COPYRIGHT STATEMENT

The author hereby certifies that the use of any copyrighted material in the thesis manuscript entitled:

"Preferred Occlusal Cant for Patients with Orbital Dystopia"

is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

[redacted]

Catherine L. Kubera, D.D.S., LCDR, DC, USN
Tri-Service Orthodontic Residency Program
Air Force Post Graduate Dental School
June 2018

Preferred Occlusal Cant for Patients with Orbital Dystopia

Catherine L. Kubera

APPROVED:

[redacted]

Brian W.B. Penton, D.D.S., M.S.D., Supervising Professor and Program Director

[redacted]

David P. Lee, D.M.D., M.S., Chairman

6/30/18

Date

APPROVED:

[redacted]

Jay D. Graver, D.M.D., M.S., Dean, Air Force Postgraduate Dental School

Preferred Occlusal Cant for Patients with Orbital Dystopia

A THESIS

Presented to the Faculty of

Uniform Services University of Health Sciences

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

by

Catherine L. Kubera, D.D.S.

San Antonio, TX

June 30, 2018

The views expressed in this study are those of the authors and do not reflect the official policy of the United States Air Force, the Department of Defense, or the United States Government. The authors do not have any financial interest in the companies whose materials are discussed in this article.

Preferred Occlusal Cant for Patients with Orbital Dystopia

Catherine L. Kubera

APPROVED:

_____

Brian W.B. Penton, D.D.S., M.S.D., Supervising Professor and Program Director

_____

David P. Lee, D.M.D., M.S., Chairman

_____

Date

APPROVED:

_____

Jay D. Graver, D.M.D., M.S., Dean, Air Force Postgraduate Dental School

ACKNOWLEDGEMENTS

I would like to thank Dr. Brian Penton for his mentorship, time, and enthusiasm to this project. Dr. Jsiuk Park was instrumental in my statistical analysis and for her positivity and unabashed willingness to help, I thank her sincerely. A special thanks is due to the Tri-Service Orthodontic Residency staff for their guidance and patience.

Lastly, I owe a huge thank you to my fellow residents Anthony, Katie, Rob, Christy, Jake, and Meghan for their uncensored humor, unconditional friendship, and unparalleled comradery.

DEDICATION

This thesis is dedicated to my husband, Colin. I have known no other kinder, gentler, selfless person than you. I am blessed to go through this journey of life together with you by my side, my hand in yours, and up in the sky in our RV.

COPYRIGHT STATEMENT

The author hereby certifies that the use of any copyrighted material in the thesis manuscript entitled:

"**Preferred Occlusal Cant for Patients with Orbital Dystopia"**

is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

Catherine L. Kubera, D.D.S., LCDR, DC, USN
Tri-Service Orthodontic Residency Program
Air Force Post Graduate Dental School
June 2018

Uniformed Services University of the Health Sciences
Postgraduate Dental College

ABSTRACT

Preferred Occlusal Cant for Patients with Orbital Dystopia

Catherine L. Kubera

Purpose: The purpose of this study is to evaluate the preferred frontal occlusal cant for patients with orbital dystopia from the perspective of the layperson and dental professional.

Methods: Frontal smiling photographs of three subjects of different ethnicities were digitally altered to simulate orbital dystopia by tilting the interpupillary line either 4° clockwise or counterclockwise. The occlusal plane was subsequently altered four times to produce four varying degrees of a frontal occlusal cant: matching the degree of simulated orbital dystopia (defined as a 0° difference), 2° less than the degree of simulated orbital dystopia (2° difference), parallel to the horizon (4° difference), and 2° past the horizon in the opposite direction of the simulated orbital dystopia (6° difference). These four images were displayed side-by-side on a single sheet of paper and were rated according to perceived attractiveness on a 50mm VAS (visual analogue scale) by 50 laypeople and 50 dental professionals; 100 questionnaires were distributed in total. Non-normally distributed data were presented as median and interquartile range (IQR) and were analyzed using Wilcoxon's signed ranks test (non-parametric paired t-test), Mann-Whitney test (non-parametric independent t-test) or Friedman's rank test (non-parametric repeated measures analysis of variance) where appropriate.

Results: Dental professionals and laypeople preferred frontal occlusal planes parallel to the true horizon and rated an occlusal plane parallel to the orbital dystopia as least attractive. The images of the occlusal plane parallel to the horizon were rated significantly higher than images with occlusal cants parallel to the interpupillary line cant. Dental professionals consistently rated the 6° difference as the least attractive (lowest on the VAS) for all three subjects, while laypeople rated the 0° difference consistently as the least attractive. Laypeople rated deviations of the occlusal plane in relation to the horizon statistically similarly, regardless of if it was towards or away from the interpupillary line cant. Dental professionals rated occlusal plane deviations toward the orbital dystopia more favorably. They rated an occlusal plane parallel to the horizon and deviated 2° in the direction of the orbital cant similarly.

Conclusions: People generally prefer an occlusal cant parallel to the horizon in patients with orbital dystopia of 4°. When evaluating facial esthetics in patients with orbital dystopia, dental professionals rate attractiveness based on the relationship between the frontal occlusal plane to the interpupillary line, and they may be more willing to accept an occlusal plane cant deviated in the direction of the interpupillary line. Laypeople base their attractiveness ratings independently from the presence of an orbital cant. TO achieve the most esthetic outcome when planning changes to the frontal occlusal plane, dental professionals should evaluate patients in natural head position and use the true horizon as the guiding reference line.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

*SOD = Simulated orbital dystopia
*SFOP = Simulated frontal occlusal plane

Chapter 1. BACKGROUND

1.1 A BRIEF HISTORY OF ORTHODONTIC ESTHETIC IDEALS

As far back as 1000 BC, humankind has not only recognized the malady of malaligned teeth but has also undertaken great lengths to correct it. An esthetic alignment of teeth was the principle goal up until just before the turn of the 20th century when Edward H. Angle, the "Father of modern orthodontics" advanced the concept of a molar classification system. His efforts shifted the dental profession's focus from malalignment to malocclusion. Modern day perspective admits that a major omission to this methodology was that no consideration was given to what the teeth looked like in relation to the rest of the face, including soft tissue and facial proportions, known as the soft tissue paradigm.

Progression through the 1900's brought an explosion of new ideas and methodologies, propelled by the innovations in technology and changes in public perception. The rapid development and improvement of cephalometric radiology allowed the practitioner not only to harmonize the occlusion but improve the maxillary and mandibular relationships as well. Convenient personal cameras revolutionized society and people began smiling in photographs. As the invention of film and mass distribution of movies infiltrated society, Hollywood starlets became the poster children for universal beauty. Fast forward into the 'selfie' culture of today, there seems to be no other time in history in which society has focused more on facial esthetics.

Orthodontics in the 21st century remains focused on the soft tissue paradigm, in which the soft tissue esthetics are of significant importance during treatment planning. Soft tissue esthetics includes not only the profile and portrait patient views, but also how the soft tissue drape frames the smile, which Sarver describes as macro-esthetics. Dental literature today is beset with research exploring smile esthetics and popular opinion on

what features comprise esthetic and unesthetic smiles. Several studies have shown that laypersons, dentists, and orthodontists can detect asymmetries above a certain threshold. One such topic of recent abundant research is the frontal occlusal cant, also referred to as the frontal occlusal plane, and degree at which it becomes perceptible and unesthetic.

1.2 The Frontal Occlusal Cant and Previous Studies

A frontal occlusal cant may be defined as the divergence of the occlusal plane from the horizontal axis[12] and may be of either dentoalveolar or skeletal origin. Upon clinical exam, occlusal cants may be evaluated by placing a Fox plane or tongue depressor at the premolar or canine region and evaluating the resulting horizontal line in relation to the interpupillary line. Certainly, if a cant is large enough, it may be noticeable upon smiling. Additionally, PA cephalograms may also be used to confirm and quantify occlusal cants[27]. Treatment of an extreme maxillary cant in the frontal occlusal plane due to skeletal asymmetry may require a LeFort I orthognathic surgery to correct, which also typically requires a mandibular surgical procedure.

In the last twenty years, several studies have been performed to determine the threshold of perception and esthetic acceptability of occlusal cants in the frontal occlusal plane. The first study of subjective evaluation of occlusal plane canting was performed by Padwa and associates in 1997[19]. Their results showed that a 4° occlusal cant (measured from maxillary first molar cusps in relation to a horizontal line drawn tangent to the supraorbital rim on a PA cephalogram) is the threshold at which occlusal cants are detected with greater than 90% frequency and 3° is the threshold for greater than 50% frequency. There were no statistically significant differences between medical residents (“laypeople”) and oral surgeons (“professionals”). However, the major pitfall to this study was that there were only 9 observers – four medical residents and five oral and

maxillofacial surgeons. Nonetheless, this pioneering study explored a previously undiscussed, but very relevant, topic of dental cant asymmetries.

The first systematic and statically-sound study to evaluate and establish thresholds for esthetic criteria of an individual's perception of graduated degrees of abnormality of anterior dental esthetics, including dental canting, was performed by Kokich et al. in 1999[14]. Digitally modified images of smiles (no other portion of a face were shown aside from lips, dentition and the surrounding skin) were created so that each alteration in occlusal canting varied by 1mm increments by rotating the occlusal plane around a central point at the incisal embrasure between the central incisor crowns relative to the true horizon. Both orthodontists and general dentists could detect a 1mm incisal plane asymmetry (dental cant), whereas laypeople were less able to detect a dental cant. A 3mm cant (equivalent to 4°) was required for the lay group to rate it as noticeably less attractive. Of all the variables studied (including changes in smile arc, buccal corridors, gingival display, canine and posterior crown torque, midlines, overbite, gingival height discrepancy, incisal steps, and incisal ratios), the occlusal plane cant was found to be the most overwhelmingly displeasing smile characteristic.

In 2005, Geron and Wasserstein[6] compared the perception of incisal plane tilting by male and female laypeople and concluded that tilting of the incisal plane was noticed for images with 2° of deviation from parallelism (zero inclination defined as parallelism between the most gingival portion of maxillary lateral crowns to the upper lip margin). A study by Ker et al. in 2008[12] found the majority of lay raters rated occlusal cants up to 4° as attractive, substantiating a previous finding by Kokich and collegues[14]. This study also found that one-third of the laypeople respondents even accepted cants as attractive up to 6° (the maximum cant studied). Furthermore, a study by Oliveres and associates[18] in 2013 found that all three of their evaluator groups (laypersons, dentists, and orthodontists) were sensitive to a cant of 4°, and that orthodontists were less permissive with the 4° cant

(rated as “unacceptable) than the general dentists and laypersons (who rated 4° as “moderately acceptable”).

Kaya and collegues[11] not only investigated an occlusal plane acceptability threshold, but also considered the influence of gingival display on the perception of smile attractiveness with occlusal canting. Results showed that there was a significant interaction between gingival display and occlusal cant. However, regardless of gingival display excess or insufficiency, occlusal plane cants up to 1° were perceived as the most attractive. The influence of the occlusal cant becomes less remarkable when gingival display increased and the raters’ sensitivity to distinguish occlusal canting was much higher with less gingival display. A study by Shiyan et al. [25] published in 2016 also evaluated the impact of smile height (analogous to gingival display) on the acceptable range of occlusal cants. Unlike the study by Kaya and collegues [11] that included only the lips and dentition, this study included the entire face of the subject being studied. Confirming the conclusion of Kaya el al.[11], the results showed that as smile height increased, the acceptable range of occlusal cants decreased. Laypeople’s acceptance was 4° for low smiles and 2° for high smiles. Orthodontists had approximately 1° lower acceptable range of transverse anterior canting than laypeople.

A goal of dental professionals, especially prosthodontists, orthodontists, and oral surgeons, may be to mimic the frontal occlusal plane with the interpupillary line. However, varying degrees of orbital dystopia may be present in any given patient. Skeletal asymmetries may be masked by soft tissue or by posturing of the head to one side[17,19]. However, if orbital dystopia is severe enough, surgery may be performed to level the interpupillary line cant. A 0° cant by is considered ideal by definition[11]. Furthermore, ideally the frontal occlusal plane is parallel the interpupillary line, which in turn is parallel with the horizon. During the planning phases of orthognathic surgery, the frontal occlusal plane should be parallel to the orbital plane as seen on the PA cephalogram[13]. However,

one must consider the clinical scenario in which a patient has clinically significant vertical orbital dystopia.

1.3 Vertical Orbital Dystopia

Vertical orbital dystopia is defined as "that condition in which one eye is higher or lower than the other"[4] and, more specifically, as "a malposition of the entire orbital cavity associated with a vertical globe malposition"[32]. This occlusal canting is synonymous with an interpupillary line cant. Orbital dystopia may be a finding of a larger syndrome, including hemifacial microsomia, craniofacial dysostosis, craniofrontonasal dysplasia, frontonasal dysplasia, and some forms of orbitofacial clefting (Tessier cleft numbers 2, 4, 5, 10) [7,32]. In order of most common to least common causes, orbital dystopias may be congenital (57-62%), post-traumatic (13-26%), torticollis (11%), neoplastic (11%), iatrogenic (4%), or idiopathic (4%)[7,32].

Wolfe and Sassani[32] outline the many causes of orbital dystopia. Congenital causes include craniosynostoses, hemifacial microsomia, oculoauriculovertebral spectrum, hypoplasia of the lesser wing of the sphenoid, and facial clefting syndromes. Trauma may be caused by irradiation therapy in a young child, or via mechanical insults including intra-uterine pressure, fractures, and gunshot wounds. Neoplasms include fibrous dysplasia, carcinoma of the antrum, tumors, Von-Recklinghausen's disease, and angiomatoses. Iatrogenic causes include osteomas and eosinophilic granulomas. Lastly, Perry Rhomberg is an example of idiopathic, and even possibly of autoimmune origin. Such a finding may be readily evident or discovered upon clinical evaluation or via a PA cephalogram.

Correction of orbital dystopia is achieved by orbital translocation via a box osteotomy or facial bipartition[7]; however, careful consideration must be taken into account

when evaluating the cost and risks, including death, of the procedure. The amounts of medial and lateral vertical orbital dystopia movements required for surgery are determined by marking the midline of the face and the amount the medial and lateral canthi need to move to make them level[28].

1.4 The Relation of Occlusal Plane Canting to Orbital Dystopia

Oftentimes, one aim of orthodontic treatment or oral surgery is to obtain facial symmetry, including the alignment of the intercanine occlusal table with the right and medial canthi, upper lip and angular relationship of maxillary canines and intermolar plane to the true horizontal[27]. However, for those with untreated orbital dystopia, the reference plane for the frontal occlusal plane is lost. This begs the question, if a skeletal facial asymmetry exists in the midface and orbital regions, should the frontal occlusal plane be aligned with the interpupillary line or to the true horizon? In patients with untreated orbital dystopia, treatment goals for the frontal occlusal plane may change depending upon what is perceived to be the most esthetic relationship between the frontal occlusal plane and the interpupillary line.

Although several studies have investigated the threshold beyond which laypeople and dental professionals notice asymmetrical anterior dental discrepancies in relation to symmetrical facial features such as the lips, alar base, or interpupillary line, none have explored the situation comparing dental asymmetries when a facial skeletal asymmetry exists, such as orbital dystopia. The aim is of this study is to evaluate the preferred occlusal cant for patients with orbital dystopia from the perspective of the layperson and dental professional (to include general dentists, orthodontists, oral surgeons, periodontists, prosthodontists, and endodontists).

Chapter 2. OBJECTIVES

2.1 PURPOSE OF STUDY

The purpose is of this study is to evaluate the preferred occlusal cant for patients with orbital dystopia from the perspective of the layperson and dental professional (including general dentists, orthodontists, oral surgeons, periodontists, prosthodontists, and endodontists).

2.2 HYPOTHESES 1

Dental professionals and laypeople will rate occlusal plane variations differently in patients with orbital dystopia.

2.3 NULL HYPOTHESES 1

Dental professionals and laypeople will not rate occlusal plane variations differently in patients with orbital dystopia.

2.4 HYPOTHESES 2

A frontal occlusal plane parallel to the horizon will be preferred over a frontal occlusal plane parallel to the interpupillary line in patients with orbital dystopia.

2.5 NULL HYPOTHESES 2

A frontal occlusal plane parallel to the horizon will not be preferred over a frontal occlusal plane parallel to the interpupillary line for patients with orbital dystopia.

Chapter 3. MATERIALS AND METHODS

3.1 SAMPLE

There were two groups of raters in this study: 50 laypeople and 50 dental professionals. The dental professional group consisted of active duty military general dentists, orthodontists, periodontists, oral surgeons, and endodontists. The lay group consisted of people who have never worked in the dental profession; professions included nurse practitioners, teachers, geologists, pilots, intelligence officers, and other assorted workers. Each rater was given as little information possible about the research study being conducted. In total, 100 surveys were distributed. The age range of the dental professionals was 26 to 65 years old. Of the dental professionals, 30 were male and 20 were female. The age range of the laypeople was 19 to 74 years old, 33 were male and 17 were female.

3.2 IMAGE SELECTION AND MANIPULATION

Smiling frontal photographs of two men and one woman, all in their 30's and of differing ethnicities (Caucasian, Asian, and African American) with esthetically pleasing smiles and grossly symmetrical faces were digitally modified to produce either a 4° clockwise or counterclockwise interpupillary line cant in relation to the horizon to simulate orbital dystopia. The occlusal plane was subsequently digitally altered an additional four times per each image to produce four varying degrees of a frontal occlusal cant. The center of the rotation was at the contact point between the maxillary central incisors. The four alterations of occlusal cant are as follows:

1. Matching the degree of orbital dystopia of 4° or - 4° (i.e. either a 4° clockwise or 4° counterclockwise rotation of the frontal occlusal plane, respectively)
2. 2° less than the degree of orbital dystopia
3. 0° (parallel to the horizon)
4. 2° past the horizon in the opposite rotational direction of the orbital dystopia

The difference between the orbital planes and occlusal planes were 0°, 2°, 4°, and 6°, respectively.

All images were then cropped just above the eyebrows superiorly to just below the mentolabial sulcus inferiorly to eliminate rating biases related to the subject's hair, ears, forehead length, chin, and face shape. The digital photographs were manipulated in Adobe Photoshop CC 2015.5.0 Release using an Apple Computer.

3.3 Survey Details

The survey binder consisted of 3 pages in total, each page presenting one subject's four digitally modified images. These four images were arranged in landscape format, progressing from most negative frontal occlusal plane angle to most positive, from left to right. Refer to figures 3-14 to 3-16 for survey page examples.

Three different surveys were fabricated containing a different order of the subjects as follows from page one to page three:

Survey A: Subject 1, Subject 2, Subject 3

Survey B: Subject 3, Subject 2, Subject 1

Survey C: Subject 2, Subject 1, Subject 3

Each survey was accompanied by a single page of rating scales in which to rate each image. A 50mm visual analogue scale (VAS) was used to rate perception of

attractiveness of each photo. The left border at 0mm was labeled “least attractive” and the right border at 50mm was labeled “most attractive” (see example in Appendix B).

3.4 Data Collection and Processing

Before the survey was distributed, written and verbal instructions were given to each rater regarding survey anonymity, how to rate attractiveness along a VAS, and not to return to any previous pages once turned. Each rater was also asked to write down their age, sex, and profession. Information containing PII or information relating to HIPAA was not collected. Each survey was contained in a binder with matte plastic page protectors containing each page of the color images; these binders were handed out to 50 dental professionals and 50 laypeople. Dental professionals were gathered from the Air Force Postgraduate Dental School (AFPDS), Dunn Dental Clinic, and Fort Sam Houston’s Dental Clinic. Each rating sheet was collected and each mark along every one of the 12 visual analogue scales was measured to the nearest one-hundredth of a millimeter using a Whitworth digital caliper and recorded in a Microsoft Excel 2013 spreadsheet.

3.5 Sample Size Estimation/Power Analysis

A total of 100 (50 per group) achieved 95% power detecting mean rating differences between laypeople and dental professionals, with large effect sizes (Cohen’s $d \geq 0.8$) for a 2-sided test with a significance level α of 0.05

3.6 STATISTICAL ANALYSIS METHOD

The descriptive statistics of the demographic characteristics for dental professional and laypeople groups were compared. Continuous variables were assessed for normality by the Shapiro-Wilks test, which indicated that the outcome variables were not normally distributed. Therefore, the non-parametric tests were used for statistical analyses. Non-normally distributed data are presented as median and interquartile range (IQR) and were analyzed using Wilcoxon's signed ranks test (non-parametric paired t-test), Mann-Whitney test (non-parametric independent t-test) or Friedman's rank test (non-parametric repeated measures analysis of variance) where appropriate. Categorical data were presented as the number (percentage) of participants, and the Pearson Chi-square was used to test for association. Statistical analysis was performed using SAS version 9.4 (Statistical Analysis Software, Cary, NC).

3.7 Schematic Representation of Orbital and Occlusal Cant Variations

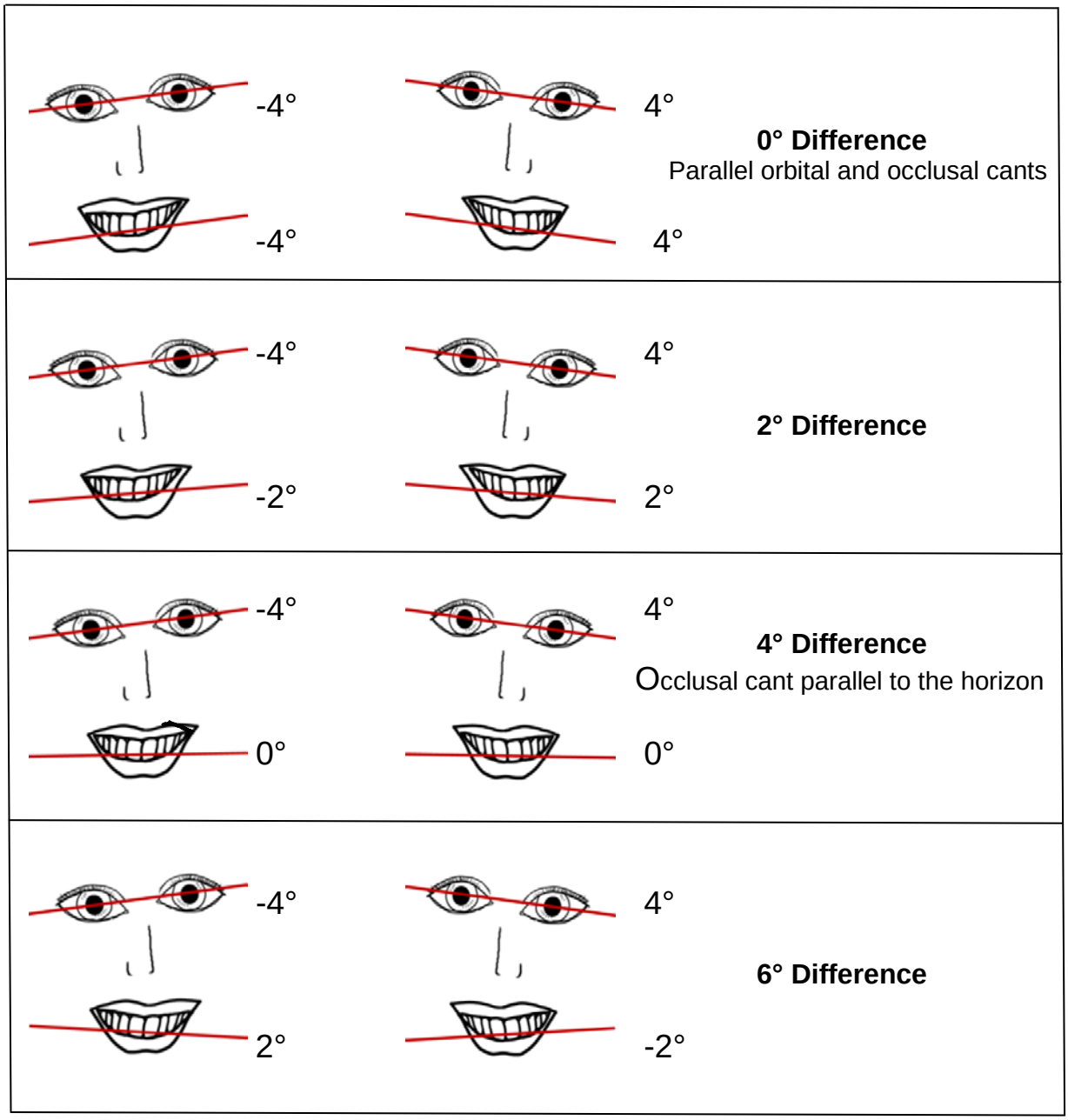


Figure 3-1 Schematic Representation of the Orbital and Occlusal Cant Variations in this Study

3.8 FIGURES OF DIGITALLY MODIFIED IMAGES

Figure 3-2 Subject 1 with -4° simulated orbital dystopia and -4° simulated frontal occlusal plane (0° difference)

Figure 3-3 Subject 1 with -4° simulated orbital dystopia and -2° simulated frontal occlusal plane (2° difference)

Figure 3-4 Subject 1 with -4° simulated orbital dystopia and 0° simulated frontal occlusal plane (4° difference)

Figure 3-5 Subject 1 with -4° simulated orbital dystopia and +2° simulated frontal occlusal plane (6° difference)

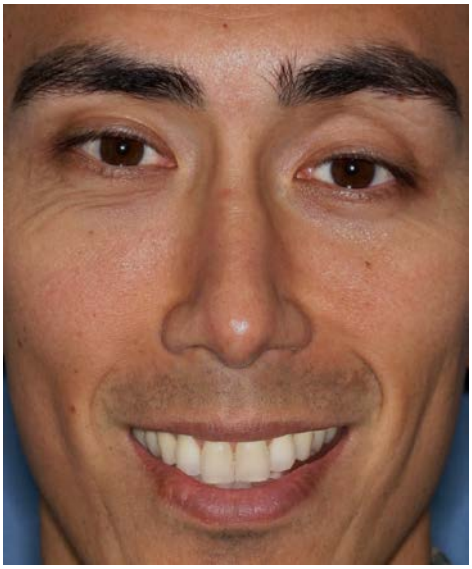


Figure 3-6 Subject 2 with +4° simulated orbital dystopia and -2° simulated frontal occlusal plane (6° difference)

Figure 3-7 Subject 2 with +4° simulated orbital dystopia and 0° simulated frontal occlusal plane (4° difference)

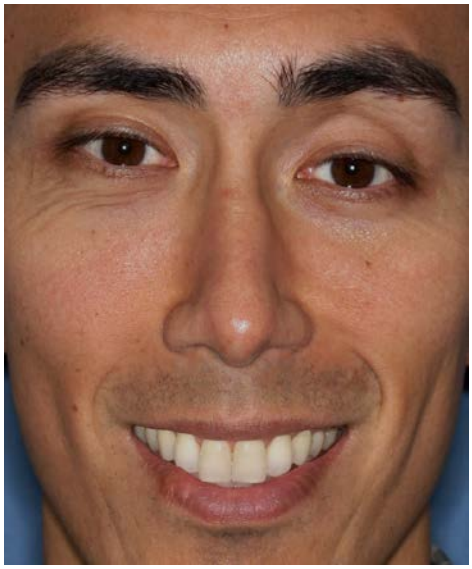


Figure 3-8 Subject 2 with +4° simulated orbital dystopia and +2° simulated frontal occlusal plane (2° difference)

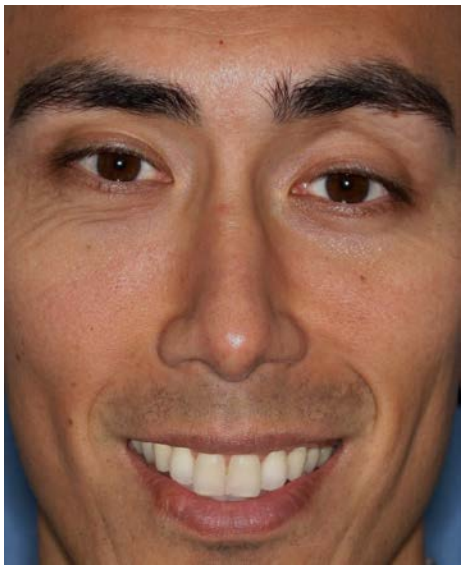


Figure 3-9 Subject 2 with +4° simulated orbital dystopia and +4° simulated frontal occlusal plane (0° difference)

Figure 3-10 Subject 3 with -4° simulated orbital dystopia and -4° simulated frontal occlusal plane (0° difference)

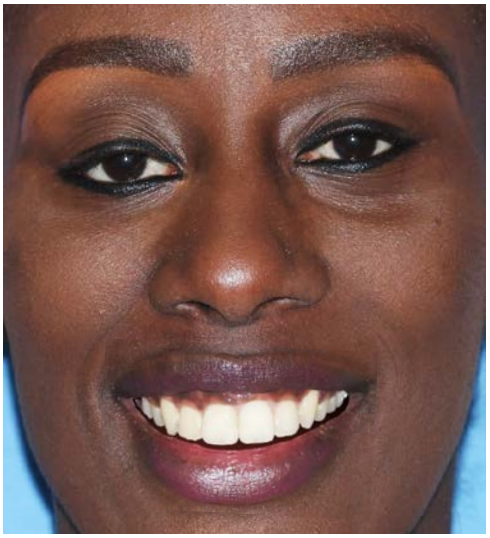


Figure 3-11 Subject 3 with -4° simulated orbital dystopia and -2° simulated frontal occlusal plane (2° difference)

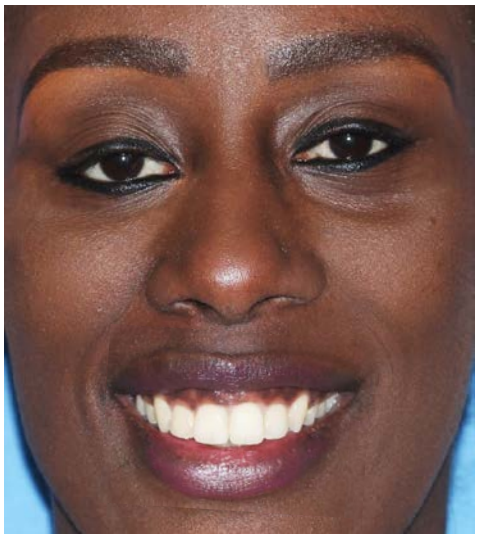


Figure 3-12 Subject 3 with -4° simulated orbital dystopia and 0° simulated frontal occlusal plane (4° difference)

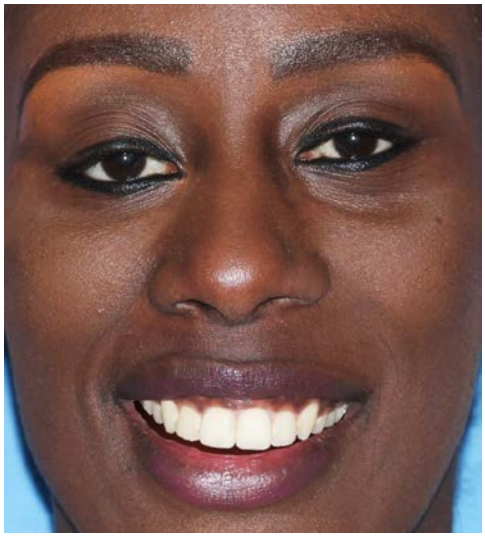


Figure 3-13 Subject 3 with -4° simulated orbital dystopia and +4° simulated frontal occlusal plane (6° difference)

3.9 EXAMPLE OF SURVEY PAGES – SURVEY A

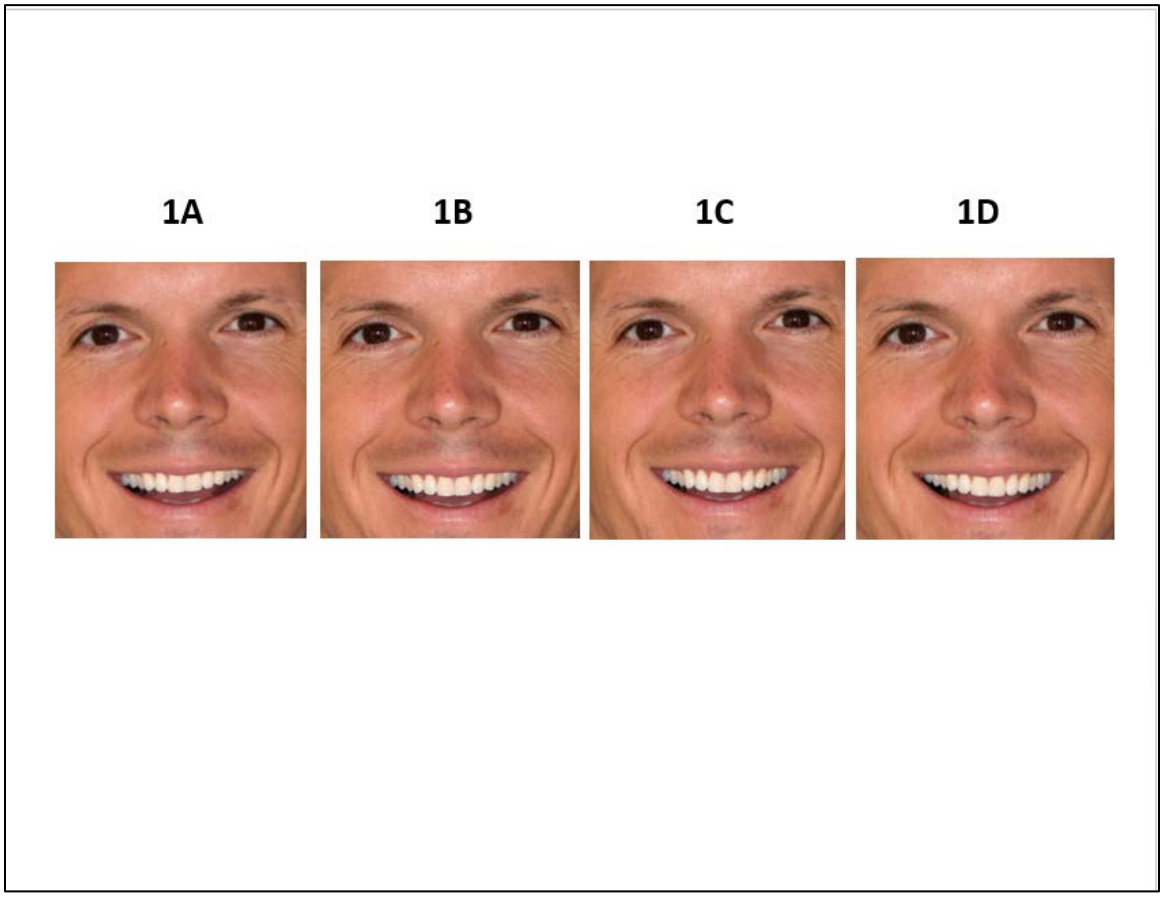


Figure 3-14 Survey A Page 1: Subject 1
Difference in orbital cant (-4°) vs. occlusal plane cant listed in ascending order: 0°, 2°, 4°, 6°

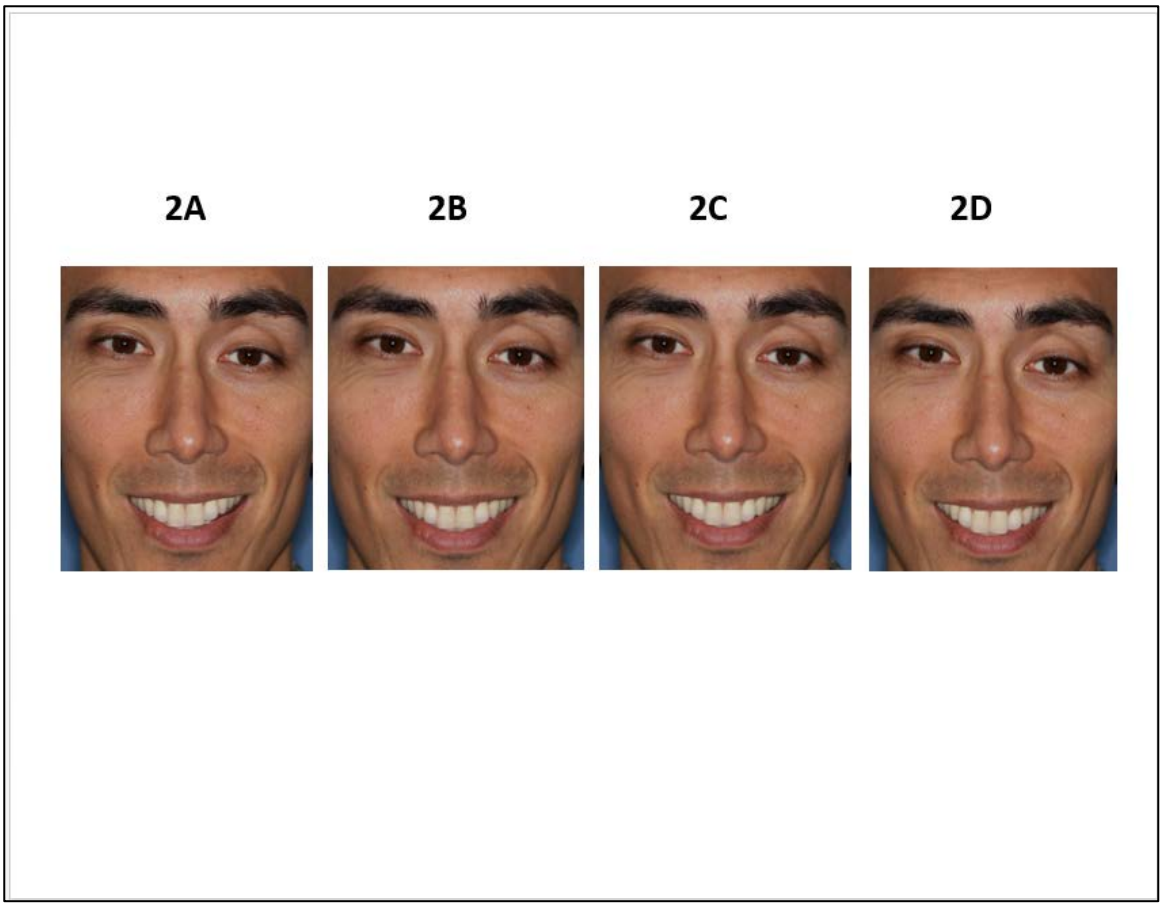


Figure 3-15 Survey A Page 2: Subject 2
Difference in orbital cant (4°) vs. occlusal plane cant listed in descending order: 6°, 4°, 2°, 0°

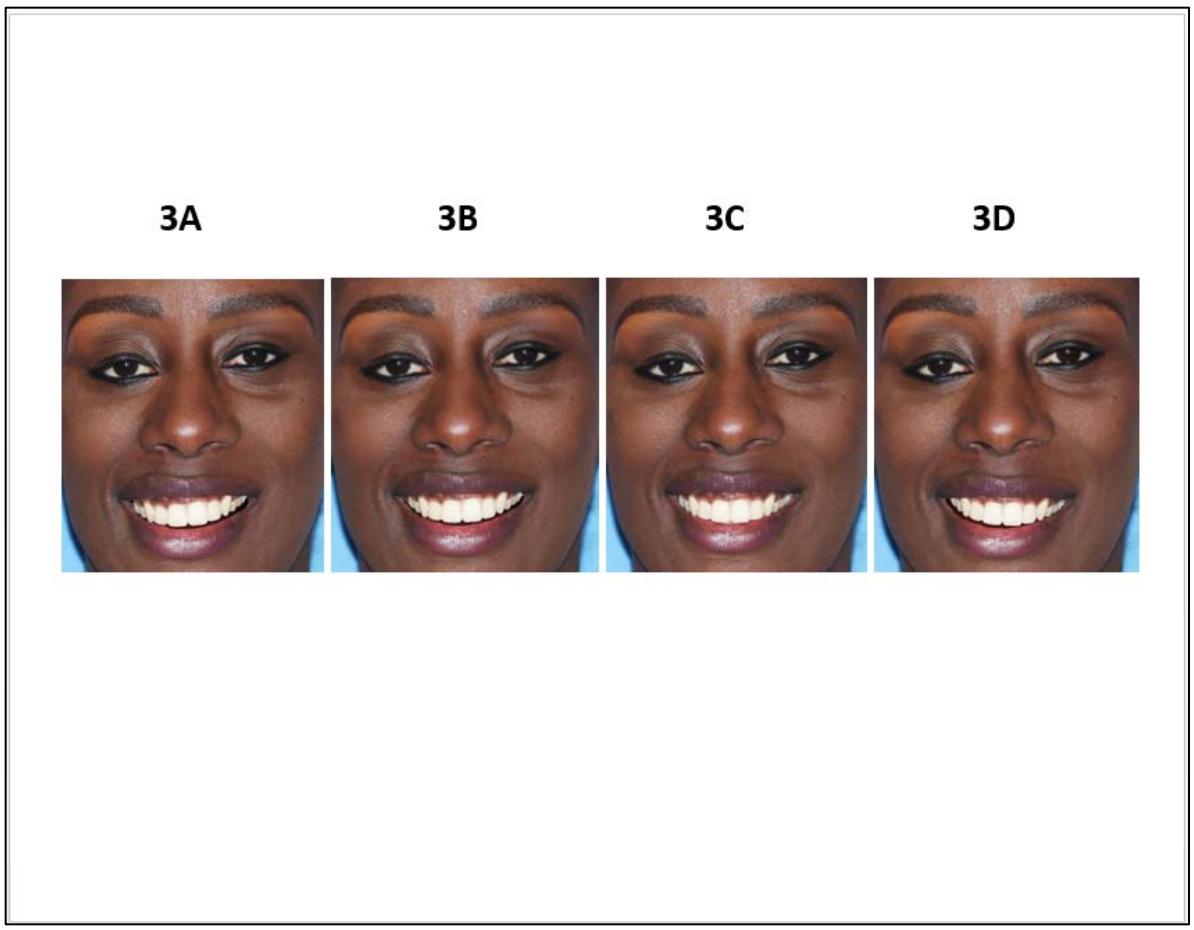


Figure 3-16 Survey A Page 3: Subject 3
Difference in orbital cant (-4°) vs. occlusal plane cant listed in ascending order: 0°, 2°, 4°, 6°

Chapter 4. RESULTS

4.1 DESCRIPTION OF RESULTS

For the sake of simplicity and uniformity, results will be displayed and discussed in *degrees of difference* between the occlusal plane and orbital cant, instead of absolute degrees of the occlusal cant. For instance, for the images with an orbital cant of -4° and an occlusal cant of -4°, it will simply be stated that there is a 0° difference, indicating that the occlusal plane and orbital cant are parallel to each other. The images with an orbital cant of -4° (or 4°) and an occlusal cant of 0° (occlusal plane is parallel with the horizon) will be described as a 4° difference. Refer to table 3-1 for a schematic diagram, and Appendix C for complete list of survey results.

4.2 DEMOGRAPHIC CHARACTERISTICS

The participants included similar gender ratios between the dental professional group and the laypeople group. However, the median age for the laypeople group was significantly higher than the dental professional group (38.5 vs. 34.0; p = 0.0006). This is most likely because the dental professional group consisted mostly of young Active Duty dentists and dental residents, whereas the laypeople group included retirees, senior professionals, and Active Duty members.

Characteristic	Total	Dental Professionals (n = 50)	Laypeople (n = 50)	p
Gender N (%)				0.53
Female	37 (37.0)	17 (34.0)	20 (40.0)	
Male	63 (63.0)	33 (66.0)	30 (60.0)	
Median age in years (IQR)	35.0 (31.0-43.5)	34.0 (31.0-37.0)	38.5 (32.0-50.0)	**0.0006***

* $p < 0.05$ is statistically significant

Table 4-1 Gender distribution and median age of raters

4.3 Comparison of Groups for Occlusal Plane Ratings

Least Esthetic Ratings

Dental professionals consistently rated the 6° difference as least esthetic by VAS rating for all three subjects, while laypeople rated the 0° difference consistently the lowest. Dental professionals rated 6° difference significantly lower than laypeople for subjects 1 ($p=0.001$) and 3 ($p<0.0001$), and for combined subject rating ($p<0.0001$).

Most Esthetic Ratings

Dental professionals and laypeople rated a 4° difference as the most attractive for all three subjects and for the combined subject rating, with the exception of dental professionals who rated a 2° difference as the most attractive for subject 2; however, this was not found to be significantly different from the 4° difference preference (table 4-4, $p=0.91$). Dental professionals consistently rated the 2° difference higher than laypeople did, although the differences for subject 1 was only marginally significant ($p < 0.10$).

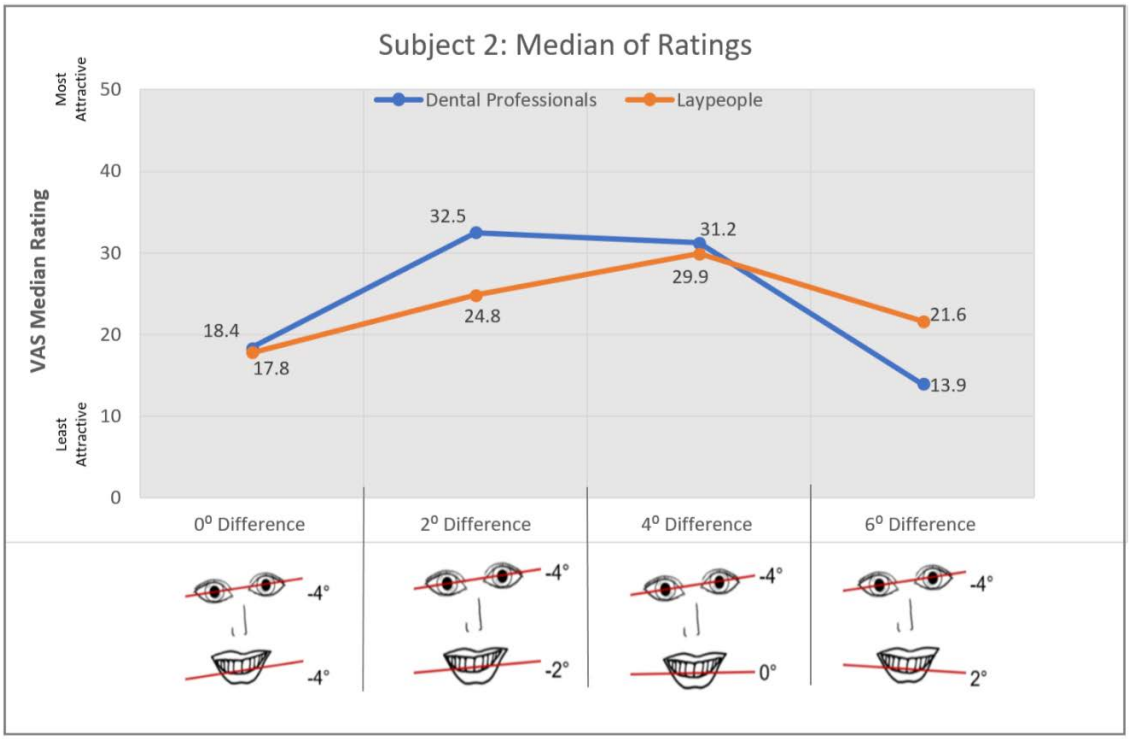
		Median (IQR)		p
		Dental Professionals	Laypeople	
Subject 1	0^0 Difference	13.3 (5.3-24.5)	13.7 (7.6-24.2) ↓	0.61
	2^0 Difference	34.6 (24.8-39.3)	26.1 (18.2-37.1)	0.06
	4^0 Difference	37.8 (28.6-42.2) ↑	37.8 (24.5-44.1) ↑	0.84
	6^0 Difference	13.2 (7.0-26.6) ↓	26.8 (17.2-37.1)	**0.001***
Subject 2	0^0 Difference	18.4 (10.6-28.4)	17.8 (9.7-27.3) ↓	0.93
	2^0 Difference	32.5 (22.5-37.8) ↑	24.8 (14.9-33.4)	**0.02***
	4^0 Difference	31.2 (20.5-41.7)	29.9 (17.9-38.8) ↑	0.53
	6^0 Difference	13.9 (4.3-24.6) ↓	21.6 (7.8-34.5)	0.05
Subjects 3	0^0 Difference	13.7 (5.1-22.7)	18.9 (7.9-25.3) ↓	0.11
	2^0 Difference	32.5 (24.0-37.7)	25.0 (16.0-34.8)	**0.04***
	4^0 Difference	40.4 (26.3-45.2) ↑	36.5 (24.1-42.6) ↑	0.30
	6^0 Difference	9.3 (4.6-18.9) ↓	23.4 (12.4-34.9)	**<0.0001***
Combined Subjects	0^0 Difference	13.7 (10.1-23.3) ↓	18.4 (14.0-24.7) ↓	0.12
	2^0 Difference	31.7 (26.9-36.4)	25.7 (19.3-31.5)	**0.002***
	4^0 Difference	33.0 (26.5-41.8) ↑	32.1 (27.1-39.7) ↑	0.46
	6^0 Difference	15.0 (8.6-21.1)	24.1 (18.4-32.7)	**<0.0001***

* $p < 0.05$ is statistically significant
↓ Lowest rating for subject ↑ Highest rating for subject

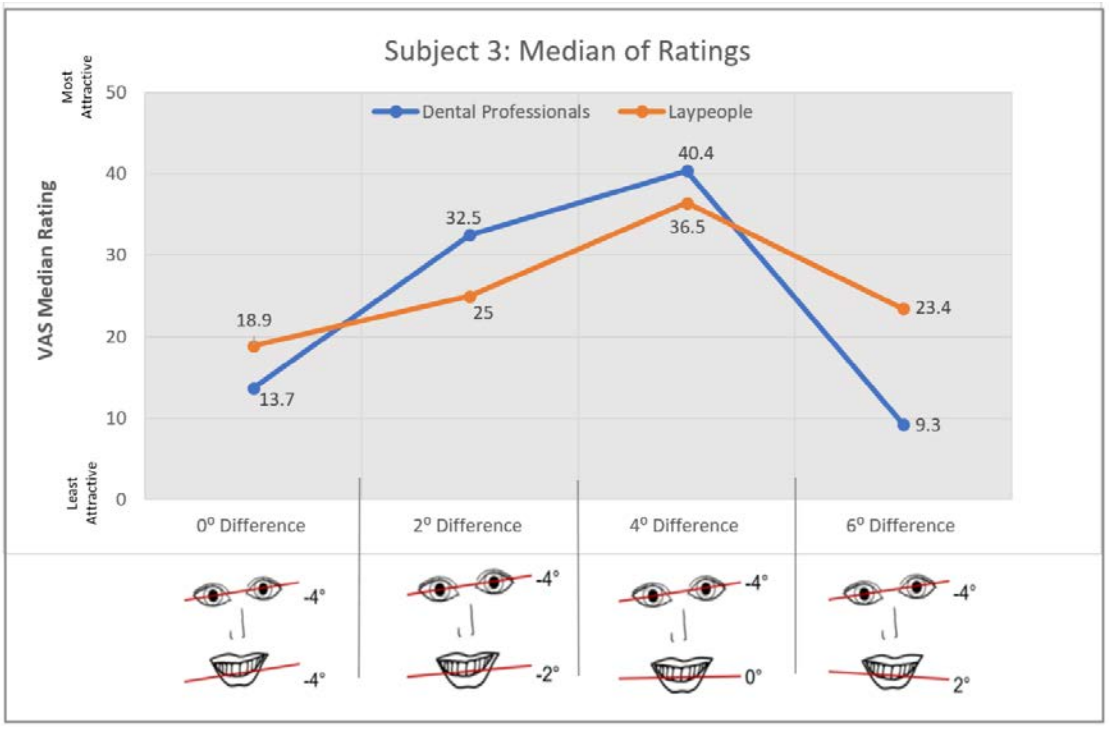
Table 4-2 Group ratings and differences for all subjects using Mann-Whitney Tests

The first hypothesis of this study stated that dental professionals and laypeople will rate occlusal plane variations differently in patients with orbital dystopia. Because there were statistically significant highest and lowest esthetic ratings between dental professionals and laypeople in six of the sixteen comparisons, hypothesis 1 is proven.

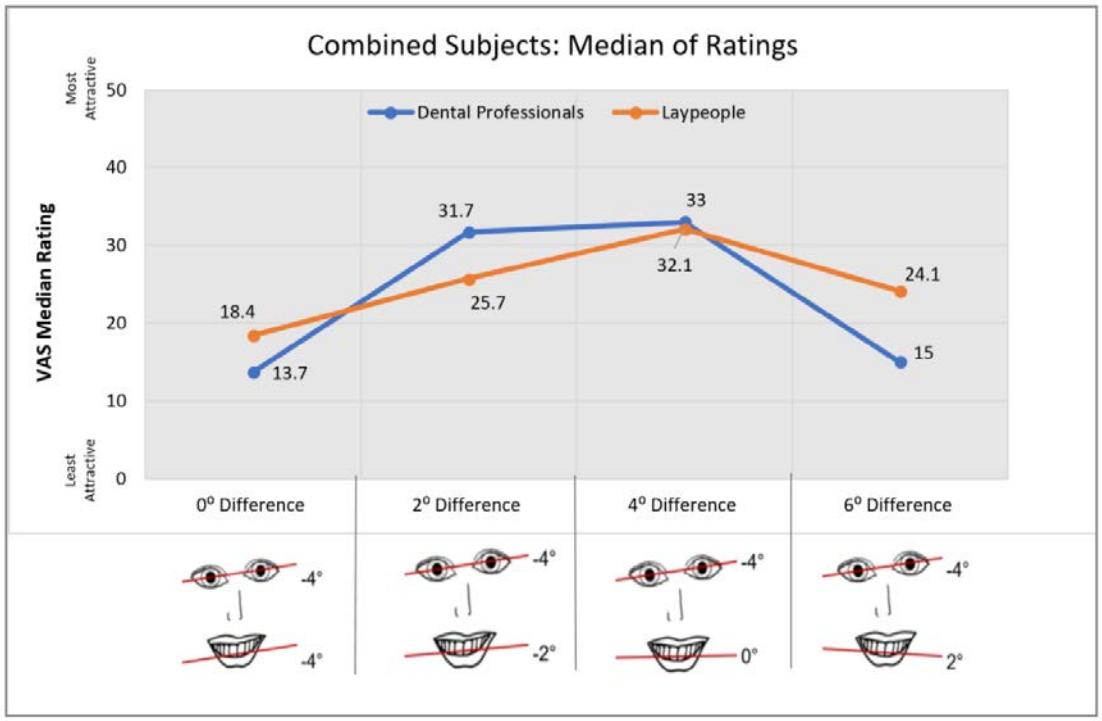
Graph 4-1 VAS Median Ratings for Subject 1



Graph 4-2 VAS Median Ratings for Subject 2



Graph 4-3 VAS Median Ratings for Subject 3



Graph 4-4 Median of VAS Ratings for combined subjects

4.4 COMBINED GROUP PREFERENCES

Occlusal Plane Parallel to the Horizon (4°Difference) Comparisons

The second hypothesis of this study stated that a frontal occlusal plane parallel to the horizon will be preferred over a frontal occlusal plane parallel to the interpupillary line in those with orbital dystopia. In other words, the 4° difference (occlusal plane parallel with the horizon) will be rated more attractive than a 0° difference (occlusal plane parallel to the interpupillary line). To test this hypothesis, non-parametric paired t-tests (Wilcoxon's signed ranks test) of the median of combined groups were used.

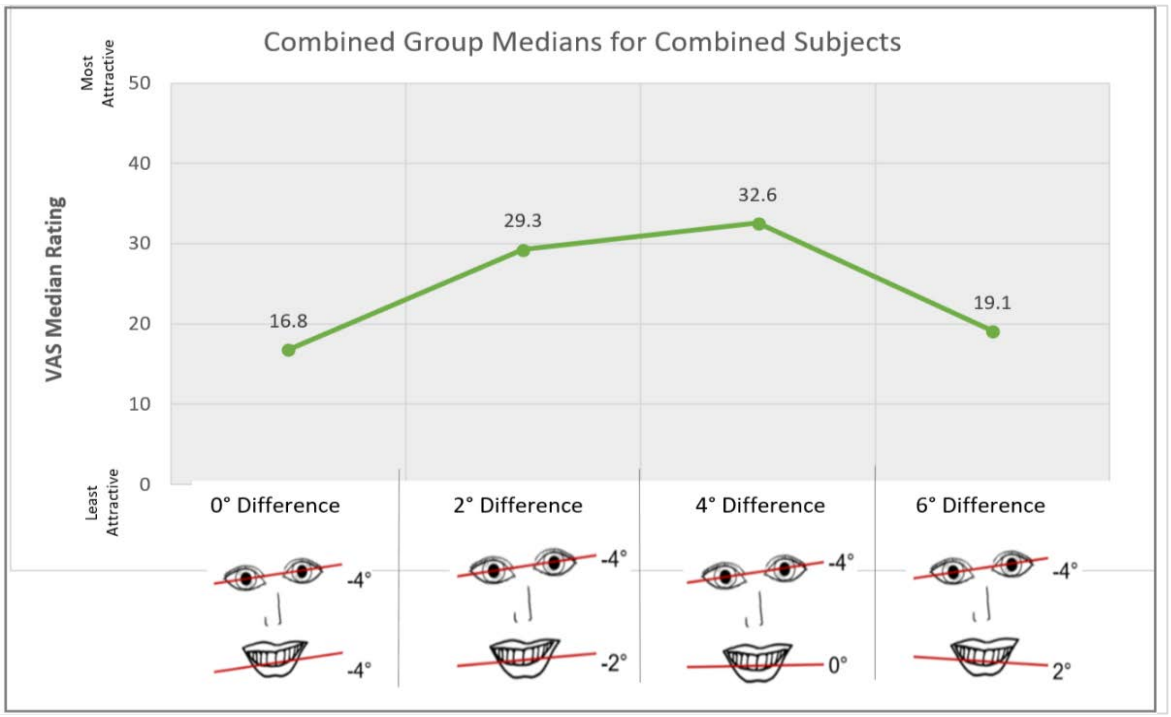
Combing all ratings of dental professionals and laypeople for all three subjects, the images of the 4° difference was rated significantly higher than the images with a 0° difference ($p<0.0001$). Therefore, hypothesis 2 that occlusal plane parallel to the horizon will be preferred over an occlusal plane parallel to the interpupillary line is proven true.

Furthermore, for combined subject ratings, an occlusal plane parallel to the horizon is also preferred over the other two occlusal cants (2° and 6° differences) for combined groups ($p=0.0004$, $p<0.0001$, respectfully).

Difference (Combined Subjects)	Median (IQR) (Combined Groups)	p value
4^0 Difference vs. 0^0 Difference	32.6 (26.6-40.7) vs. 16.8 (11.3-24.1)	**<0.0001***
4^0 Difference vs. 2^0 Difference	32.6 (26.6-40.7) vs. 29.3 (22.6-35.3)	**0.0004***
4^0 Difference vs. 6^0 Difference	32.6 (26.6-40.7) vs. 19.1 (12.3-27.1)	**<0.0001***

***** $p < 0.05$ is statistically significant

Table 4-3 Occlusal Plane Preference for Combined Subject Ratings of Combined Groups for Comparison of a 4° Difference using Non-Parametric Paired t-Tests (Wilcoxon's Signed Ranks Test)



Graph 4-5 Combined Group Medians for Combined Subjects

4.5 Comparison of Occlusal Cant Preferences of Both Groups

Combined Subject Ratings for 4° Difference Comparisons

Evaluating the combined subject rating between both groups of dental professionals and laypeople, a frontal occlusal plane parallel to the horizon was preferred over all other occlusal cant variations (0°, 2°, and 6° differences). All preferences were statistically significant, except for one (the dental professional rating for subject 2 for the 4° difference preference over the 2°; p=0.09).

Comparison (Combined Subjects)	Group	Median (IQR)	p value
4^0 Difference vs. 0^0 Difference	Dental professionals	33.0 (26.5-41.8) vs. 13.7 (10.1-23.3)	< **0.0001***
	Laypeople	32.1 (27.1-39.7) vs. 18.4 (14.0-24.7)	< **0.0001***
4^0 Difference vs. 2^0 Difference	Dental professionals	33.0 (26.5-41.8) vs. 31.7 (26.9-36.4)	0.09
	Laypeople	32.1 (27.1-39.7) vs. 25.7 (19.3-31.5)	**0.001***
4^0 Difference vs. 6^0 Difference	Dental professionals	33.0 (26.5-41.8) vs. 15.0 (8.6-21.1)	< **0.0001***
	Laypeople	32.1 (27.1-39.7) vs. 24.1 (18.4-32.7)	**0.0001***

***** $p < 0.05$ is statistically significant

Table 4-4 Occlusal Plane Cant Comparisons to a 4° Difference for Combined Subjects for Both Groups using Non-Parametric Independent t-Tests (Mann Whitney Test)

Individual Subject Ratings for 4° Difference Comparisons

For each subject rated individually (for a total of nine variations), dental professionals and laypeople separately rated a 4° difference the most attractive for all subjects, except in one circumstance (dental professionals for subject 2: 4° vs the 2° difference) and this difference was not statistically significant (p=0.91). Three comparisons in total were not statistically significant: dental professional rating for subjects 1 and 2: 4° vs the 2° difference (p=0.25, p=0.91, respectively), and the layperson rating for subject 2: 4° vs the 2° difference (p=0.20). Interestingly, all three of the comparisons that were not statistically significant were comparing a 2° difference to a 4° difference, suggesting that a 2° difference might be an acceptable compromise to an occlusal cant parallel to the horizon.

Comparison (Subject 1)	Group	Median (IQR)	p value
4^0 Difference vs. 0^0 Difference	Dental professionals	37.8 (28.6-42.2) vs. 13.3 (5.3-24.5)	< **0.0001***
	Laypeople	37.8 (24.5-44.1) vs. 13.7 (7.6-24.2)	< **0.0001***
4^0 Difference vs. 2^0 Difference	Dental professionals	37.8 (28.6-42.2) vs. 34.6 (24.8-39.3)	0.25
	Laypeople	37.8 (24.5-44.1) vs. 26.1 (18.2-37.1)	**0.01***
4^0 Difference vs. 6^0 Difference	Dental professionals	37.8 (28.6-42.2) vs. 13.2 (7.0-26.6)	< **0.0001***
	Laypeople	37.8 (24.5-44.1) vs. 26.8 (17.2-37.1)	**0.01***
Comparison (Subject 2)	Group	Median (IQR)	p value
4^0 Difference vs. 0^0 Difference	Dental professionals	31.2 (20.5-41.7) vs. 18.4 (10.6-28.4)	**0.005***
	Laypeople	29.9 (17.9-38.8) vs. 17.8 (9.7-27.3)	**0.005***
4^0 Difference vs. 2^0 Difference	Dental professionals	31.2 (20.5-41.7) vs. 32.5 (22.5-37.8)	0.91
	Laypeople	29.9 (17.9-38.8) vs. 24.8 (14.9-33.4)	0.20
4^0 Difference vs. 6^0 Difference	Dental professionals	31.2 (20.5-41.7) vs. 13.9 (4.3-24.6)	< **0.0001***
	Laypeople	29.9 (17.9-38.8) vs. 21.6 (7.8-34.5)	**0.01***
Comparison (Subject 3)	Group	Median (IQR)	p value
4^0 Difference vs. 0^0 Difference	Dental professionals	40.4 (26.3-45.2) vs. 13.7 (5.1-22.7)	< **0.0001***
	Laypeople	36.5 (24.1-42.6) vs. 18.9 (7.9-25.3)	< **0.0001***
4^0 Difference vs. 2^0 Difference	Dental professionals	40.4 (26.3-45.2) vs. 32.5 (24.0-37.7)	**0.03***
	Laypeople	36.5 (24.1-42.6) vs. 25.0 (16.0-34.8)	**0.02***
4^0 Difference vs. 6^0 Difference	Dental professionals	40.4 (26.3-45.2) vs. 9.3 (4.6-18.9)	< **0.0001***
	Laypeople	36.5 (24.1-42.6) vs. 23.4 (12.4-34.9)	**0.0008***

***** $p < 0.05$ is statistically significant

Table 4-5 Occlusal Plane Cant Comparisons in All Subjects for Both Group using Non-Parametric Independent t-Tests (Mann Whitney Test)

Combined Subject Ratings for All Degrees Difference Comparisons

For all combined subject rating comparisons for both groups using non-parametric independent t-tests (Mann Whitney Test), all occlusal plane differences are statistically different from another, except in three instances. The first is the dental professionals rating between a 2° and 4° difference (p=0.09); another is the laypeople rating for the 2° and 4° difference (p=0.38); the last is the dental professionals rating for the 0° and 6° difference (p=0.44).

Additional data for occlusal plane preferences for all subjects of combined groups may be found in Appendix D.

Comparison (Combined Subjects)	Group	Median (IQR)	p value
0^0 Difference vs. 2^0 Difference	Dental professionals	13.7 (10.1-23.3) vs. 31.7 (26.9-36.4)	< **0.0001***
	Laypeople	18.4 (14.0-24.7) vs. 25.7 (19.3-31.5)	< **0.0001***
2^0 Difference vs. 4^0 Difference	Dental professionals	31.7 (26.9-36.4) vs. 33.0 (26.5-41.8)	0.09
	Laypeople	25.7 (19.3-31.5) vs. 32.1 (27.1-39.7)	**0.001***
4^0 Difference vs. 6^0 Difference	Dental professionals	33.0 (26.5-41.8) vs. 15.0 (8.6-21.1)	< **0.0001***
	Laypeople	32.1 (27.1-39.7) vs. 24.1 (18.4-32.7)	**0.0001***
2^0 Difference vs. 6^0 Difference	Dental professionals	31.7 (26.9-36.4) vs. 15.0 (8.6-21.1)	< **0.0001***
	Laypeople	25.7 (19.3-31.5) vs. 24.1 (18.4-32.7)	0.38
0^0 Difference vs. 4^0 Difference	Dental professionals	13.7 (10.1-23.3) vs. 33.0 (26.5-41.8)	< **0.0001***
	Laypeople	18.4 (14.0-24.7) vs. 32.1 (27.1-39.7)	< **0.0001***
0^0 Difference vs. 6^0 Difference	Dental professionals	13.7 (10.1-23.3) vs. 15.0 (8.6-21.1)	0.44
	Laypeople	18.4 (14.0-24.7) vs. 24.1 (18.4-32.7)	**0.001***

***** $p < 0.05$ is statistically significant

Table 4-6 All Occlusal Plane Cant Comparisons for Combined Subjects for Both Groups using Non-Parametric Independent t-Tests (Mann Whitney Test)

Chapter 5. DISCUSSION

5.1 STUDY DESIGN

Several studies in the past have evaluated the influence of an occlusal cant on attractiveness[6,11,12,14,18,19,25]. However, none have considered the situation in which a patient has an existing uncorrected facial asymmetry such as orbital dystopia (also defined as having a cant of the interpupillary line). The goal of this study was to evaluate the perception of frontal occlusal cant attractiveness among dental professionals and laypeople for patients with orbital dystopia.

Three extra-oral photographs of three subjects were altered to produce an interpupillary line cant of either positive or negative 4° (i.e. a 4° clockwise or counterclockwise rotation, respectively). These images were subsequently digitally altered four additional times to produce an occlusal cant that was different from the orbital cant by 0°, 2°, 4°, and 6°. These images were then cropped to include only the upper limits of the eyebrows to just inferior to the mentolabial sulcus to diminish inadvertent influences of other facial features such as facial shape, hair style and color, ear anatomy, etc. Although the three subjects varied greatly physically (skin color, sex, eye color, eyebrows, nose shape, tooth shape, degree of smile animation, negative space around the dentition, etc.), variation in this study was important to ensure results were related to the variations in the occlusal cant rather than other physical attributes. The consistent results of this study among all three subjects confirm that the raters were indeed evaluating the variability of occlusal cants.

All four digitally altered images of each subject were displayed on a single page of the survey so that the raters had a baseline of comparison by which to rate each image. Because this study displayed a smile and orbital dystopia, there were many confounding and distracting factors (skin color, sex, eye color, eyebrows, nose shape, tooth shape,

degree of smile animation, etc.) that could potentially skew a subject's rating, or a rater might not have even noticed the slight 2° difference of occlusal plane cant if each of these images were displayed on individual pages. Displaying all four digitally altered images of each subject on a single page in order of descending or ascending occlusal cant deviation from the orbital plane acted as a slider bar.

5.2 Comparison of Dental Professional and Laypeople Ratings

A frontal occlusal cant of 0° (parallel to the horizon) is the ideal frontal occlusal plane position[11], even in the presence of orbital dystopia. One of the most important findings in this study is that the combined group ratings of dental professionals and laypeople showed a significant preference of an occlusal cant parallel to the horizon (4° difference) despite the presence of a +/- 4° interpupillary cant (orbital cant). Therefore, despite the presence of an orbital dystopia, a frontal occlusal plane parallel with the horizon is still considered ideal.

Another notable result from this study is that laypeople deemed a 2° and 6° difference as equivalent (no significant difference) in attractiveness ratings for all three subjects. Therefore, laypeople rated an absolute difference of 2° from the horizon of the occlusal cant similarly, regardless of the direction of the orbital dystopia. The least attractive rating for laypeople was a 0° difference; in other words, the occlusal cant deemed the least attractive was the one with most deviation (4°) from the horizon. These findings imply that laypeople evaluate the attractiveness of an occlusal plane cant with respect to an absolute deviation from the horizon without taking into consideration the presence of an interpupillary line cant (i.e. orbital dystopia).

Dental professionals deemed a 2° difference significantly more attractive than a 6° difference. Dental professionals also rated a 2° and a 4° difference similarly (no significant

differences in attractiveness ratings) in subjects 1 and 2, and for combined subject ratings (for subject 3, the 4° difference was rated statistically most attractive). The dental professional group also rated the 0° and 6° differences as the least attractive and statistically similar in attractiveness rating in combined subjects and in subjects 2 and 3. Therefore, when dental professionals rate attractiveness, they seem to take into consideration factors beyond just smile esthetics, also considering factors like the presence of an interpupillary line cant. This study found that dental professionals are willing to accept an occlusal cant that is an average of ideal occlusal plane (parallel to the horizon) and the interpupillary line cant. Kokich and colleagues[14] concluded that health professionals and laypeople found an occlusal plane cant to be an overwhelming displeasing smile characteristics. However, in this investigation, dental professionals were willing to accept an occlusal plane cant deviated in the direction of the interpupillary line cant in patients with orbital dystopia. This study's findings indicate that dental professionals may take into consideration the orbital cant when evaluating dental occlusal cants, whereas laypeople focus primarily on the deviation of the occlusal plane from the horizon without regard to the orbital cant. This finding most likely stems from the fact that through dental education, dental professionals are commonly taught to evaluate the frontal occlusal plane relative to the interpupillary line.

Another significant finding is that both laypeople and dental professionals could discern differences (and therefore have different attractiveness ratings) between the varying degrees of occlusal cants in increments of 2°. This is in contrast to several other occlusal cant studies that found that dental professionals were either more perceptive than general dentists in detecting minor degrees of cant variations, or that they tolerated a lower range of transverse occlusal canting[12,14,18,25]. The reason laypeople surveyed in this study might be more perceptive to small 2° incremental differences between occlusal cants is that all four images of each subject were displayed on the same page in ascending or

descending order of occlusal cant to interpupillary line differences, whereas the three of the four aforementioned studies displayed similar images on separate slides or pages. The sequence of the subjects in this study created a makeshift sliderbar on paper, similar to the digital slider used by Ker and colleagues[12], except they used much smaller increments of one-quarter degrees.

5.3 Clinical Implications

Uncorrected orbital dystopia is a concern for the dental professional, especially orthodontists, oral surgeons, and prosthodontists who can readily alter the frontal occlusal plane, at least to some degree, through either orthodontic treatment, orthognathic surgery, or dental prostheses. The dental professional must decide whether to match the occlusal plane with a reference point other than the interpupillary line, perhaps to the true horizon.

This study has shown that people generally prefer a frontal occlusal plane parallel to the horizon, regardless of the patient's orbital dystopia (at least to some degree; in this case at least up to +/-4°). However, dental professionals may take a middle-ground approach and are willing to accept an occlusal cant somewhere in between an ideal (parallel to the horizon) occlusal plane[11] and the degree of orbital dystopia present. Even though dental professionals may accept an occlusal plane canted in the direction of the interpupillary line as esthetically acceptable, we should more heavily weigh what laypeople prefer, as laypeople are both patients and the 'viewer' of dental treatment.

5.4 Visual Analog Scale

In this study, attractiveness ratings were marked with a vertical line along a 50mm visual analog scale (VAS) and recorded to the nearest one-hundredth of a millimeter.

Utilizing a VAS to rate attractiveness has multiple advantages. For instance, it provides a rater with a simple, quick, and reliable method for analyzing facial attractiveness without restricting raters to discrete numbers or categories, especially when measuring subjective phenomenon[31]. A VAS is also easy to administer, explain its use, and grasp by raters[31]. Having a continuous scale also allows a statistical interpretation of ratings as continuous variations, allowing more freedom in how that data may be analyzed[8].

However, a VAS to may unintentionally cause misinterpretation of results. Assessment of facial esthetics is highly subjective and raters might have difficulty conceptually using a VAS as a representation of an abstract concept; a mark along the VAS is totally dependent on the rater's interpretation of "most attractive" and "most attractive" [31]. The VAS was of most value in this study when looking at changes within subjects because there was at least a basis of comparison; however, it was of vastly less value for comparison between subjects because there were so much many compounding physical differences.

5.5 Future Research

This study has the potential for several follow-on research studies. A future study might include the effect of negative space around the maxillary dentition on the perception of esthetics. Comparison among different volumes of negative space is not possible in this study, although varying degrees of negative space were present for all three subjects, because there were too many other distracting influences between each subject (eye brow position, skin color, hair color, eye shape, eye color, etc.). To study the impact on of negative space on smile attractiveness in patients with orbital dystopia, the same subject with different displays of negative space should be used to eliminate other possible biases.

A more in-depth investigation of this study could be to add smaller increments of degrees for the occlusal cant (instead of 2° increments, perhaps consider 1° or even 0.5° differences). Upper and lower limits of acceptability could be investigated using a digital slider using one-quarter degree increment changes of the occlusal cant, as in the study by Ker and colleagues[12]. Other possible studies include investigating the perception of attractiveness by varying the orbital cant degrees in relation to a constant occlusal cant, or by varying the amounts of gingival display as previously referenced.

This study is the first study of dental esthetics to consider incorporating a constant facial asymmetry in addition to a variable dental asymmetry. Future studies might integrate other facial asymmetries such as an asymmetric alar base, smile animation, or philtrum (as might be the case in cleft lip patients), or perhaps an evaluation of a chin point or nasal tip point deviation.

Chapter 6. Study Conclusions

Within the limitations of the study, the following conclusions may be made:

1. People generally prefer a frontal occlusal cant parallel to the horizon, regardless of the presence of orbital dystopia.
2. When evaluating facial esthetics in patients with orbital dystopia, dental professionals rate attractiveness based on the frontal occlusal plane's relationship to the interpupillary line.
3. Dental professionals may be more willing to accept an occlusal plane cant deviated in the direction of the interpupillary line cant in patients with orbital dystopia.
4. Laypeople base their attractiveness ratings in independently from the presence of an orbital cant.

The overarching conclusion that is most into clinical practice is that to achieve the most esthetic outcome when planning changes to the frontal occlusal plane, dental professionals should evaluate patients in natural head position and use the true horizon as the guiding reference line. Using the interpupillary line in the presence of orbital dystopia could lead to a less favorable esthetic outcome.

LITERATURE CITED

1. Ackerman AL, Ackerman MB, Brensinger CM, Landis JR. A morphometric analysis of the posed smile. Clin Orth Res 1998;1:2-11.

2. Ackerman AL, Ackerman MB. Smile Analysis and design in the digital era. JCO 2002;36(4)221-236.

3. Chang CA, Fields Jr. HW, Beck FM, Springer NC, Firestone AR, Rosenstiel S, Christensen JC. Smile esthetics from patient's perspectives for faces of varying attractiveness. Am J Orthod Dentofacial Orthop 2011;140:e171-e180.

4. Edgerton M.T., et. al. Vertical orbital dystopia – surgical correction. Journal of the American Society of Plastic Surgeons. February 1981;67(2):121-138.

5. Fernandes L, Pinho T. Esthetic evaluation of dental and gingival asymmetries. International Orthodontics 2015;13:221-231.

6. Geron S, Wasserstein A. Influnece of sex on the perception of oral and smile esthetics with different gingival display and incisal plane inclination. Angle Orthod 2005;75:778-784.

7. Glass GE, Von KAV, Bowman R, Jones, BM, Dunaway DJ, Birtto JA. Ocular morbidity in the correction of orbital hypertelorism and dystopia: A 15 year experience. Plast Reconstr Surg 2017;139:967-975.

8. Howells DJ, Shaw WC. The validity and reliability of ratings of dental and facial attractiveness for epidemiologic use. Am J Orthod Dentofacial Orthop 1995;88:402-408.

9. Jeon YJ, Kim YJ, Son WS, Hans MG. Correction of a canted occlusal plane with miniscrews in a patient with facial asymmetry. Am J Orthod Dentofacial Orthop 2006;130:244-52.

10. Johnston CD, Burden DJ, Stevenson MR. The influence of dental to facial midline discrepancies on dental attractiveness ratings. European Journal of Orthodontics 1999;21:517-22.

11. Kaya B, Uyar R. The impact of occlusal plane cant along with gingival display on smile attractiveness. Orthod Cranifac Res 2016;19:93-101.

12. Ker AJ, Chan R, Fields HW, Beck M, Rosenstiel S. Esthetics and smile characteristics from the layperson's perspective: a computer based survey study. Jada October 2008;139.

13. Ko EW, Huang CS, Chen YR. Characteristics and corrective outcome of face asymmetry by orthognathic surgery. J Oral Maxillofac Surg 2009;67:2207-2209.

14. Kokich VO, Kiyak HA, Shapiro PA. Comparing the perception of dentists and lay people to altered dental esthetics. J Esthetic Dent 1999; 11(6):311-324.

15. Kokich VO, Kokich VG, Kiyak HA. Perceptions of dental professionals and laypersons to altered dental esthetics: asymmetric and symmetric situations. Am J Orthod Dentofacial Orthop 2006;130(2):141-151.

16. Nainai FB, Gill DS. Facial aesthetics: 2. Clinical assessment. Dent Update 2008;35:159-170.

17. Oh S, Ahn J, Nam KU, Hong J. Frankfort horizontal plane is an appropriate three-dimensional reference in the evaluation of clinical and skeletal cant. J Korean Assoc Oral Maxillofac Surg 2013; 39:71-76.

18. Oliveres A. Vincente A, Jacobi C, Molina SM, Rodriguez A, Bravo LA. Canting of the occlusal plane: Perceptions of dental professionals and laypersons. Med Oral Patol Oral Cir Bucal 2013;18(3)e516-e520.

19. Padwa BL, Kaiser MO, Kaban LB. Occlusal Cant in the Frontal Plane as a Reflection of Facial Asymmetry. J Oral Maxillofac Surg 1997;55:811-816

20. Peck S, Peck L, Kataja M. The gingival smile line. The Angle Orthodontist 1992;62(2):91-100.

21. Peck S, Peck L. Selected aspects of the art and science of facial esthetics. Seminars in Orthodontics June 1995;1(2):105-126.

22. Peck S, Peck L, Katja M. Skeletal asymmetry in esthetically pleasing faces. The Angle Orthodontist 1990;61(1)43-48.

23. Pinho S, Ciriaco C, Faber J, Lenza MA. Impact of dental asymmetries on the perception of smile esthetics. Am J Orthod Dentofacial Orthop 2007;132:748-753.

24. Sarver DM, Ackerman MB. Dynamic smile visualization and quantification: Part 2. Smile analysis and treatment strategies. Am J Orthod Dentofacial Orthop 2003;124:116-27.

25. Shiyan H, Xu Q, Nanquan R, Xiaobing L. Orthodontists' and laypeople's perception of smile height aesthetics in relation to varying degrees of transverse cant of anterior teeth. Aust Orthod J 2016;32:55-63.

26. Silva BP, Jimenez-Castellano E, Martinez-de-Fuentes R, Greenberg JR, Chu S. Laypersons' perception of facial and dental asymmetries. Int J Periodontics Restorative Dentistry 2013;33:e162-e171.

27. Susarla SM, Dodson TB, Kaban LB. Measurement and interpretation of a maxillary occlusal cant in the frontal plane. J Oral Maxillofac Surg 2008;66:2498-2502.

28. Tan ST, Ashworth G, Czypionka S, Poole MD, Briggs M. Vertical orbital dystopia. Plast Reconstr Surg 1996;97:1349-1361.

29. Vaidya N, Seth V, Shankar S. Indian Journal of Dental Sciences 2014:4(6):137-140.

30. Wahl N. Orthodontics in 3 millenia. Chapter 1: Antiquity to the mid-19th Century. Am J Orthod Dentofacial Orthop 2005;127:255-9.

31. Wewers ME, Lowe NK. A critical review of visual analogue scales in the measurement of clinical phenomena. Research in Nursing & Health 1990;13:227-236.

32. Wolfe SA, Sassani R. Vertical orbital dystopia: definition, classification, and treatment. Scand J Plast Reconstr Hand Surg Suppl 1995;27:49-65.

APPENDIX A

INFORMED CONSENT DOCUMENT

I, _____, hereby authorize the Department of Defense (DoD) and the United States Air Force, to include 59th Medical Wing's Multimedia center, and all individuals acting pursuant to its authority to photograph my face and digitally modify this image. I hereby expressly consent to allow all lawful uses of these images. The term "lawful uses" shall include, but is not limited to, the right to reproduce, distribute, transmit, publish, exhibit, or otherwise use such photographs or any portion thereof. This permission is granted with the complete understanding that such photographs may be published but not limited to, medical education, per established Public Affairs Regulations as desired by the United States Air Force and the Department of Defense.

This authorization does not expire and I authorize use of my digitally altered images even when the service member conducting the survey is no longer employed by the Department of Defense.

I understand that my eligibility for care and/or benefits is not conditioned upon signing this authorization.

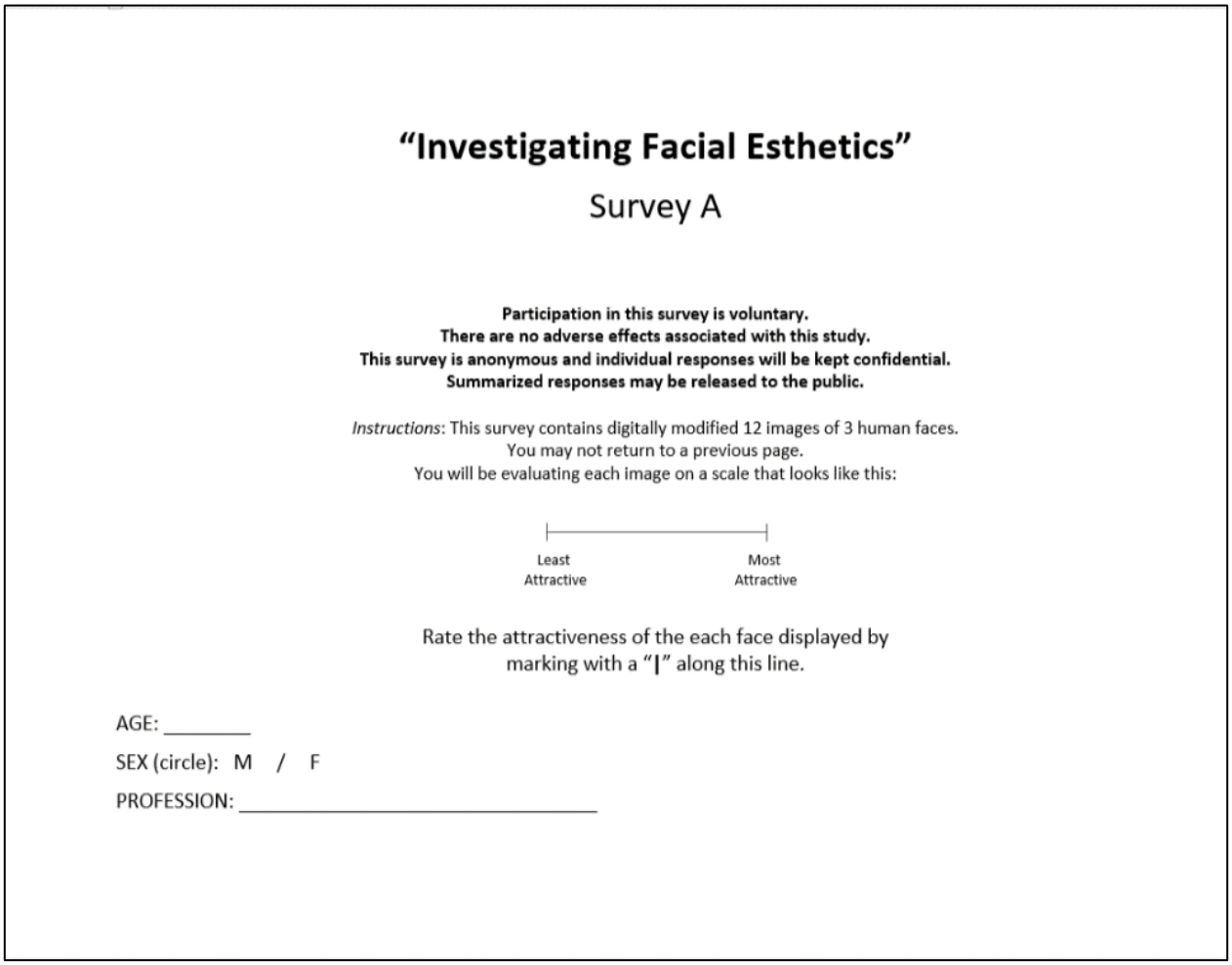
Information regarding the study "Preferred Occlusal Cant for those with Orbital Dystopia":

1. This study involves research of facial esthetics. The purpose is to evaluate the perception of attractiveness by lay people and dental professionals through evaluating digitally modified photographs of 3 individuals. Four digitally modified images will be used for each individual; each image will be evaluated for facial esthetics on a 50mm visual analogue scale, for no longer than ten seconds per photo.
2. No foreseeable risks or discomforts exist in participating in this survey or for being included in the images of this survey.
3. The benefits include contributing to the mission of AFPDS through participating in a research survey that will enable a resident to earn a Master's Degree.
4. There are no alternative ways to participate in the survey.
5. No PII or information relating to HIPPA will be collected. Therefore, confidentiality of records is not at risk.
6. Participation in this survey is voluntary. Refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled, and the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.
7. A total of 100 subjects will be recruited to take the survey.
8. There is no cost to participate in the survey.
9. Any pertinent questions regarding this research may contact myself at AFPDS.

_____	_____	_____
Printed Name	Signature	Date

APPENDIX B

SURVEY RATING PAGES



"Investigating Facial Esthetics"

Survey A

Participation in this survey is voluntary.
There are no adverse effects associated with this study.
This survey is anonymous and individual responses will be kept confidential.
Summarized responses may be released to the public.

Instructions: This survey contains digitally modified 12 images of 3 human faces.
You may not return to a previous page.
You will be evaluating each image on a scale that looks like this:

Least Attractive — Most Attractive

Rate the attractiveness of the each face displayed by marking with a "|" along this line.

AGE: _____

SEX (circle): M / F

PROFESSION: _____

Figure B-1 Front View of Visual Analogue Scale Rating Page

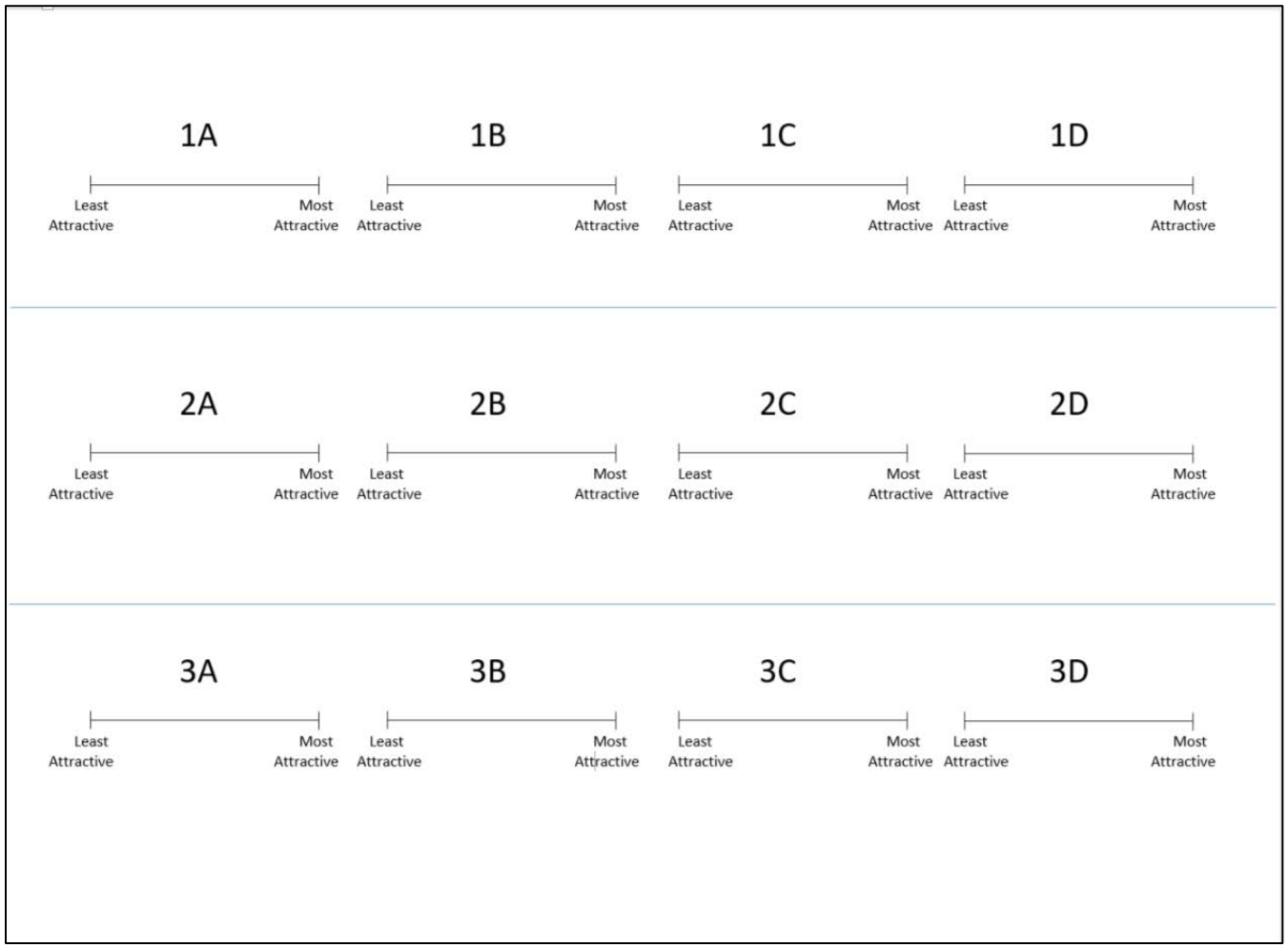


Figure B-2 Back View of Visual Analogue Scale Rating Page

Figure B-3 50mm Visual Analogue Scale to Size

APPENDIX C

RAW SURVEY RESULTS

Table C-1 Laypersons Rating for Subject 1

Rater ID	Age	Gender	Subject 1 0^0 Difference	Subject 1 2^0 Difference	Subject 1 4^0 Difference	Subject 1 6^0 Difference
1	37	M	35.16	13.04	0.65	47.72
2	29	M	10.18	50.00	0.00	36.25
3	47	M	25.40	24.07	23.70	26.05
4	30	M	35.96	11.08	36.98	46.32
5	48	M	9.54	18.19	39.35	5.60
6	56	M	15.12	24.15	41.00	33.00
7	52	F	24.40	24.06	39.93	46.95
8	35	M	2.54	34.22	13.17	46.20
9	32	F	24.17	28.03	43.55	38.48
10	37	M	5.66	40.61	17.59	18.31
11	19	F	11.53	40.45	50.00	26.27
12	38	M	3.76	22.24	45.84	32.75
13	40	M	22.68	30.88	38.34	8.67
14	40	F	7.62	22.65	34.73	44.71
15	37	F	6.00	36.39	30.86	16.83
16	39	M	8.70	13.35	23.08	18.98
17	34	M	5.17	24.06	47.15	1.99
18	73	F	0.00	23.33	50.00	21.83
19	74	M	12.28	18.79	37.09	23.70
20	31	F	12.90	20.80	44.79	31.95
21	33	F	4.62	14.34	32.09	46.58
22	48	M	7.27	41.30	22.72	32.18
23	49	M	25.21	24.80	39.08	23.68
24	55	M	11.22	31.11	37.47	24.33
25	50	F	21.24	45.74	50.00	21.22
26	31	F	2.08	24.21	44.13	10.27
27	32	M	5.87	33.11	45.73	16.77
28	32	M	16.83	27.40	35.79	14.30
29	34	M	33.18	42.61	33.23	11.93
30	40	F	22.52	50.00	35.79	33.03
31	46	M	10.78	16.50	40.06	27.36
32	65	M	9.02	50.00	38.34	25.38
33	62	F	9.96	33.83	50.00	17.19
34	54	F	23.38	43.42	43.48	42.79
35	50	M	23.31	30.74	41.71	32.45
36	32	F	32.31	40.22	25.04	22.00
37	49	M	8.89	36.32	44.77	8.01
38	26	F	15.14	28.60	10.85	39.71
39	31	F	29.96	10.51	24.66	39.05
40	38	M	9.56	0.00	50.00	34.78
41	35	M	22.03	37.11	24.41	31.53
42	37	M	4.15	45.09	27.16	37.08
43	24	F	14.60	6.86	40.41	46.04
44	30	F	37.59	8.90	44.24	5.53
45	59	M	20.28	3.38	45.53	28.87
46	55	F	28.62	14.59	22.78	44.30
47	38	M	4.99	50.00	22.46	33.60
48	66	M	14.57	36.65	38.15	13.69
49	43	F	50.00	20.00	24.54	22.21
50	45	M	41.51	10.02	22.03	10.69

Table C-2 Dental Professionals Rating for Subject 1

Rater ID	Age	Gender	Subject 1 0^0 Difference	Subject 1 2^0 Difference	Subject 1 4^0 Difference	Subject 1 6^0 Difference
51	31	M	15.06	46.09	37.77	1.91
52	26	F	24.79	6.25	9.53	8.62
53	37	M	0.00	15.00	38.55	50.00
54	30	M	39.97	25.51	32.67	6.32
55	49	M	9.84	1.78	33.56	50.00
56	30	M	24.55	28.22	25.23	21.07
57	40	M	47.56	9.78	33.77	20.60
58	35	M	36.41	2.90	34.54	20.86
59	36	M	2.53	39.19	14.42	50.00
60	36	F	3.69	32.11	42.43	17.44
61	38	F	15.31	8.38	28.65	29.90
62	29	M	24.38	10.83	35.58	43.46
63	36	M	1.88	13.89	28.50	41.86
64	31	M	8.53	33.91	41.23	11.01
65	31	F	23.10	24.67	31.96	45.65
66	32	F	11.98	39.21	22.46	3.58
67	35	F	23.42	29.96	19.98	15.06
68	37	M	28.66	34.22	35.86	7.80
69	34	M	11.46	14.63	17.42	22.24
70	32	M	16.51	47.24	34.88	1.36
71	31	F	0.00	50.00	38.72	11.38
72	45	F	35.41	41.52	32.60	12.02
73	65	M	17.82	26.27	32.03	6.93
74	42	M	1.83	48.67	26.73	28.36
75	34	F	26.68	46.85	46.00	29.68
76	46	M	2.75	45.44	19.01	8.95
77	44	M	7.28	44.44	41.98	17.18
78	30	M	21.03	41.69	31.07	35.36
79	30	F	2.08	22.20	22.37	13.26
80	29	M	4.86	37.87	41.15	10.61
81	37	F	1.92	47.98	10.85	19.29
82	30	F	9.08	41.39	36.05	15.95
83	39	M	6.09	39.76	33.75	15.30
84	35	M	3.92	13.46	12.39	11.67
85	35	M	31.95	43.79	15.83	6.27
86	31	M	23.33	22.53	42.93	19.84
87	38	M	1.37	5.84	19.63	27.67
88	31	M	35.64	30.38	38.82	13.77
89	30	M	6.36	45.94	37.41	21.04
90	34	M	18.34	29.58	30.22	34.33
91	33	M	11.95	33.66	39.98	15.76
92	35	M	36.35	40.78	17.32	3.88
93	29	M	25.15	25.96	24.37	24.95
94	35	F	12.75	39.25	32.33	28.15
95	32	F	45.03	14.05	26.86	4.02
96	31	F	7.93	20.54	38.75	43.20
97	32	F	4.29	43.65	35.59	19.89
98	35	M	1.39	48.30	8.91	4.02
99	30	M	24.29	24.58	27.50	24.90
100	34	F	17.96	24.44	41.23	34.20

Table C-3 Laypersons Rating for Subject 2

Rater ID	Age	Gender	Subject 2 0^0 Difference	Subject 2 2^0 Difference	Subject 1 4^0 Difference	Subject 2 6^0 Difference
1	37	M	9.58	32.37	43.11	0.98
2	29	M	50.00	0.00	12.01	35.56
3	47	M	11.87	15.09	13.45	14.85
4	30	M	12.08	14.57	33.36	13.91
5	48	M	6.78	34.18	13.43	7.40
6	56	M	11.50	16.23	39.53	11.99
7	52	F	41.54	38.75	6.37	17.07
8	35	M	47.47	39.34	1.95	13.44
9	32	F	37.35	25.90	31.39	40.16
10	37	M	4.71	10.98	41.37	0.00
11	19	F	0.00	23.43	50.00	39.43
12	38	M	16.16	44.36	7.79	32.04
13	40	M	7.64	40.81	29.48	15.99
14	40	F	5.47	23.22	45.31	34.09
15	37	F	5.03	7.68	28.33	14.00
16	39	M	21.57	12.93	24.19	24.38
17	34	M	1.56	11.77	43.34	23.01
18	73	F	50.00	23.05	15.43	0.00
19	74	M	15.54	22.83	31.59	21.64
20	31	F	10.79	38.28	23.52	20.66
21	33	F	2.86	46.74	35.24	13.09
22	48	M	30.05	40.57	21.67	5.73
23	49	M	24.02	26.18	28.98	25.73
24	55	M	12.11	14.04	23.65	27.25
25	50	F	7.07	50.00	32.11	0.00
26	31	F	8.76	44.33	22.98	16.95
27	32	M	23.93	46.61	36.02	18.21
28	32	M	21.59	33.93	20.09	8.83
29	34	M	40.20	28.69	26.24	9.70
30	40	F	35.05	50.00	22.78	26.35
31	46	M	39.44	21.74	11.90	11.27
32	65	M	50.00	38.21	10.00	25.63
33	62	F	30.24	42.66	19.89	21.07
34	54	F	32.05	25.10	45.47	38.20
35	50	M	40.39	31.20	41.79	24.22
36	32	F	13.69	17.89	19.77	28.03
37	49	M	4.84	34.46	13.15	43.73
38	26	F	7.76	36.30	10.85	39.71
39	31	F	34.49	43.87	26.72	8.20
40	38	M	24.13	24.48	25.34	24.88
41	35	M	3.51	35.95	28.09	3.88
42	37	M	32.28	3.62	13.74	41.57
43	24	F	34.37	46.10	15.35	2.22
44	30	F	6.36	32.49	34.69	9.73
45	59	M	18.26	32.49	8.02	44.77
46	55	F	43.34	23.53	14.92	17.47
47	38	M	23.72	25.86	25.47	26.03
48	66	M	21.98	34.79	16.31	14.99
49	43	F	50.00	10.01	37.76	0.00
50	45	M	27.65	16.58	27.67	44.01

Table C-4 Dental Professionals Rating for Subject 2

Rater ID	Age	Gender	Subject 2 0^0 Difference	Subject 2 2^0 Difference	Subject 2 4^0 Difference	Subject 2 6^0 Difference
51	31	M	15.06	46.09	37.77	1.91
52	26	F	24.79	6.25	9.53	8.62
53	37	M	0.00	15.00	38.55	50.00
54	30	M	39.97	25.51	32.67	6.32
55	49	M	9.84	1.78	33.56	50.00
56	30	M	24.55	28.22	25.23	21.07
57	40	M	47.56	9.78	33.77	20.60
58	35	M	36.41	2.90	34.54	20.86
59	36	M	2.53	39.19	14.42	50.00
60	36	F	3.69	32.11	42.43	17.44
61	38	F	15.31	8.38	28.65	29.90
62	29	M	24.38	10.83	35.58	43.46
63	36	M	1.88	13.89	28.50	41.86
64	31	M	8.53	33.91	41.23	11.01
65	31	F	23.10	24.67	31.96	45.65
66	32	F	11.98	39.21	22.46	3.58
67	35	F	23.42	29.96	19.98	15.06
68	37	M	28.66	34.22	35.86	7.80
69	34	M	11.46	14.63	17.42	22.24
70	32	M	16.51	47.24	34.88	1.36
71	31	F	0.00	50.00	38.72	11.38
72	45	F	35.41	41.52	32.60	12.02
73	65	M	17.82	26.27	32.03	6.93
74	42	M	1.83	48.67	26.73	28.36
75	34	F	26.68	46.85	46.00	29.68
76	46	M	2.75	45.44	19.01	8.95
77	44	M	7.28	44.44	41.98	17.18
78	30	M	21.03	41.69	31.07	35.36
79	30	F	2.08	22.20	22.37	13.26
80	29	M	4.86	37.87	41.15	10.61
81	37	F	1.92	47.98	10.85	19.29
82	30	F	9.08	41.39	36.05	15.95
83	39	M	6.09	39.76	33.75	15.30
84	35	M	3.92	13.46	12.39	11.67
85	35	M	31.95	43.79	15.83	6.27
86	31	M	23.33	22.53	42.93	19.84
87	38	M	1.37	5.84	19.63	27.67
88	31	M	35.64	30.38	38.82	13.77
89	30	M	6.36	45.94	37.41	21.04
90	34	M	18.34	29.58	30.22	34.33
91	33	M	11.95	33.66	39.98	15.76
92	35	M	36.35	40.78	17.32	3.88
93	29	M	25.15	25.96	24.37	24.95
94	35	F	12.75	39.25	32.33	28.15
95	32	F	45.03	14.05	26.86	4.02
96	31	F	7.93	20.54	38.75	43.20
97	32	F	4.29	43.65	35.59	19.89
98	35	M	1.39	48.30	8.91	4.02
99	30	M	24.29	24.58	27.50	24.90
100	34	F	17.96	24.44	41.23	34.20

Table C-5 Laypersons Rating for Subject 3

Rater ID	Age	Gender	Subject 3 0^0 Difference	Subject 3 2^0 Difference	Subject 3 4^0 Difference	Subject 3 6^0 Difference
1	37	M	25.44	1.04	48.14	23.79
2	29	M	0.00	34.82	15.32	50.00
3	47	M	15.33	16.02	26.09	17.87
4	30	M	8.02	16.88	26.71	39.87
5	48	M	29.02	28.77	41.39	6.35
6	56	M	14.65	20.17	38.23	13.55
7	52	F	42.14	36.34	24.92	11.62
8	35	M	38.62	1.19	14.63	46.10
9	32	F	16.04	32.86	40.41	13.73
10	37	M	7.81	46.49	31.24	10.66
11	19	F	24.47	50.00	35.96	0.00
12	38	M	6.15	16.68	40.60	31.96
13	40	M	19.35	28.36	41.41	6.09
14	40	F	4.74	24.06	36.21	45.59
15	37	F	18.52	34.79	11.16	7.58
16	39	M	10.79	30.87	26.15	18.11
17	34	M	2.38	22.84	47.51	1.82
18	73	F	25.60	26.16	50.00	0.00
19	74	M	11.06	11.78	21.44	39.30
20	31	F	24.10	32.48	43.80	12.40
21	33	F	4.81	18.50	45.46	35.13
22	48	M	43.90	34.18	15.31	9.59
23	49	M	38.14	24.91	26.78	25.11
24	55	M	21.23	24.92	35.44	23.24
25	50	F	23.70	46.95	50.00	23.31
26	31	F	3.03	14.84	47.38	26.44
27	32	M	5.82	16.85	44.60	22.05
28	32	M	10.33	29.90	27.43	19.21
29	34	M	44.15	36.84	23.45	13.12
30	40	F	25.28	50.00	36.69	42.63
31	46	M	11.61	16.01	15.88	37.28
32	65	M	7.49	50.00	40.06	23.97
33	62	F	19.90	40.67	23.50	33.78
34	54	F	32.29	45.99	19.41	34.94
35	50	M	31.08	38.31	46.29	22.58
36	32	F	19.63	12.94	14.25	28.44
37	49	M	20.62	8.51	42.33	24.98
38	26	F	24.80	30.33	38.40	23.54
39	31	F	14.95	15.77	40.63	34.38
40	38	M	22.84	25.07	24.08	39.33
41	35	M	9.33	23.19	23.90	9.11
42	37	M	42.88	20.05	6.49	19.43
43	24	F	7.15	17.39	38.21	47.40
44	30	F	8.82	13.92	37.41	10.32
45	59	M	6.31	11.14	45.18	25.76
46	55	F	22.90	26.49	45.18	30.79
47	38	M	50.00	43.55	25.39	6.98
48	66	M	23.99	31.30	31.29	16.74
49	43	F	0.00	12.47	50.00	36.37
50	45	M	7.91	8.91	42.61	36.05

Table C-6 Dental Professionals Rating for Subject 3

Rater ID	Age	Gender	Subject 3 0^0 Difference	Subject 3 2^0 Difference	Subject 3 4^0 Difference	Subject 3 6^0 Difference
51	31	M	16.41	33.14	45.42	2.66
52	26	F	4.18	42.77	43.91	27.37
53	37	M	50.00	37.10	14.18	1.12
54	30	M	23.85	33.29	32.97	19.65
55	49	M	47.77	26.29	10.05	1.40
56	30	M	15.30	32.38	32.75	34.45
57	40	M	4.70	32.29	46.67	18.30
58	35	M	2.09	5.91	44.09	11.45
59	36	M	33.47	48.69	0.91	10.78
60	36	F	13.47	32.65	41.72	4.58
61	38	F	38.35	21.54	12.33	5.26
62	29	M	19.28	36.76	27.29	7.42
63	36	M	13.95	43.31	24.74	2.27
64	31	M	3.87	26.37	45.75	3.99
65	31	F	38.67	43.31	28.15	18.88
66	32	F	7.11	43.52	23.65	8.38
67	35	F	24.30	34.58	26.33	20.29
68	37	M	5.68	36.89	45.85	6.53
69	34	M	15.71	23.96	16.45	5.25
70	32	M	17.24	36.03	47.89	1.09
71	31	F	8.26	38.49	50.00	0.00
72	45	F	7.12	22.92	23.53	36.75
73	65	M	9.92	19.57	25.41	38.42
74	42	M	1.33	23.43	48.52	27.84
75	34	F	3.10	28.45	40.51	2.91
76	46	M	20.60	24.56	42.07	1.87
77	44	M	6.60	8.47	44.40	35.58
78	30	M	13.90	35.93	44.79	12.04
79	30	F	5.12	23.41	33.67	4.35
80	29	M	12.82	44.11	4.09	26.22
81	37	F	4.73	21.89	48.13	2.20
82	30	F	8.09	26.43	45.20	9.55
83	39	M	34.95	35.80	40.25	5.49
84	35	M	22.60	8.12	35.36	19.02
85	35	M	4.38	35.85	47.22	9.05
86	31	M	2.18	42.85	30.84	7.57
87	38	M	14.87	41.90	25.33	8.10
88	31	M	6.23	16.08	41.21	16.92
89	30	M	19.06	37.90	46.25	3.50
90	34	M	7.50	17.55	21.86	14.41
91	33	M	5.94	25.96	33.92	11.80
92	35	M	22.31	38.23	34.81	5.03
93	29	M	22.73	30.20	33.75	10.09
94	35	F	4.24	35.57	43.52	14.72
95	32	F	31.72	4.51	44.93	16.10
96	31	F	30.65	41.39	48.22	13.00
97	32	F	25.99	37.68	43.02	5.46
98	35	M	2.60	28.88	49.23	18.94
99	30	M	5.10	31.29	41.54	4.90
100	34	F	24.90	29.45	37.99	20.86

APPENDIX D

ADDITIONAL RESULTS

Table D-1 Additional occlusal plane preferences for all subjects of combined groups using non-parametric paired t-tests (Wilcoxon's signed ranks test)

Difference (Combined Subjects)	Median (IQR) (Combined Groups)	p value
0^0 Difference vs. 2^0 Difference	16.8 (11.3-24.1) vs. 29.3 (22.6-35.3)	**<.0001**
0^0 Difference vs. 6^0 Difference	16.8 (11.3-24.1) vs. 19.1 (12.3-27.1)	0.14
2^0 Difference vs. 6^0 Difference	29.3 (22.6-35.3) vs. 19.1 (12.3-27.1)	**<.0001**

Difference (Subject 1)	Median (IQR) (Combined Groups)	p value
4^0 Difference vs. 0^0 Difference	37.8 (26.6-43.6) vs. 13.4 (6.6-24.3)	**<.0001**
4^0 Difference vs. 2^0 Difference	37.8 (26.6-43.6) vs. 32.0 (22.1-39.2)	**0.01**
4^0 Difference vs. 6^0 Difference	37.8 (26.6-43.6) vs. 22.1 (9.6-34.1)	**<.0001**
0^0 Difference vs. 2^0 Difference	13.4 (6.6-24.3) vs. 32.0 (22.1-39.2)	**<.0001**
0^0 Difference vs. 6^0 Difference	13.4 (6.6-24.3) vs. 22.1 (9.6-34.1)	**0.002**
2^0 Difference vs. 6^0 Difference	32.0 (22.1-39.2) vs. 22.1 (9.6-34.1)	**0.001**

Difference (Subject 2)	Median (IQR) (Combined Groups)	p value
4^0 Difference vs. 0^0 Difference	30.8 (19.2-40.8) vs. 17.8 (10.2-28.1)	**<.0001**
4^0 Difference vs. 2^0 Difference	30.8 (19.2-40.8) vs. 28.4 (19.3-35.9)	0.37
4^0 Difference vs. 6^0 Difference	30.8 (19.2-40.8) vs. 16.3 (6.6-30.1)	**<.0001**
0^0 Difference vs. 2^0 Difference	17.8 (10.2-28.1) vs. 28.4 (19.3-35.9)	**<.0001**
0^0 Difference vs. 6^0 Difference	17.8 (10.2-28.1) vs. 16.3 (6.6-30.1)	0.43
2^0 Difference vs. 6^0 Difference	28.4 (19.3-35.9) vs. 16.3 (6.6-30.1)	**<.0001**

Difference (Subject 3)	Median (IQR) (Combined Groups)	p value
4^0 Difference vs. 0^0 Difference	37.7 (25.4-44.7) vs. 15.1 (6.5-24.4)	**<.0001**
4^0 Difference vs. 2^0 Difference	37.7 (25.4-44.7) vs. 29.2 (19.8-36.8)	**0.001**
4^0 Difference vs. 6^0 Difference	37.7 (25.4-44.7) vs. 15.4 (6.8-37.0)	**<.0001**
0^0 Difference vs. 2^0 Difference	15.1 (6.5-24.4) vs. 29.2 (19.8-36.8)	**<.0001**
0^0 Difference vs. 6^0 Difference	15.1 (6.5-24.4) vs. 15.4 (6.8-37.0)	0.76
2^0 Difference vs. 6^0 Difference	29.2 (19.8-36.8) vs. 15.4 (6.8-37.0)	**<.0001**

*****$p < 0.05$ is statistically significant