© Copyright 2017

Derek J. Hou

The Effect of Digital Diagnostic Setups on Orthodontic Treatment Planning

Derek J. Hou

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science in Dentistry

University of Washington

2017

Committee:

Greg J. Huang, Chair

Burcu Bayirli

Raquel T. Capote

Daniel C. N. Chan

Program Authorized to Offer Degree:

Orthodontics

University of Washington

Abstract

The Effect of Digital Diagnostic Setups on Orthodontic Treatment Planning

Derek J. Hou

Chair of the Supervisory Committee:
Greg J. Huang, Professor and Chair
Department of Orthodontics

The purpose of this study was to explore the effect of viewing digital setups on orthodontic treatment planning. Six cases were identified from the UW Graduate Clinic to represent different case types that could benefit from a diagnostic setup. The cases included adolescent and adult patients with a variety of conditions, such as missing teeth, dental crowding, or subdivisions. Twenty-two orthodontists and seven orthodontic residents treatment planned each case, indicating their most recommended plan and up to two alternative plans. After treatment planning each case, digital setups of each treatment plan indicated by the practitioner were viewed. After viewing the setup(s) for each case, practitioners were asked if they still recommended the same plan as they had originally, or if they would now choose a different plan.

Their confidence levels in the success of their plans were recorded before and after viewing the setups.

After viewing the digital setups, 23.6% of treatment plans changed, with changes that included adding or removing IPR, change in extraction pattern, or change in the management of missing teeth. In addition, practitioner confidence level increased after viewing the setups. While initial confidence levels were lower for a) complex cases, b) cases where the treatment plan changed, and c) orthodontic residents, the final confidence levels were uniformly high among all practitioners. The most helpful features of digital setups were the abilities to: superimpose the setup with the original model, determine the amount of tooth movement needed, check the final incisal relationship (overjet and overbite), and establish the IPR amount required.

Digital setups can influence treatment plans and the level of confidence the practitioner has in the plan. Setups can be helpful when deciding on the most recommended treatment plan prior to starting treatment.

TABLE OF CONTENTS

List of Figures ii

List of Tables ii

Chapter 1. Introduction 1

Chapter 2. Material and Methods 3

Chapter 3. Results 10

Chapter 4. Discussion 16

Chapter 5. Conclusions 22

Bibliography 23

Appendix 24

LIST OF FIGURES

Figure 2.1. SureSmile digital setup showing the final occlusion for a canine substitution treatment plan. 6
Figure 2.2. SureSmile digital setup showing the final overjet. 6
Figure 2.3. SureSmile digital setup showing the maxillary occlusal with a superimposition of the initial (teal) and final (white) tooth positions. 7
Figure 2.4. SureSmile setup with tooth movement chart showing the exact movements of each tooth in the maxillary arch. In this case, the maxillary left second molar was not moved in order to visually indicate the amount of space closure required. 7

LIST OF TABLES

Table 2.1. Description of Cases 4
Table 3.2. Description of practitioners 10
Table 3.3. Description of practitioners' clinical experiences 11
Table 3.4. Description of each case with most recommended treatment plans 11
Table 3.5. Changing treatment plan by practitioner experience 13
Table 3.6. Number of treatment plan changes per case 13
Table 3.7. Change in confidence level before and after viewing setups 14
Table 3.8. How helpful was the setup? 15

ACKNOWLEDGEMENTS

The author would like to acknowledge and express gratitude to the University of Washington, the Department of Orthodontics, and the UW Orthodontic Alumni for providing the resources and funding for this project. Special thanks is given to the committee for their time and support. Additionally, the author would like to thank Dr. Greg Huang for his guidance, confidence, and support.

Chapter 1. INTRODUCTION

Since Kesling first recommended the use of diagnostic setups in 1947, setups have been used to simulate treatment and help with treatment planning.[1] Creating multiple setups to represent different treatment plans assists the orthodontist in making decisions on extraction patterns, interproximal reduction, anchorage management, and treatment mechanics, and also facilitates case presentation to the patient and other dentists.[2,3] Nonetheless, wax setups are infrequently used because the time needed to perform the lab work often outweighs the perceived benefit.[3]

With the transition to digital study models, diagnostic setups can now be created digitally.[4,5,6,7] Similar to a wax setup, the digital setup is a tool that helps with treatment planning and it is up to the creator of the setup to respect the biologic limitations of tooth movement and mimic realistic biomechanics. Previous studies have shown that digital setups can be as accurate and reliable as wax setups.[8,9] Barretoa et al. reported that the creation of a digital setup is much faster than creating a wax setup due to the lab work required when working with plaster.[9]

In addition to the potential time savings, working with digital setups offers advantages that were not possible with plaster, such as the ability to superimpose the setup with the original models and also the ability to determine the precise amount of movement for each tooth.[9] Digital setups can also be easily stored and shared by transmitting an electronic file.

Although setups are widely believed to be helpful[3], the influence of setups on treatment planning has not been studied. This study examined if viewing a digital setup could change an orthodontist's treatment plan or confidence level in their treatment plan. The null hypotheses were threefold: 1) viewing digital setups would not influence a practitioner's decision on

treatment planning; 2) viewing digital setups would not influence a practitioner’s confidence level in their treatment plan; and 3) viewing digital setups would not have a greater influence on less experienced orthodontists.

Chapter 2. MATERIAL AND METHODS

This study was reviewed and approved by the University of Washington Institutional Review Board and was supported by the University of Washington Orthodontic Alumni Association. OraMetrix, the company that offers SureSmile, provided assistance in creating approximately two-thirds of the digital setups but did not provide any direct funding.

A panel of three orthodontists reviewed a list of forty cases generated from patients treated at the UW Graduate Orthodontics Clinic within the past three years and for whom treatment planning involved multiple plaster setups. Six cases were selected for the study. The panel felt that six cases was a reasonable number to ask a practitioner to treatment plan without occupying too much of their time or causing them to suffer from fatigue. Cases were selected based on the criteria that they could benefit from a setup, were representative of cases typically seen in practice, and were not so complex that they represented an extremely rare case. The cases used for this study are described in Table 2.1 below. Of the 6 cases selected, 3 were adolescent patients and 3 were adult patients. Three cases were Class I, two were Class II, and a single case was a Class III tendency.

Table 2.1. Description of Cases

Case #	Description of Case
1	15-year-old female, Class I, full profile, proclined incisors, mild maxillary and mandibular crowding
2	21-year-old female, Class I, thin upper lip, 95% overbite, moderate mandibular anterior crowding
3	36-year-old male, Class I, excess overjet/overbite, retained maxillary left primary canine, missing maxillary left permanent canine, missing one lower incisor, moderate arch length deficiency on lower
4	13-year-old male, subdivision with Class II on right, straight profile, thin lips, severe maxillary and mandibular crowding
5	12-year-old female, end-on Class II, convex profile, thin lips, excess overjet and minimal overbite, missing maxillary lateral incisors
6	48-year-old female, Class III tendency, increased overjet and overbite, severe mandibular anterior crowding, recently extracted #10 due to root fracture

The records assembled included intra-oral and extra-oral photos, panoramic and lateral cephalometric radiographs, cephalometric tracing and measurements, tooth size measurements, Bolton analysis, and the 3D digital model of the teeth. All records were de-identified.

The records were imported into SureSmile software (OraMetrix, Richardson, TX) to generate the digital setups. Once the records were uploaded into the software, an order was placed to create a diagnostic model, which meant that the SureSmile lab technicians virtually sectioned the individual teeth but left the teeth in their initial position. Once the diagnostic model was created, the teeth could be moved to create the desired setups. The same panel of three orthodontists met to identify as many potential treatment plans as possible for each case so that these setups could be prepared prior to practitioner enrollment. During the study, if a practitioner proposed a treatment plan that had not been anticipated, the setup was created and shown to the practitioner within several days.

For the six cases, a total of forty-four digital setups were created, with an average of seven setups per case. Approximately one-third of the setups were created by DH. The remaining

two-thirds of setups were created by SureSmile technicians. For those setups, a prescription form was sent to the technician to describe the extraction pattern, final molar and canine positions, desired IPR, midline, arch forms, anchorage, anteroposterior movements, and occlusal plane correction.

Each setup was reviewed individually by at least two out of the three orthodontists on the panel and any suggested revisions to the setups were made by DH to better simulate realistic biomechanics and anchorage loss.

If present, the third molars were removed from the digital setup. Second molars were not moved and served as vertical stops and references for anchorage loss in extraction cases.

All of the de-identified records were loaded into a Keynote (Apple, Cupertino, CA) presentation file to show practitioners. A screencapture video recording showing the different views in each digital setup was made using Monosnap Software (Farminers Limited) and loaded into the Keynote presentation. By pre-recording each digital setup and adding it to the presentation, the process of viewing the setups was standardized and more efficient. All of the recordings displayed the setups in the same order: front, right, left, oblique final showing overjet and overbite, maxillary occlusal, mandibular occlusal, superimposition over initial models, tooth movement animation, tooth movement chart, and any AP movement achieved via elastics or orthognathic surgery. Figures 2.1-4 show samples of the views shown to practitioners participating in the study.

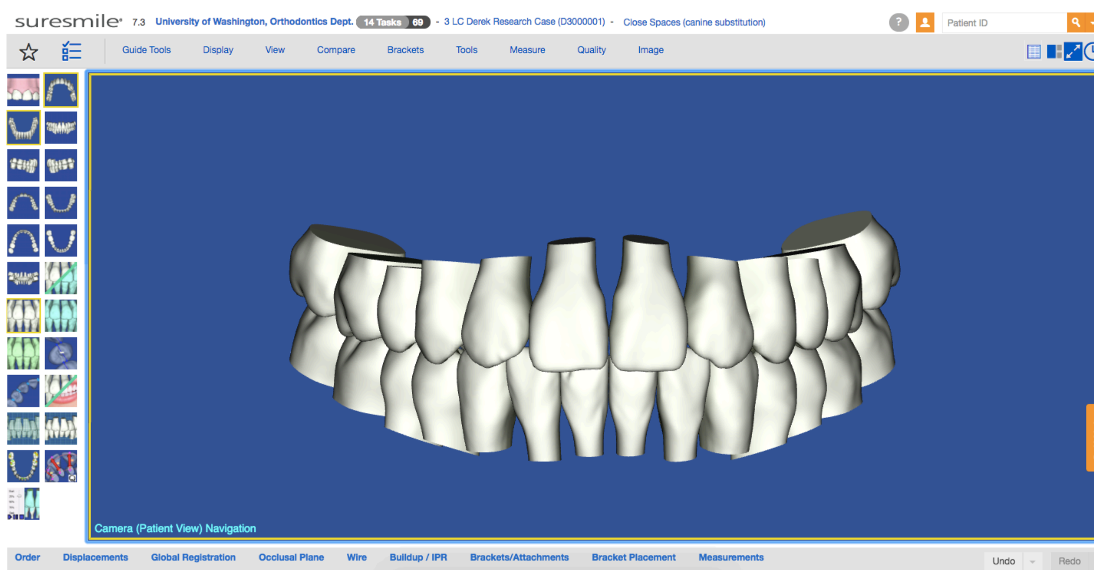


Figure 2.1. SureSmile digital setup showing the final occlusion for a canine substitution treatment plan.

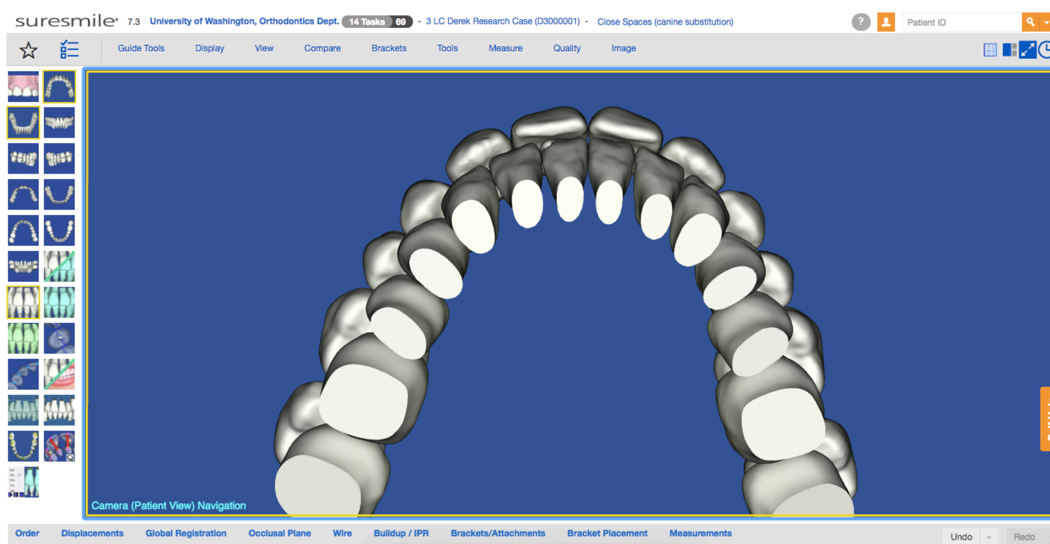


Figure 2.2. SureSmile digital setup showing the final overjet.

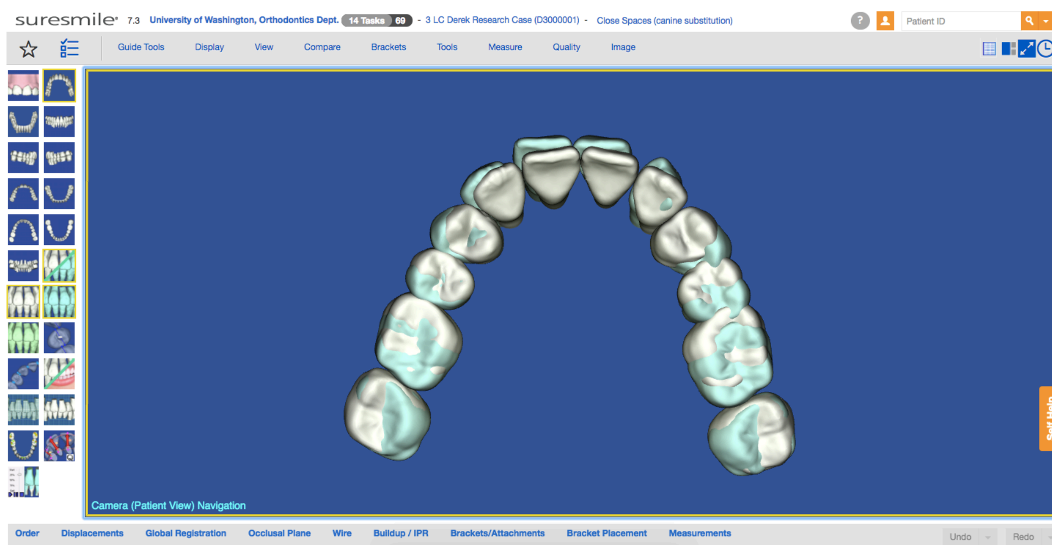
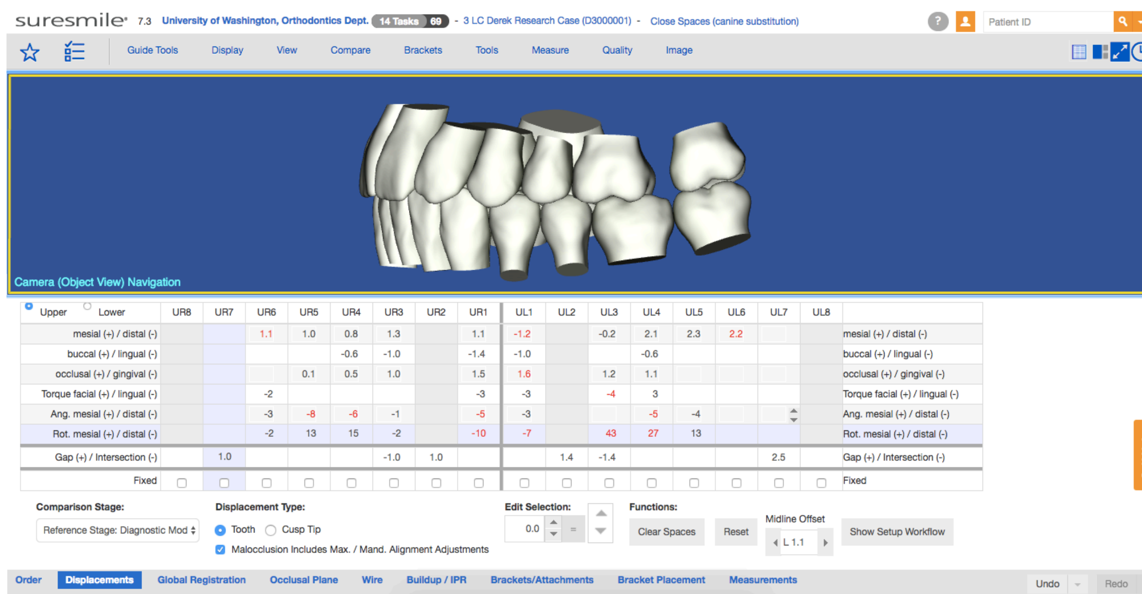


Figure 2.3. SureSmile digital setup showing the maxillary occlusal with a superimposition of the initial (teal) and final (white) tooth positions.



Upper / Lower	UR8	UR7	UR6	UR5	UR4	UR3	UR2	UR1	UL1	UL2	UL3	UL4	UL5	UL6	UL7	UL8	
mesial (+) / distal (-)			1.1	1.0	0.8	1.3		1.1	-1.2		-0.2	2.1	2.3	2.2			mesial (+) / distal (-)
buccal (+) / lingual (-)					-0.6	-1.0		-1.4	-1.0			-0.6					buccal (+) / lingual (-)
occlusal (+) / gingival (-)				0.1	0.5	1.0		1.5	1.6		1.2	1.1					occlusal (+) / gingival (-)
Torque facial (+) / lingual (-)			-2					-3	-3		-4	3					Torque facial (+) / lingual (-)
Ang. mesial (+) / distal (-)			-3	-8	-6	-1		-5	-3			-5	-4				Ang. mesial (+) / distal (-)
Rot. mesial (+) / distal (-)			-2	13	15	-2		-10	-7		43	27	13				Rot. mesial (+) / distal (-)
Gap (+) / Intersection (-)		1.0				-1.0	1.0			1.4	-1.4				2.5		Gap (+) / Intersection (-)
Fixed																	Fixed

Figure 2.4. SureSmile setup with tooth movement chart showing the exact movements of each tooth in the maxillary arch. In this case, the maxillary left second molar was not moved in order to visually indicate the amount of space closure required.

The orthodontic practitioner was the subject in this study. Using simulation modeling, a sample size of 29 orthodontists and orthodontic residents was decided upon. This number of

study participants would provide an expected margin of error between 5-6% if the probability of switching treatment plans was between 10-30%.

Twenty-two orthodontists and 7 orthodontic residents were recruited to participate in the study. In order to participate, practitioners must have been enrolled in or have graduated from an orthodontic residency program and have had no involvement in the treatment of any of the 6 cases used in the study. Orthodontists who used SureSmile on a routine basis for creating digital setups or for treatment were excluded. All of the orthodontic residents recruited for the study had minimal experience creating digital setups using SureSmile software.

Orthodontists were shown the records of the six cases in random order. Upon viewing the records, orthodontists were asked to list up to three treatment plans (the most recommended plan, the second most recommended plan, and the third most recommended plan) using a treatment planning worksheet that standardized and simplified the responses. The worksheet asked if any of the following treatment modalities would be used: fixed appliances, clear aligners, extractions, interproximal reduction, elastics, headgear, maxillary expander, functional appliance (Herbst, Mara), orthognathic surgery, temporary anchorage devices, or habit appliance (ie. tongue crib). Practitioners could also write in additional treatment modalities. Practitioners were asked to indicate their confidence level in the successful outcome of their most recommended plan on a visual analog scale.

After indicating and ranking their treatment plans, practitioners were shown digital setups representing each of their recommended treatment plans. Practitioners were only able to view setups for plans that they had indicated on the treatment planning worksheet. After viewing the setups, practitioners were again asked which plan was their most recommended treatment plan and their confidence level in the successful outcome of this plan. Practitioners were also asked to

indicate on a visual analog scale how helpful the setup was for treatment planning. After viewing all six cases, practitioners were asked to complete a post-test survey. Examples of the treatment planning worksheet and post-test survey are included in the appendix.

For statistical analysis, the orthodontists were divided into three groups: current residents, those with ≤5 years in practice, and those with >5 years in practice. Based on the three hypotheses, the statistical analysis of the data focused on answering: 1) how often did practitioners keep or change their most recommended plan after viewing the setups; 2) did practitioners' confidence levels change after viewing the setups; and 3) did the rate of treatment plan change and confidence level change differ among the three groups of orthodontists.

After data collection, the data was analyzed using SPSS Version 19 (IBM Corp, Armonk, NY). The probability of changing the most recommended treatment plan and associated confidence intervals were estimated using a binomial regression model with log link using GEE to account for multiple observations per practitioner and also used to compare the different experience levels. To determine the change in confidence interval, a linear regression on change in confidence using GEE was used with case and plan change incorporated into the model.

Chapter 3. RESULTS

A total of 29 practitioners participated in the study. The practitioners were stratified into three groups based on experience (Table 3.2), with seven second- or third-year orthodontic residents (residents), thirteen orthodontists with five years or fewer in practice (inexperienced practitioners), and nine orthodontists with over five years in practice (experienced practitioners). The group of inexperienced practitioners had an average of 2.1 years in practice with a range of one to four years of experience. The group of experienced practitioners had an average of 25.1 years in practice with a range of eight to forty years of experience.

Table 3.2. Description of practitioners

	# of practitioners	**Avg Years in Practice (range)**	**Avg Years in Residency (range)**	**Male**	**Female**
Residents	7		2.3 (2-3)	2	5
≤5 years in practice	13	2.1 (1-4)		8	5
>5 years in practice	9	25.1 (8-40)		6	3
Total	29			16	13

Table 3.3 describes the clinical experiences of the practitioners. The average of all practitioners was 117 cases starts in the past 12 months with 16% of these cases as Invisalign, 4% of these cases requiring a digital setup, and 3% of these cases requiring a plaster setup. Nine of the 29 practitioners exclusively use digital models for diagnosis, 12 use no digital models, and the remaining 8 practitioners use digital models for a range of 5-50% of cases.

Of the practitioners in the study, only the residents have had previous experience with SureSmile software. The residents have used the software to create digital setups but have not used SureSmile to order wires or directly treat patients. On average, the residents reported creating SureSmile setups for 8% of their patient cases, with a range of 0-20%. None of the inexperienced or experienced practitioners had used SureSmile to create digital setups or treat patients.

Table 3.3. Description of practitioners' clinical experiences

	Avg # of starts in past 12 months (range)	**% Invisalign Cases (range)**	**% Digital Setups (range)**	**% Plaster Setups (range)**
Residents (n=7)	51 (40-60)	9% (5-10)	6% (0-20)	3% (0-10)
≤5 years in practice (n=13)	119 (0-300)	17% (0-50)	4% (0-30)	3% (0-10)
>5 years in practice (n=9)	164 (0-300)	19% (0-50)	4% (0-15)	4% (0-10)
Total (n=29)	117 (0-300)	16% (0-50)	4% (0-30)	3% (0-10)

The top two most recommended treatment plans by practitioners for each of the six cases in the study are listed in Table 3.4.

Table 3.4. Description of each case with most recommended treatment plans

Case #	**Description of Case**	**Most Recommended Treatment Plans**
1	15-year-old female, Class I, full profile, proclined incisors, mild maxillary and mandibular crowding	1. Extract all first premolars 2. Extract all second premolars
2	21-year-old female, Class I, thin upper lip, 95% overbite, moderate mandibular anterior crowding	1. Non-extraction with mandibular IPR 2. Extract one lower incisor

3	36-year-old male, Class I, excess overjet/overbite, retained maxillary left primary canine, missing maxillary left permanent canine, missing one lower incisor, moderate arch length deficiency on lower	1. Replace missing UL3 with implant and maxillary IPR 2. Close UL3 space by protracting maxillary left posterior teeth
4	13-year-old male, subdivision with Class II on right, straight profile, thin lips, severe maxillary and mandibular crowding	1. Non-extraction with maxillary expansion 2. Extract all first premolars
5	12-year-old female, end-on Class II, convex profile, thin lips, excess overjet and minimal overbite, missing maxillary lateral incisors	1. Bilateral canine substitution to close missing lateral incisor space 2. Open space for maxillary lateral implants
6	48-year-old female, Class III tendency, increased overjet and overbite, severe mandibular anterior crowding, recently extracted #10 due to root fracture	1. Non-extraction with mandibular IPR 2. Extract one lower incisor

In this study, 29 practitioners each treatment planned 6 cases and generated a total of 174 treatment planning events. After the practitioners viewed the digital setups, the most recommended plan was changed 41 out of 174 times, giving a change rate of 23.6% (Table 3.4). Residents changed at a rate of 21.4%, inexperienced practitioners changed at a rate of 29.5%, and experienced practitioners changed at a rate of 16.7%. This difference in change rate based on practitioner experience was not statistically significant; however, it does show an interesting trend with the experienced practitioners having the lowest change rate and the inexperienced practitioners having a higher change rate than residents.

Table 3.5. Changing treatment plan by practitioner experience

	% changing	relative risk of changing	95% confidence interval		p-value*
Residents (n=7)	21.4%	1	.	.	.199
≤5 years in practice (n=13)	29.5%	1.38	0.82	2.32	
>5 years in practice (n=9)	16.7%	0.80	0.38	1.65	
Total (n=29)	23.6%				

* adjusting for case in binomial regression model with log link using GEE to account for multiple observations per judge

Out of the 41 changes in treatment plans, 16 were to add or remove IPR, 13 were to change extraction pattern, 4 were to add TADs to help anchorage and space closure, 3 were a change from opening space for implants to closing space for canine substitution, 2 were to switch from fixed appliances to clear aligners or vice versa, 1 was to add advancement genioplasty, 1 was to add a maxillary expander, and 1 was to remove mandibular IPR and build up the maxillary lateral incisors. The number of changes per case is shown in Table 3.6.

Table 3.6. Number of treatment plan changes per case

	# of Changes	% of all plans that changed
Case 1	5	17.2%
Case 2	4	13.8%
Case 3	10	34.5%
Case 4	8	27.6%
Case 5	4	13.8%
Case 6	10	34.5%
Total	41	23.6%

When practitioners were asked “How confident are you that your most recommended plan will result in a successful outcome?” on a visual analog scale, there was an overall

confidence level of 83 prior to viewing the digital setups and 89 after viewing the digital setups (Table 3.7). Case 3 had the largest change in confidence level, going from 74 to 87, and case 1 had the smallest change in confidence level, going from 89 to 90. When the treatment plan did not change, the confidence level increased from 84 to 89, whereas when the treatment plan did change, the confidence level increased from 77 to 88. When broken out by experience level of the practitioner, residents had the lowest initial confidence level of 72 compared to a confidence level of 86 for inexperienced and experienced practitioners. The final confidence levels in all three groups increased to 81 for residents, 91 for inexperienced orthodontists, and 92 for experienced orthodontists.

Table 3.7. Change in confidence level before and after viewing setups

			Confidence before				Confidence after				Change in confidence			
		N	Mean (%)	95% CI		p-value*	Mean (%)	95% CI		p-value*	Mean (%)	95% CI		p-value*
Total		174	83	78	87		89	86	91		6	4	9	0.000002**
Case	1	29	89	85	93	0.00000003	90	86	93	0.001	1	-2	4	0.00001
	2	29	85	80	90		92	89	95		7	3	10	
	3	29	74	67	81		87	83	90		13	8	18	
	4	29	83	79	87		86	82	90		3	-0.2	6.7	
	5	29	81	76	87		89	85	93		8	4	12	
	6	29	83	76	90		90	86	93		7	2	12	
Change in treatment plan	Kept original plan	133	84	80	88	0.003	89	86	92	0.37	5	3	7	0.003
	Changed plan	41	77	71	84		88	84	91		10	6	15	
Experience of practitioner	Residents	42	72	60	83	0.067	81	76	86	0.0003	9	1	18	0.55
	≤5 years in practice	78	86	82	91		91	88	94		5	3	7	
	>5 years in practice	54	86	81	91		92	89	95		6	3	9	

* linear regression using GEE; ** comparing before vs. after

When practitioners were asked "Was the digital setup helpful for treatment planning this case?" on a visual analog scale, the overall reported level was 74, with a reported level of 70 if there was no change in the most recommended treatment plan, and a reported level of 86 when there was a change in the most recommended treatment plan (Table 3.8). Residents reported a level of 63, inexperienced practitioners reported a level of 77, and experienced practitioners reported a level of 78.

Table 3.8. How helpful was the setup?

	Was the setup helpful for treatment planning this case?
Overall	74
If no change in treatment plan	70
If treatment plan changed	86
Residents	63
≤5 years in practice	77
>5 years in practice	78

When practitioners were asked which features of the digital setup were most helpful in treatment planning these cases, the top four responses were the abilities to: superimpose the setup with the original model, determine the amount of tooth movement needed, check the final incisal relationship (overjet and overbite), and establish the amount of IPR required.

Chapter 4. DISCUSSION

Few studies have looked at the effect of a diagnostic setup on orthodontic treatment planning. In our study, practitioners made a change to their treatment plan in 23.6% of all cases after viewing the digital setup. The most common changes were adding or removing IPR or changing extraction patterns. Other changes included closing space for canine substitution instead of opening space for lateral implants or adding TADs to help with anchorage requirements. While some of these changes could have been made during the course of treatment, knowing the definitive treatment plan from the start could result in more efficient treatment and decreased treatment time.

Overall, practitioners' confidence levels in the plan increased after viewing the setups. The biggest increase in confidence level was found when the practitioner started with a lower initial confidence level, which occurred in three main categories of situations: a difficult case, an eventual change in treatment plan after viewing the setups, and among residents. Case 3 had the lowest initial confidence level and the biggest gain in confidence after viewing the setup. This case was an adult interdisciplinary case involving a missing maxillary canine and lower incisor – this was certainly the most complex case in the study so it was no surprise that practitioners had the lowest initial confidence in their treatment plan for this case. The second category describes practitioners who changed their plans after viewing the setup. These practitioners might have lacked confidence in their plans to begin with, which more readily led to their change in most recommended treatment plan after viewing the setup. Finally, residents had the lowest initial confidence level of the three experience level groups, and subsequently had the largest increase in confidence after viewing the setup. Regardless of what the initial confidence level was, the final confidence level was uniformly high for all individuals after viewing the setups. The setups

helped to bridge the gap in confidence level and allowed practitioners to have a stronger level of confidence in their treatment plan, even if they began with a lower confidence level.

As other authors have stressed[3], a setup is only realistic and helpful if it can simulate the practitioner's treatment goals. For some of the setups, practitioners commented that the setup did not exactly mimic the tooth movements that they envisioned. The inability to exactly simulate the practitioner's plan was one of the largest limitations of this study. The biggest concerns of the practitioners were the amount of anchorage loss and the amount of IPR. Despite the setups having been reviewed by a panel of orthodontists prior to the study, some practitioners wanted more or less retraction or more or less IPR. There was not one single change that all practitioners wanted; instead, different practitioners wanted opposing changes to the setups. Ultimately, this conveys the importance of allowing the treating orthodontist to quickly and easily modify the parameters of the digital setup to suit their treatment goals. If practitioners were able to modify the setups to suit their preferences, it is likely that the confidence levels and helpfulness ratings would be higher than what we found in the study.

In order to reduce the time required to participate in the study, all of the setups were created ahead of time and we did not allow practitioners to customize the setups. Of course, in practice, the practitioner would be able to modify and customize the setup to their preferences. Unfortunately, it is not yet easy or fast enough to make these modifications on the fly. By creating the setups ahead of time, we were mimicking our desired future development of the software where setups could be made automatically with a few quick clicks on a mouse.

Another limitation was that the study was based on 6 cases that we felt could benefit from a setup. Although we strived for a good mix of cases, it may not exactly represent a typical caseload seen in private practice since we were looking for slightly more difficult cases. The

23% change rate that we found may be lower when applied to all patients seen in private practice because the general pool of patients may be less complex.

Ultimately the change in treatment plan and change in confidence level are surrogate markers for successful completion of orthodontic treatment. An increased confidence level in the plan does not guarantee that the treatment plan will result in a well-finished case and satisfied patient. The assumption in this study is that by viewing the setup, a practitioner would be able to better select a treatment plan that would more reliably result in a successful outcome, as defined by the treatment goals of the practitioner.

During the course of the study, practitioners proposed 10 treatment plans that were not initially identified by the panel. Once digital setups were created for these 10 treatment plans and shown to the practitioners who suggested them, the practitioners generally remarked that their the plan was unreasonable or that they initially missed something when treatment planning the case. None of these 10 treatment plans were selected as the most recommended plan after viewing the setups. Interestingly, the digital setup served its purpose, as it helped practitioners recognize shortcomings in those proposed plans. For example, for case 6, the patient had a slight Class III tendency. A small number of practitioners selected extraction of the LR4 or extraction of both lower 4s as a treatment plan. After viewing the setups, these same practitioners realized that the Class III was not as significant as they had thought and that there was too much space to close, and therefore did not select these plans in the end. This finding also reinforced the work of the panel prior to recruiting practitioners, as all of the reasonable treatment plans were brainstormed ahead of time.

When beginning this study, we looked at various software options for creating the digital setups. We examined SureSmile, OrthoInsight (Motion View, Chattanooga, TN), Incognito (3M,

St. Paul, MN), ClinCheck Pro (Align Technology, San Jose, CA), and Invisalign Outcome Simulator (Align Technology, San Jose, CA) as potential software platforms for creating the digital setups. Most of the software platforms offered similar features, but we ultimately chose SureSmile because it offered full control of the teeth and allowed both the company techs and investigators at UW to prepare setups.

For SureSmile, the cost of virtually sectioning the teeth and setting up the model for use is approximately $40 per case. The company donated the technicians' time to create approximately 2/3 of the required 44 setups. To create a setup after the teeth are virtually sectioned, it could take as little as 2 minutes to make minor changes, or up to 20 minutes from start to finish to create a complicated setup. The software does not have many features to automate the setup process, and some time must be spent in order to become proficient with the software. None of the software companies have yet created an interface that allows for quick, easy, and simple generation of various setups. The time and effort to generate a virtual setup must be reduced before setups can be adopted for routine clinical use.

The Invisalign Outcome Simulator (Align Technology, San Jose, CA) has some features that we believe would be important to increase the utility of simulations in routine practice. The Outcome Simulator is completely automated and will instantly create a setup to mimic non-extraction, extraction, and IPR treatment plans. But the software must be faster and allow the practitioner to have more control over tooth movement, as otherwise, it would suffer from the problem we described earlier when orthodontists wished to better manage things like anchorage loss, IPR, or incisor angulation.

The next step would be if the software were able to incorporate a large database of actual records and apply big data analytics and machine learning to better understand how teeth move

during treatment. The software could learn how much anchorage loss or how much incisor proclination to expect with various treatment modalities and incorporate these findings automatically into the default setups, with further modification by the orthodontist, as desired.

From our results, this study has shown that digital setups have an effect on the treatment plan and could be a valuable part of the treatment planning process. Previous studies have examined the effect of each component of the records on treatment planning[10] and the digital setup appears to have as much of or an even greater effect that other records that are routinely taken. Nijkamp et al. examined the effect of lateral cephalometric radiographs and found no significant differences in treatment planning with or without cephalometric information for adolescents with Class II division 1 malocclusion.[11] Han et al. examined the incremental benefit of facial photographs, panoramic radiograph, lateral cephalogram, and cephlometric tracing on treatment planning and found that the majority of cases (55%) could be treatment planned with study models alone and that each of the other records provided had a small benefit.[12] For something as difficult as treatment planning a case with impacted maxillary canines, Haney et al. found that the 3D CBCT image changed the treatment plan for the impacted tooth 27% of the time when compared to conventional 2D radiographs.[13]

Revisiting our original hypotheses, we found that digital setups did influence a practitioner's decision on treatment planning and resulted in a change rate of 23.6%. Viewing digital setups also increased the confidence level of practitioners, with the largest effect on those with a lower initial confidence level. The treatment plan change rate of the practitioners was not influenced by experience level; however, residents experienced a larger increase in confidence after viewing the setup when compared to the inexperienced and experienced orthodontists.

With our findings on the effect of a digital setup, we believe that setups have a strong impact on treatment planning and once software improves to allow setups to be created simply, quickly, and accurately, generating several digital setups could become a routine and instrumental part of the treatment planning process.

Chapter 5. CONCLUSIONS

These results suggest that digital setups influence treatment planning, as viewing digital setups resulted in a change in the most recommended treatment plan for 23.6% of cases in this study. Viewing the setup also increased the overall confidence level of the practitioners. Digital setups facilitate treatment planning and could result in more successful outcomes for the patient. The software to generate setups needs to improve to generate setups quickly, accurately, and realistically before it can become widely incorporated into routine treatment planning.

BIBLIOGRAPHY

1. Kesling HD. Predetermined pattern as diagnostic aid. AJODO, 1947;33(1):43-44.
2. Kesling, H. D. (1956). The diagnostic setup with consideration of the third dimension. *American Journal of Orthodontics*, *42*(10), 740–748. doi:10.1016/0002-9416(56)90042-2
3. Mattos, C. T., Gomes, A. C. R., Ribeiro, A. A., Nojima, L. I., & Nojima, M. D. C. G. (2012). The importance of the diagnostic setup in the orthodontic treatment plan. *International Journal of Orthodontics (Milwaukee, Wis.)*, *23*(2), 35–39.
4. Peluso, M. J., Josell, S. D., Levine, S. W., & Lorei, B. J. (2004). Digital models: An introduction. *Seminars in Orthodontics*, *10*(3), 226–238. doi:10.1053/j.sodo.2004.05.007
5. Macchi, A., Carrafiello, G., Cacciafesta, V., & Norcini, A. (2006). Three-dimensional digital modeling and setup. *American Journal of Orthodontics and Dentofacial Orthopedics*, *129*(5), 605–610. doi:10.1016/j.ajodo.2006.01.010
6. Sinthanayothin, C., & Tharanont, W. (n.d.). Orthodontics treatment simulation by teeth segmentation and setup (pp. 81–84). Presented at the 2008 5th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), IEEE. doi:10.1109/ECTICON.2008.4600377
7. Kihara, T., Tanimoto, K., Michida, M., Yoshimi, Y., Nagasaki, T., Murayama, T., et al. (2012). Construction of orthodontic setup models on a computer. *American Journal of Orthodontics and Dentofacial Orthopedics*, *141*(6), 806–813. doi:10.1016/j.ajodo.2011.10.027
8. Im, J., Cha, J.-Y., Lee, K.-J., Yu, H.-S., & Hwang, C.-J. (2014). Comparison of virtual and manual tooth setups with digital and plaster models in extraction cases. AJODO, 145(4), 434–442.
9. Barreto, M. S., Faber, J., Vogel, C. J., & Araujo, T. M. (2016). Reliability of digital orthodontic setups. The Angle Orthodontist, 86(2), 255–259.
10. Rischen, R. J., Breuning, K. H., Bronkhorst, E. M., & Kuijpers-Jagtman, A. M. (2013). Records Needed for Orthodontic Diagnosis and Treatment Planning: A Systematic Review. PloS One, 8(11), e74186–8.
11. Nijkamp, P. G., Habets, L. L. M. H., Aartman, I. H. A., & Zentner, A. (2008). The influence of cephalometrics on orthodontic treatment planning. The European Journal of Orthodontics, 30(6), 630–635.
12. Han, U. K., Vig, K. W. L., Weintraub, J. A., Vig, P. S., & Kowalski, C. J. (1991). Consistency of orthodontic treatment decisions relative to diagnostic records. American Journal of Orthodontics and Dentofacial Orthopedics, 100(3), 212–219.
13. Haney, E., Gansky, S. A., Lee, J. S., Johnson, E., Maki, K., Miller, A. J., & Huang, J. C. (2010). Comparative analysis of traditional radiographs and cone-beam computed tomography volumetric images in the diagnosis and treatment planning of maxillary impacted canines. *Ymod*, *137*(5), 590–597.

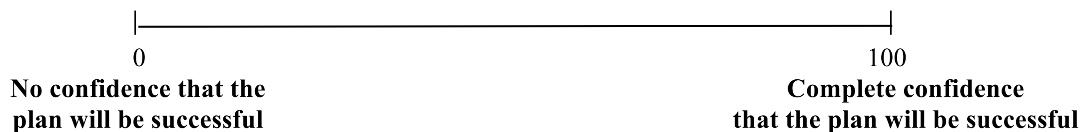
APPENDIX

Attachment 1: Treatment Planning Worksheet, Part 1
Case 1 Female 14 years 1 month
Chief Complaint: "I really hate that I have vampire fangs".
First Menses: 2 years ago

Assuming reasonable patient compliance, please indicate the components of your most recommended treatment plan, and 2nd or 3rd most recommended treatment plans, if applicable.

Treatment	**Most Recommended Treatment Plan**	**2nd Most Recommended Treatment Plan (if applicable)**	**3rd Most Recommended Treatment Plan (if applicable)**
Fixed Appliances	□	□	□
Clear Aligners	□	□	□
Extractions other than 3rd molars (circle teeth)	Right Left 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7	Right Left 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7	Right Left 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7
Interproximal Reduction (IPR)	□ Maxilla □ Mandible	□ Maxilla □ Mandible	□ Maxilla □ Mandible
Elastics	□	□	□
Headgear	□	□	□
Maxillary expander	□	□	□
Functional Appliance (Herbst, Mara, Forsus, twin block, etc)	□	□	□
Orthognathic Surgery	□ Maxilla □ Mandible	□ Maxilla □ Mandible	□ Maxilla □ Mandible
Temporary Anchorage Devices (TADs)	□	□	□
Habit appliance (ie. tongue crib)	□	□	□
Other			

Assuming reasonable patient compliance, how confident are you that your most recommended plan will result in a successful outcome?

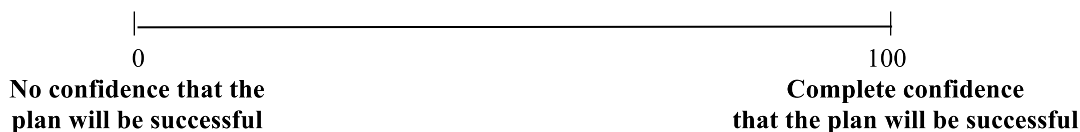


Attachment 2: Treatment Planning Worksheet, Part 2

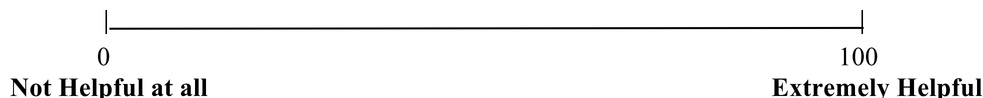
1. After reviewing the digital setups of the options you presented in Part 1, which of those, if any, is now your most recommended plan?

□ 1st option	□ 2nd option	□ 3rd option	□ **I would not choose any of my previous treatment plans.** (If you choose this option, please indicate your new treatment plan in the grid below)

2. After viewing the setups and assuming reasonable patient compliance, how confident are you that the plan you have chosen in Part 2 will result in a successful outcome?



3. Was the digital setup helpful for treatment planning this case?



4. If you have changed your recommended treatment plan after viewing the digital setup, please list the components of your new treatment plan below:

Treatment	**New Most Recommended Treatment Plan**
Fixed Appliances	□
Clear Aligners	□
Extractions (circle teeth)	Right Left 8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8 8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8
Interproximal Reduction (IPR)	□ Maxilla □ Mandible
Elastics	□
Headgear	□
Maxillary expander	□
Functional Appliance (Herbst, Mara, Forsus, twin block, etc)	□
Orthognathic Surgery	□ Maxilla □ Mandible
Temporary Anchorage Devices (TAD)	□
Habit appliance (ie. tongue crib)	□
Other	

Attachment 3: Post-Treatment Planning Survey

1. Gender: Male ____ Female ____
2. Orthodontic residency program ______________________________
3. Approximate number of comprehensive starts in the last 12 months ______________
4. Years in Practice as an orthodontist: _________
   OR Current year in orthodontic residency: _________

5. Please check up to three features of the digital setup that were most helpful in treatment planning these cases:

- ☐ Visualize final molar and canine relationship
- ☐ Predict proclination of incisors
- ☐ Check final incisal relationships (overjet and overbite)
- ☐ Determine IPR amount needed
- ☐ Determine amount of tooth movement needed
- ☐ Determine need for extractions
- ☐ Visualize occlusal contacts
- ☐ Ability to superimpose setup with the original model
- ☐ Case presentation and consultation tool with the patient
- ☐ Communication tool with other dental providers
- ☐ Other: ____

6. In what percent of your patients do you employ these techniques?

Treat patients using Invisalign and use Clincheck software _______

Take digital models for diagnosis _______

Create digital setups using SureSmile software _______

Use SureSmile for treatment _______

Create digital setups using Incognito, Orthoinsight, or other software _______

Create plaster setups _______