DIGITAL TECHNOLOGY AND DIGITAL WORKFLOW

APPLICATION IN THE CURRENT LANDSCAPE OF

PRIVATE PRACTICE ORTHODONTICS

A THESIS IN
Oral and Craniofacial Sciences

Presented to the Faculty of the University
Of Missouri-Kansas City in partial fulfillment of
the requirements for the degree

MASTER OF SCIENCE

by
MEGAN WELK

B.S., University of Wyoming, 2015
D.D.S., University of Nebraska Medical Center, 2019

Kansas City, Missouri
2021

DIGITAL TECHNOLOGY AND DIGITAL WORKFLOW

APPLICATION IN THE CURRENT LANDSCAPE OF

PRIVATE PRACTICE ORTHODONTICS

Megan Welk, Candidate for the Master of Science Degree

University of Missouri-Kansas City, 2021

ABSTRACT

This study examined which demographic factors and practice characteristics influence orthodontists to utilize a digital workflow in their private practice, as well as which factors influence their opinions on the current and future landscape of digital technology in orthodontics. For this study, digital workflow was defined as acquiring a digital scan to generate a study model via intraoral scanning or cone-beam computed tomography (CBCT) and utilizing in-office 3D printing for any orthodontic purpose. A 22-question survey, approved by the UMKC IRB, was distributed to 2,256 corporate or private practice orthodontists via email through the American Association of Orthodontists Partners in Research program. The survey was divided into three domains including orthodontist demographic factors, orthodontic practice characteristics, and technology usage and opinions. Demographic factors considered in the survey were gender, age, race, residency graduation year, etc. Orthodontic practice characteristics examined were primary office location, number of employees, number of active patients, and number of adult patients, among others. Technology usage focused on intraoral scanners, CBCT, and 3D printing, while opinion questions addressed the benefit of using a digital workflow, the future use of digital

technology in orthodontics, and the practicality of in-house aligner fabrication. To determine associations between utilization of a digital workflow and all variables, Fisher's Exact or Chi-squared tests were used. Survey data revealed a statistically significant association between utilization of a digital workflow and male gender, job status of sole owner, practices with greater than 10 employees, practices with less than 300 active patients or greater than 700 active patients, and practices that treat greater than 30% of their cases with clear aligners. Opinion questions revealed that cost and work/time required were the two factors mentioned most often when orthodontists were asked about their views concerning digital workflow use in orthodontics. Overall, results of this study suggest that some orthodontist demographics and orthodontic practice characteristics are significantly associated with use of a digital workflow in private practice.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Dentistry, have examined a thesis titled "Digital Technology and Digital Workflow Application in the Current Landscape of Private Practice Orthodontics," presented by Megan Welk, candidate for the Master of Science Degree in Oral and Craniofacial Sciences, and hereby certify that in their opinion it is worthy of acceptance.

Supervisory Committee

JoAnna M. Scott, Ph.D., Committee Chair
Department of Research & Graduate Programs

Mary P. Walker, D.D.S., Ph.D., Committee Co-Chair
Department of Oral & Craniofacial Sciences

Sarah L. Dallas, Ph.D.
Department of Oral & Craniofacial Sciences

Stefan Lohfeld, Ph.D.
Department of Oral & Craniofacial Sciences

CONTENTS

ILLUSTRATIONS

TABLES

ACKNOWLEDGMENTS

I would like to give thanks and express my sincere appreciation to:

Dr. Mary Walker, for her guidance and support through this process.

Dr. JoAnna Scott, for her guidance, assistance with statistics used in this thesis, and much appreciated encouragement.

Dr. Stefan Lohfeld, for his excellent input and expertise in 3D printing.

Dr. Sarah Dallas, for her prompt feedback and exceptional attention to detail.

UMKC part-time orthodontic faculty, for evaluating my survey and offering suggestions to improve it.

Marie Thompson, for her guidance in formatting this thesis.

Barbara Adkins, for her assistance with the IRB process.

My husband, Dr. John Welk, for being my biggest supporter and inspiriting my project through his own digital orthodontic endeavors.

My family, friends, and co-residents, for their love and support.

CHAPTER 1

INTRODUCTION

Due to technological advances in orthodontics, digital devices and procedures have come to play an increasingly prevalent role in the specialty. It is now possible, and even common, for orthodontists to use everything from digital impressions to in-office 3D printing in the routine treatment of their patients.

Evolution of Digital Orthodontics

For this study, digital workflow will be defined as acquiring a digital scan to generate a study model (via intraoral scanning or cone-beam computed tomography [CBCT]) and utilizing in-office 3D printing for any orthodontic purpose (models, bonding setups, custom brackets, etc.). The utilization of a digital workflow in private practice is seen by many orthodontists as beneficial, as the list of advantages to a digitally operating office is extensive. A digital workflow not only increases appointment efficiency, but it also allows for expedited laboratory processes, streamlines exchange of patient information between offices, and improves scheduling dynamics for patients and staff (Groth et al. 2018). Considering the state of the profession only 50 years ago, when orthodontists treated patients by individually banding every tooth and adding first, second, and third order bends to every wire, progressing to the digital landscape that exists today has been no small feat.

Influence from Outside Professions

While the orthodontic discipline has certainly come a long way, it is interesting to note that many major advances in orthodontics were not brought about by orthodontists

themselves. One well-known example is Align Technology Inc.'s creation of Invisalign®[1], a brand of clear aligner therapy (CAT) that is now regularly used in modern orthodontic offices. Invisalign® was invented by two MBA students attending Stanford University, neither having any training in dentistry or orthodontics (Moshiri 2021). Today, Align Technology is a significant player in the orthodontic world, with their product used regularly by both dentists and orthodontists. One article by William Gierie reported that as of 2018, Invisalign® had been used to treat more than 6.1 million people and had a 35% share of the adult orthodontic market (2018). Now in 2021, Align's website currently states that their product has been used to treat 9 million patients worldwide (Moshiri 2021).

Another example of an orthodontic device that was born outside of the profession is the intraoral scanner, which has been implemented as an alternative option to conventional dental impressions (Pulluru 2017). Scanners that are used in orthodontics today to capture entire dental arches and occlusions were previously used in dentistry for fabrication of simple restorations as part of a computer-aided design and computer-aided milling (CAD/CAM) system. Prior to dental use, CAD/CAM was used in the aircraft and automotive industries (Davidowitz and Kotick 2011). Over time, the intraoral scanner evolved not just in its distribution across professions, but also in its accuracy. One 2014 article that compared scanned models to plaster models reported that the accuracy of digital impressions taken with an intraoral scanner falls well within the established clinically relevant threshold (Kim et al.). This is noteworthy because a more efficient method of obtaining precise dental models is necessary for progression in the orthodontic field, as traditional impression-making materials

[1] Align Technology, Inc., 2820 Orchard Parkway, San Jose, CA 95131

have limitations related to dimensional stability, gag reflex, disinfection process, modulus of elasticity, etc. (Pulluru 2017). Additionally, the added capabilities that accompany the intraoral scanner are also of paramount importance. Because orthodontists can create digital impressions, they then have an avenue for digital diagnosis and treatment planning. In combination with the introduction of 3D printing in orthodontics, these technologies allow for several ways in which the profession can enhance the current approaches to orthodontic treatment and appliance manufacturing (Kirschneck et al. 2018).

Direct-to-Consumer Orthodontic Companies

The examples of Invisalign® and intraoral scanners have shown that the orthodontic specialty has benefitted in some ways from other's contributions. However, a new player in the orthodontic arena, direct-to-consumer (DTC) aligner companies, have caused a shift in this dynamic. DTC companies, also called do-it-yourself (DIY) companies, were born with the idea of bypassing the orthodontic office altogether and providing custom CAT directly to patients via mail. Claiming advantages such as lower costs, quicker treatment, and less office visits, these companies target patients with mild malalignments and financial limitations. They typically require that the consumer either visit one of their locations to have an intraoral scan taken or make their own impressions at home with the company's impression starter kit (Kravitz et al. 2016). The impressions are sent back to the company, scanned, and a digital workflow is used to create a series of about 20 clear aligners that are returned to the consumer. Radiographs are not taken at any point during treatment and at no time is the patient required to meet in person with a licensed dental professional, even though these companies claim the treatment to be "doctor-directed" (Kravitz et al. 2016).

While some argue that there is a place for remote monitoring of orthodontic treatment, many orthodontists disagree with the concept of DTC alignment treatments that completely bypass in-office doctor visits. Literature suggests that orthodontists believe a DIY method may not meet the needs of their patients. They warn that a lack of formal training and imprecise techniques used by these companies may lead to ill-fitting aligners and/or poor results, and that the companies do not consider the safety and effectiveness of the procedures (Behrents 2016). Kravitz et al. warn that undergoing direct-purchase orthodontic treatment without in-person evaluations by an orthodontist can potentially lead to less-than-ideal results or undiagnosed pathologies (2016). Concern for patients and questionable ethics are common topics among orthodontists discussing DTC aligner companies, but another question being raised is the potential threat of competition. An article by Jacox et al. reported recently that CAT business models such as direct-to-consumer companies were seen by orthodontists as a growing trend and a major threat to orthodontic jobs (2019).

Although DTC orthodontics has not been embraced by the dental community, it has brought to light an awareness that there is a population with a desire for limited treatment at a reduced cost. In fact, one popular DIY company claims on their website that they have treated as many as one million patients since their founding in 2014 (Smile direct club 2021). Currently, it is not financially realistic for an orthodontist to offer aligner treatment at costs similar to DTC companies because of the high price of utilizing aligner supply companies like Invisalign®. In fact, the cost for an orthodontist to treat a case with Invisalign® can be significantly greater than treating a case with traditional braces. Perhaps, if private orthodontic practices were to adopt an in-house digital workflow, essentially

cutting out the ‘middle-man,’ they could create a new avenue to provide for this population and offer a safer alternative to DIY orthodontics.

Implementing a Digital Workflow

Transitioning from traditional orthodontic techniques to a fully digital workflow can dramatically alter the dynamics of a practice. Orthodontists who decide to make this change may do so for many different reasons. They may wish to be able to offer limited treatment at lower costs in order to compete with DTC companies, or they may simply wish to stay on the forefront of innovation within their field. Regardless, the first step in the transition process is understanding and incorporating the necessary digital care concepts and associated equipment. Many orthodontists have already started by adopting intraoral scanners for digital impression making. However, gaining a more thorough understanding of the capabilities and potential of a digital scan, including how to apply it alongside 3D radiology and 3D printing in digital manufacturing will allow for even further implementation of digital procedures.

Intraoral Scanning

There are a few different ways that one can create digital models. Scanning a patient’s actual dentition with an intraoral scanner or CBCT machine is considered a “direct” method of generating a digital model. There is also an indirect method, which includes scanning either an impression or plaster model with an intraoral scanner, desktop scanner, or CBCT (Taneva et al. 2015, p. 147-88). While both approaches can result in a digital study model, literature supports the value of the direct method of intraoral scanning. Direct intraoral scanning can produce a digital model that is just as accurate as one obtained from an alginate impression or plaster cast, and in less time with fewer steps required (Park and Laslovich 2016). If an orthodontist values this and believes that adopting an intraoral scanner

would be of benefit to their practice, their next move would be to explore which scanners are available for purchase.

Selecting a scanner should be done on an individual basis depending on the needs of the practice, as there are several scanning systems available today that are suitable for use in orthodontics. In 2019, the Institute of Digital Dentistry (IDD) published a review of digital scanners that was completed over a period of five days during the 2019 International Dental Show in Cologne, Germany. Table 1 outlines the main orthodontic scanners that are used in orthodontics today and includes information from the 2019 IDD review (Al-Hassiny). In addition to providing comparisons of intraoral scanners, the reviewers also commented on the impressive pace at which scanning technology has improved over the last several years. Today, there are many innovative and unique features that exist within the various scanning systems. These including touch-screen display, wireless capabilities, optional voice command, color capabilities, anti-fog wands, interproximal caries detection, and the ability to complete a full mouth scan in only seconds. However, there are also some drawbacks that are associated with certain features. For example, systems that have increased capabilities might also require a larger wand, which can be uncomfortable for the patient. One feature most all scanning systems have in common is that they store scans in open STL format, which is an acronym for ‘standard tessellation language’ or ‘standard triangle language.’ STL format is paramount in the digital workflow because it is compatible with most all CAD software programs and is currently the standard or ‘default’ file format for 3D printing (Kravitz et al. 2018).

TABLE 1

ORTHODONTIC INTRAORAL SCANNERS

Scanner	Company	Year Launched	*Scan Speed (1-5)	*Cost	Weight (grams)	Product Website
iTero Element®5D	Align Technology Inc.[2], San Jose, CA	2021	3.5	$$$$	500	www.itero.com
TRIOS® 4	3Shape®[3], Copenhagen, Denmark	2019	5	$$$$	375	www.3shapedental.com
CEREC Primescan™	Dentsply Sirona Inc.[4] Charlotte, NC	2019	5	$$$$$	524	https://www.dentsplysirona.com/en-us
Carestream™ CS 3700	Carestream Dental LLC[5], Atlanta, GA	2019	3	$$$	316	www.carestream dental .com
Planmeca Emerald™	E4D Technologies[6], Richardson, TX	2019	4	$$$	235	http://planmecacadcam .com
Medit i500	Medit[7], Seoul, South Korea	2018	4.5	$	280	https://www.medit.com/dental-clinic-i500

*Outline of the most popular intraoral scanners used in orthodontics today. The most recently released models are presented for each scanner type. *Scan speed and cost information taken are from 2019 IDS review of intraoral scanners. Scan speed includes time taken to scan both arches and occlusion, and is ranked from 1-5 with 5 being the fastest (Al-Hassiny 2019).

[2] Align Technology, Inc., 2820 Orchard Parkway, San Jose, CA 95131
[3] 3Shape, Holmens Kanal 7, 1060 Copenhagen, Denmark
[4] Dentsply Sirona Inc. 13320-B, Ballantyne Corporate Pl, Charlotte, NC 28277
[5] Carestream Dental LLC, 1765 The Exchange, Atlanta, GA 30339
[6] E4D Technologies, 650 International Parkway, Richardson, TX 75081
[7] MEDIT corp. 23 Goryeodae-ro 22 gil, Seongbuk-gu, Seoul, South Korea

As mentioned, personal preference does play a role in choosing an intraoral scanner for one's practice. However, more recently, an orthodontist's scanner selection may also be impacted by various manufacturer protocols, as some prominent aligner companies of late have limited their consumers to the use of certain scanners. For example, in January of 2018, Align Technology released a statement that they will cease to accept scans for Invisalign® treatment from TRIOS® scanners in the United States, China, and Japan. This announcement ultimately sparked a lawsuit between Align and the well-known scanner company 3Shape (Mendel 2018). 3Shape, innovators of the 3Shape TRIOS® intraoral scanner, claimed that Align is illegally holding onto their monopoly of clear aligners by effectively forcing dental professionals to buy their intraoral scanner, the iTero® (Mendel 2018). Orthodontists are also frustrated by these new limitations that dictate which intraoral scanner they must purchase if Invisalign® is something they hope to offer in their practice (Burger 2018). Some argue that Align's ability to dominate the market allows them to charge more for their aligners, and these increased costs affect not only the dental providers, but ultimately trickle down to the patients who are seeking affordable clear aligner treatment (Mendel 2018). Thus, company-enforced limitations may be another consideration for the argument of private practice orthodontists learning to implement in-house aligner fabrication and decrease reliance on third-party aligner suppliers.

Cone Beam Computed Tomography

Another method of obtaining a digital model that does not involve an intraoral scanner is by way of CBCT (Kim 2020). While intraoral scanners use various light sources and optical components to capture images, CBCT uses ionizing radiation, the same as used in

standard dental radiographs (Jha et al. 2021). The typical file format of most CBCT machines is DICOM, or Digital Imaging and Communication in Medicine. With various third-party software programs, these DICOM files can be converted to STL format, which results in a dramatic and necessary reduction in data volume (Kamio et al. 2020). As previously stated, STL is compatible with most all CAD software programs and is currently the standard or 'default' file format for 3D printing.

CBCT for dental use was first introduced in the United States in 2001, and today has many applications in orthodontics. Scanning, either directly or indirectly, to create 3D digital models is one of these applications, but not the main one. More commonly, CBCT is used in orthodontics to assist with evaluating and addressing various orthodontic scenarios including impacted teeth, supernumerary teeth, root resorption, temporomandibular joint (TMJ) pathology, airway morphology, potential locations for mini-screw placement, etc. (Kapila and Nervina 2015).

Today, many orthodontists have adopted CBCT machines into their own practice. While studies show that CBCT is not the preferred method for creating digital models (Park and Laslovich 2016), it is still a viable option for those who have a CBCT machine but do not have an intraoral scanner, and prefer to have digital casts of each patient. As mentioned, digital models created via CBCT can be made either directly or indirectly. For the indirect method, the orthodontist can scan the patient's plaster cast with their CBCT machine. In this scenario, no radiation exposure is delivered to the patient or the operator because only the alginate impression or plaster cast is being scanned. Conversely, if the orthodontist needed a direct CBCT of the patient for any reason, they could scan the patient and use that 3D radiograph to construct a digital model. An advantage of this particular scenario is that

certain anatomical structures that are captured in CBCT radiographs (but not captured in impressions or intraoral scans) can be incorporated into the model, including bone levels, root positions, and precise positions and relationships of impacted teeth (Park and Laslovich 2016).

Digital Model Manipulation and Capabilities

Once a digital scan is obtained in STL file format, the next step in the digital workflow is to convert it into a digital model. This involves modifying the STL file in various ways. Specifically, the model must be digitally cleaned, repaired, and a base added, which can be done directly with available software or outsourced to a lab. This is necessary for many reasons. First, a raw unedited STL file only represents an object's surface characteristics and is referred to often as an "open shell". This means that STL files are small and simple to use, but they lack depth. They are essentially a 3D image on a screen, not a 3D model. Furthermore, a raw STL file is likely to contain unwanted structures such as cheeks or tongue that were captured unintentionally. The artifacts must be removed, and a base must be added to the model in order to complete its structure. Figure 1 demonstrates how this transformation appears in the software (Kravitz, 2018).

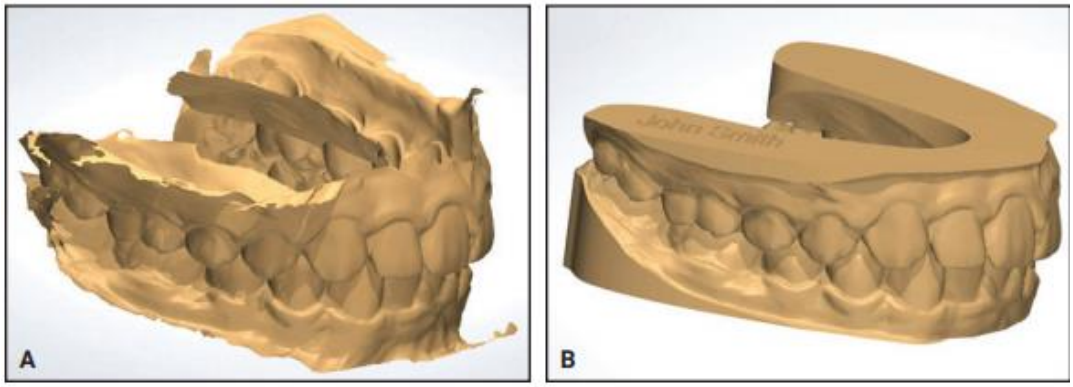


Figure 1. Conversion of an STL file to a digital model: A. An STL file that was obtained from an intraoral scan. B. The same scan has been cleaned, repaired, and based, and is now a digital model that can be 3D printed. From Kravitz ND, Groth C, Shannon T. Cad/cam software for three-dimensional printing. J Clin Orthod 2018;52:22-7.

Once this process is complete, there is a long list of tasks for which the digital model can now be used. Diagnosis is typically the first and involves virtual manipulation of the model through different planes of space. Some studies have shown that one reason for the use of plaster casts is the advantage of tactile input, which is not possible with a digital cast (Shastry and Park 2014). However, the digital model can be viewed from any angle like a plaster model, but the digital cast can also be temporarily or permanently sectioned and manipulated to assist with more accurate diagnoses of arch form, spacing and crowding, and classification of malocclusion (Taneva et al. 2015, p. 149). In addition to superior viewing capabilities, the digital casts can also be measured in different software programs to assess overbite, overjet, arch length, tooth-size, Bolton discrepancy, and more. Studies have shown that this can all be done with the same accuracy that is achieved on physical models,

reporting differences in reproducibility that are clinically insignificant (Taneva et al. 2015, p. 149).

Like diagnosis, treatment planning capabilities are also enhanced when approached digitally. Namely, the ability to simulate several different treatment outcomes quickly and efficiently is a significant advantage to using digital models. It gives the orthodontist more information to confidently choose one treatment plan over another, because they can see a rough predication of how every option would result. Outcome simulation is also possible by performing a traditional wax-up on a stone model, but would require hours of manual work, especially if multiple outcomes were desired. Using a digital workflow, several outcomes can be simulated in minutes, and with less error.

If a digital model is to be applied in a digital workflow to create clear aligners, the next step would be to utilize one of the several software programs that are available to virtually section the teeth and move them to different positions. When the teeth are rearranged to the correct positions and the desired outcome is established, a series of models are developed that each represent a small but progressive change from the original model towards the final setup. Many different biomechanical strategies are employed by the orthodontist in this process that dictate the order, speed, and type of tooth movements that will most efficiently and predictably achieve the desired outcome. Each individual model that is generated would then be 3D printed and used to create several thermoformed clear aligners that the patient would wear in chronological order, up to the last aligner where the teeth should reach the final position.

As mentioned, there are several other tasks for which the digital model can be used. This includes performing superimpositions to assess changes that occurred during treatment,

enhancing communication between specialists in interdisciplinary cases, and simplifying storage of patient records. Furthermore, digital models can also be applied in 3D printing, which can be useful in a majority of cases and has many applications as well. As with intraoral scanners, there are several different types of 3D printers available for use in orthodontics, with several different applications.

3D Printing

As previously discussed, one method of manufacturing in dentistry would be using CAD/CAM to mill small dental restorations. This process, which utilizes subtractive manufacturing to fabricate the desired product, is not as applicable in orthodontics. Manufacturing to supplement orthodontic treatment typically requires reproduction of full dental arches as opposed to an individual tooth or groups of teeth and milling an entire dental arch would be time consuming and expensive. Instead, a more promising technique that has been used for orthodontic manufacturing is 3D printing or "additive manufacturing." 3D printing describes a process where a certain material is joined in successive layers under automated computer control (Taneva et al. 2015, p. 170)

While 3D printing was founded in only 1990, today it is available in a wide variety of products. The many types of 3D printers all use additive manufacturing, but they attain their final products in different ways and with different materials. For example, 3D printers that use selective laser sintering (SLS) work by using a high energy laser beam to melt metallic powder and create complex metal parts (Taneva et al. 2015, p. 172). Fused deposition modeling (FDM) printers use a heated nozzle to extrude thermoplastic materials in layers that harden instantly. FDM is the most widely used process of 3D printing today (Taneva et al. 2015, p. 172).

Two methods of 3D printing that are used frequently in orthodontics are stereolithography (SLA), and digital light processing (DLP). SLA and DLP printing work similarly by using a light source to selectively cure resin that is "pulled out" of a liquid vat, layer by layer (Groth 2018). The difference between the two is that SLA's laser scans or 'traces' with a single point, while DLP can project its light onto the entire surface of resin, working somewhat like a stamp. These methods are ideal for printing dental arches because they can quickly and reliably print a large number of resin models simultaneously. They also create models that are accurate enough to be used for clear aligner fabrication. In fact, Align Technology uses an SLA printing system to fabricate models for their Invisalign® trays (Taneva et al. 2015, p. 175). Traditionally, in fabricating clear aligners using a digital workflow, models are printed with 3D printing technology and sheets of clear aligner material are heated and vacuum-formed to each individual model. The trays are then trimmed and polished and made suitable for intraoral use. The concept of companies or orthodontists printing the aligners directly has formerly been out of reach due to difficulties in finding a material that can be printed accurately and is also transparent, biocompatible, durable, etc. However, as new materials develop, this certainly seems like the next advance in aligner fabrication.

3D printers have several other orthodontic applications besides creating models for clear aligner fabrication. They can also construct appliances, customized brackets and archwires, and occlusal splints. Some appliances can all also be fabricated directly on models that are 3D printed, with excellent fit on the teeth and soft tissues (Taneva et al. 2015, p. 179). Overall, the 3D printer is an important component in a digital workflow and allows for several expedited lab processes. As new technologies emerge and material qualities are

improved, additive manufacturing will only continue to offer more feasible and affordable applications in orthodontics. This will enhance the way orthodontists treat and interact with their patients.

Influence of Technology on the Orthodontic Practice

Implementing any type of change in an orthodontic practice can be time consuming, expensive, and distract from normal operations. Adopting a digital workflow is no exception. It is a process that involves purchasing new equipment, researching and understanding how to navigate new technology, training staff, and figuring out how to efficiently implement new procedures. Though this may seem like a daunting task, over time it can positively impact numerous aspects of a practice. Clinically, one of the largest changes would be exchanging the intraoral scanner for all the materials and supplies needed for making alginate impressions and pouring up plaster casts. This provides many advantages such as a more comfortable experience for the patient, less risk of allergy, less messy materials to assemble and clean up, reduced transport issues, less concern over broken models, and reduced need for physical storage space (Martin et al. 2015).

Another main change that comes with adopting a digital workflow is the laboratory setup. In a 2018 article, Kravitz et al. explain the process of setting up a digital lab. They outline the process of replacing old equipment such as stone dispensers, investment vibrators, and model trimmers with new digital technology that includes a computer workspace, 3D printers, and a post-print processing station. The new lab must also be free from disturbances that can affect the digital equipment. For example, dust and vibrations can interfere with the accuracy of a 3D-printed product and must be controlled for (2018). The main benefits of this new lab setup are increased efficiency and a cleaner workspace. The drawbacks are the cost

of the equipment and associated software and subscriptions, as well as maintenance of the printers and computers.

Patient management and scheduling are other practice aspects that will be affected in the digital implementation process. When traditional impressions are used for appliance fabrication, there are several steps involved. For example, in order to fabricate a space maintaining appliance, the patient can be seen as many as four times before the appliance is delivered. With a digital workflow, this process can be streamlined and completed in less time. This is partly because appliances and retainers are more easily fabricated in a digital office, so communication with and delivery to and from the lab is no longer necessary. It is also faster because the intraoral scanner eliminates the need for fitting bands and making impressions. Figure 2 illustrates the comparison of these concepts. In general, a digital workflow means fewer patient trips to the office and therefore less chair time needed for each patient.

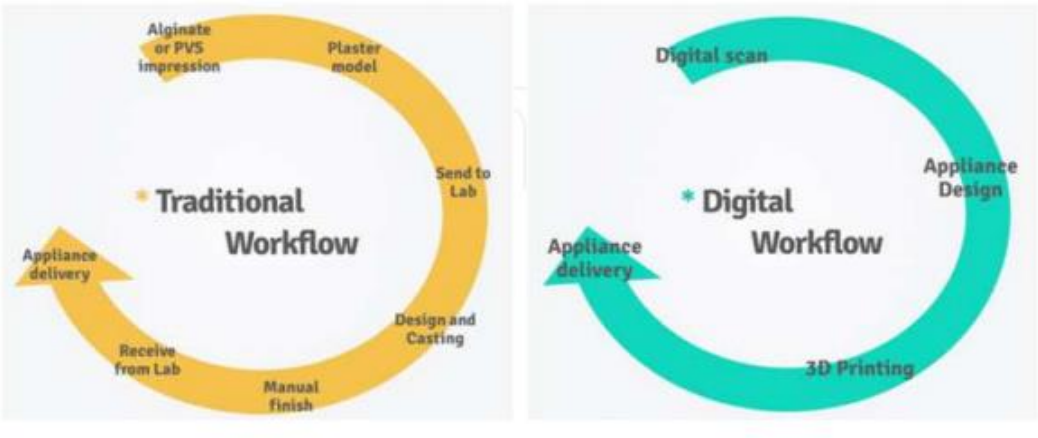


Figure 2. Appointment differences between traditional and digital workflows. Showing how a digital workflow requires fewer steps in the process of appliance fabrication. From Taneva E, Kusnoto B, Evans C. 3D scanning, imaging, and printing in orthodontics. In: Issues in contemporary orthodontics. F Bourzgui editor; 2015, p. 148.

The last major benefit of a digital practice, and one that has been alluded to previously, is that it is more realistic for orthodontists to offer limited treatment plans for esthetically conscious patients. This applies to patients who have very mild malalignment, have had small relapses after treatment, or who wish to simply align their teeth without addressing occlusion issues and insist on using clear aligners. An internal digital workflow would allow the orthodontist to fabricate aligners in-office, therefore reducing overhead and making these limited esthetic treatments more cost effective and a better fit for the overall practice budgetary plan. In other words, this could potentially eliminate the orthodontist's dependence on third-party clear aligner companies that currently exist, at least for limited or simple cases. To eliminate reliance on 3rd party aligner companies altogether is unlikely, as they have spent decades gathering proprietary information that allows them to treat complex cases very effectively. It would take a similar amount of data, time, and research for private practice orthodontists to understand how to deliver the same outcomes with in-house equipment.

Characteristics of Orthodontists Implementing a Digital Workflow

There are limited studies currently available that have investigated the characteristics of orthodontists that utilize digital technology, or where in the United States most digital-focused practices are located. One 2019 study by Jacox et al. explored this topic by interviewing 24 privately practicing orthodontists in North Carolina and Massachusetts. Their questions aimed to identify which factors orthodontists see as incentives or barriers to technology procurement, and how they regard the influence that digital tools have on practice dynamics. The interviewees were categorized as early, middle, and late adopters depending

on their extent of technology utilization. They reported the main incentives to be reduced cost, added capabilities, increased efficiency and ease of use, and improved performance. Likewise, they found that many of the reported incentives were also some of the main barriers, including cost, capabilities, ease of use, and workflow. Overall, they found that cost was the most significant factor that influenced their decisions, whether it was being viewed as an incentive or a barrier. They also found that early adopters, or orthodontists who have adopted or tested many or all of the main orthodontic technologies available, tended to be younger, work in more recently established practices, and have larger practices with more staff and patients. Early adopters also focused significantly more than middle or late adopters on using technology to enhance the patient experience including safety, comfort, and customer service (2019). These findings are salient and useful, and they suggest that cost may need to be adjusted before more orthodontists will consider adopting a digital workflow. However, these responses are not representative of all U.S. orthodontists, and likely over-represent a specific region in the United States. A national survey would be the next step in verifying these findings.

Another study that was published in 2016 attempted to provide an up-to-date picture of technology trends among U.S. orthodontists by investigating their use of digital study models, intraoral scanners, and CBCT. The study utilized a survey that was distributed to members of the American Association of Orthodontists (AAO) and revealed many useful findings, including the fact that 54% of the responding orthodontists used plaster study models in their practice, while 46% used digital models. They cited cost and simplicity as the main reasons for a preference for plaster models. However, when those who use plaster models were asked if they planned to switch to digital models, 34% of respondents said yes,

with 64% of them planning to do so within 5 years. In general, this article predicts a future increase in numbers of clinicians using CBCT and intraoral scanners to create digital models (Park and Laslovich 2016).

It is important to note that this survey was completed in 2016. Since that time, the landscape of digital orthodontics has changed significantly. It is likely that a similar survey now may yield different results, as direct-to-consumer companies have entered the orthodontic arena, new methods for digital diagnosis, treatment planning, and manufacturing have emerged, and available technology has improved. Also, while the information from this study is noteworthy, it is limited in that it does not consider the demographics of the respondents or many of the characteristics of the practices in which they work. They did some demographic information on job status and range of years in practice, but not how they relate to technology usage. A survey that addresses all of these factors will give a stronger indication of not only what demographic of orthodontists are most likely to participate in technology adoption and utilization, but what the future might hold. There have been previous studies that included survey questions related to orthodontist demographics and practice characteristics that demonstrated differences in factors such as evidence-based practice, pro-bono treatment of underserved patients, and treating patients from a variety of ethnic backgrounds. However, to date, surveys of orthodontists related to digital technology and digital workflow use have not typically included clinician or practice demographics that might also influence their adoption and utilization.

Problem Statement

While ample research currently exists on the available products that allow for a digital workflow, there is limited up-to-date information to aid in identifying the frequency

with which these products are actually procured and how they are used in orthodontic offices across the United States. Furthermore, the literature has yet to identify which practice characteristics and clinician demographics are perhaps associated with some orthodontists implementing the technology more than others, or what orthodontists think about outside companies utilizing technology to treat malocclusions. Understanding these factors and relationships is important because they can provide an indication of the role that orthodontists will play in determining the future of the discipline, and whether or not they will serve as leaders in the digital orthodontic evolution.

The purpose of this study is to determine the prevalence of a modern digital workflow in U.S. private or corporate-owned orthodontic practices, where it is most likely to be used, and by whom. Information regarding varieties of technology that exist in one's practice will be gathered, but specifically how that technology is used and the presence or not of a digital workflow will be the focus. This will shed light on what orthodontic professionals can expect for the future of their specialty and help to guide orthodontic innovation.

Hypotheses

1. Certain demographic factors of an orthodontist, such as age, gender, and when they graduated from an orthodontic residency, will have an impact on their likelihood to adopt a digital workflow.
2. Practice characteristics such as location, number of orthodontists, and percentage of adult patients will play a role in an office's decision to adopt a digital workflow.

CHAPTER 2

METHODS

Construction and Aim of Survey

A survey consisting of 22 questions was developed to gather information regarding digital technology implementation and digital workflow application in U.S. private or corporate-owned orthodontic practices. This survey was a modified version of a similar study done to assess implementation of digital study models in private practice (Greenburg 2017). Use of intraoral scanners, CBCT, and 3D printing were assessed within the survey, as well as practitioner's attitudes regarding the prevalence and role of digital technology in the orthodontic field in general.

The survey has three main domains, with the first being orthodontist demographics. This section includes questions regarding age, gender, ethnicity, year of orthodontic residency graduation, regional location of residency program, working status as a private practice orthodontist, etc. This section also contains a screener question that prompts the survey to terminate if the participant is not currently a U.S. orthodontist in a private or corporate-owned practice setting. The second domain of the study is orthodontic practice characteristics, including regional location of the practice, number of office locations, population type of the area being served, number of orthodontists practicing in the office, etc. The third domain of the survey focuses on which specific technologies, if any, are employed in the practice and to what extent they are utilized. This section also contains additional questions that determine orthodontist's opinions about aligner fabrication and the role of increasing technology in the profession, as these may lend additional insight.

In the process of developing a final version of the survey, several part-time orthodontic faculty members in the UMKC Advanced Orthodontic Clinic were asked to evaluate the content, order, and clarity of the questions. After the evaluators reviewed a paper-copy of the survey, they were then given an evaluation form and asked to leave feedback, including comments and recommendations for improvement. The feedback evaluation form is in Appendix A. Comments were considered when revising and updating the survey.

Upon submission of the survey and accompanying application to the AAO Partners in Research program, several changes were suggested by the AAO legal and review teams. These suggestions were used to further update the survey. A copy of the final survey that was approved by the AAO Partners in Research program can be found in Appendix B.

Survey Distribution and Data Collection

The survey was distributed electronically through the AAO Partners in Research program following the payment of a 75-dollar fee. The survey was intended to be taken by practicing orthodontists who are current members of the American Association of Orthodontists (AAO). As of January 2020, the AAO claims to represent 19,332 members in total, of which 9,222 members are practicing in the United States. This survey was sent out by email to 2,256 orthodontists that were randomly selected by the AAO from the pool of 9,222 United States members. The email with the survey request and survey link is located in Appendix C. After approximately three weeks, the same email was sent again to the original 2,256 recipients to remind them to complete the survey if they had not already done so. This was the extent of communication that occurred with the recipients.

As mentioned, the survey was distributed in electronic format. This was chosen for several reasons, including cost and ease of distribution. The electronic version allows for termination of the survey at different points, as well as branching questions, which is an advantage in avoiding survey fatigue. The survey was constructed and stored securely in Research Electronic Data Capture (REDCap) (Harris et al. 2009) which is hosted by The Center for Health Insights of UMKC. When the survey was entered into the REDCap software, it was taken by several UMKC faculty members prior to distribution to evaluate for any errors and ensure proper functioning while navigating through the questions.

Also prior to distribution, the survey and proposed distribution protocol were reviewed and approved by the University of Missouri-Kansas City (UMKC) Institutional Review Board (IRB). An approval letter (IRB# 267318) is in Appendix D.

Experimental Design

The design of this study is cross-sectional, non-experimental with two factors. There are two groups of independent variables including orthodontist demographics and orthodontic practice characteristics. The dependent variable is utilization of a digital workflow in orthodontic practice. The study design is outlined in table 2.

Data Analysis

For all variables from the survey data, descriptive statistics including percentages and counts were calculated. To evaluate the hypotheses of the study, several statistical tests were utilized with a statistical software program[8]. To determine any associations between utilization of digital workflow and all variables, Fisher's Exact or Chi-squared tests were

[8] SPSS Statistics for Windows, Version 21.0. IBM Corp. 1 New Orchard Road, Armonk, NY 10504

used. For all written comments for the three opinion questions in the third domain of the study, responses were categorized into five main categories. Significance for all testing was set at $p \leq 0.05$.

TABLE 2

EXPERIMENTAL DESIGN

Independent variables	Specific Questions within Survey	Dependent variables
Orthodontist demographics	• Year of orthodontic residency graduation (Q1) • Residency location by region (Q2) • Gender (Q3) • Age (Q4) • Race/Ethnicity (Q5) • Academic setting participation (Q6)	Utilization of a digital workflow in orthodontic practice
Orthodontic practice characteristics	• Orthodontist status in practice (Q8) • Number of office locations (Q9) • Number of orthodontists practicing in the total network (Q9b) • Number of orthodontists practicing in the primary office (Q10) • Number of employees besides orthodontists (Q11) • Population type of area being served (Q12) • Office location by region (Q13) • Number of current active patients (Q14) • Percentage of adult patients (Q15) • Percentage of clear aligner cases (Q16)	
Sample size (n) = # orthodontists responding to survey		

CHAPTER 3

RESULTS

This survey was distributed to 2,256 AAO members. Of those, 98 members initiated the survey, and 85 members completed the survey. The 85 completed surveys were used in the final statistical analysis.

Orthodontist Demographics

Table 3 illustrates the associations between the use of a digital workflow and various demographics of the survey respondents (Hypothesis 1). Most respondents to this survey were male (63.1%), of the Caucasian race (81.1%), graduated from orthodontic residency in either 2010 or later (56.5%), and are not involved in an academic orthodontic setting (82.4%). Most were between the ages of 25-34 (40.0%), attended a residency located in the Midwest (36.5%) and are sole owners of their practice (30.5%).

There was a statistically significant relationship between use of a digital workflow and gender (p=0.030) for male orthodontists. Male orthodontists were more likely to use a digital workflow than female orthodontists (34.6% vs. 12.9%). There was also a statistically significant relationship between use of a digital workflow and job status of sole owner (p=0.045). Orthodontists who use a digital workflow were more likely to be a sole owner than not (36.4% vs. 17.1%, respectively). The relationship between age and gender was also tested to determine if any bias exists for these factors, which is represented in figure 3 below.

TABLE 3

RELATIONSHIP OF DIGITAL WORKFLOW USE
WITH ORTHODONTIST DEMOGRAPHICS

	Overall	Uses a Digital Workflow		
		No	Yes	
	(N = 85)	(N = 62)	(N = 23)	
	# (%)	# (%)	# (%)	p-value*
Gender				0.030‡
Male	52 (63.1%)	34 (65.4%)	18 (34.6%)	
Female	31 (36.9%)	27 (87.1%)	4 (12.9%)	
Race				0.215
Caucasian	69 (81.1%)	48 (69.6%)	21 (30.4%)	
Other	16 (18.9%)	14 (87.5%)	2 (12.5%)	
Age				0.918
25-34	34 (40.0%)	26 (76.5%)	8 (23.5%)	
35-44	20 (23.5%)	14 (70.0%)	6 (30.0%)	
45-54	12 (14.1%)	8 (66.7%)	4 (33.3%)	
55-64	19 (22.4%)	14 (73.7%)	5 (26.3%)	
Year of Orthodontic Residency Graduation				0.701
1980 to 1989	3 (3.5%)	3 (100%)	0 (0.0%)	
1990 to 1999	20 (23.5%)	14 (70.0%)	6 (30.0%)	
2000 to 2010	14 (16.5%)	9 (64.3%)	5 (35.7%)	
2010 or after	48 (56.5%)	36 (75.0%)	12 (25.0%)	
Residency Location				0.868
Pacific	9 (10.6%)	6 (66.7%)	3 (33.3%)	
Rocky Mountains	4 (4.7%)	2 (50.0%)	2 (50.0%)	
Southwest	4 (4.7%)	3 (75.0%)	1 (25.0%)	
Midwest	31 (36.5%)	23 (71.9%)	9 (28.1%)	
Southeast	16 (18.8%)	12 (75.0%)	4 (25.0%)	
Northeast	20 (23.5%)	16 (80.0%)	4 (20.0%)	
Noncontiguous	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Academic Involvement				0.336
Yes	15 (17.6%)	13 (86.7%)	2 (13.3%)	
No	70 (82.4%)	49 (70.0%)	21 (30.0%)	

Table 3 Continued

		Overall	Uses a Digital Workflow		
			No	Yes	
		(N = 85)	(N = 62)	(N = 23)	
		# (%)	# (%)	# (%)	p-value*
Job Status**					
Sole Owner					0.045‡
	Yes	44 (30.5%)	28 (63.6%)	16 (36.4%)	
	No	41 (69.5%)	34 (82.9%)	7 (17.1%)	
Partner					0.757
	Yes	16 (18.8%)	11 (68.8%)	5 (31.3%)	
	No	69 (81.2%)	51 (73.9%)	18 (26.1%)	
Associate					0.770
	Yes	17 (20.0%)	12 (70.6%)	5 (29.4%)	
	No	68 (80.0%)	50 (73.5%)	18 (26.5%)	
Independent Contractor					0.449
	Yes	13 (15.3%)	11 (84.6%)	2 (15.4%)	
	No	72 (84.7%)	51 (70.8%)	21 (29.2%)	
Employee in corporate-owned practice					0.105
	Yes	9 (10.6%)	9 (100%)	0 (0.0%)	
	No	76 (89.4%)	53 (69.7%)	23 (30.3%)	

* Fisher's Exact tests used unless otherwise noted by ‡ then Chi-square test used

**Multiple options able to be selected, may not result in exactly 100%

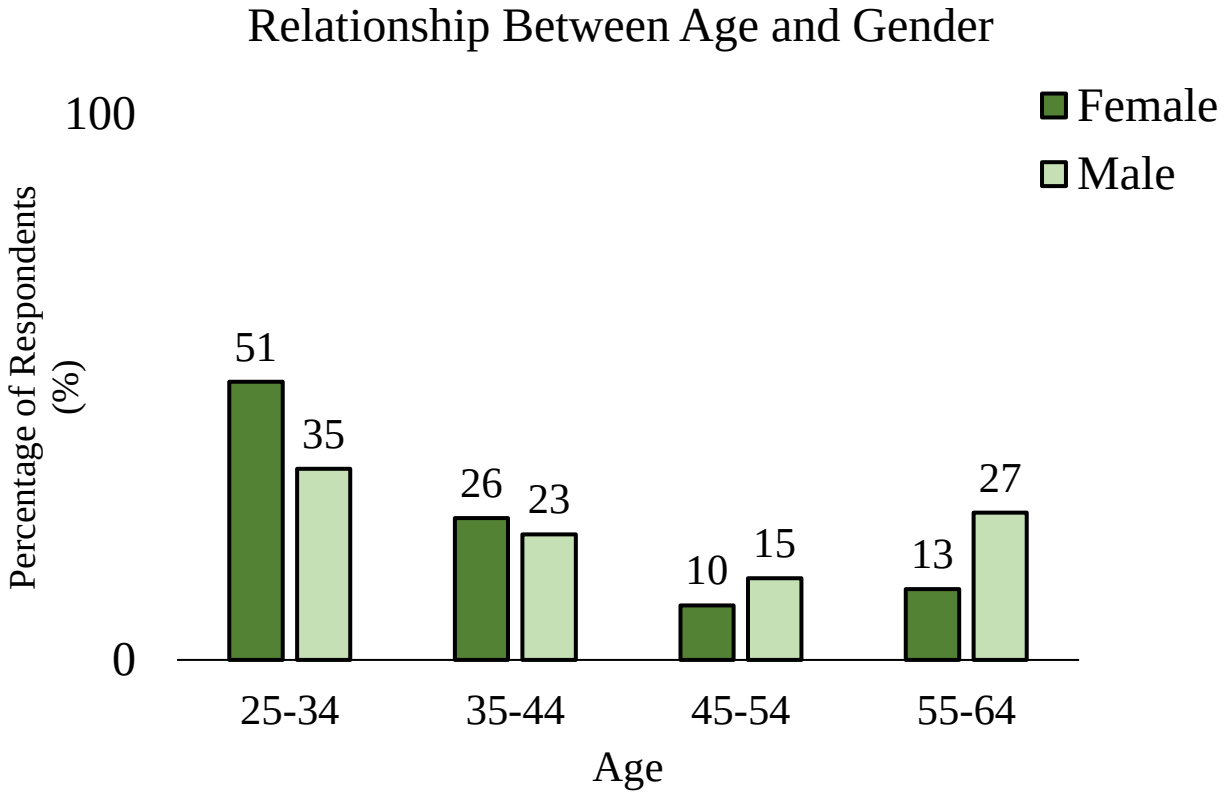


Figure 3. Relationship between age and gender of survey respondents. While female respondents did tend to be younger than male respondents, there was no statistically significant association between age and gender (p=0.322).

Orthodontic Practice Characteristics

Table 4 shows the associations between the use of a digital workflow and various orthodontic practice characteristics of the survey respondents (Hypothesis 2). The majority of respondents to this survey work in practices with 1-2 orthodontists in their total practice network (75.5%), one orthodontist in their primary office location (68.2%), and 10 or less employees (65.9%). Most respondents' practices serve a suburban population type (71.8%), have 40% or less adult patients (83.3%), treat 30% or less of their cases with clear aligners (75.0%) have one office location (42.4%), are located in the Midwest (34.5%), and have between 301 and 500 active patients (32.5%).

There was a statistically significant relationship between use of a digital workflow and number of employees, number of active patients, and percentage of clear aligner patients ($p=0.032$, $p=0.005$, and $p= 0.016$, respectively). A digital workflow was more likely to be used in practices with greater than 10 employees in their primary office than practices with 10 or less employees (41.4% and 19.6%, respectively). A digital workflow was also more likely to be used in small practices that have 300 or less active patients (43.8%) or large practices with 701 to 900 (54.5%) and greater than 900 patients (45.5%). In contrast, medium-sized practices with 300 to 500 or 501 to 700 patients were less likely to use a digital workflow (11.1% for both). Furthermore, a practice that treats greater than 30% of their cases with clear aligners are more likely to use a digital workflow than practices that treat 30% or less of their cases with clear aligners (47.6% vs. 20.6%, respectively).

TABLE 4

RELATIONSHIP OF DIGITAL WORKFLOW USE WITH ORTHODONTIC PRACTICE CHARACTERISTICS

	Overall	Uses a Digital Workflow		
		No	Yes	
	(N = 85)	(N = 62)	(N = 23)	
	# (%)	# (%)	# (%)	p-value*
Number of Office Locations				0.762**
1	36 (42.4%)	25 (69.4%)	11 (30.6%)	
2-3	27 (31.8%)	21 (77.8%)	6 (22.2%)	
4 or more	22 (25.9%)	16 (72.7%)	6 (27.3%)	
Number of Orthodontists in Total Network				0.999
1-2	37 (75.5%)	28 (75.7%)	9 (24.3%)	
3 or greater	12 (24.5%)	9 (75.0%)	3 (25.0%)	
Number of Orthodontists in Primary Office				0.873**
1	58 (68.2%)	42 (72.4%)	16 (27.6%)	
2 or greater	27 (31.8%)	20 (74.1%)	7 (25.9%)	
Number of Employees in Primary Office				0.032**
10 or less	56 (65.9%)	45 (80.4%)	11 (19.6%)	
Greater than 10	29 (34.1%)	17 (58.6%)	12 (41.4%)	
Population Type				0.334
Rural	14 (16.5%)	8 (57.1%)	6 (42.9%)	
Suburban	61 (71.8%)	46 (75.4%)	15 (24.6%)	
Urban	10 (11.8%)	8 (80%)	2 (20%)	
Primary Office Location				0.706
Pacific	11 (13.1%)	8 (72.7%)	3 (27.3%)	
Rocky Mountains	5 (6.0%)	2 (40.0%)	3 (60.0%)	
Southwest	7 (1.2%)	5 (71.4%)	2 (28.6%)	
Midwest	29 (34.5%)	21 (72.4%)	8 (27.6%)	
Southeast	22 (26.2%)	17 (77.3%)	5 (22.7%)	
Northeast	10 (11.9%)	8 (80.0%)	2 (20.0%)	
Noncontiguous	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Number of Active Patients				0.005*
300 or less	16 (19.3%)	9 (56.3%)	7 (43.8%)	
301-500	27 (32.5%)	24 (88.9%)	3 (11.1%)	
501-700	18 (21.7%)	16 (88.9%)	2 (11.1%)	
701-900	11 (13.3%)	5 (45.5%)	6 (54.5%)	
Greater than 900	11 (13.3%)	6 (54.5%)	5 (45.5%)	

Table 4 Continued

	Overall	Uses a Digital Workflow		
		No	Yes	
	(N = 85)	(N = 62)	(N = 23)	
	# (%)	# (%)	# (%)	p-value*
Percentage of Adult Patients				0.192
40% or less	70 (83.3%)	53 (75.5%)	17 (24.3%)	
Greater than 40%	14 (16.7%)	8 (57.1%)	6 (42.9%)	
Percentage of Clear Aligner Patients				0.016**
30% or less	63 (75.0%)	50 (79.4%)	13 (20.6%)	
Greater than 30%	21 (25.0%)	11 (52.4%)	10 (47.6%)	

*Fisher's Exact tests used unless otherwise noted by ** then Chi-square test used.

General Use of Digital Technology in Orthodontics

The third domain of the survey began with three questions related to general usage of digital technology. Survey respondents were asked about their usage of intraoral scanners, CBCT, and 3D printing in their private practice. Figure 4 summarizes the responses.

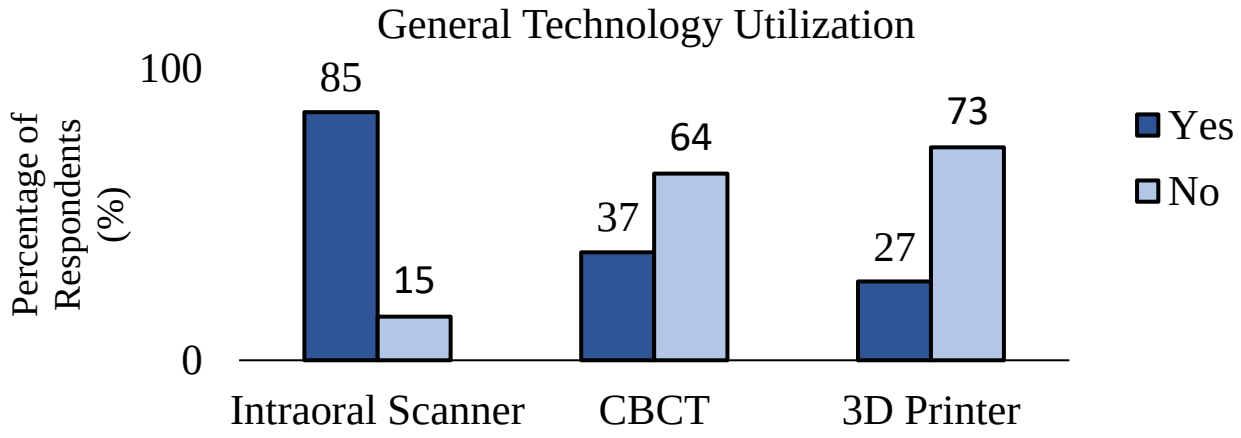


Figure 4. General utilization of digital technology in private practice: Survey results showed that 85% of respondents use an intraoral scanner in their practice on a weekly basis, 37% use CBCT on a weekly basis, and 27% use 3D printing for orthodontic purposes.

Orthodontist Opinions on Digital Workflow and Observations Related to Comments

The third domain of the survey also included three questions regarding orthodontists' opinions on digital workflow use in private practice. Respondents were able to answer in a simple yes/no/I don't know format. The questions and the responses to those questions are summarized in table 5 below. Most orthodontists that took this survey felt that adopting a digital workflow in private practice is beneficial (89.4%), that use of a digital workflow in orthodontic offices will increase over the next 20 years (97.6%), and that a digital workflow is a practical way to directly provide clear aligner treatment to patients (71.4%). Table 5 also shows the relationships between simple yes/no/I don't know answers and use of a digital workflow. None of the associations between answers to the three opinion questions and the orthodontists' use of a digital workflow were statistically significant.

TABLE 5

INFLUENCE OF DIGITAL WORKFLOW USE ON OPINIONS CONCERNING DIGITAL ORTHODONTICS

	Overall	Uses a Digital Workflow		
		No	Yes	
	(N = 85)	(N = 62)	(N = 23)	
	# (%)	# (%)	# (%)	p-value*
Question 1: Do you feel that adopting a digital workflow in private orthodontic practice can be beneficial?				0.105
Yes	76 (89.4%)	53 (85.5%)	23 (100.0%)	
No/I don't know	9 (10.6%)	9 (14.5%)	0 (0.0%)	
Question 2: Do you believe that use of a digital workflow in orthodontic offices will increase over the next 20 years?				0.999
Yes	81 (97.6%)	58 (96.7%)	23 (100.0%)	
I don't know	2 (2.4%)	2 (3.3%)	0 (0.0%)	
Question 3: Do you feel that utilizing a digital workflow is a practical way for orthodontists to directly provide clear aligner treatment?				0.088
Yes	60 (71.4%)	41 (67.2%)	19 (82.6%)	
No	8 (9.5%)	5 (8.2%)	3 (13.0%)	
I don't know	16 (19.0%)	15 (24.6%)	1 (4.3%)	

* Fisher's Exact test

Survey respondents also had the option of leaving a written comment for the three questions noted in table 5 above. Specific factors or concerns mentioned in the written comments were classified into five main categories: efficiency, materials and storage, patient experience, cost, and work/time required. Table 6 summarizes for each of the opinion questions how frequently each category was mentioned, and how those categories are distributed across strata of digital workflow use (yes or no) and the closed response to each question (yes, no, I don't know). The comments in the table are also further categorized as either positive or negative.

The factors that were mentioned most often in comments among all three opinion questions were cost (n= 20) and work/time required (n=15). For both categories, there were more negative comments overall than positive comments. The most common factors mentioned for question 1 were materials/storage and efficiency (n= 7 for both). Most of the comments regarding materials/storage for question 1 were from respondents who did not use a digital workflow and answered ‘yes’ that they feel that adopting a digital workflow in a private orthodontic practice can be beneficial (n= 5). About half of the mentions of efficiency for question 1 were from respondents who did not use a digital workflow and answered ‘yes’ that they feel that adopting a digital workflow in a private orthodontic practice can be beneficial, and the other half were from respondents who did use a digital workflow and answered ‘yes’ that they feel that adopting a digital workflow in a private orthodontic practice can be beneficial (n= 3 for both)

For question 2 regarding the future use of digital workflows, the most common factor mentioned was cost (n= 7). Most of the comments in the cost category were from respondents who did not use a digital workflow and answered ‘yes’ that they believe that use of a digital workflow in orthodontic offices will increase over the next 20 years (n= 6).

The most common category mentioned for question 3 was work/time required (n= 8), and most of the comments in this category were from respondents who did use a digital workflow and answered ‘yes’ that they believe that use of a digital workflow is a practical way for orthodontists to directly provide clear aligner treatment (n= 3).

TABLE 6

DIGITAL WORKFLOW USE RELATED TO OBSERVATIONAL QUESTION RESPONSES

		Specific Factors Mentioned in Observational Comments				
		Efficiency *N = # (+,-) N=11 (8,3)	Materials/ Storage N = # (+,-) N=8 (8,0)	Patient Experience N = # (+,-) N=6 (6,0)	Cost N = # (+,-) N=20 (8,12)	Work/Time Required N = # (+,-) N=15 (7,8)
Question 1: Do you feel that adopting a digital workflow in private orthodontic practice can be beneficial?						
Uses a Digital Workflow	Answer to Question 1					
Yes	Yes	3 (3,0)	2 (2,0)	3 (3,0)	1 (1,0)	2 (2,0)
No	Yes	3 (3,0)	5 (5,0)	3 (3,0)	3 (1,2)	2 (2,0)
No	No/I don't know	1 (0,1)			2 (0,2)	2 (0,2)
Question 2: Do you believe that use of a digital workflow in orthodontic offices will increase over the next 20 years?						
Uses a Digital Workflow	Answer to Question 2					
Yes	Yes	1 (1,0)			1 (1,0)	
No	Yes	1 (0,1)	1 (1,0)		6 (1,5)	1 (0,1)
Question 3: Do you feel that utilizing a digital workflow is a practical way for orthodontists to directly provide clear aligner treatment?						
Uses a Digital Workflow	Answer to Question 3					
Yes	Yes	1 (1,0)			5 (4,1)	3 (3,0)
Yes	No					
No	Yes					2 (0,2)
No	No				1 (0,1)	1 (0,1)
No	I don't know	1 (0,1)			1 (0,1)	2 (0,2)

*For each factor, in addition to identifying the number (#) of comments, the classification of each comment as either positive or negative (+,-) was also included

CHAPTER 4

DISCUSSION

This study explored how clinician demographics and practice characteristics of private practice orthodontists influence their use of a digital workflow as well as their opinions on digital orthodontics in general by administering a survey to currently practicing AAO members. The results showed that 23 out of 85 orthodontists (27%) use a digital workflow in their practice.

Results from the survey revealed that gender and job status were the only orthodontist demographics significantly associated, with males and sole owners being more likely to use a digital workflow. The association with gender might be explained by the fact that more males responded to the survey, likely because there are currently more male orthodontists in private practice overall. The relationship between gender and age was also tested to ensure that no bias existed for these two factors. No significant associations were found, but it was noted that the responding females tended to be younger than responding males.

While previous studies suggest that younger orthodontists are more likely to be early adopters of digital technology (Jacox et al. 2019), the current study did not find an association between orthodontist age and use of a digital workflow. The study by Jacox et al., however, was not a national survey and only collected information from doctors in North Carolina and Massachusetts. Furthermore, there is no other comparative literature as of now that has explored an association between orthodontic job status and use of a digital workflow.

The current study found several practice characteristics to be significantly associated with digital workflow use. Specifically, practices with greater numbers of employees, small practices with 300 or less active patients or large practices with greater than 700 patients, and

practices that treat a greater number of cases with clear aligners were more likely to use a digital workflow. Jacox et al. similarly found that orthodontists who are early adopters of digital technology have larger practices with more staff and patients (2019). It is understandable that larger and busier practices would be more likely to use a digital workflow. The more staff a practice has, the more opportunity there would be for the clinician to delegate some of the digital responsibilities and having many patients would allow the orthodontist to utilize the technology to its full potential and maximize return on investment. Orthodontists in small practices may also be likely users of a digital workflow because they have more time to dedicate to technology implementation. However, Jacox et al.'s findings disagreed with the current study in that they found late adopters of technology to have smaller practices with less patients and staff (Jacox et al. 2019).

The third domain of the survey included questions that analyzed the general usage of digital technology in an individual's private practice, as well as questions about orthodontist's opinions on directly providing aligner treatment and the role of increasing technology in the profession. This led to several interesting findings. For example, when asked if they believe use of a digital workflow will increase in the next 20 years, almost all respondents (98%) answered yes, despite 11% answering that they did not think a digital workflow is beneficial or did not know if it was beneficial. Jacox et al. also reported that a vast majority of their respondents (22 out of 24) anticipated the future standard of care to include an intraoral scan, digital tooth setup, and fabrication of CAD/CAM appliances (2019). A survey administered by Park and Laslovich in 2016 had comparable results, stating that 54% of the responding orthodontists used plaster models in their practice, compared to 46% that used digital models. However, when those who used plaster models were asked if

they planned to switch to digital models, 34% of respondents said yes (2016). The current study found that 85% of responding orthodontists use an intraoral scanner in their private practice and 37% are using CBCT. This is a significant increase in digital model utilization since the article by Park and Laslovich was published in 2016 and demonstrates the rapid rate at which digital tools are being accepted as standard practice in orthodontics. It is worth noting that this 2016 study did not report on any of the clinician demographic factors or practice characteristics of survey respondents, other than their job status and years spent in practice.

While none of the responses to the opinion questions were significantly associated with use of a digital workflow or lack thereof, there did appear to be some identifiable trends. For example, when respondents who use a digital workflow gave explanations for their answers, they tended to mention different practice elements than those who do not use a digital workflow. Those who use a digital workflow mentioned efficiency and patient experience most often in their explanation for why they felt a digital workflow is beneficial to have in their practice. This confirms findings of Jacox et al. (2019) which also reported that early adopters of digital technology tend to focus more on patient experience. Conversely, the current study found that non-users of a digital workflow highlighted cost and materials/storage most often as benefits to using a digital workflow. This might suggest that once an orthodontist adopts a digital workflow, they will have a different understanding of how it truly influences their practice.

The third and final opinion question which asked, “Do you feel that utilizing a digital workflow is a practical way for orthodontists to directly provide clear aligner treatment?” was a more debatable topic with a wider variety of responses. Even some who do use a

digital workflow in their practice answered no or I don't know (17%). Specific comments regarding this question focused largely on cost and the work/time required to implement a digital workflow and included both positive and negative types of comments. Jacox et al. had similar results regarding cost, where it was found to being the largest incentive as well as the largest barrier to technology adoption (2019). They did not report significant findings on work/time required. It is not surprising that responses to the third opinion question were so scattered, as the idea of taking on large-scale cases with an in-house digital workflow is a relatively new concept. The limitations of the currently available software may not allow orthodontists to accomplish high quality results for complex cases in the same way that Invisalign® can at present, as Align Technologies has been collecting data for decades and that has allowed them to improve their software.

Clinical Implications

Current survey responses and those from prior studies show that a main barrier to adopting a digital workflow is the cost associated with equipment and implementation (Park and Laslovich 2016; Jacox et al. 2019). As cost declines and barriers to entry become more reasonable for equipment like 3D printers, intraoral scanners, digital model editing software, and orthodontic tooth movement software, there will likely be more practitioners willing to adopt digital tools and systems into their practice. An increase in digital adoption has the potential to impact the extent to which orthodontists utilize third party aligners companies that are guided by corporations rather than by dental specialists. There may also be change due to orthodontists becoming more frustrated with the limitations placed on them by aligner companies, like Align Technology requiring orthodontists to purchase the iTero® scanner in order to use their Invisalign® service. However, the chance of completely severing reliance

on these companies in the near future is unlikely, as they have a several-decade head start in developing algorithms for efficiently treating complex cases that is not as simply attainable through current in-house software. It will also take time for newly adopting orthodontists to determine how to best implement and refine in-house digital systems, which will likely require the orthodontist providing clear and useful feedback to the digital system developers.

Study Limitations

A significant limitation of this study is a small sample size of 85 orthodontists. This could be due to a few different phenomena. First, this study was distributed towards the end of 2020 at a time when the COVID-19 pandemic was still at its peak. Several COVID-19 related surveys had been distributed to AAO members in an attempt gather information about how the virus had affected aspects of their practice, finances, and life. In addition to these AAO surveys, many individuals were also asked to complete surveys as members of school districts and local and regional affiliations. Therefore, the recipients of the email invitation to take this survey could have been experiencing survey fatigue, decreasing their willingness to participate. The survey delivery method could have also influenced the response rate. Perhaps a more personal invitation or different route of communication could have drawn more participants.

Of the 85 orthodontists that took the survey, 23 reported to be using a digital workflow in their practice. This would infer that around 27% of orthodontists use a digital workflow in the United States, which is unexpectedly high. This study could be over-estimating this percentage due to non-response bias, with people who were more interested in the topic being more willing to take the survey. A more generic survey title might have controlled for this.

A last limitation is that some survey respondents may have answered questions without having a full understanding of what it means to use a digital workflow in one's practice. This was demonstrated by the fact that in the opinion question responses, some orthodontists made comments that teledentistry should not overtake the field of orthodontics and that patients still need to be seen in person under an orthodontist's care. A digital workflow is not the same concept as teledentistry, but both are relatively new topics that may be easy to confuse.

Future Investigations

Due to the quickly evolving digital landscape in orthodontics, a similar follow-up study in five years would be useful to see if more orthodontists are adopting a digital workflow. That survey could also incorporate information about how prices and software have changed, as these were two main barriers to digital use in the current study. It would also be useful to ask those orthodontists who use a digital workflow for aligner fabrication if they feel that they utilize third party aligner companies any less since implementing their own in-house systems.

Another possible future investigation could be to assess the implementation of digital technology into residency programs, and to survey residents on their eagerness to incorporate a digital workflow based on what they learned during their training. It would be useful in this study to determine not only what type of digital technology is being utilized in schools, but to what extent the technology is being used to treat patients and to what extent the residents are being taught to utilize and understand different workflows.

Finally, another future investigation could be to replicate this study and perform it a second time, but with an attempt to increase the sample size. One way to reach more

orthodontists might be to post the survey on a popular social media group page that has many members. This may have potential to be successful in increasing sample size as these groups exist with the purpose of advancing the field through friendly collaboration, and members are typically active participants. In a scenario with unlimited funds, there could also be some added incentive for taking the survey through whichever route is chosen. For example, the study developer could offer to donate a dollar to a dental-based charity for every survey taken or enter participants into a raffle for a gift card upon completing the survey. However, even with an incentive, the time required to take the survey still may prove to be the largest barrier to participation.

CHAPTER 5

CONCLUSIONS

1. Gender and job status were the only clinician demographics that were significantly associated with utilization of digital workflow within their private practice. Specifically, males and sole owners were more likely to use a digital workflow.
2. Several practice characteristics were significantly associated with utilization of a digital workflow in private practice. Specifically, practices with greater numbers of employees, small practices with 300 or less active patients or large practices with greater than 700 patients, and practices that treat a greater number of cases with clear aligners were more likely to use a digital workflow.

LITERATURE CITED

Al-Hassiny A. Review of the intraoral scanners at IDS 2019. Available from https://instituteofdigitaldentistry.com/cad-cam/review-of-the-intra-oral-scanners-at-ids-2019/. Accessed October 25, 2021.

Behrents RG. Do-it-yourself impressions and clear retainers: A fairy tale. Am J Orthod Dentofacial Orthop 2016;150:205-7.

Burger D. Invisalign dispute disrupts orthodontists' workflow. Available from https://www.ada.org/en/publications/ada-news/2018-archive/january/invisalign-dispute-disrupts-orthodontists-workflow. Accessed October 25, 2021.

Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. Dent Clin North Am 2011;55:559-70, ix.

Gierie WV. Clear aligner therapy: An overview. J Clin Orthod 2018;52:665-74.

Greenburg M. The use of digital study models and perceptions towards existing digital model software in orthodontic practice. Kansas City, Missouri, University of Missouri Kansas City; 2017.

Groth C, Kravitz ND, Shirck JM. Incorporating three-dimensional printing in orthodontics. J Clin Orthod 2018;52:28-33.

Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42:377-81.

Jacox LA, Mihas P, Cho C, Lin FC, Ko CC. Understanding technology adoption by orthodontists: A qualitative study. Am J Orthod Dentofacial Orthop 2019;155:432-42.

Jha N, Kim YJ, Lee Y, Lee JY, Lee WJ, Sung SJ. Projected lifetime cancer risk from cone-beam computed tomography for orthodontic treatment. Korean J Orthod 2021;51:189-98.

Kamio T, Suzuki M, Asaumi R, Kawai T. DICOM segmentation and STL creation for 3d printing: A process and software package comparison for osseous anatomy. 3D Print Med 2020;6:17.

Kapila SD, Nervina JM. CBCT in orthodontics: Assessment of treatment outcomes and indications for its use. Dentomaxillofac Radiol 2015;44:20140282.

Kim J, Heo G, Lagravere MO. Accuracy of laser-scanned models compared to plaster models and cone-beam computed tomography. Angle Orthod 2014;84:443-50.

Kim YH. Linear accuracy of full-arch digital models using four different scanning methods: An in vitro study using a coordinate measuring machine. Applied Sciences 2020;10.

Kirschneck C, Kamuf B, Putsch C, Chhatwani S, Bizhang M, Danesh G. Conformity, reliability and validity of digital dental models created by clinical intraoral scanning and extraoral plaster model digitization workflows. Comput Biol Med 2018;100:114-22.

Kravitz ND, Burris B, Butler D, Dabney CW. Teledentistry, do-it-yourself orthodontics, and remote treatment monitoring. J Clin Orthod 2016;50:718-26.

Kravitz ND, Groth C, Shannon T. CAD/CAM software for three-dimensional printing. J Clin Orthod 2018;52:22-7.

Martin CB, Chalmers EV, McIntyre GT, Cochrane H, Mossey PA. Orthodontic scanners: What's available? J Orthod 2015;42:136-43.

Mendel B. 3shape files lawsuit against Align Technology for alleged abuse of monopoly power. Available from https://www.3shape.com/-/media/files/press-release-pdf/2018/align-technology-for-alleged-abuse-of-monopoly-power-28-08-2018.pdf?v=. Accessed October 25, 2021.

Moshiri M. Product review and demonstration of the invisalign clear aligner system. AJODO Clinical Companion 2021;1:7-21.

Park JH, Laslovich J. Trends in the use of digital study models and other technologies among practicing orthodontists. J Clin Orthod 2016;50:413-9.

Pulluru M, Karre D, Swathi SS, Penmetcha S, Reddy S, Nagolla SP. Intraoral digital scanners – an overview. Research & Reviews: Journal of Dental Sciences 2017;6:38-43.

Shastry S, Park JH. Evaluation of the use of digital study models in postgraduate orthodontic programs in the United States and Canada. Angle Orthod 2014;84:62-7.

Smile direct club. Available from https://smiledirectclub.com/?utm_source=google&utm_medium=cpc&utm_campaign=11474177244&utm_term=118873538823&utm_content=511291986162&gclid=CjwKCAjwzt6LBhBeEiwAbPGOgck_JRmWe5wTh8z03JdiydIPE9JkLGJblbVKFgWbebCBHBC1dobsVRoCk8cQAvD_BwE. Accessed October 25, 2021.

Taneva E, Kusnoto B, Evans C. 3d scanning, imaging, and printing in orthodontics. In: Issues in contemporary orthodontics. F Bourzgui editor; 2015, pp. 147-88.

APPENDIX A

SURVEY EVALUATION FEEDBACK FORM FOR FACULTY

Dear Dr. (XXXXX),

I would very much appreciate your effort in taking time to **evaluate the attached survey for clarity and content**.

This survey is part of the thesis project I am conducting at UMKC which investigates the use of digital technology and digital workflow in orthodontic private practices. It is intended to be sent to private-practicing orthodontists in an aim to gather more information on this up-and-coming topic. The final survey will be distributed electronically.

Please note that the questions in this paper format will have prompts in parentheses such as, "(if answered no for Q6, skip to Q24)." Therefore, the survey will be shorter for some than others based on specific responses.

You need not complete the survey, but instead examine each question critically, and leave comments where you feel necessary. Your comments will greatly help me to improve the survey prior to its final distribution to AAO members throughout the United States.

Thank you for your assistance and feedback. I greatly appreciate your time and willingness to help with my project.

Respectfully,

Megan Klein, DDS
UMKC School of Dentistry
Resident, Dept. of Orthodontics & Dentofacial Orthopedics
MS Candidate, Dept. of Oral and Craniofacial Sciences

APPENDIX B

SURVEY

Digital Technology in Orthodontics

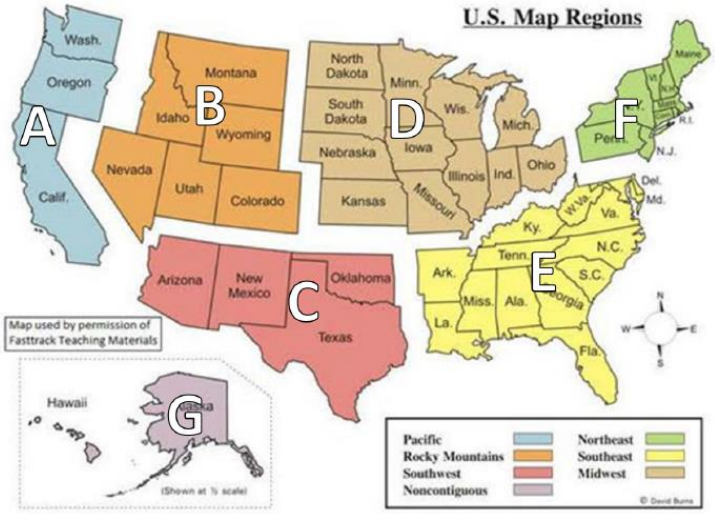
Section 1 of 3: Orthodontist Demographics

1. In what year did you graduate from orthodontic residency?

   ◯ Prior to 1960
   ◯ 1960-1969
   ◯ 1970-1979
   ◯ 1980-1989
   ◯ 1990-1999
   ◯ 2000-2009
   ◯ 2010 or after

2. In which region is the orthodontic program from which you graduated? See map below for regions.

   ◯ A. Pacific
   ◯ B. Rocky Mountains
   ◯ C. Southwest
   ◯ D. Midwest
   ◯ E. Southeast
   ◯ F. Northeast
   ◯ G. Noncontiguous
   ◯ H. Training was completed outside of the United States



3. What is your gender?

◯ Female
◯ Male
◯ Other/Prefer to self-describe
◯ Do not wish to answer

You selected 'Other/Prefer to self-describe' for gender. Please write in your preference.

_____

4. What is your age?

◯ 24 or younger
◯ 25-34
◯ 35-44
◯ 45-54
◯ 55-64
◯ 65-74
◯ 75 or older

5. What is your race/ethnicity? Select all that apply.

☐ White/Caucasian
☐ Black/African American
☐ Hispanic/Latino
☐ Native American Indian or Alaska Native
☐ Asian
☐ Native Hawaiian/Pacific Islander
☐ Other/Prefer to self-describe
☐ Do not wish to answer

You selected 'Other/Prefer to self-describe' for race/ethnicity. Please write in your preference.

_____

6. Do you spend any amount of time working in an academic setting?

◯ Yes ◯ No

7. Are you currently an orthodontist working in a private practice or corporate-owned practice setting?

◯ Yes ◯ No

Because you selected "No" for Question #7, you will now be directed ahead to Question #20.

8. What is your current status as an orthodontist? Select all that apply.

☐ Sole Owner
☐ Partner
☐ Associate
☐ Independent contractor
☐ Employee in corporately-owned practice

Section 2 of 3: Practice Characteristics

9. How many office locations belong to the practice in which you work (your practice network)?

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 or greater

9b. Within your practice's multiple locations, approximately how many orthodontists in total practice in the network?

◯ 1-2 ◯ 3-4 ◯ 5-10 ◯ Greater than 10 ◯ I don't know

10. How many orthodontists practice in your primary office?

◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 or greater

11. How many employees, besides orthodontists, work at your primary office location?

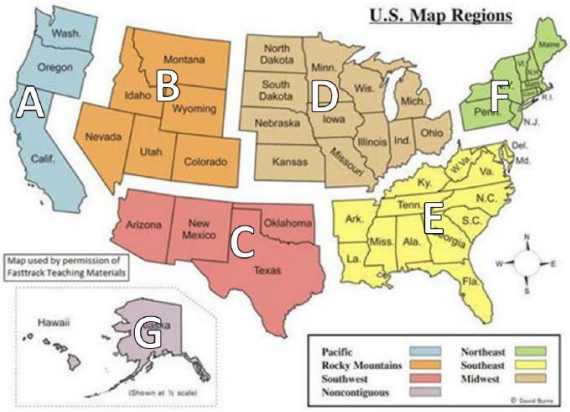
◯ 5 or less ◯ 6-10 ◯ 11-15 ◯ 16-20 ◯ Greater than 20

12. How would you describe the population of the area that your primary office is serving?

◯ Rural ◯ Suburban ◯ Urban

13. In which region is your primary office located? See map below for regions.

◯ A. Pacific
◯ B. Rocky Mountains
◯ C. Southwest
◯ D. Midwest
◯ E. Southeast
◯ F. Northeast
◯ G. Noncontiguous



14. Approximately how many active patients are currently being treated at your primary office? This includes all comprehensive, limited, and phase I patients but does NOT include patients in retention.

◯ 300 or less ◯ 301-500 ◯ 501-700 ◯ 701-900 ◯ Greater than 900

15 Approximately what percentage of the active patients treated at your primary office are adults (over age 18)?

◯ 0-20% ◯ 21-40% ◯ 41-60% ◯ 61-80% ◯ 81-100%

16. Approximately what percentage of the active patients in your primary office location are treated with clear aligners (Invisalign, Clear correct, In-office printed aligners, etc.)?

◯ 10% or less ◯ 11-30% ◯ 31-50% ◯ 51-70% ◯ Greater than 70%

Section 3 of 3: Digital Technology Utilization

17. Does your primary office have an intraoral scanner that is used on at least a weekly basis?

○ Yes ○ No

17b. Which most closely represents the role of the intraoral scanner in your primary office? Select all that apply.

☐ For digital record taking
☐ To create digital impressions that are sent to 3rd party aligner companies
☐ To create digital impressions that are sent to outside orthodontic labs for appliance or retainer fabrication
☐ To create a digital scan that will be used in virtual setups and treatment simulations
☐ Other

You selected 'Other.' Please write in the role of intraoral scanning in your primary office.

_____

18. Within your primary office or practice network, do you have access to a cone beam computed tomography (CBCT) machine?

○ Yes ○ No

18b. Which most closely represents the role of the CBCT in your practice? Select all that apply.

☐ For routine record taking on every new patient exam
☐ To take 3D images to assess features such as TMJ pathology, impactions, root positions, etc. in particular cases
☐ To take 3D images of patient's maxilla/mandible in order to generate a digital model that can be used for diagnosis and treatment planning
☐ To scan impressions or plaster casts to generate a digital model that can be used for diagnosis and treatment planning
☐ Other

You selected 'Other.' Please write in the role of CBCT in your office.

_____

19. Within your primary office or practice network, do you have access to a 3D printer that is used for orthodontic purposes?

○ Yes ○ No

19b. Which most closely represents the role of 3D printing for orthodontic purposes within your practice? Select all that apply.

☐ To print models that will assist in diagnosis and treatment planning
☐ To print models for fabricating retainers
☐ To print models for fabricating thermoformed aligners
☐ To print models to be used for in-office direct fabrication of metal appliances
☐ To print setups for indirect bonding
☐ To directly print clear aligners or clear retainers
☐ Other

You selected 'Other.' Please write in the role of 3D printing in your office.

_____

Please use the following definition of a digital workflow to answer questions 20, 21, and 22.

Digital Workflow:

- Acquiring a digital scan to generate a study model (via intraoral scanning or CBCT)
  AND
- Utilizing in-office 3D printing for any orthodontic purpose (models, bonding setups, custom brackets, etc.)

20. Do you feel that adopting a digital workflow in private orthodontic practice can be beneficial?

    ◯ Yes ◯ No ◯ I don't know

20b. If you would like to elaborate on your answer to question 20, please do so here:

21. Do you believe that use of a digital workflow in orthodontic offices will increase over the next 20 years?

    ◯ Yes ◯ No ◯ I don't know

21b. If you would like to elaborate on your answer to question 21, please do so here:

22. Do you feel that utilizing a digital workflow is a practical way for orthodontists to directly provide clear aligner treatment for their patients?

    ◯ Yes ◯ No ◯ I don't know

22b. If you would like to elaborate on your answer to question 22, please do so here:

APPENDIX C

AAO SURVEY EMAIL PROMPT

Dear AAO Member,

My name is Megan Klein and I am an orthodontic resident and MS candidate in the Oral and Craniofacial Sciences program in the School of Dentistry at the University of Missouri-Kansas City. My thesis project is focused on educational research related to digital technology utilization in private practice orthodontic offices. Specifically, the goal is to better understand how the use of a digital workflow in private or corporate-owned practice might be influenced by orthodontist demographics and practice characteristics. To accomplish this goal, I am requesting that you complete a survey that can be accessed via the link provided below.

The 22-question survey should take approximately 5-10 minutes to complete. All survey responses are anonymous with no identifying marker linked to your responses.

Your participation is entirely voluntary; you may skip any questions that you don't want to answer or choose to stop participating at any time.

No personally identifying information is being collected. You will not be identified in any reports about this research.

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, and I thank you in advance for your time.

If you have any questions concerning the survey, you may contact me at kleinmm@umkc.edu.

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

If you want to participate, click this link to start the survey:

[insert link]

Sincerely,

Megan Klein, DDS

APPENDIX D

IRB APPROVAL LETTER

UMKC **Institutional Review Board**
University of Missouri-Kansas City

5319 Rockhill Road
Kansas City, MO 64110
816-235-5927
umkcirb@umkc.edu

July 07, 2020

Principal Investigator: Mary P Walker
Department: Dean, School of Dentistry

Your IRB Application to project entitled "DIGITAL TECHNOLOGY AND DIGITAL WORKFLOW APPLICATION IN THE CURRENT LANDSCAPE OF PRIVATE PRACTICE ORTHODONTICS-- OCS MS Klein" was reviewed and determined to qualify for IRB exemption according to the terms and conditions described below:

IRB Project Number	2025239
IRB Review Number	267318
Initial Application Approval Date	July 07, 2020
IRB Expiration Date	N/A
Level of Review	Exempt
Exempt Categories	45 CFR 46.101b(2)

Approved Documents
email_script_klein_v3_07-07-20.docx
klein_research_proposal_to_committee.docx
klein_redcap_survey.pdf

The principal investigator (PI) is responsible for all aspects and conduct of this study. The PI must comply with the following conditions of the determination:

1. No subjects may be involved in any study procedure prior to the determination date.
2. Changes that may affect the exempt determination must be submitted for confirmation prior to implementation utilizing the Exempt Amendment Form.
3. The Annual Exempt Form must be submitted 30 days prior to the determination anniversary date to keep the study active or to close it.
4. Maintain all research records for a period of seven years from the project completion date.

If you are offering subject payments and would like more information about research participant payments, please click here to view the UM system Policy on Research Subject Payments: https://www.umsystem.edu/oei/sharedservices/apss/nonpo_vouchers/research_subject_payments

If you have any questions, please contact the IRB at 816-235-5927 or umkcirb@umkc.edu.

Thank you,
UMKC Institutional Review Board

VITA

NAME: Megan Welk

DATE AND PLACE OF BIRTH: March 11, 1993; Gillette, WY

EDUCATION:

5/2011	Diploma	Campbell County High School Gillette, WY
5/2015	B.S. Physiology and Honor Studies	University of Wyoming Laramie, WY
5/2019	D.D.S.	University of Nebraska Medical Center College of Dentistry Lincoln, NE
12/2021 In Process	M.S. Oral & Craniofacial Sciences	University of Missouri-Kansas City School of Dentistry Kansas City, MO
12/2021 In Process	Orthodontics & Dentofacial Orthopedics	University of Missouri-Kansas City School of Dentistry Kansas City, MO

PROFESSIONAL ORGANIZATIONS:

2015-Present	American Dental Association
2019-Present	American Association of Orthodontists

HONORS:

2016-2019	High Academic Achievement Award UNMC College of Dentistry
2019	Omicron Kappa Upsilon Inductee