on the rise. From 2003 to 2006, the use of CAD/CAM in-office restorations rose from 3.3% to 8.3% among practicing dentists (American Dental Association. Survey 2007). In 2006, 10.5% of dentists also reported using CAD/CAM with dental laboratory support (American Dental Association. Survey 2007). These surveys demonstrate the rise in use of digital impressions for CAD/CAM use.

Digital Orthodontics

Digital dentistry is gradually overtaking the analog systems of the past. These same changes are occurring in the orthodontic specialty. The Journal of Clinical Orthodontics (JCO) conducted surveys in 1986, 1990, 1996, 2002, 2008, and 2014 concerning results and trends in orthodontics. In photography, for example, there has been a rapid swing from film to digital. In 1996, 82% of orthodontists took pretreatment extraoral photographs with a conventional film camera, but by 2008 this dropped to just 8 percent (Keim et al. 2014). In 2008, 87% of orthodontists took pretreatment extraoral photographs with a digital camera and by 2014 this number jumped to 95 percent (Keim et al. 2014). Digital impressions and digital models of patients are also showing an increase in

orthodontics. Eighteen percent of orthodontists routinely used pretreatment digital models in 2008, but by 2014 this number increased to 27 percent (Keim et al. 2014).

Orthodontic residency programs are also showing an increased interest and use in digital study models; however, many programs find the plaster models to be helpful in a teaching environment. In a 2013 survey of accredited orthodontic postgraduate programs, 38% of graduate clinic directors and chairpersons felt that plaster models were better for learning than digital models (Shastry and Park 2014). Plaster models are easy to pass around among residents and for residents to see the case from every angle. Thirty-five percent of the programs are using digital study models on most of their cases and of the 65% who aren't using digital models, 37% of those programs stated that they want to switch to digital models (Shastry and Park 2014). In addition, 75% of the programs that want to switch wish to make the switch within 3 years (Shastry and Park 2014).

A 2016 survey of practicing orthodontists investigated their use of digital study models, intraoral scanner, and cone-beam computed tomography (CBCT) (Park and Laslovich 2016). This study found that 54% of orthodontists primarily use plaster study models while 46% primarily use digital models (Park and Laslovich 2016). Of those that used plaster models, 34% planned to switch to digital models, most desiring to make this transition in the next 5 years (Park and Laslovich 2016). The respondents to this survey felt the main advantages of plaster models were three-dimensional feel and low cost, while the main advantage of digital models was ease of storage and retrieval (Park and Laslovich 2016). For those that did not want to switch primarily to digital models, the main reason was the cost of making the transition (Park and Laslovich 2016). Digital models in orthodontics are a relatively recent addition to orthodontists' armamentarium but are becoming more prevalent in private practice and in residency programs.

Digital Impressions and Study Models in Orthodontics

Digital study models in orthodontics were not made commercially available until 1999 with the advent of OrthoCAD®[1] (Dragstrem 2015). This software allowed what had been previously unavailable to a private practice orthodontist, digital study models. At first, OrthoCAD® required users

[1] Align Technology, Inc., San Jose, CA 95131

to send alginate impression and wax bites to them via overnight mail. These impressions were then scanned at the OrthoCAD® service center and within a week sent over the internet to the practitioner's computer (Marcel and Marcel 2001). Digital study models offer many advantages, such as not requiring physical storage, allowing fast retrieval and transferability, not being subject to physical damage or deterioration, decreasing storage space and costs, and allowing digital diagnostic setups (Peluso et al. 2004; Favero et al. 2009).

The early procedure of taking impressions and sending them into a company is now supplemented by other scanning options like in-office model/impression scanners and intraoral scanners. In-office laser scanners can be used to scan stone study models or impressions into digital study models without having to send anything to another company for scanning (Barry 2011). These scanners rely on laser light being reflected off the surface of the impression or model and then capturing this reflected light on two cameras in order to create a digital study model (Kuroda et al. 1996; Barry 2011). Digital intraoral scanners simplify this process even further by eliminating the steps of taking conventional impressions or making plaster models. Digital intraoral scanners use either white light or laser light which is then reflected off the surface of the teeth and gums back into a camera or sensor inside the scanning wand (Kravitz et al. 2014). The data from this reflected light is assembled to create a digital study model of the teeth and gums (Kravitz et al. 2014).

A major concern with all types of digital models is their accuracy compared to standard analog models. Fortunately, digital models rely on evolving hardware and software that is updated to correct measurement errors and other issues. OrthoCAD® is the main software program used in orthodontics and therefore has the most studies concerning accuracy of measurements (Park and Laslovich 2016). When OrthoCAD® was still relatively new the tooth widths and overbite were underestimated by the software when compared to measurements performed on analog study models using a Boley gauge (Santoro et al. 2003). While these differences were statistically significant there appeared to be no clinically relevant difference (Santoro et al. 2003). OrthoCAD® showed high accuracy and reproducibility but did not show the same level of accuracy and reproducibility as digital calipers did on plaster models (Zilberman et al. 2003). Again, in 2004, a

statistical difference between OrthoCAD® measurements and those made with a digital caliper on plaster models was found. Overbite, overjet, intermolar distances, intercanine distances, available space, and required space were all examined. For overbite and overjet the digital models underestimated values, but in all other measurements the digital measurements were found to be larger than the plaster model measurements (Quimby et al. 2004). Once again, these differences were not found to be clinically significant as these differences would most likely not change a diagnosis or a treatment plan (Quimby et al. 2004). OrthoCAD® demonstrated accuracy in generating models that were as accurate as analog models.

Bolton analysis is another important measurement tool in orthodontics used to determine tooth-size discrepancies. This analysis determines a relative difference between the total width of maxillary and mandibular teeth (Proffit et al. 2013). In 2001, OrthoCAD® and other software solutions for digital measurements of Bolton discrepancies were found to have clinically significant differences from measurements obtained via Vernier calipers; however, these software solutions were significantly faster in completing the analysis (Tomassetti et al. 2001). The early software options for model analysis still needed improvement in measuring accuracy, but offered increased efficiency over caliper measurements. By 2007 the difference between a software calculation of the Bolton analysis and calculations made from plaster models were found to be both clinically and statistically insignificant (Mullen et al. 2007). The software proved to be accurate in determining an important measurement tool in orthodontics, the Bolton analysis. Digital study models have been shown to be as accurate as conventional study models for the measurements utilized in orthodontics.

Orthodontic Study Model Software

Many options for software exist for generating and manipulating orthodontic digital study models. The software options are often associated with the manufacturer of an intraoral scanner or in-office impression/model scanner. Table 1 shows a representative list of companies, the scanners they make, whether those scanners are intraoral or impression/model scanners, and the software associated with the scanners (Martin et al. 2015).

TABLE 1

AVAILABLE ORTHODONTIC SCANNERS AND SOFTWARE

Company	Scanners Made	Type of Scanner: Intraoral (IO) or impression/model (I/M)	Software
3Shape®[2]	R500, R700, R900	I/M	Ortho Analyzer™
3Shape®	TRIOS®	IO	Ortho Analyzer™
AGE Solutions[3]	Maestro® 3D Dental Scanner	I/M	Ortho Studio
Dental Wings[4]	iSeries, 3Series, 7Series	I/M	DWOS
Motion View[5]	Ortho Insight 3D® Digital Scanner	I/M	Ortho Insight 3D®
Ormco™[6]	Lythos Scanner™	IO	Ormco Insignia™ Advanced Smile Design
3M™ Espe[7]	3M™ True Definition	IO	Unitek Treatment Management Portal Digital Model
Align Technology Inc.[8]	iTero®	IO	OrthoCAD®
E4D Technologies[9]	Planmeca PlanScan®	IO	Planmeca Romexis® 3D Ortho Studio
IOS Technologies Inc.[10]	IOS FastScan	IO	Orchestrate Core
Carestream® Dental[11]	CS 3500 Intraoral Scanner	IO	Orthotrac®

As noted in Table 1, approximately ten software programs associated with scanners appear to be available to assist the orthodontist in creating and utilizing digital study models. Software programs that are not associated with scanning hardware are also available, such as DigiModel® by

[2] 3Shape, Holmens Kanal 7, 1060 Copenhagen, Denmark
[3] AGE Solutions, Rinaldo Piaggio Avenue, 32, 56025 Pontedera, Italy
[4] Dental Wings Inc., 2251, av Letourneux, Montreal H1V 2N9, Canada
[5] Motion View, LLC, 2730 Kanasita Dr, Hixson, TN 37343
[6] Ormco, 1717 West Collins Ave, Orange, California 92867
[7] 3M, 3M Center, St. Paul, MN 55144
[8] Align Technology, Inc., San Jose, CA 95131
[9] E4D Technologies, 650 International Parkway, Richardson, TX 75081
[10] IOS Technologies Inc., 3978 Sorrento Valley Blvd, Suite 200, San Diego, CA 92121
[11] Carestream Dental LLC, 1765 The Exchange, Atlanta, GA 30339

OrthoProof USA™[12] and O3DM®[13] by OrthoLab (Westerlund et al. 2015). Both OrthoProof USA™ and OrthoLab create digital models by scanning models or impressions sent to them by orthodontists and then offer their software that allows viewing and manipulation of the digital models (Westerlund et al. 2015).

Current Orthodontic Study Model Software Usability

While many programs exist for creating and manipulating digital study models there appears to be only one study to date examining the usability of these programs by orthodontists. That study also does not examine the integration of digital study models into an orthodontic practice or the overall satisfaction of orthodontists with the software programs.

The previously mentioned study was conducted in 2015 and examined the services, features, and usability of several orthodontic digital study model software programs (Westerlund et al. 2015). The study was limited in that four programs were evaluated by four orthodontists. The evaluated programs included OrthoCAD®, O3DM®, Digimodel®, and OrthoAnalyzer™ using digital study models created from submitted plaster pretreatment models (Westerlund et al. 2015). With these programs, after the study models are generated and provided to the clinician, the software is also provided for viewing and potential treatment planning with the digital model (Westerlund et al. 2015). The services and features of these four programs were found to be similar; however, the usability of the programs was found to be lacking (Westerlund et al. 2015). The four tasks that were evaluated to test program usability were opening a patient file, viewing the digital models from multiple angles, measuring overjet and overbite, and performing space analysis (Westerlund et al. 2015). Based on the study results, all of these tasks were not intuitive to the software user and the software requires further development (Westerlund et al. 2015). These tasks demonstrate some of the items needed to plan treatment of an orthodontic case, but the results of this study are limited due to the small sample size. The integration of digital study models with software-based treatment planning in orthodontic offices needs to be examined on a larger scale.

[12] OrthoProof USA, 5201 Venice Ave NE, Suite C, Albuquerque, NM 87113
[13] OrtoLab Sp. Z o.o., ul. Krotka 29/31, 42-200 Czestochowa, Polska

Problem Statement

No research to date has explored the perceptions and challenges of practicing orthodontists when it comes to digital study models and using those models for treatment planning. Previous research suggests that usability of digital model software programs is lacking and that these programs need further development. As digital study models become more widespread in their use, it will be imperative to have intuitive programs that allow straightforward manipulation and measurement of digital study models for treatment planning. The purpose of this study was to survey practicing orthodontists to determine what demographic factors lead to these practitioners creating digital study models and then taking the additional step of using those models in treatment planning. Another purpose of this study was to determine potential weaknesses in current digital study model software, so that manufacturers can address those items in future updates.

Hypothesis and Observations

1. The demographics of an orthodontist and their office play a role in incorporating digital study models into their practice and in whether they use those models in treatment planning.
2. Based on observational survey responses, information regarding the benefits, challenges and potential improvements in existing digital model programs will be gathered to aid in improving these programs.

CHAPTER 2

MATERIALS AND METHODS

Survey Development and Description

To study the creation and use of digital study models by private practicing orthodontists a 22-item questionnaire was created. The questions solicited information regarding the use of digital study models, their feelings about the current software for digital models, and their use of other digital records.

The 22-question survey focused on two domains: (1) orthodontist demographics, and (2) orthodontic office demographics. The first domain, orthodontist demographics, solicited information concerning the orthodontist's year of dental school graduation, year of orthodontic residency graduation, gender, working status, and number of offices working in currently.

The second domain, orthodontic office demographics, focused only on the primary office location of the orthodontist. The primary office location was defined as the location where the orthodontist spends most of his or her time. This domain solicited information concerning office location by region, population density surrounding the office, number of orthodontists practicing in the office, office ownership, use of digital health/dental records, and use of digital radiographs.

These two domains were utilized to determine whether they play a role in the practitioner creating digital study models for patients and whether those digital models are used in treatment planning. Additional questions were observational and focused on the benefits, challenges and possible improvements in current software available for digital model capturing and manipulation.

Before finalizing the survey, a focus group of part-time orthodontic faculty in the UMKC Advanced Orthodontic Clinic evaluated the survey for clarity and content. The focus group was given an evaluation form as well as a paper copy of the survey. Feedback from the focus group was used to update the survey prior to distribution. A research committee also evaluated the survey for clarity and content prior to distribution.

A paper copy of the final version of the survey is located in Appendix 1. The focus group evaluation form is located in Appendix 2.

Survey Distribution and Data Collection

This study was directed toward practicing orthodontists who are active members of the American Association of Orthodontists (AAO). The survey was distributed electronically through the AAO Partners in Research program for a fee of 75 dollars. As of April 4th, 2016, the AAO consisted of approximately 17,627 members including international members. In the United States, 9,226 practicing orthodontists are members of the AAO. The Partners in Research program distributed the survey electronically via email to approximately 2,300 randomly selected members in the United States. A copy of that email is located in Appendix 3. One additional email was sent to these selected members approximately 3 weeks after the initial email to remind them about taking the survey. This email was the same email that was sent initially. No additional communication occurred with possible survey participants.

The final version of the survey was in electronic format and was designed and implemented using Research Electronic Data Capture (REDCap). The Center for Health Insights of UMKC hosts REDCap and allows data entry through electronic forms which are then stored securely. This software allowed nested questions and termination of the survey at different points, which was not possible using a paper format. The electronic version was also easier to distribute.

The survey and the distribution protocol were reviewed and approved by the University of Missouri-Kansas City (UMKC) Institutional Review Board (IRB Protocol 15-186). The informed script that was at the beginning of the survey is located in Appendix 4. The approval letter from the IRB is included in Appendix 5.

Experimental Design

As was previously discussed a convenience sample of approximately 2,300 orthodontists, who are members of the AAO, received this survey via email. This study used a non-experimental design with two factors. The two independent variables were the orthodontist demographics and the orthodontic office demographics. These two independent variables were broken into more specific details that may influence the use of digital study models in private practice. The dependent variables to be assessed by this study included the creation of digital study models by the practitioner and the

use of those models in orthodontic treatment planning. The overall experimental design of this study is shown in Table 2.

TABLE 2

EXPERIMENTAL DESIGN: INDEPENDENT AND DEPENDENT VARIABLES

Specific details	Independent variables	Dependent variables
Year of dental school graduation	Orthodontist demographics	1. Creation of digital study models 2. Use of digital study models for treatment planning
Year of orthodontic residency graduation		
Gender		
Working status		
Number of offices working in currently		
Office location by region	Orthodontic office demographics	
Population density surrounding the office		
Number of orthodontists practicing in the office		
Office ownership		
Use of digital health/dental records		
Use of digital radiographs		
Sample size (n) = 156 orthodontists		

Data Analysis

For the two domains, orthodontist demographics and orthodontic office demographics, a composite score was generated. The composite scoring was developed based on the hypothesis that demographics do play a role in the use of digital study models. Higher scores were assigned to demographic factors that appear to increase the likelihood of an orthodontist using such models. The following reasoning explains the composite scores for each question. For questions 2 and 3, a recent graduate would be more likely to have exposure to digital model technology and therefore be more likely to be using such models. For question 5, an orthodontist who owns their office would have the freedom to make decisions to use digital models unlike an independent contractor who has little say in the office. For question 6, an orthodontist who works in multiple offices is more likely to have exposure to digital models and therefore would be more likely to use them. For question 8, urban areas tend to have more of a technological focus than rural areas due to the faster pace of life and so

the use of digital study models would be higher in urban areas. For question 9, a practice with more orthodontists would tend to have more cash flow and therefore be more likely to purchase the equipment for digital models. For questions 11 and 12, the use of other digital modalities would increase the likelihood of using digital study models. The composite scoring was based on assumptions as demonstrated in the previous explanations.

Additionally, the composite score allowed effect testing and correlation testing between overall demographics as well as specific contributing factors to the dependent variables. For example, whether specific demographic details do play a role in digital model use. Appendix 6 shows the scoring rubrics for the two domains.

Data collected from the responses to the survey were coded and input into a statistics software program[14]. Appropriate descriptive statistics were computed including central tendencies and frequency distributions. To evaluate the effect of orthodontist demographics and orthodontic office demographics on digital study model use the one-way ANOVA test was used. In addition, chi-square and Fisher exact testing were used to examine individual variables. A significance level of $\alpha = 0.05$ was used for all testing.

[14] IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY 10504

CHAPTER 3

RESULTS

The survey was distributed to approximately 2,300 orthodontists, of which 193 orthodontists initiated the survey, and 166 orthodontists completed the survey. This number of completions leads to a total response rate of 7.2 percent. Ten of those that completed the survey were not in private practice, so 156 respondents were used in the final statistical analyses.

Demographics and Statistical Significance

Table 3 presents how many of the respondents created digital study models as well as how many used these study models for treatment planning. Demographic data is also provided in this table. The majority of the respondents (51%) graduated from orthodontic residency between 1980 and 1999. The majority of the respondents were male (87%), owners of their practice (87%), work in 1 office (50%), work in urban areas (59%), work in offices that have only 1 orthodontist (74%), work in offices owned by an orthodontist (94%), use digital health records (84%), and use digital radiographs (97%).

Statistical significance of the responses was first determined using one-way ANOVA testing. Through this testing, this survey found a significant association between orthodontist composite score and creating digital models ($p = 0.012$), between orthodontist composite score and using digital models for treatment planning ($p = 0.005$), and between orthodontic office score and creating digital study models ($p = 0.023$). These results support hypothesis 1.

Since overall associations were present in the responses, individual predictors of interest were examined and analyzed using the chi-square test or the Fisher's exact test. Table 3 relates the dependent variables to the independent variables and shows the statistical significance.

Several predictors of interest showed statistical significance as shown in Table 3. There was a statistically significant association between year of orthodontic residency graduation and the practitioner creating digital study models ($p=0.032$); however, no such statistically significant association was present between graduation year and the practitioner using such models in treatment planning ($p=0.083$). Recent graduates were more likely to create digital study models. Primary office

location and the use of digital health records also demonstrated a statistically significant association to the creation of digital study models (p=0.044 and p=0.001, respectively). Practitioners in the southwest region were more likely to create digital models while those in the Rocky Mountain region were less likely. Orthodontists who used digital health records were more likely to create digital models. In contrast, none of the predictors of interest showed a statistically significant association to the use of digital model treatment planning.

TABLE 3

RELATIONSHIP OF DIGITAL STUDY MODEL CREATION AND USE IN TREATMENT PLANNING WITH VARIOUS PREDICTORS OF INTEREST

	Created Digital Study Models		Used Models for Tx Planning	
	No (N = 56) N (%)	Yes (N = 100) N (%)	No (N = 25) N (%)	Yes (N = 75) N (%)
Year of Orthodontic Residency Graduation	p-value = 0.032*		p-value = 0.083*	
1960 to 1979	19 (33.9%)	16 (16.2%)	2 (8.0%)	14 (18.9%)
1980 to 1999	26 (46.4%)	53 (53.5%)	11 (44.0%)	42 (56.8%)
2000 or after	11 (19.6%)	30 (30.3%)	12 (48.0%)	18 (24.3%)
Gender	p-value = 0.821*		p-value > 0.999‡	
Male	48 (85.7%)	87 (87.0%)	22 (88.0%)	65 (86.7%)
Female	8 (14.3%)	13 (13.0%)	3 (12.0%)	10 (13.3%)
Job Status	p-value = 0.703‡		p-value = 0.233‡	
Independent Contractor	1 (1.8%)	4 (4.0%)	1 (4.0%)	3 4.0%)
Employee	3 (5.4%)	3 (3.0%)	0 (0.0%)	3 (4.0%)
Associate	4 (7.1%)	5 (5.0%)	3 (12.0%)	2 (2.7%)
Owner	48 (85.7)	88 (88.0%)	21 (84.0)	67 (89.3%)
Number of Offices Working In	p-value = 0.091‡		p-value = 0.137‡	
1	31 (55.4%)	47 (47.0%)	11 (44.0%)	36 (48.0%)
2	10 (17.9%)	28 (28.0%)	4 (16.0%)	24 (32.0%)
3	6 (10.7%)	14 (14.0%)	7 (28.0%)	7 (9.3%)
4	7 (12.5%)	3 (3.0%)	1 (4.0%)	2 (2.7%)
5 or more	2 (3.6%)	8 (8.0%)	2 (8.0%)	6 (8.0%)
Primary Office Location	p-value = 0.044*		p-value = 0.372‡	
Pacific/Noncontiguous	8 (14.3%)	13 (13.0%)	3 (12.0%)	10 (13.3%)
Rocky Mountains	9 (16.1%)	6 (6.0%)	4 (16.0%)	2 (2.7%)
Southwest	2 (3.6%)	16 (16.0%)	4 (16.0%)	12 (16.0%)
Midwest	18 (32.1%)	21 (21.0%)	5 (20.0%)	16 (21.3%)
Southeast	10 (17.9%)	25 (25.0%)	5 (20.0%)	20 (26.7%)
Northeast	9 (16.1%)	19 (19.0%)	4 (16.0%)	15 (20.0%)

Table 3 Continued

	Created Digital Study Models		Used Models for Tx Planning	
	No (N = 56) N (%)	Yes (N = 100) N (%)	No (N = 25) N (%)	Yes (N = 75) N (%)
Approximate Population of Area Served by Office	p-value = >0.999*		p-value = 0.558‡	
Rural (<2,500 residents)	1 (1.8%)	3 (3.0%)	1 (4.0%)	2 (2.7%)
Urban Cluster (2,500 to 50,000 residents)	22 (39.3%)	38 (38.0%)	11 (44.0%)	27 (36.0%)
Urban (>50,000 residents)	33 (58.9%)	59 (59.0%)	13 (52.0%)	46 (61.3%)
Number of Orthodontists Working in Office	p-value = 0.084*		p-value = 0.856‡	
1	48 (85.7%)	68 (68.0%)	16 (64.0%)	52 (69.3%)
2	6 (10.7%)	23 (23.0%)	7 (28.0%)	16 (21.3%)
3	2 (3.6%)	8 (8.0%)	2 (8.0%)	6 (8.0%)
4	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
5 or more	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (1.3%)
Type of Office Ownership	p-value = 0.064*		p-value = 0.296‡	
Privately Owned	50 (89.3%)	97 (97.0%)	24 (96.0%)	73 (97.3%)
Corporately Owned	4 (7.1%)	1 (1.0%)	1 (4.0%)	0 (0.0%)
Other	2 (3.6%)	2 (2.0%)	0 (0.0%)	2 (2.7%)
Use Digital Health Records	p-value = 0.001*		p-value = 0.444‡	
No	16 (28.6%)	9 (9.0%)	1 (4.0%)	8 (10.7%)
Yes	40 (71.4%)	91 (91.0%)	24 (96.0%)	67 (89.3%)
Use Digital Radiology	p-value = 0.056*		p-value = 0.250‡	
No	4 (7.1%)	1 (1.0%)	1 (4.0%)	0 (0.0%)
Yes	52 (92.9%)	99 (99.0%)	24 (96.0%)	75 (100.0%)

*Chi-square tests used.
‡Fisher's Exact test used.

Digital Models in Treatment Planning

Table 4 focuses on the percentage of practitioners that create digital models and take the additional step of doing digital model treatment planning. Please note that none of these differences were significant. For orthodontists that graduated from residency in 2000 or after, 60.0% used digital model treatment planning while those that graduated from 1960 to 1979 and from 1980 to 1999, the use was 87.5% and 79.2% respectively. This difference is not statistically significant. Males and females both had similar use of digital models for treatment planning at 74.7 and 76.9 percent,

respectively. Associate orthodontists showed the lowest percentage among job statuses at 40.0 percent use in treatment planning. Only 50.0% of orthodontists working in 3 offices utilized these models in treatment planning while all others used them 66.7% or more.

TABLE 4

PERCENTAGE OF THOSE THAT CREATE DIGITAL STUDY MODELS AND USE THEM FOR TREATMENT PLANNING

	Creates Digital Models (N)	Uses Digital Models for Tx Planning (N)	Percent Who Use Digital Models for Tx Planning (%)
Year of Orthodontic Residency Graduation		p-value = 0.083*	
1960 to 1979	16	14	87.5
1980 to 1999	53	42	79.2
2000 or after	30	18	60.0
Gender		p-value > 0.999‡	
Male	87	65	74.7
Female	13	10	76.9
Job Status		p-value = 0.233‡	
Independent Contractor	4	3	75.0
Employee	3	3	100.0
Associate	5	2	40.0
Owner	88	67	76.1
Number of Offices Working In		p-value = 0.137‡	
1	47	36	76.6
2	28	24	85.7
3	14	7	50.0
4	3	2	66.7
5 or more	8	6	75.0
Primary Office Location		p-value = 0.372‡	
Pacific/Noncontiguous	13	10	76.9
Rocky Mountains	6	2	33.3
Southwest	16	12	75.0
Midwest	21	16	76.2
Southeast	25	20	80.0
Northeast	19	15	78.9
Approximate Population of Area Served by Office		p-value = 0.558‡	
Rural (<2,500 residents)	3	2	66.7
Urban Cluster (2,500 to 50,000 residents)	38	27	71.1
Urban (>50,000 residents)	59	46	78.0
Number of Orthodontists Working in Office		p-value = 0.856‡	
1	68	52	76.5
2	23	16	69.6
3	8	6	75.0
4	0	0	
5 or more	1	1	100.0
Type of Office Ownership		p-value = 0.296‡	
Privately Owned	97	73	75.3
Corporately Owned	1	0	0.0
Other	2	2	100.0

Table 4 Continued

	Creates Digital Models (N)	Uses Digital Models for Tx Planning (N)	Percent Who Use Digital Models for Tx Planning (%)
Use Digital Health Records		p-value = 0.444‡	
No	9	8	88.9
Yes	91	67	73.6
Use Digital Radiology		p-value = 0.250‡	
No	1	0	0.0
Yes	99	75	75.8

*Chi-square tests used.
‡Fisher's Exact test used.

The primary orthodontic office characteristics also played a role in whether digital models were used in treatment planning; however, these characteristics were not statistically significant. Those in the Rocky Mountain region showed a lower percentage use (33.3%) of these models in treatment planning compared to all other regions. The percentage of digital model treatment planning increased from rural (66.7%) to urban cluster (71.1%) and from urban cluster to urban (78.0%). The number of orthodontists in the office showed no difference in using digital models for treatment planning (76.5, 69.6, and 75.0 respectively). Interestingly, offices that did not use digital health records were more likely to use digital model treatment planning (88.9%) than those that did use digital health records (73.6%). Most offices that use digital radiography also use digital models for treatment planning (75.8%).

Observational Data

Table 5 shows some of the responses to observational questions asked in the survey. The top two reasons for not using digital study models were cost and preference for plaster models. Nineteen respondents selected "other" and the top response within that answer choice was that a good set of photographs eliminates the need for models. The majority of those that created digital study models did receive training in that software (71.0%). Of those that use digital models for treatment planning, 39% used the advanced capabilities of the digital model software.

TABLE 5

BREAKDOWN OF MODEL USE RESPONSES AND RESPONSES TO OBSERVATIONAL QUESTIONS

Reasons Not Using Digital Models				
Prefer Plaster Models	Too Difficult to Use	Cost	Would Use Them if Could	Other
16	0	17	4	19
Received Training in the Selected Software				
No			Yes	
29			71	
Use Advanced Capabilities of Software for Treatment Planning				
No			Yes	
46			29	

Other observational questions examined which software the orthodontist used as well as their likes and dislikes of that software. Responding orthodontists used a wide range of software to store and utilize digital models for treatment planning. OrthoCAD® (44%) was used most often for creating digital study models, OrthoTrac® (9%) was second and SureSmile®[15] (6%) was third. OrthoCAD® (47%) was also used most often to manipulate digital models for treatment planning, SureSmile® (12%) was second, and Invisalign® ClinCheck®[16] (8%) was third. The top three aspects of the software the practitioner liked were, first, the user interface is intuitive, second, the software creates open source STL files, third, the software creates digital setups with ease. The top response for aspects that the practitioner didn't like was that they had nothing specific they did not like about the software. The next highest dislike was licensing fees followed by a non-intuitive user interface and that the software does not offer all the features desired.

[15] Orametrix, Inc., Richardson, TX 75082
[16] Align Technology, Inc., San Jose, CA 95131

CHAPTER 4

DISCUSSION

This study evaluated the creation of digital models and treatment planning with these models by private practice orthodontists. A few surveys have been performed that evaluate digital study models use, but none have examined the use of digital study models for treatment planning. The JCO surveys practicing orthodontists periodically about diagnosis and treatment procedures (Keim et al. 2014). These surveys ask about digital models, but they do not ask about their use beyond whether the models were created. Another survey, of orthodontic residencies, looked at digital model use and the advantages and disadvantages of these models (Shastry and Park 2014). The survey did not extend beyond residency programs and did not examine how often digital models were used in treatment planning. A recent survey, in 2016, focused on the use of digital models by private practice orthodontists and found that the majority of the 213 respondents primarily used plaster study models (Park and Laslovich 2016). This contradicts the results presented in this study, which showed that 64% of respondents created digital models. The contradiction is most likely because the 2016 study also focused on intraoral scanners and CBCT usage, which probably appealed to a broader base of orthodontists. In addition, the title of the study presented here most likely discouraged participants that had no interest in digital models, thus skewing the numbers to show more digital model usage then is actually occurring. The 2016 study also showed that the most used software for digital models was OrthoCAD®, which agreed with the findings of this study. The 2016 survey did not examine the use of digital models in treatment planning which this study evaluated. The point of the study presented in this thesis was to explore the use of digital study models in treatment planning by practicing orthodontists, which has not been explored by previous studies.

Significant Demographic Factors

The survey results do show a significant association between the demographics of orthodontists and their offices and the use of digital models. It was surprising that only a few demographic factors had a significant association with the creation of digital models by the practitioner and none of the factors had a significant association with actually using the models in

treatment planning. Orthodontic graduation year does play a role in the creation of digital models by the practitioner; however, it is interesting that no such connection was found between graduation year and the use of such models in treatment planning. With a p-value of 0.083, there may have been a significant association between graduation year and the utilization of digital treatment planning with a larger sample size. The trend seen for the creation of digital models, as shown in Table 3, shows that the more recent graduates were more likely to create digital study models. This might be due to residency programs having digital study model technologies that residents can utilize. In contrast, recent graduates were less likely to use these models in treatment planning as shown in Table 4. This result is perhaps due to the large debt of the recent graduates and that they feel their time is better utilized in another area, such as marketing. Recent graduates are not as efficient as more experienced orthodontists since they are still trying to figure out their treatment style and their techniques. These orthodontists are conceivably filling their time with activities that will increase their patient pool and their efficiency in treating patients in the clinical chair.

Another possibility is that graduate programs are not emphasizing the use of digital treatment planning. These programs may not be demonstrating the value of such planning, since it will help determine the best possible treatment plan for the patient. Less recent graduates did not get exposure to digital models in residency and therefore learned about this technology while in private practice. These graduates also moved teeth manually in plaster models to determine treatment outcomes. This was a very time consuming process, as the teeth had to be cut from the plaster model and set in wax in their post-orthodontic position. The more experienced orthodontists might see the benefits of digital treatment planning compared to the methods of the past and understand the benefit of this technology.

Primary office location was also significant as an indicator for the practitioner creating digital models. The Rocky Mountain region was the only region where most of the respondents did not create digital models. All other regions showed that more orthodontists created digital models than not. Nearly 90% of the practitioners in the southwest region created digital models, which was significantly higher than all other regions. Although not statistically significant, the Rocky Mountain

region also showed much lower use of such digital models in treatment planning, just 33 percent. All other regions showed 75% or more. Most of the orthodontists in this area may be from certain residency programs in the Rocky Mountain region and these programs might not emphasize the value of digital models. The opposite may be true of the residency programs in the southwest region, which may emphasize digital models more than other regions.

The use of digital health records also showed an association to the creation of digital models by practitioners. Orthodontists that used digital records were more likely to create digital models. This is probably because they are already familiar with digital modalities, so they are comfortable switching to digital models. Surprisingly, those that did not use digital health records were more likely to use digital treatment planning. Orthodontists that use paper charting may be most cost conscious and therefore want to get the most value from their digital study model software by using all of its features, including digital model treatment planning.

Observational Responses

The observational items of this study were also interesting. Cost and preference for plaster models were the two most common reasons for not using digital models. This is not surprising as the initial cost of desktop or intraoral scanners is expensive (Kravitz et al. 2014). Analog models require inexpensive materials that are fast and accurate. The materials for analog models are also familiar to clinicians and the switch to digital models requires training staff, which could cause an initial loss in office efficiency. Some orthodontists preferring plaster models is also not surprising as plaster models are easy to manipulate and view and they offer a tactile feel that digital models cannot.

Some of the “other” responses for why orthodontists did not take digital models were interesting. One orthodontist said, “When will the profession grow up and quit using models AT ALL. They are completely meaningless and a waste of time. Color pictures of the face and teeth tell us everything we need to know. As long as the orthodontic profession continues to focus on teeth we will continue to be nothing more than a trade and certainly not a health care profession.” This orthodontist is not alone in his thoughts as eight other respondents shared similar thoughts. Another orthodontist wrote, “My published AJODO master's thesis was about the accuracy of digital models. I

used them from the beginning of my practice for a few years and then quit because models are useless for my diagnosis and useless for records with good photographs. Along with most orthodontists in my area and neighboring states where my friends practice, the consensus is that models for records are a waste of time and money. They are no longer the standard of care." Several orthodontists feel that a good set of photographs is sufficient to diagnose and treatment plan a case. The orthodontist quoted above mentions that pretreatment models are not the standard of care; however, the American Association of Orthodontists (AAO) says that pretreatment records should include extra and intraoral photographs, dental models, a panoramic radiograph, and a lateral cephalometric radiograph (Orthodontists 2014). The standard of care is fluid and may change if less and less orthodontists use models in treatment.

The majority of respondents who use digital models did receive training for the accompanying software. Such training is very important, as orthodontists are more likely to use software with which they are familiar. This training will reduce stress and time invested to figure out the features of such software. On another note, it is slightly discouraging that most of the respondents did not use the advanced capabilities of the software in order to facilitate treatment planning. These tools can greatly improve a providers understanding of issues that may be present in a patient. Orthodontists conceivably do not use these tools, as it requires an additional investment of time. They may figure that they can handle any issue that arises during treatment rather than identifying such issues before starting treatment.

This survey did not consider the use of Invisalign® and SureSmile® in orthodontic treatment. These treatment modalities were not included as choices in the survey, but respondents wrote them in the "other" category. Both of these services require the approval of digital setups of the completed treatment before proceeding with treatment. Invisalign® is a clear aligner treatment that aligns teeth without traditional braces while SureSmile® bends wires that will ideally finish a traditional braces case. Since digital treatment planning is not optional in these services, they were not included as choices in the survey. The orthodontists that use these two options may not realize that they are using digital treatment planning. This survey was intended to examine the use of digital model

treatment planning in cases where such planning is not required, such as cases where the orthodontist bonds teeth and does all adjustments on their own. This survey does show that Invisalign® and SureSmile® are among the most commonly used digital treatment modalities.

Clinical Implications

Increased education on digital treatment planning for orthodontic residents is needed. Less recent graduates seem to understand the value of such planning while more recent graduates do not. It may be that residency programs are not teaching the value of models and digital treatment planning. If programs are not focused on this, then curriculums need to place more emphasis on the value of such digital model treatment planning and teach the residents how to use it effectively and efficiently. Many of these more recent graduates are probably busy and feel that doing this planning would just add one more thing to do in a busy practice. What these graduates fail to realize is that such planning may actually save them time during treatment. This planning will help them catch potential problems prior to starting treatment. Those experienced with treatment planning could help these more recent graduates learn this valuable skill.

Another aspect that could arise from not doing digital treatment planning is less than ideal results. This type of planning allows the orthodontist to see what they must do to reach the result they desire. They can see if build-ups are needed to resolve tooth size differences between the maxillary or mandibular arch or see if anchorage is needed to hold the molars back during treatment. A more experienced orthodontist may recognize these potential problems, but the less experienced orthodontist, the one who needs the most help recognizing such problems, is not using such planning like their more experienced peers. This may lead to a decrease in the quality of orthodontic finishes as “good enough” becomes the standard.

Survey responses also show that there is a group of orthodontists that feel dental models are unnecessary. Despite having a standard of care as defined by the AAO, there is no way to enforce it. An orthodontic case may be diagnosed from pictures and radiographs, but photos may not show occlusion or other aspects that cannot be noticed in a 2D image. Analog or digital models provide a 3D representation of the patient’s occlusion and provide information that cannot be obtained from

another source. This group of orthodontists feel that dental models do not add value to their practice and time is money.

Study Limitations

The main limitation of this study is the small sample size of 166 orthodontists, which was due to a response rate of only 7.2 percent. The low response rate was likely due to the impersonal email distribution of the survey. A more active approach of reaching out to these individuals may help them feel a commitment to respond.

Additionally, the survey had a title that mentioned digital models, which may have discouraged those with no interest in digital models from taking the survey. This may have led to an underrepresentation of those who do not use digital models. To limit this possibility the survey title could have been "Study Model Use in Orthodontic Practice."

As was mentioned earlier, the survey did not include software such as Invisalign® ClinCheck® or SureSmile®. Invisalign® ClinCheck® is the software component for treating with Invisalign®. These were not intended to be options, but the survey instructions could have explained that the goal of this study was to evaluate digital treatment planning in instances where such planning is not required by the software. Both Invisalign® ClinCheck® and SureSmile® require digital model treatment planning to pursue or continue orthodontic treatment. Another option could be to include additional questions addressing the use of software systems such as Invisalign® or SureSmile®. This would have offered additional insight into what orthodontists are using in private practice.

Future Directions

Opinions of digital models appear to be split in the orthodontic community. Some appear to embrace the technology while others see no use for it. Future studies could focus on why such a rift exists in the private practice community. A survey could ask questions specifically about why models are or are not necessary for orthodontic treatment. The answers to such questions could help the AAO more clearly address the standard of care.

Another possible future direction is to address the use of Invisalign® and SureSmile® as these were not included in this survey. A future study could examine the use of such technologies and see

how much each orthodontist is utilizing these options. Understanding how many practices use Invisalign® and SureSmile® as well as what percentage of treatment these modalities constitute in those practices would be helpful. Both of these options eliminate the orthodontists need to bend wire to finish cases ideally. Knowing why orthodontists are choosing these options would also be beneficial.

CHAPTER 4

CONCLUSIONS

1. The demographics of an orthodontist and their office play a significant role in incorporating digital study models into their practice. In particular, more recent orthodontic residency graduates, orthodontists that use electronic dental records, and certain locations of the primary orthodontic office were more likely to create digital models. No demographic factors played a significant role in the use of digital models in treatment planning.
2. Based on observational survey responses, information regarding the benefits, challenges and potential improvements in existing digital model programs was gathered to aid in improving these programs.
    - Based on these responses:
        - The majority of those that created digital study models did receive training in that software.
        - Less than half of those that used digital treatment planning used the advanced software capabilities.
        - The main reason orthodontists liked their digital model software was it was intuitive.
        - Most orthodontists did not have any dislike of their software.

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APPENDIX A

SURVEY

1. **Are you currently practicing in a private orthodontic clinic?**
    a. Yes
    b. No (If no, then end survey)
2. **Year of dental school graduation:**
    a. Prior to 1960
    b. 1960 to 1969
    c. 1970 to 1979
    d. 1980 to 1989
    e. 1990 to 1999
    f. 2000 to 2009
    g. 2010 or after
3. **Year of orthodontic residency graduation:**
    a. Prior to 1960
    b. 1960 to 1969
    c. 1970 to 1979
    d. 1980 to 1989
    e. 1990 to 1999
    f. 2000 to 2009
    g. 2010 or after
4. **Gender:**
    a. Male
    b. Female
5. **What is your current status as a private practice orthodontist?** (multiple choices may be selected)
    a. Independent contractor
    b. Employee
    c. Associate
    d. Owner
6. **How many orthodontic office locations do you work in currently?**
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5 or more

Please answer the following questions for your primary office location ONLY (The office where you spend most of your time)

7. **In which region is the office located?**
    a. Pacific/Noncontiguous (California, Oregon, Washington, Alaska, Hawaii)
    b. Rocky Mountains (Montana, Idaho, Wyoming, Nevada, Utah, Colorado)
    c. Southwest (Arizona, New Mexico, Texas, Oklahoma)
    d. Midwest (North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio)
    e. Southeast (Arkansas, Louisiana, Kentucky, Tennessee, Mississippi, Alabama, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Delaware, Maryland)
    f. Northeast (Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, Pennsylvania)

8. **What is the approximate population of the area you are serving?**
    a. Rural (<2,500 residents)
    b. Urban cluster (2,500 to 50,000 residents)
    c. Urban (>50,000 residents)
9. **How many orthodontists practice in the office?**
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5 or more

10. **What type of ownership exists in the office?**
    a. Privately owned (owned by an orthodontist or corporation owned by an orthodontist)
    b. Corporately owned (owned by a company and not an orthodontist)
    c. Other, please explain: _____
11. **Do you use digital health/dental records in the office?**
    a. No
    b. Yes
12. **Do you use digital radiographs (including scanned film radiographs) to help develop your treatment plans?**
    a. No
    b. Yes
13. **Do you take or create digital (virtual) models of patients?**
    a. Never (if selected, then move to question 14 and end survey)
    b. Sometimes (if selected, then skip question 14 and answer questions 15 and 16)
    c. Often (if selected, then skip question 14 and answer questions 15 and 16)
    d. Always (if selected, then skip question 14 and answer questions 15 and 16)
14. **Why don't you choose to use digital models at this time?**
    a. Prefer plaster models
    b. Too difficult to use
    c. Cost
    d. I'm not in a position to make the decision to use digital models, but I would use them if I could
    e. Other, please explain: _____

End of survey here if answered "a" in question 13

15. **What is the primary software you use to store digital models?**
    a. Ortho Analyzer
    b. Ortho Studio
    c. DWOS (Dental Wings Open System)
    d. Ortho Insight 3D
    e. Insignia Advanced Smile Design
    f. Unitek Treatment Management Portal Digital Model
    g. OrthoCAD
    h. Planmeca Romexis 3D Ortho Studio
    i. Orchestrate Core
    j. Orthotrac
    k. OrthoProof
    l. OrthoLab
    m. Other, please explain: _____
16. **Have you received training in the selected software?**
    a. No
    b. Yes
17. **How often do you use the digital (virtual) models in treatment planning?**
    a. Never (if selected, then end survey)
    b. Sometimes (if selected, then answer questions 17-20)
    c. Often (if selected, then answer questions 17-20)
    d. Always (if selected, then answer questions 17-20)

End of survey here if answered "a" in question 17

18. **What software do you primarily use to manipulate your digital models for treatment planning?**
    a. Ortho Analyzer
    b. Ortho Studio
    c. DWOS
    d. Ortho Insight 3D
    e. Insignia Advanced Smile Design
    f. Unitek Treatment Management Portal Digital Model
    g. OrthoCAD
    h. Planmeca Romexis 3D Ortho Studio
    i. Orchestrate Core
    j. Orthotrac
    k. OrthoProof
    l. OrthoLab
    m. Other, please explain: _____
19. **Do you use advanced software capabilities to facilitate the development of these treatment plans, such as digital setups?**
    a. No
    b. Yes
20. **What do you like about the software you use?** (check all that apply)
    a. User interface is intuitive
    b. Creates open source STL files
    c. Creates digital setups with ease
    d. Offers features that I could not find in other software
    e. Inexpensive
    f. Other, please explain: _____
21. **What don't you like about the software you use**? (check all that apply)
    a. User interface is not intuitive
    b. Difficult to rotate and move the models
    c. Software is slow and shutters when moving models
    d. Does not offer all of the features that I would like
    e. Too expensive
    f. Licensing fees
    g. There is nothing specific I don't like
    h. Other, please explain: _____
22. **Besides items you dislike about the software, are the any additional suggestions for improvements?**
    a. Please write down your suggestions below:
        i. _____
        _____
        _____
        _____
        _____
        _____

APPENDIX B

FOCUS GROUP EVALUATION FORM

Dear Dr. XXX,
The research I am working on at UMKC investigates the use of digital study models in orthodontic private practices. The attached survey will eventually be sent to private practicing orthodontists in hopes of better understanding their use of digital models. No personal identification information will be gathered from this survey. The final survey will be distributed in electronic form and will automatically end the survey or give additional questions depending on user responses. The questions will not have the prompts in parentheses as you see in this paper format such as, "if selected, then move to question XX." Please take the time to evaluate the attached survey for clarity and content. You are not expected to complete the survey, but rather to examine it with a critical eye. Please feel free to write comments on the attached survey if necessary.

Please fill out and return this page once you have completed your evaluation of the survey. A prepaid envelope is attached to this evaluation for easy return. Please mail the completed evaluation back to me within 1-2 weeks of receiving it. Your comments will help improve the survey prior to distribution to orthodontists throughout the country. If you receive this survey through the American Association of Orthodontists in the future, then please do NOT complete the survey. Thank you so much for your time in evaluating this survey. I could not succeed in this program without you.

Gratefully,
Mark Greenburg, DDS
UMKC School of Dentistry
Resident, Dept. of Orthodontics & Dentofacial Orthopedics
MS Candidate, Dept. of Oral and Craniofacial Sciences

Evaluation of Survey

- Are there any questions within the survey that are unclear or could be worded differently to improve the survey? If so, please explain.

- Are there any errors present in the survey such as grammatical errors? If so, please explain.

- Are there any questions that could be omitted from the survey? If so, please explain.

- Please give any other suggestions you might have to improve the survey.

APPENDIX C

SURVEY EMAIL PROMPT

Dear AAO Member,
My name is Mark Greenburg and I am an orthodontic resident and MS candidate in the Oral and Craniofacial Sciences at the University of Missouri-Kansas City. My thesis project is focused on educational research related to digital study models and their use in treatment planning in private orthodontic offices. On this topic, I am asking you to complete a survey for research purposes, the survey is accessible via the link provided below. The survey also requests your feedback on any potential improvements in programs that are currently being used for these models.

This survey is 20 questions in length and should take approximately 10 minutes to complete. All responses to this survey are anonymous and responses will be used to examine how digital study models are used in private practice. Although there is no direct benefit to you, your participation will provide data that will facilitate and enhance orthodontic education, treatment and care as related to digital study model programs.

Please complete this survey within 10 days of receiving it from the AAO.

Any survey responses you provide will be a valued contribution to this project, thank you in advance for your time.

Gratefully,

Mark Greenburg, DDS

APPENDIX D

INFORMED SCRIPT FOR SURVEY

You are being asked to participate in a research study.

This survey is being conducted to gather data on the use of digital (virtual) models in orthodontic practices.

Your participation in this study will involve completing a survey that includes 20 questions. The survey should take approximately 10 minutes to complete. If you decide to participate in this survey, your participation is kept confidential and is voluntary. The alternative to participation is not to participate. If you chose not to participate or to withdraw from the online study at any time, you may do so without penalty or loss of benefit to yourself. The results of the survey may be published but your identity will remain confidential.

In this research, there are no foreseeable risks to you in completing the survey. No identifying marker will be linked to your survey response. Although there is no direct benefit to you, your participation will provide data that will assist with a better understanding of digital study model use and treatment planning in private practice orthodontic offices.

If you have any questions concerning the survey, you may contact Mark Greenburg at greenburgm@umck.edu.

If you have any questions regarding your rights as a research participant, you may contact the UMKC IRB at 816-235-5927.

APPENDIX E

IRB APPROVAL LETTER

UMKC
Office of Research Services

UMKC
5319 Rockhill Road
Kansas City Missouri
TEL: 816 235-5927
FAX: 816 235-5602

NOTICE OF EXEMPT DETERMINATION

Principal Investigator: Mary Walker
00251 DS Oral Bio
Kansas City, MO 64109

Protocol Number: 16-184
Protocol Title: THE USE OF DIGITAL STUDY MODELS AND PERCEPTIONS TOWARDS EXISTING DIGITAL MODEL SOFTWARE
Type of Review: Exempt

Date of Determination: 05/16/2016

Dear Dr. Walker,

The above referenced study was reviewed and determined to be exempt from IRB review and approval in accordance with the Federal Regulations 45 CFR Part 46.101(b).

Determined to qualify under Exempt Category #2 as follows:
Research involving the use of educational tests (cognitive, diagnostic, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation.

This determination includes the following documents:

Attachments

Greenburg Research Proposal Approval Form
Email Introduction_16-184 MG_V1.0_05-12-16
Survey_16-184 MG_V1.0_05-12-16
Informed Script_16-184 MG_V1.0_05-12-16

You are required to submit an amendment request for all changes to the study, to prevent withdrawal of the exempt determination for your study. When the study is complete, you are required to submit a Final Report.

Please contact the Research Compliance Office (email: umkcirb@umkc.edu; phone: (816)235-5927) if you have questions or require further information.

Thank you,

Simon MacNeill
UMKC IRB

APPENDIX F

COMPOSITE SCORE RUBRIC

COMPOSITE SCORES SHOWN IN RED PARENTHESES

1. **Are you a currently practicing in a private orthodontics clinic?**
    a. Yes
    b. No (If no, then end survey)

Orthodontist Composite Score: Q2-6 (Possible Total Score = 19)

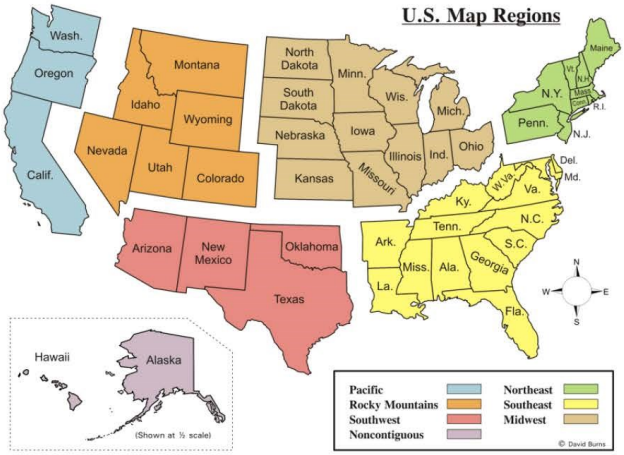
2. **Year of dental school graduation:**
    a. Prior to 1960 (0)
    b. 1960 to 1969 (1)
    c. 1970 to 1979 (2)
    d. 1980 to 1989 (3)
    e. 1990 to 1999 (4)
    f. 2000 to 2009 (5)
    g. 2010 or after (6)
3. **Year of orthodontic residency graduation:**
    a. Prior to 1960 (0)
    b. 1960 to 1969 (1)
    c. 1970 to 1979 (2)
    d. 1980 to 1989 (3)
    e. 1990 to 1999 (4)
    f. 2000 to 2009 (5)
    g. 2010 or after (6)
4. **Gender:**
    a. Male
    b. Female
5. **What is your current status as a private practice orthodontist?** (multiple choices may be selected)
    a. Independent contractor (0)
    b. Employee (1)
    c. Associate (2)
    d. Owner (3)
6. **How many orthodontic offices do you work in currently?**
    a. 1 (0)
    b. 2 (1)
    c. 3 (2)
    d. 4 (3)
    e. 5 or more (4)

COMPOSITE SCORES SHOWN IN RED PARENTHESES

Please answer the following questions for your primary office location ONLY (The office where you spend most of your time)

Orthodontist Composite Score: Q7-12 (Possible Total Score = 8)

7. **In which region is the office located?**
   a. Pacific/Noncontiguous (California, Oregon, Washington, Alaska, Hawaii)
   b. Rocky Mountains (Montana, Idaho, Wyoming, Nevada, Utah, Colorado)
   c. Southwest (Arizona, New Mexico, Texas, Oklahoma)
   d. Midwest (North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio)
   e. Southeast (Arkansas, Louisiana, Kentucky, Tennessee, Mississippi, Alabama, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Delaware, Maryland)
   f. Northeast (Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, Pennsylvania)



Map used by permission of Fasttrack Teaching Materials

8. **What is the approximate population of the area you are serving?**
   a. Rural (<2,500 residents) (0)
   b. Urban cluster (2,500 to 50,000 residents) (1)
   c. Urban (>50,000 residents) (2)
9. **How many orthodontists practice in the office?**
   a. 1 (0)
   b. 2 (1)
   c. 3 (2)
   d. 4 (3)
   e. 5 or more (4)
10. **What type of ownership exists in the office?**
    a. Privately owned (owned by an orthodontist or corporation owned by an orthodontist)
    b. Corporately owned (owned by a company and not an orthodontist)
    c. Other, please explain: _____
11. **Do you use digital health/dental records in the office?**
    a. No (0)
    b. Yes (1)

COMPOSITE SCORES SHOWN IN RED PARENTHESES

12. **Do you use digital radiographs (including scanned film radiographs) to help develop your treatment plans?**
    a. No (0)
    b. Yes (1)
13. **Do you take or create digital (virtual) models of patients?**
    a. Never (if selected, then move to question 14 and end survey)
    b. Sometimes (if selected, then skip question 14 and answer questions 15 and 16)
    c. Often (if selected, then skip question 14 and answer questions 15 and 16)
    d. Always (if selected, then skip question 14 and answer questions 15 and 16)
14. **Why don't you choose to use digital models at this time?**
    a. Prefer plaster models
    b. Too difficult to use
    c. Cost
    d. I'm not in a position to make the decision to use digital models, but I would use them if I could
    e. Other, please explain: _____

End of survey here if answered "a" in question 13

15. **What is the primary software you use to store digital models?**
    a. Ortho Analyzer
    b. Ortho Studio
    c. DWOS (Dental Wings Open System)
    d. Ortho Insight 3D
    e. Insignia Advanced Smile Design
    f. Unitek Treatment Management Portal Digital Model
    g. OrthoCAD
    h. Planmeca Romexis 3D Ortho Studio
    i. Orchestrate Core
    j. Orthotrac
    k. OrthoProof
    l. OrthoLab
    m. Other: _____
16. **Have you received training in the selected software?**
    a. No
    b. Yes
17. **How often do you use the digital (virtual) models in treatment planning?**
    a. Never (if selected, then please stop survey)
    b. Sometimes (if selected, then answer questions 17-20)
    c. Often (if selected, then answer questions 17-20)
    d. Always (if selected, then answer questions 17-20)

End of survey here if answered "a" in question 17

COMPOSITE SCORES SHOWN IN RED PARENTHESES

18. **What software do you primarily use to manipulate your digital models for treatment planning?**
    a. Ortho Analyzer
    b. Ortho Studio
    c. DWOS
    d. Ortho Insight 3D
    e. Insignia Advanced Smile Design
    f. Unitek Treatment Management Portal Digital Model
    g. OrthoCAD
    h. Planmeca Romexis 3D Ortho Studio
    i. Orchestrate Core
    j. Orthotrac
    k. OrthoProof
    l. OrthoLab
    m. Other: _____
19. **Do you use advanced software capabilities to facilitate the development of these treatment plans, such as digital setups?**
    a. No
    b. Yes
20. **What do you like about the software you use?** (check all that apply)
    a. User interface is intuitive
    b. Creates open source STL files
    c. Creates digital setups with ease
    d. Offers features that I could not find in other software
    e. Inexpensive
    f. Other, please explain: _____
21. **What don't you like about software you use**? (check all that apply)
    a. User interface is not intuitive
    b. Difficult to rotate and move the models
    c. Software is slow and shutters when moving models
    d. Does not offer all of the features that I would like
    e. Too expensive
    f. Licensing fees
    g. There is nothing specific I don't like
    h. Other, please explain: _____
22. **Besides items you dislike about the software, are the any additional suggestions for improvements?**
    a. Please write down your suggestions below:
        i. _____
        _____
        _____
        _____
        _____
        _____

VITA

NAME: Mark Greenburg

DATE AND PLACE OF BIRTH: July 4, 1983; Denver, CO

EDUCATION:

5/2001	Diploma	Wheat Ridge High School Wheat Ridge, CO
4/2008	BS/Civil Engineering	Brigham Young University Provo, UT
5/2015	D.D.S.	University of Colorado School of Dental Medicine Aurora, CO
12/2017 In Process	M.S. Oral & Craniofacial Sciences	University of Missouri-Kansas City School of Dentistry Kansas City, MO

RESIDENCY:

2015-2017	Orthodontics & Dentofacial Orthopedics	University of Missouri-Kansas City School of Dentistry Kansas City, MO

PROFESSIONAL ORGANIZATIONS:

2015-Present	American Association of Orthodontists
2010-Present	American Dental Association

ACHIEVEMENTS:

2013-Present	Developed, produced, and marketed Luck O' The Dice game

HONORS:

2015	Omicron Kappa Upsilon Inductee
2014	William S. Kramer Award of Excellence
2013	Omicron Kappa Upsilon Acknowledgment of Recognition
2001	Eagle Scout