University of Alberta

Analysis of Anterior Dentofacial Aesthetic Characteristics and their Association to Post-Phase I Orthodontic Treatment Decisions

by

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Dedication

This thesis is dedicated to my family.

To Jacqui - for your strength in the face of adversity over the last year

To Paul - for your lifelong mentorship

To Kortney - for being there through thick and thin

To Tessa - for taking us on to the next chapter

Abstract

Background. Researchers have conducted extensive studies regarding dentoalveolar factors that affect anterior dental aesthetics; however, there is no consensus regarding how these factors affect orthodontic treatment decisions.

Methods. A systematic search of electronic databases was conducted to develop a list of key aesthetic factors for use in analysis of photos of 60 children (23 males, 37 females) having received Phase I orthodontic treatment with the Xbow appliance. Logistic regression was used to determine which factors related to a patient's likelihood of receiving further orthodontic treatment.

Results. Only the angulation of the right maxillary incisors was significantly related to a patient's likelihood to proceed to Phase II orthodontic treatment following Phase I orthodontic treatment with the Xbow appliance. Other factors demonstrated trends but were not statistically significant.

Conclusions. Angulation of the maxillary right incisors is the most significant factor influencing orthodontic treatment decisions, however other factors may also be important.

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Chapter 1: Introduction

PHASE I AND PHASE II ORTHODONTIC TREATMENT

Orthodontic treatment of malocclusions in children and adolescents can be accomplished in either one phase or two phases. A one-phase treatment regime employs only comprehensive treatment in adolescence, in an attempt to solve all occlusal and aesthetic problems simultaneously. A two-phase treatment regime employs a Phase I (limited) treatment in preadolescence followed by a Phase II (comprehensive) treatment in adolescence[1].

Two-phase treatment regimes for the treatment of Class II malocclusions (i.e., a malocclusion characterized by prominent upper front teeth) are not indicated for most children[1]. It appears that providing early orthodontic treatment for children with Class II malocclusions is no more effective than providing one course of orthodontic treatment when the child is in early adolescence[2]. The increased time and financial commitments typically required by a two-phase treatment regime is of even greater concern to patients and parents. However, patients and orthodontists may still opt for two-phase orthodontic treatment based on a perceived need to alleviate a social handicap created by the malocclusion.

In the case of a two-phase orthodontic treatment, patients and their parents have the opportunity to discontinue orthodontics after Phase I treatment. In some cases, it appears that a number of patients and parents are satisfied with the results of the Phase I treatment and do not opt for Phase II treatment despite a suggestion to continue with treatment to finish detailing of the occlusion. There are a multitude of reasons why a patient may choose to discontinue treatment, but it is likely that dental aesthetics plays a large role since it is the primary reason parents and patients seek orthodontic treatment to begin with[1, 3].

DENTAL AESTHETICS AND THE LAYPERSON

Contemporary dental patients are arguably more educated and more discerning than ever, with a keen focus on aesthetic procedures. This is understandable given the influence that physical attractiveness may have on a patient's personal success in life[4-6]. Moreover, it is likely that public awareness of aesthetic dentistry has been increased by the popularity of reality "makeover" television shows and direct-to-consumer advertising featuring "invisible braces" and tooth-whitening products[7].

It appears that the dental industry "has evolved from primarily a health service to a hybrid profession that in some cases is physical health care and in many other cases is an elective cosmetic service."[8] As such, the field of orthodontics has also undergone a paradigm shift towards aesthetically-driven treatment[1] with the realization that patients are more concerned about their appearances than the function of their occlusions. Thus, a thorough understanding of dentofacial aesthetics is of paramount importance to today's orthodontic practitioner.

Several factors have been shown to play a role in the layperson's perception of dentofacial aesthetics: Tooth shape[9-12], tooth size and proportion[11-17], incisor position (including tooth angulation and presence of a diastema)[11-15, 18-24], midline deviation[13, 14, 19, 20, 24-27], gingival display[14, 15, 18-20, 28-31] and morphology[14, 15, 27, 32, 33], smile arc[11, 12, 19, 20, 24, 28, 31, 34, 35], lip thickness[31], and buccal corridors[19, 20, 28, 31, 34-41].

Previous studies have shown that the lay public is able to identify factors that detract from an aesthetic smile, however for they are less critical than dental professionals with regards to some elements.[14, 15, 35, 37] Therefore, it would be valuable to investigate the aesthetic factors that appear to bias laypersons towards discontinuing orthodontic treatment after Phase I treatment.

There is little research[28, 31, 34] examining the relative importance of multiple aesthetic factors and the ways in which they interact to influence the layperson's perspective of dentofacial aesthetics. Furthermore, there appears to be even less information regarding the influence these factors have on a patient's orthodontic treatment decisions.

EVALUATION SCALES IN AESTHETIC DENTAL RESEARCH

There are a number of different ways that a layperson's perspective of dental aesthetics may be measured. Popular methods include Likert scale[16, 18, 19, 21, 24, 25, 27, 29, 30, 33, 42-46], visual analog scale (VAS)[9, 14, 15, 27, 31, 34, 35, 37, 39-41], and selecting or ranking on the basis of preference[10, 12, 13, 17, 22, 28, 32, 38, 47]. Owing to the developments in photographic morphing capabilities, recent studies have measured layperson preferences by allowing survey participants to modify an image to match their preferences[20, 48]. It is likely that this method may be more common in the future.

The VAS is a psychometric scale that is commonly used in questionnaires for pain management and research. It is a means of measuring characteristics or attitudes that are based on a continuum of values that cannot easily be directly measured[49]. Dentofacial aesthetics can be thought of as existing on a continuum in such a manner, ranging from an "unpleasant" smile to a "pleasant" smile. This implies that there are no distinct separate categories between the two ends of the continuum. A VAS is usually a 100 mm horizontal line with descriptive words anchoring each end. Survey respondents mark a vertical line to intersect the VAS at the point they feel represents their reaction to the survey stimulus (e.g., a photograph of a smile). The VAS score, out of 100, is determined by measuring the millimetre distance from the left hand end of the line to the marked point.

A Likert scale is a way of measuring a questionnaire respondent's level of agreement with a statement. The statement is presented, and the respondent is

presented with a range of options, for example: "strongly disagree", "disagree somewhat", "no opinion", "agree somewhat", and "strongly agree". For the purposes of a research in dental aesthetics, the statement may be accompanied with a photograph of a smile, and the selection of options would reflect possible reactions to the photograph, such as: "most unpleasant", "somewhat unpleasant", "no opinion", "somewhat pleasant", "most pleasant".

It is suggested that in terms of sensitivity and reproducibility, the VAS scale is better than a 5-point Likert scale[50]. However, the application of these scales may influence their relative performance and there appears to be no research that compares the sensitivity and reproducibility of these scales with regards to dental aesthetics research.

Rating scales like the Likert scale and VAS are prone to both intentional and unintentional bias. Sources of bias inherent in these scales include: the terms or numbers that label the scales, "forced choice" (i.e., respondents unable to respond with "no opinion" or "don't know"), unbalanced scales (i.e., an uneven number of positive terms versus negative terms or vice versa), order effects (i.e., which terms are on the left versus the right), the direction of comparison (i.e., item "X" compared to item "Y" versus item "Y" compared to item "X"), the number of points, and context effects (i.e., using previous questions to interpret the meaning of a question and/or to determine what the "proper" answer is supposed to be)[51]. Furthermore, survey respondents may demonstrate a central tendency bias, avoiding the extremes of the scales.

Rank ordering of survey stimuli is a less than ideal tool for dental aesthetic research. Ranking forces survey respondents to decide which aesthetic arrangement they prefer, thereby preventing them from assigning the same grade to more than one photograph. As a result, two images that are essentially of equal value in the judge’s opinion must receive different scores. From a statistical point of view, ranking never is independent because each rank can be

used only once. Furthermore, rank-ordered scoring does not reflect real-life scenarios because people do not judge one person's dentofacial esthetics in direct comparison with those of another person.

Since every measurement scale has its own inherent biases, it is virtually impossible to create an unbiased survey; however, it behooves a researcher to counteract these effects whenever possible.

THE XBOW APPLIANCE

Although this study could have been conducted on any population receiving Phase I orthodontic treatment, this study uses a sample of growing patients treated with a Phase I appliance called the Xbow from a private orthodontic practice. The Xbow (pronounced "crossbow", a patented appliance design by Duncan W. Higgins from Delta, BC) consists of a maxillary expansion appliance, a Triple "L" mandibular arch, the Forsus Fatigue Resistant Device (3M Unitek, Monrovia, CA), and Gurin locks (Figures 1-1, 1-2, 1-3). It is indicated for Phase I treatment in the late mixed dentition or early permanent dentition. Treatment during Phase I with the Xbow may also include fixed orthodontic appliances across the maxillary incisors (i.e., a "2x4" treatment) if alignment of these teeth is desired or necessary to provide overjet for Class II correction (Figure 1-4).

Figure 1-1: The Xbow appliance in use intra-orally (lateral view)

Figure 1-2: The Xbow appliance in use intra-orally (maxillary occlusal view)

Figure 1-3: The Xbow appliance in use intra-orally (mandibular occlusal view)

Figure 1-4: The Xbow appliance with "2x4" in use intra-orally (frontal view)

Flores-Mir et al[52] found that Phase I treatment with the Xbow appliance in Class II patients resulted in favorable dental and skeletal changes in the direction of Class II correction. Skeletal changes included a decrease in maxillary protrusion without a mandibular advancement; whereas dental changes included an increase in mandibular incisor protrusion without maxillary incisor movement as well as distalization of the upper molars with mesialization of the lower molars. Treatment length with this approach usually only takes a few months and it is not deemed to fully correct all the skeletal and dental occlusal and aesthetic imbalances.

Phase I treatment with the Xbow may or may not be followed by a Phase II treatment with conventional braces. It appears that a number of patients and parents are satisfied with the occlusal and aesthetic results of the Phase I Xbow treatment and do not opt for Phase II treatment despite a recommendation to continue with treatment. This recommendation is usually based on a goal of attaining final occlusal and aesthetic details.

STATEMENT OF THE PROBLEM

Following any Phase I orthodontic treatment, patients and their families must decide whether or not they would like to continue with a Phase II orthodontic treatment. It is currently unknown which, if any, of the frontal dentofacial aesthetic factors influence this treatment decision.

Photographs of patients after their Phase I treatment with an Xbow appliance will be analysed to measure a series of frontal dentofacial aesthetic factors. The data will be examined in order to discover if there is a link between any of these frontal dentofacial aesthetic factors and a patient's likelihood to proceed to Phase II orthodontic treatment.

RESEARCH OBJECTIVE

- to determine which frontal dentofacial aesthetic factors are associated with the decision to continue onto Phase II orthodontic treatment following Phase I orthodontic treatment with the Xbow appliance.

NULL HYPOTHESIS

- there are no frontal dentofacial aesthetic factors that are significantly associated with the decision to continue onto Phase II orthodontic treatment following Phase I orthodontic treatment with the Xbow appliance.

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Chapter 2: Laypeople's preferences regarding frontal dentofacial aesthetics: Tooth-related factors

(This chapter has been already published in: Witt M, Flores-Mir C. Laypeople's preferences regarding frontal dentofacial esthetics: Tooth-related factors. Journal of the American Dental Association. 2011 Jun;142(6):635-45)

INTRODUCTION

Dental care professionals can change tooth-related aesthetic factors such as position, shape, size and proportion. Researchers have shown that the lay public is able to identify a few factors that have an effect on an aesthetic smile[1-4]; however, they are less critical than are dental care professionals regarding the influence of some of these factors.[5-7] Furthermore, factors such as sex and the facial frame surrounding the teeth appear to affect the lay public's perceptions.[8]

Dentoalveolar esthetics are a popular focus of contemporary dentistry. Inquiry into and understanding of the general public's preferences with regard to dentofacial esthetics are essential to appreciate fully patients' chief concerns, their perceptions of treatment need and their expectations, as well as the way in which their peers will judge their appearances.

Therefore, the objective of this systematic review is to summarize and critique the literature regarding the lay public's aesthetic evaluations of tooth-related factors that influence the anterior region of the mouth.

METHODS

With the assistance of a health sciences reference librarian, we conducted a systematic search of electronic databases (MEDLINE, PubMed, Embase, Cochrane Library and Web of Science) until May 31, 2010. We applied no limits to the electronic searches. Appendices 1 through 5 document the search strategies.

We scrutinized the abstracts of the retrieved reports and identified those that seemed to meet our initial selection criteria of studies in which researchers investigated variables that affect dental esthetics from a layperson's perspective. For articles that did not contain an abstract (except the title, which appeared to be related to the inclusion criteria), we retrieved and reviewed the entire article

before deciding whether to include it. In cases involving differences of opinion, we discussed the article until we reached consensus.

We then obtained the complete articles that met our initial selection criteria and performed the second stage of article selection. We excluded articles at this stage if they

- were descriptive, an editorial or a letter;
- were investigations of facial esthetics only;
- without any dentoalveolar link;
- were investigations of dental esthetics from a lateral aspect rather than from a frontal aspect;
- pertained to denture teeth only or involved drawings or diagrams of teeth;
- required patients to analyze their own dental esthetics;
- did not include identification of the relative contribution of specific variables (such as smile arc, buccal corridor, tooth shape) but combined all variables together in the aesthetic evaluation;
- compared a layperson's aesthetic perspectives with those of another group according to level of agreement only without reporting the layperson's specific opinions.

We selected these criteria with the expectation that they would result in a homogeneous sample of opinions solely from a layperson's perspective regarding another person's dentoalveolar and facial appearance.

We then discussed the articles and resolved any differences of opinion to arrive at a consensus regarding the final selected articles. We then performed a secondary (manual) search by reviewing the reference lists of the selected articles to identify any article that met the initial inclusion criteria but had been missed by the electronic searches.

We then evaluated all selected articles according to criteria shown in Table 2-1 and assigned a methodological score to each report. We need to point out that we did not use scoring to exclude articles from the review. Rather, the purpose of scoring was to enable us to assign relative weights to the studies because of the myriad ways in which they were conducted. We did not validate the selected criteria.

Table 2-1: Criteria for methodological scoring of selected articles

CRITERION	SCORE/POSSIBLE SCORE
No. of Participants (Judges) involved in Evaluation	
<10	1/4
10-29	2/4
30-99	3/4
≥100	4/4
Participant Source	
Not mentioned	1/3
Patients or patients' parents from dental office	2/3
People recruited from a public space (such as a mall or neighborhood)	3/3
Presentation Type	
Patient's full-face photograph	1/6
Patient's perioral photograph	2/6
Patient's intraoral photograph	3/6
Intraoral photograph unchanged except for altered teeth	4/6
Perioral photograph unchanged except for altered teeth	5/6
Full-Face photograph unchanged except for altered teeth	6/6
Viewing Protocol	
Viewing protocol not described	1/4
Participant viewed more than one photograph at a time; participant manipulated a digital photograph to find an acceptable value	2/4
Participant viewed one photograph at a time; multiple viewings of each photograph allowed	3/4
Participant viewed one photograph at a time; no rereviewing allowed	4/4
Intraexaminer Reliability	
No test of reliability mentioned	1/2
Reliability tested (evaluation repeated or photograph viewings repeated in series)	2/2
Scoring Technique	
Rank ordering of available photographs	1/3
"Acceptable" versus "unacceptable	2/3
VAS, Likert scale, or other numerical scoring method	3/3

RESULTS

Although we geared the systematic search to identify all factors that affect perceptions of anterior dental esthetics, this systematic review focuses on four tooth-related factors only: tooth shape, tooth size, tooth proportion and incisor position. We will evaluate other factors that influence a layperson's perception of anterior dental esthetics in future systematic reviews. Examples of these are periodontal factors (midline deviation, smile arc, buccal corridors, occlusal plane orientation and gingival display) and optical factors (tooth shade and translucency).

Appendix 6 indicates the number of results yielded by the searches, the articles selected from the searches on the basis of the abstracts, and the articles that met the final inclusion criteria. Of the articles that met our initial selection criteria, only three were rejected after undergoing a comprehensive review. Researchers in one of these studies investigated only the agreement between different groups of laypeople with respect to their aesthetic perspectives[9]; investigators in one study used dentures as the survey stimulus[10]; and one article was written in Russian and could not be included because of difficulty in finding a translator[11].

Seventeen articles met our inclusion criteria for the systematic review. Table 2-2[2,5,6,12-25] provides a summary of each article that met the inclusion criteria, as well as the methodological scores assigned to them. The highest score assigned to an article was 20 points and the lowest score assigned was 13 points (out of a total of 22 possible points).

Table 2-2: Summary of articles that met inclusion criteria				
STUDY	**LAYPERSON SAMPLE**	**STUDY METHODS**	**RESULTS**	**METHODOLOGICAL SCORE**
Anderson and Colleagues,[12] 2005	102 patients selected randomly from dental college waiting room	Judges evaluated 18 color photographs of a man's or a woman's smiles displayed in a booklet; the booklet of the woman's smiles was created by taking photographs of 18 unique veneer restorations of the six maxillary anterior teeth; the booklet of the man's smiles was created by digitally transferring the photographs of the woman's teeth onto a single male smile; photographs distributed randomly; no mention of judges' rereviewing photographs or of reliability testing; scoring by visual analog scale (VAS) for esthetics	Judges did not discriminate between incisor shapes in photographs of the woman; they preferred square-round incisors to square incisors in photographs of the man; judges did not indicate a preference for canine shape in photographs of the woman; they rated flat canines as more attractive than round or pointed canines when paired with round incisors in photographs of the man	18
Brisman,[13] 1980	160 patients from the greater New York City area	Judges evaluated photographs that differed in terms of tooth shape; photographs presented simultaneously; no mention of reliability testing; scoring based on ranking images with regard to preference in general and preference with regard to one's own dentition	Sixty percent of men preferred so-called masculine square-ovoid central incisors and 40% preferred so-called feminine tapered-ovoid central incisors; 69% of women preferred square-ovoid central incisors and 31% preferred tapered-ovoid central incisors; 58% of men preferred square-ovoid central incisors and 42% preferred tapered-ovoid central incisors for their own dentition; 65% of women preferred square-ovoid central incisors and 35% preferred tapered-ovoid central incisors for their own dentition	13
Carlsson and Colleagues,[14] 1998	254 laypeople (mostly patients) from seven cities across the world	Judges evaluated five sets of frontal full-face photographs of a man and woman that had been altered digitally with respect to tooth size, tooth form, tooth color, smile line or presence of a diastema; all photographs in each set were presented simultaneously; no mention of reliability testing; judges were	Forty-six percent of judges preferred small teeth in photographs of the woman and 44% preferred medium teeth; 57% of judges preferred large teeth in photographs of the man and 38% preferred medium teeth; 56% of judges preferred oval incisors in photographs of the woman and 30% preferred rectangular	16

		asked to select the variation they liked best in each set of photographs	incisors; 71% of judges preferred rectangular incisors in photographs of the man and 23% preferred oval incisors; 96% of judges preferred no maxillary midline diastema in photographs of the woman; 94% of judges preferred no diastema in photographs of the man	
Geron and Atalia,[15] 2005	100 dental patients	Judges evaluated 75 frontal perioral photographs of people smiling and speaking in which the gingival display or tilt of the incisal plane was altered digitally; photographs were distributed randomly; no mention of rereviewing photographs or of reliability testing; scoring on a 10-level Likert aesthetic scale	Judges graded incisal plane tilting as unaesthetic if more than 2° of deviation from the horizontal plane in both clockwise and counter-clockwise directions	18
Gule-e-Erum and Fida,[16] 2008	12 laypeople (orthodontic patients, attendants, others)	Judges evaluated 46 frontal full-face photographs of a male and female model that were altered digitally with respect to buccal corridors, incisal show/lip line, smile arc, midline or axial incisal angulation; no mention of rereviewing photographs; scores invalid if inconsistent with those for contralateral side; scoring on a five level Likert aesthetic scale	Judges rated a 5° axial incisal angulation as unaesthetic in photographs of a male and female model	19
Ker and Colleagues,[17] 2008	243 laypeople from four U.S. cities	Judges evaluated frontal perioral photographs of a sex-neutral face in which numerous aesthetic parameters were modifiable continuously by a computer program; judges manipulated photographs by use of a slider bar; reliability testing done by use of weighted κ values; judges scored photographs by selecting the arrangement that was most acceptable and by selecting the first arrangement that was unacceptable	Maximum tolerable overbite was 5.7 millimeters, ideal overbite was 2.0 mm and minimum tolerable overbite was 0.4 mm; maximum tolerable maxillary central-to lateral step was 2.9 mm, ideal step was 1.4 mm; many judges preferred even incisal edges; maximum tolerable incisal cant was 4°, ideal occlusal cant was 0°	18

King and Colleagues,[18] 2008	40 clerical and research staff members at a dental college	Judges evaluated an animated frontal perioral photograph of a smiling person in which the vertical position of the maxillary lateral incisors was morphed continuously from a position 2.2 mm above the incisal edge of the central incisors to 1.4 mm past the incisal edge of the central incisors; the photograph was modified continuously; each judge took the test six times to determine ideal position and another six times to determine range of acceptability; scoring based on selection of most pleasing lateral incisor position and on selection of range of acceptable lateral incisor positions	Mean upper limit of acceptability for incisal edge of lateral incisor: 1.10 mm apical to incisal edge of central incisor; mean most pleasing position for incisal edge of lateral incisor: 0.61 mm apical to incisal edge of central incisor; mean lower limit of acceptability for incisal edge of lateral incisor: 0.26 mm apical to incisal edge of central incisor	17
Kokich and Colleagues,[5] 1999	74 laypeople from the community	Judges evaluated 40 frontal perioral photographs of smiling people that had been altered digitally in terms of maxillary central incisor crown length, maxillary lateral incisor crown width, maxillary incisor crown angulation, maxillary midline, open gingival embrasure, gingival margin, incisal plane and gingiva-to-lip distance; more than one photograph viewed at one time; no mention of reliability testing; scoring by VAS for attractiveness	Threshold for crown length was 2 mm shorter than ideal maxillary central incisor length; threshold for crown width was 4 mm narrower than ideal maxillary lateral incisor width; threshold for crown angulation was 2 mm from ideal maxillary incisor angulation; threshold for incisal plane cant was 3 mm	15
Kokich and Colleagues,[6] 2006	66 laypeople from the community	Judges evaluated 35 frontal perioral photographs of smiling female models that had been altered digitally in terms of crown length (asymmetrically), crown width (asymmetrically without altered crown length and asymmetrically with proportionally altered crown length), midline diastema, papillary height (with unilateral discrepancy and bilateral discrepancy) and gingiva-to-lip distance; more than one photograph viewed at a	Crown length threshold was a 1.5- to 2.0-mm discrepancy in length of one maxillary central incisor; crown width threshold was a 2.0-mm discrepancy in width of one maxillary lateral incisor; tooth proportion threshold was a 4.0-mm discrepancy in width (with proportionate decrease in height) of one maxillary lateral incisor; maxillary midline diastema threshold was 2.0 mm	15

		time, no reliability testing performed; scoring by VAS for attractiveness		
Ong and Colleagues,[19] 2006	12 non-dentists	Judges evaluated 60 frontal intraoral photographs for various features of teeth and gingivae (tooth alignment, color, shape, size, tooth crown proportions, dentition proportions, gingivae color and contour); all photographs presented simultaneously; interrater reliability testing performed; scoring by five-level Likert aesthetic scale for each component	Golden proportion and golden percentage were not decisive factors in determining dental attractiveness	15
Pinho and Colleagues,[20] 2007	50 university students	Judges evaluated three frontal perioral photographs of smiling female models that had been altered digitally to simulate several degrees of asymmetry of the gingival margin of a maxillary central incisor, wear of a maxillary canine cusp and a dental midline shift; photographs presented randomly; judges not allowed to rereview photographs; no reliability testing performed; scoring by VAS for attractiveness	Judges did not perceive the asymmetric change in the maxillary canine cusp (maximum wear, 2.0 mm)	16
Rodrigues and Colleagues,[21] 2009	20 patients and companions of patients	Judges evaluated perioral and full face photographs of a smiling person altered digitally to create four variations (3-mm maxillary midline deviation, 10° distal axial inclination of maxillary lateral incisors, 1-mm maxillary midline diastema and reverse smile arc); photograph sets (perioral or full face) presented in random order; all photographs in each set presented simultaneously; no mention of reliability testing; scoring by rank ordering followed by 10-level Likert aesthetic scale	Judges rated full-face and perioral photographs with maxillary midline diastemas as significantly less attractive; judges found no significant difference between full-face photographs with and without 10° distal axial inclination of maxillary lateral incisors or between perioral photographs with and without 10° inclination of maxillary lateral incisors	16
Rosenstiel and Rashid,[2] 2002	1,934 laypeople (contacted by mass	Judges evaluated frontal perioral and full-face photographs of smiling people altered digitally to create five variations (absence of incisal embrasures, midline	Ninety percent of judges preferred no diastema in comparison with a 0.5-mm diastema; younger judges, women and whites had stronger opinions against a	17

	unsolicited e-mail)	diastema, increased tooth whiteness, altered anterior tooth proportion and midline discrepancy); photographs presented in pairs; no mention of reliability testing; scoring by comparison of paired images and selecting the preferred image	diastema; 30% of judges (the largest group) had no preference for the golden proportion over teeth with normal proportions; 61.5% of judges preferred natural (unworn) incisal embrasures over straight (worn) incisal embrasures	
Thomas and Colleagues,[2] 2003	50 laypeople (patients, parents and nondental staff of the Harvard Dental Center, Boston)	Judges evaluated frontal full-face photographs of a smiling man and woman in which the maxillary dental midline had been altered digitally to the left and right at 5°, 10°, 15° and 20° angles from the facial midline; photographs presented separately in predetermined order; judges not allowed to rereview photographs; photographs repeated during test for reliability; scoring on a five-level Likert aesthetic scale and judges asked whether or not the smile was acceptable	Mean acceptable threshold for photograph of the male model was 10.7° ± 6.28°; mean acceptable threshold for photograph of the female model was 10.0° ± 6.18°; discrepancies of 10° were unacceptable to 41% of laypeople; neither the direction of the deviation nor dominant hand of the judge had a statistically significant effect on perceived attractiveness of person in the photograph	20
Wagner and Colleagues,[23] 1996	63 laypeople (mostly dental patients)	Judges evaluated five sets of full-face frontal photographs of a man and woman that had been altered digitally with respect to tooth size, tooth form, tooth color, smile line or presence of a diastema; all photographs in each set presented simultaneously; no mention of reliability testing; judges asked to select the variation they liked best in each set of photographs	Sixty-five percent of judges preferred small teeth in photograph of the woman and 17% preferred medium teeth; 46% of judges preferred large teeth in photograph of the man and 44% preferred medium teeth; 45% of judges preferred oval teeth in photograph of the woman and 44% preferred rectangular teeth; 66% of judges preferred rectangular teeth in photograph of the man and 31% preferred oval teeth; 95% of judges preferred no maxillary midline diastema in photograph of the woman; 91% of judges preferred no diastema in photograph of the man	15
Wolfart and Colleagues,[24] 2005	30 medical students	Judges evaluated one of four sets of intraoral photographs in which the central and lateral incisor angulations had been altered digitally (both symmetrically and asymmetrically); all photographs	Judges rated symmetrical teeth with ideal axes and changes in angulation of one or both lateral incisors as more attractive than changes in angulation of one or both central incisors; no significant difference	15

		presented simultaneously; reliability tested by repeating the evaluation; judges scored photographs by ranking them from most to least attractive	found between the symmetrical image with ideal angulations and the image in which the angulation of both lateral incisors was altered	
Wolfart and Colleagues,[25] 2004	179 patients	Judges evaluated 32 frontal perioral photographs of smiling people that had been altered digitally by varying width-to-length ratios of central incisors or by varying tooth-to-tooth proportions between the lateral and central incisor; all photographs presented simultaneously; no mention of reliability testing; scoring by ranking all images on one VAS for attractiveness	Width-to-length ratios of the central incisors between 75% and 85% were most aesthetic; tooth-to-tooth proportions between the lateral and central incisors of 50% to 74% were most aesthetic	15

DISCUSSION

***Methodological scoring*.** Apart from a few studies conducted by the same authors, the studies described in the selected articles used unique methodologies. As a result, direct comparison of the studies' results and conclusions was cumbersome. Consequently, we assigned methodological scores on the basis of specific criteria to facilitate our comparison of the studies' conclusions.

We penalized some studies for not including pertinent information, which may have been the result of space limitations imposed by the journal. Therefore, we attempted to contact the authors of these articles to clarify some points. We believe that the opinions of fewer than 10 laypeople are unlikely to represent those of the general public. However, it is difficult to determine the point at which the sample size becomes representative of the general public. None of the investigators in our selected studies stated how they calculated the sample size to have adequate statistical power. Thus, the range of scores is arbitrary, and we assigned higher scores to studies that included a greater number of judges.

Few articles mentioned the population from which the researchers recruited the sample of laypeople and whether they did this in a random fashion. When assigning scores to the articles, we took into consideration the type of laypeople participating in the studies. We decided that laypeople should be selected randomly from a public setting (such as a shopping mall, airport, neighborhood) because their opinions more likely would represent those of the general public. We awarded higher scores to articles in which the authors attempted to sample the general public in this manner. Participants in samples drawn from dental patient pools might have an enhanced awareness of, or education about, dentofacial aesthetic issues; therefore, they may not be representative of the general public. If this is true, the downside of valuing the opinions of the general public over those of dental patients is that dentally educated patients may

express dissatisfaction with treatment objectives that reflect the views of laypeople drawn randomly from a public setting.

Studies varied widely in terms of the presentation of photographs to laypeople (that is, judges), but we found six general types. We weighted intraoral views higher than perioral views, which, in turn, we weighted more highly than full-face views. We decided to keep to a minimum the influence of extraoral variability in photographs, because specific features, such as facial form, face and hair color, and sex, may influence the layperson's perception of the dental esthetics.[8]

With the advent of software programs to manipulate digital photographs, it is possible to alter specific dental features such as the midline, buccal corridors and gingival display while keeping other facial features constant, thereby eliminating the variability in photographs. The majority of studies involved some degree of digital manipulation of photographs.[2,5,6,12-25] However, the degree of realism that can be achieved depends on the skill of the operator performing the manipulation, and it is possible that some of the generated images were not realistic.

Several investigators justified the use of digitally altered perioral photographs rather than full-face photographs because they believed that perioral photographs focus the judges' attention on the dental esthetics and remove confounding variables.[5,6,18,20,26] However, this approach is not entirely realistic; a person's smile almost certainly will be judged within a frame that includes his or her face.[8] Because investigators are able to alter the dentition while keeping the lips, nose, chin, eyes and hair constant, we believe that it is advantageous to make use of this ability to create the most realistic scenario possible. For this reason, we assigned higher scores to studies in which the investigators digitally altered dentitions in full-face photographs while keeping other facial features constant.

The viewing procedures used in each study also varied substantially. Investigators in some studies allowed judges (that is, laypeople) to examine more than one photograph at a time with multiple viewings, while a few investigators allowed judges to view only one photograph at a time and allowed only one viewing of each photograph. The latter is a more accurate representation of real-life situations, as one typically is unable to view a person's smile while comparing it directly with someone else's smile. In addition, typically one does not have the opportunity to view a smile repeatedly within a short time span.

In the studies in which more than one photograph was presented at a time, the judges may have been able to deduce what was being tested and, thus, were biased in their decision making. In one study,[25] the investigators presented more than one photograph at a time with the intention that judges would be able to identify the small aesthetic differences in the photographs. In another study,[2] the researchers posed questions that pointed specifically to the differences between photographs. In studies in which judges were able to modify a variable continuously (for example, maxillary central to lateral step) by using a slider bar, they definitely were able to identify the variable being tested.[17] In these situations, participants were not masked and we assigned a lower score to these studies to reflect this weakness. Likewise, we assigned lower scores to studies that did not mention whether judges were permitted to rereview photographs and revise their scores.

In many of the studies, investigators did not report having conducted intra-examiner reliability testing by repeating the entire test at a later date or by presenting photographs more than once during a single test. Therefore, the results of these studies may not consistently reflect the opinions of the general public, and we assigned lower scores to them.

Judges scored aesthetic appearance in one or more of three ways:

- rank ordered the photographs;
- stated whether the photograph was acceptable or unacceptable;
- assigned a score via a Likert scale or a visual analog scale (VAS).

Each of these methods has its advantages and disadvantages.

Rank ordering. From a statistical point of view, ranking never is independent because each rank can be used only once. Rank ordering forces judges to decide which aesthetic arrangement they prefer, thereby preventing them from assigning the same grade to more than one photograph. As a result, two images that are essentially of equal value in the judge's opinion must receive different scores. Furthermore, rank-ordered scoring does not reflect real-life scenarios because people do not judge one person's dentofacial esthetics in direct comparison with those of another person.

Acceptable or unacceptable. We preferred studies that required judges to state whether a photograph was acceptable or unacceptable over those that used rank-ordered scoring, because they allowed the judges to express tolerance regarding aesthetic deviation. However, this approach is limited by the possibility that marginally acceptable dentofacial appearances received the same "acceptable" score as did ideal dentofacial appearances.

Likert scale and VAS. In this systematic review, the study authors' preferred method of scoring was via a Likert scale or VAS. These methods allowed judges to give the same score to more than one photograph, which is important in determining a layperson's sensitivity to unaesthetic dentofacial arrangements. Unfortunately, judges might not have used either extreme of the scale, resulting in a tendency to score toward the middle of the scale. This method of scoring might have been problematic in studies in which judges were not allowed to rereview photographs and revise their scores. To illustrate, if a judge awarded the highest possible score to one of the first images presented, he or she could

not award a higher score to any subsequent images, even if he or she deemed them worthy of a higher score. In two studies,[27,28] judges received several warm-up photographs before the scoring procedure to familiarize them with the range of dentofacial appearances; this may have helped the researchers control for the limitation inherent in scoring scales.

Tooth shape. For laypeople, tooth shape may be one of the most important variables determining dental attractiveness.[19] In four of the articles in our systematic review, researchers investigated tooth shape preferences among laypeople.[12-14,23] Anderson and colleagues[12] found that laypeople did not discriminate between square, square-round and round incisors when displayed in photographs of a female model, but they preferred square-round incisors to square incisors in photographs of a male model. With regard to canine shape, laypeople did not express a preference in photographs of a female model, but they found flat canines more attractive than round or pointed canines when paired with round incisors in photographs of a male model.[12] The lack of strong opinions regarding canine shape is supported by the finding in the study by Pinho and colleagues[20] that laypeople failed to notice 2.0 mm of unilateral wear on one maxillary canine.

The findings of Brisman[13] were similar to those of Anderson and colleagues[12] in that male judges preferred square-ovoid central incisors to tapered-ovoid incisors. Brisman[13] also found that female judges favored square-ovoid central incisors. This study was flawed, however, because the photograph of the tapered-ovoid incisors showed more irregularities in tooth position and less gingival display than did other tooth shapes in other photographs.

These findings are in contrast to those of Carlsson and colleagues[14] and Wagner and colleagues,[23] who found that laypeople preferred oval incisors in photographs of a female model and rectangular incisors in photographs of a male model. However, these findings might be attributed to the fact that the

investigators in the two studies did not present photographs displaying a square-round or square-ovoid tooth as an intermediate shape. Also, the investigators used the same photographs and questionnaires with different populations of judges, so it is somewhat understandable that their conclusions were the same.

Investigators in only one study[2] assessed laypeople's preference for tooth shape with regard to tooth wear and incisal embrasures. They found that laypeople preferred "natural" (unworn) incisal embrasures to "straight" (worn) incisal embrasures.

Among the studies investigating tooth shape, the study by Anderson and colleagues[12] received the highest methodological score, and the authors presented photographs displaying a range of square, square-round, and round incisors. Thus, it is likely that the results of this study represent the best data regarding tooth shape preferences. It appears that laypeople do not discriminate between square, square-round, and round incisors or between canine shapes when displayed in photographs of female models, but they prefer square-round incisors to square incisors and flat canines (when paired with round incisors) in photographs of male models. Furthermore, laypeople appear to prefer unworn dentitions, but only one study[2] investigated this variable.

Tooth size and proportion. Carlsson and colleagues[14] and Wagner and colleagues[23] conducted nearly identical studies of tooth size. In both studies, the majority of laypeople preferred small teeth to medium teeth in photographs of a female model, with only a small percentage of respondents preferring large teeth. In photographs of a male model, the majority of judges preferred large teeth to medium teeth, with only a small percentage preferring small teeth. It is important to note that tooth sizes were relative, as the researchers did not provide any actual measurements of small, medium and large teeth.

Researchers in five studies investigated tooth proportion.[2,5,6,19,24] Golden proportion does not appear to have been a decisive factor in determining dental

attractiveness from a layperson's perspective.[2,19] Wolfart and colleagues[24] reported that laypeople preferred width-to-length ratios of between 75 and 85 percent for the central incisors and tooth-to-tooth proportions of between 50 and 74 percent between the lateral and central incisors.

Kokich and colleagues[5] reported that laypeople detected variations in crown width and height among individual teeth, and they identified as unaesthetic maxillary central incisors that were 2.0 mm shorter than the ideal height and lateral incisors that were 4.0 mm narrower than the ideal width. This sensitivity increased when the crown lengths or widths were altered asymmetrically; laypeople identified a unilateral central incisor shortening of 1.5 to 2.0 mm and a unilateral lateral incisor narrowing of 2.0 mm as unesthetic.[6]

However, if the unilateral decrease in width of a lateral incisor was accompanied by a proportionate decrease in height, laypeople did not identify the change as unaesthetic until the crown was 4.0 mm narrower than the ideal width. These results reinforce the importance of symmetry and proportion to achieve harmonious smiles.[24,29]

These data indicate that judges preferred small teeth in photographs of female models and large teeth in photographs of male models. Thus, proportion appears to be important to laypeople. They detected variations in crown width or height among individual teeth, especially when the variation was unilateral. However, this sensitivity decreased when ideal crown proportions were maintained.

Incisor position. Incisor position consists of the vertical, horizontal and angular positions of the incisors. More broadly, incisor position also can describe the relationship between incisors such as the incisal plane cant, the relationship of the lateral and central incisal edges, overbite and the presence or absence of a diastema. Researchers in six studies[5,15-17,22,25] investigated laypeople's

perceptions of anterior incisal angulation, either as a group (that is, a canted occlusal plane) or with regard to individual teeth.

Ker and colleagues[17] investigated laypeople's perspectives regarding an ideal occlusal plane cant and found it to be 0°. Other researchers investigated the ability of laypeople to identify changes in the incisal plane; the results of these studies show a range of acceptability that varied from 2° to 5° of canting.[15,16] Gul-e-Erum and Fida[16] used relatively large increments (0°, 2.5° and 5°) of incisal plane canting. They reported that laypeople in their study discerned a 5° incisal plane cant. However, Ker and colleagues[17] and Geron and colleagues[15] used smaller increments, and their findings suggest that laypeople can identify smaller degrees of canting (4° and 2°, respectively). Thus, it is likely that laypeople are able to discern incisal plane cants between 2° and 5° as unaesthetic.

Kokich and colleagues[5] investigated laypeople's ability to discern incisal plane canting; however, they measured the alteration in terms of 1-millimeter–increment rotations around a point located at the incisal embrasures between the central incisors. It is unclear why they used a linear value to measure an alteration generally regarded as an angular variable. In their study, laypeople rated a 3-mm rotation as unaesthetic; however, because of the way in which incisal canting was measured, this finding is difficult to compare with those of other studies.

Researchers in three studies investigated the effect of angulation of the maxillary central incisors on esthetics.[5,22,25] Kokich and colleagues[5] reported that laypeople rated a 2-mm angulation of the maxillary incisors as unaesthetic. Again, we face the same difficulty comparing these data with those of other studies because the authors used millimeter measurements rather than angular measurements.

Wolfart and colleagues[25] altered symmetrically and asymmetrically the angulation of central and lateral crowns by 10°. They observed that laypeople preferred images of symmetrical teeth with ideal axes (with canine, lateral and

central incisors diverging by a maximum of ±2°) and images in which the lateral incisor angulations were changed (unilaterally or bilaterally) by 10°. They rated as less attractive images in which the angulation of one or both central incisors had been altered, indicating that a smile must be more symmetrical nearer the midline to appear harmonious. The findings of this study were supported by those of Thomas and colleagues,[22] who observed that midline angulations of 10° were unacceptable to 41 percent of laypeople. In another study, laypeople did not notice a 10° distal angulation of the lateral incisors, which supports the supposition that they are less aware of aesthetic deviations that are farther from the midline.[21]

Researchers in two studies[17,18] investigated laypeople's preferences regarding the relationship between the central and lateral incisal edges (that is, the maxillary central to lateral step). Both studies used continuously modifiable variables but with different methods. Judges in the study conducted by Ker and colleagues[17] used a slider bar to modify the images, whereas King and colleagues[18] used an animated photograph in which the length of the lateral incisors increased until the judges stopped it at the desired relationship.

Ker and colleagues[17] found that the maximum tolerable step was 2.9 mm, with the ideal step being 1.4 mm. They noted, however, that many laypeople preferred even incisal edge relationships, so it may be prudent for practitioners to ask patients what they prefer. These findings differed from those of King and colleagues,[18] who found a maximum tolerable step of 1.10 mm, an ideal step of 0.61 mm and a minimum tolerable step of 0.26 mm. The methodology used by Ker and colleagues[17] might have generated more accurate results because it did not rely on judges' reaction time and judges were able to fine-tune their responses. Furthermore, in the study by King and colleagues,[18] the length of the lateral incisors increased without proportionate changes in crown width, which may have influenced the judges' perception of esthetics. Therefore, the findings

of the study by Ker and colleagues[17] likely represent the best current data regarding laypeople's perceptions of the relationships between the incisal edges of the maxillary central and lateral incisors.

Only one study[17] investigated laypeople's preferences regarding overbite. The results show that the ideal overbite was 2.0 mm, while the maximum and minimum tolerable values were 5.7 mm and 0.4 mm, respectively. Clearly, further studies are required to elucidate laypeople's preferences regarding overbite.

Investigators in five studies examined laypeople's attitudes toward maxillary midline diastemas.[2,6,14,21,23] Rosenstiel and Rashid,[2] Carlsson and colleagues[14] and Wagner and colleagues[23] reported that more than 90 percent of respondents found images of diastemas unaesthetic. Younger judges, women, and whites had stronger opinions against diastemas.[2,21] Rodrigues and colleagues[21] reported that a diastema of 1 mm was noticeable when presented in a full-face or perioral photograph; however, Kokich and colleagues[6] found that laypeople did not notice diastemas in a perioral photograph unless they were 2.0 mm or larger. Although the overwhelming majority of laypeople found a diastema unaesthetic, they found them somewhat more acceptable in photographs of men than in photographs of women.[14,23]

It appears that laypeople are able to discern an incisal plane cant of between 2° and 5° as unaesthetic, and they are able to discern a 10° angulation of one or both central incisors as being less attractive than a 2° angulation. The majority of laypeople preferred a 1.4-mm step between the incisal edges of maxillary central and lateral incisors but tolerated a maximum step of 2.9 mm; however, many laypeople preferred even incisal-edge relationships. Judges in one study preferred an overbite of 2.0 mm, but they tolerated a maximum overbite of 5.7 mm and a minimum overbite of 0.4 mm. Most laypeople preferred dentitions

without diastemas; however, diastemas tended to go unnoticed if they were smaller than 2.0 mm.

CONCLUSIONS

The results of this systematic review show that most laypeople did not discriminate between square, square-round and round incisors or canine shapes when displayed in photographs of female models, but they preferred square-round incisors to square incisors and flat canines (when paired with round incisors) when displayed in photographs of male models. In addition, laypeople preferred unworn dentitions and small teeth in images of female models and large teeth in images of male models. Most laypeople appeared to prefer width-to-length ratios of between 75 and 85 percent in the central incisors and tooth-to-tooth proportions of between 50 and 74 percent between the lateral and central incisors. They also detected variations in crown width or height among individual teeth, especially when the variation was unilateral. Laypeople's sensitivity to variations in crown width or height appears to be diminished when the variation maintains ideal crown proportions and when the variation is not in the midline.

The study results also show that laypeople discerned a 10° angulation of one or both central incisors as being less attractive than a 2° angulation. The majority of laypeople preferred a 1.4-mm step between the incisal edges of maxillary central and lateral incisors, but they tolerated a maximum step of 2.9 mm. However, many laypeople preferred even incisal-edge relationships. In addition, according to the results of one study,[17] they preferred an overbite of 2.0 mm and tolerated maximum and minimum overbites of 5.7 mm and 0.4 mm, respectively. They also preferred no diastemas and tended to notice a diastema larger than 1 mm.

Laypeople have varying degrees of sensitivity to certain dental aesthetic issues. Consequently, clinicians can expect their patients to be more attentive to some aesthetic factors than to others.

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Chapter 3: Laypeople's preferences regarding frontal dentofacial esthetics: Periodontal factors

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INTRODUCTION

Dental care professionals should not underestimate the importance of dentofacial esthetics. Dental esthetics appears to be associated with a person's self-confidence and may be an important aspect of one's overall physical attractiveness, which might be correlated with career and social success.[1-3]

General practitioners and specialists have some level of control over aesthetic factors such as midline deviation, smile arc, buccal corridors and gingival display. The results of previous studies have shown that the lay public is able to identify factors that detract from an aesthetic smile;[4-7] however, they are less critical than are dental care professionals with regard to the effect of some of these factors.[8-10] Furthermore, the lay public's awareness of dental aesthetic issues appears to be influenced by the viewer's sex and the way in which the dentition is framed (that is, the extent of the surrounding structures shown).[11]

Thus, a comprehensive understanding of the general public's preferences with regard to dentofacial esthetics is essential to appreciate fully patients' chief concerns, their perceptions of the need for treatment, their expectations of treatment and the ways in which their peers will evaluate their appearance. Therefore, our objective in this systematic review was to summarize and critique the literature regarding the lay public's aesthetic evaluation of factors such as midline deviation, smile arc, buccal corridors and gingival display.

METHODS

With the assistance of a health sciences reference librarian, we conducted a systematic search of electronic databases (MEDLINE, PubMed, Embase, Cochrane Library and Web of Science) until May 31, 2010. Appendix 1 documents the search strategy (involving the use of Boolean operators) we used in MEDLINE, and appendices 2 through 5 document an adapted version of this

strategy that we used for the other databases. We applied no limits to the electronic searches, and we identified and removed all duplicate results.

We scrutinized the abstracts of the retrieved reports and identified those that seemed to meet our initial selection criteria of studies in which researchers investigated variables that affect dental esthetics from a layperson's perspective. For articles that did not contain an abstract but whose title appeared to be related to the inclusion criteria, we retrieved and reviewed the complete article before making a decision. In cases involving differences of opinion, we discussed the report until we reached consensus.

We then obtained the full articles that met the initial selection criteria and performed the second stage of article selection. We excluded articles at this stage if they

- were descriptive, an editorial or a letter;
- were investigations of facial esthetics only, without any dentoalveolar link;
- were investigations of dental esthetics from a lateral aspect rather than from a frontal aspect;
- pertained to denture teeth only or involved drawings or diagrams of teeth;
- involved patients analyzing their own dental esthetics;
- did not include identification of the relative contribution of specific variables (such as smile arc, buccal corridor, tooth shape) but combined all variables together in the aesthetic evaluation;
- did not describe laypeople's perspectives but merely reported the level of agreement with another group (usually dental care professionals).

We chose our inclusion and exclusion criteria with the expectation that the resulting group of selected studies would yield a sample of opinions regarding

another person's dentoalveolar/facial appearance that were solely from a layperson's perspective and that had been analyzed by study investigators according to specific aesthetic characteristics.

We discussed the articles and resolved any discrepancies to arrive at a consensus regarding the final selections. After selecting the articles, we performed a secondary manual search in which we reviewed the reference lists of the selected articles to identify any report that met the initial inclusion criteria but had been missed in the electronic searches.

We then evaluated all selected articles according to criteria shown in Table 3-1[12] and assigned a methodological score to each report. We need to point out that we did not use scoring to exclude reports from the review. Rather, the purpose of scoring was to allow us to assign relative weights to the studies because of the myriad ways in which they were conducted. We did not validate the selected criteria.

RESULTS

Although we geared our systematic search to identify all factors that affect perceptions of anterior dental esthetics, this review focused on periodontal factors only: midline deviation, gingival and incisal display, smile arc and buccal corridors. We analyzed inherent tooth-related factors in a previous review.[12]

Appendices 1-6 document the number of results yielded by the searches, the articles selected from the searches on the basis of the abstracts and the articles that met the final inclusion criteria. Of the articles that met our initial selection criteria, only three were rejected after undergoing a comprehensive review. Researchers in one of these studies investigated only the agreement between different groups of laypeople[13] with respect to their aesthetic perspectives;

Table 3-1: Criteria for methodological scoring of selected articles	
CRITERION	**SCORE/POSSIBLE SCORE**
No. of Participants (Judges) involved in Evaluation	
<10	1/4
10-29	2/4
30-99	3/4
≥100	4/4
Participant Source	
Not mentioned	1/3
Patients or patients' parents from dental office	2/3
People recruited from a public space (such as a mall or neighborhood)	3/3
Presentation Type	
Patient's full-face photograph	1/6
Patient's perioral photograph	2/6
Patient's intraoral photograph	3/6
Intraoral photograph unchanged except for altered teeth	4/6
Perioral photograph unchanged except for altered teeth	5/6
Full-Face photograph unchanged except for altered teeth	6/6
Viewing Protocol	
Viewing protocol not described	1/4
Participant viewed more than one photograph at a time; participant manipulated a digital photograph to find an acceptable value	2/4
Participant viewed one photograph at a time; multiple viewings of each photograph allowed	3/4
Participant viewed one photograph at a time; no rereviewing allowed	4/4
Intraexaminer Reliability	
No test of reliability mentioned	1/2
Reliability tested (evaluation repeated or photograph viewings repeated in series)	2/2
Scoring Technique	
Rank ordering of available photographs	1/3
"Acceptable" versus "unacceptable	2/3
VAS, Likert scale, or other numerical scoring method	3/3

researchers in one study used denture teeth as the survey stimulus[14]; and one article was written in Russian and could not be included because of difficulty in finding a translator.[15]

Thirty-two articles met our inclusion criteria for the systematic review. Table 3-2[4-10,16-40] presents a summary of each article that met the inclusion criteria, as well as the methodological scores assigned to them. The highest score assigned to an article was 21 points, the lowest score assigned was 9 points, and the mean score was 15.9 points (of a total of 22 possible points).

Table 3-2: Summary of articles that met inclusion criteria				
STUDY	**LAYPERSON SAMPLE**	**STUDY METHODS**	**RESULTS**	**METHODOLOGICAL SCORE**
An and Colleagues,[16] 2009	500 patients from perio-dontal clinic	Judges evaluated frontal intraoral photographs that were altered digitally in terms of relative gingival marginal levels of lateral incisors, gingival margin shape of the central incisor or inter proximal contact length; all photographs were presented simultaneously; no reliability testing; scoring by rank order according to aesthetic preference	Judges preferred gingival margin of lateral incisor that was 0.5 millimeters coronal to that of central incisor; judges preferred a gingival zenith with intermediate "flatness" and an interproximal contact (and papillae) length that was two-thirds of the crown length	14
Beyer and Lindauer,[17] 1998	30 parents, 30 adolescent patients	Judges evaluated eight frontal full-faced photographs of a smiling man and woman with digitally altered midline deviations ranging between 0 and 4.9 mm; photographs presented in predetermined sequence; participants not allowed to rereview photographs; photographs repeated for reliability testing; photographs scored as "acceptable" or "not acceptable"	Adolescent judges tolerated a mean (± standard deviation) maxillary midline deviation of 2.80 ± 1.23 mm (male photograph) and 2.43 ± 0.99 mm (female photograph); adult judges tolerated 2.48 ± 0.86 mm (male photograph) and 2.02 ± 0.88 mm (female photograph)	19
Carlsson and Colleagues,[18] 1998	254 laypeople (mostly patients) from seven cities around the world	Judges evaluated two sets of five images in which full frontal photographs of a man and woman had been altered digitally in terms of tooth size, tooth form, tooth color, smile line or presence of diastema; all photographs in each set presented simultaneously; no mention of reliability testing; judges asked to select the variation they liked best in each set of photographs	Seventy-four percent of judges preferred a consonant smile arc in women, 21% preferred a flat smile arc in women; 56% of judges preferred a consonant smile arc in men, 39% preferred a flat smile arc in men	16
Dunn and Colleagues,[19] 1996	297 laypeople from military base and surrounding community	Judges evaluated perioral photographs of eight smiling men and eight smiling women that had been evaluated by a panel of dentists for independent variables of shade, natural versus restored teeth, width of teeth displayed, smile	Number of teeth displayed an important factor in perceived smile attractiveness; variables of symmetry and height of lip line were found to contribute the least in predicting perceived attractiveness	13

		symmetry and height of lip line; all photographs were presented simultaneously; no mention of reliability testing; participants scored photographs by ranking them from most to least attractive		
Geron and Atalia,[20] 2005	100 dental patients	Judges evaluated 75 frontal perioral photographs of people smiling and speaking in which the gingival display or tilt of incisal plane was altered digitally; photographs distributed randomly; no mention of rereviewing photographs or of reliability testing; scoring on a 10-level Likert aesthetic scale	Highest mean score for image with lip coverage of about 0.5 mm of maxillary central incisors' crowns and about 2.0 mm of mandibular central incisors' crowns; the most attractive images of people speaking were those with about 0-2.0 mm of lip coverage of maxillary central incisors' crowns and 1.0-2.6 mm of lip coverage of mandibular central incisors' crowns; maxillary gingival exposure during smiling and speaking graded in the aesthetic range up to 1.0 mm; aesthetic range for mandibular incisors was no gingival exposure at all; judges scored images as less attractive as the amount of upper and lower gingival display increased during smiling and speaking	18
Gracco and Colleagues,[21] 2006	1,275 laypeople (no mention of source)	Judges evaluated three digitally altered frontal perioral photographs of smiling people: one with minimal corridors (18.46% of smile width), another with large corridors (31.08%) and a third with moderate corridors (24.77%); all three photographs were presented simultaneously; no mention of reliability testing; scored by ranking the three photographs from most to least attractive	Eight hundred thirty-eight judges (65.72%) preferred minimal corridors, 91 (7.13%) preferred evident corridors, 346 (27.14%) preferred moderate corridors; homogeneous distribution of results among age groups; 67% of male judges and 66% of female judges chose decreased buccal corridors	14
Gul-e-Erum and Fida,[22] 2008	12 laypeople (orthodontic patients, attendants,	Judges evaluated 46 frontal full-face photographs of a man and woman that were altered digitally for buccal corridors, incisal show/lip line, smile arc, midline or axial incisal angulation; no mention	Maxillary midline deviation (maximum 2.0 mm) not rated as unattractive in the photograph of the man; midline deviation (1.0 or 2.0 mm) rated as unattractive in the photograph of the	19

	others)	of rereviewing photographs; scores invalid if inconsistent with contralateral side; scoring on five-level Likert aesthetic scale	woman; zero gingival display with zero incisal coverage preferred in the photograph of the man; incisal display with 2.0-mm gingival display preferred in the photograph of the woman; flat smile arc preferred in the photograph of the man; flat smile arc and consonant smile arc preferred almost equally in the photograph of the woman; broad smile with no lateral negative space preferred in the photograph of the man; 10% buccal corridor preferred in the photograph of the woman	
Hulsey,[23] 1970	20 laypeople (no mention of source)	Judges evaluated frontal perioral photographs of 10 smiling men and 10 smiling women after treatment and 10 frontal perioral photographs of 10 smiling men and 10 smiling women before treatment; photographs were analyzed for independent variables of smile arc, symmetry, buccal corridors, upper lip height and upper lip curvature; all 40 photographs were presented simultaneously; reliability tested by repeating evaluation; judges scored photographs by distributing them among five categories ranging from “poor” to “excellent,” with no more than eight photographs allowed in each category	Judges rated the most attractive smiles as those with upper lip height at the gingival margin of the upper incisor; upper lip curvature most desirable when corners of the mouth were above the midline of the upper lip; photographs with consonant smile arcs were rated higher than those without; buccal corridors appeared to be of no significance with respect to an attractive smile; no images of patients with asymmetrical smiles received high scores	11
Hunt and Colleagues,[24] 2002	120 university students	Judges evaluated 14 frontal full-face photographs of smiling men and women (seven each) with nonideal dentition in which the gingival display was altered digitally from −2 mm to +4 mm; photographs presented randomly; judges not allowed to rereview photographs; no mention of reliability testing; scoring on a 10-level Likert aesthetic scale	Judges gave highest ratings to images of smiles with zero gingival display; attractiveness ratings were higher for images of smiles in which the amount of gingival display was −2 to +2 mm; attractiveness scores decreased substantially when gingival display was 3 mm or more	21

Isiksal and Colleagues,[25] 2006	10 parents	Judges evaluated frontal and three-fourths frontal perioral photographs of 25 smiling patients who underwent extraction of premolars, 25 patients who did not undergo extraction of premolars and 25 untreated control patients; judges were allowed to rereview photographs; investigators conducted reliability testing by repeating the test two months later; scoring on a five level Likert aesthetic scale	Judges did not differentiate photographs showing ideal occlusions from those of patients with Class I malocclusion treated with or without premolar extraction with respect to smile esthetics	14
Jahanbin and Pezeshkirad,[26] 2008	Two laypeople (no mention of source)	Judges evaluated perioral photographs of 30 smiling women who underwent orthodontic treatment without tooth extraction and of 33 untreated women with normal occlusion; photographs presented randomly; judges were not allowed to rereview photographs; investigators conducted reliability testing by repeating test five weeks later; scoring on a 100-level Likert aesthetic scale	Judges did not perceive any difference in upper lip thickness between the treated and untreated groups; upper lip height had no effect on smile ratings	13
Johnson and Smith,[27] 1995	10 laypeople (from personal contacts)	Judges evaluated frontal perioral photographs of 15 smiling male patients who underwent extraction, 15 smiling male patients who did not undergo extraction, 15 smiling female patients who underwent extraction and 15 smiling female patients who did not undergo extraction; all 60 photographs presented simultaneously; reliability tested by repeating the evaluation; scoring on a five-level Likert aesthetic scale and ranking photographs accordingly	Study results showed no predictable relationship between extraction of premolars and perceived smile esthetics (such as buccal corridors)	14
Johnston and Colleagues,[4] 1999	20 university students	Judges evaluated a frontal full-face photograph of a smiling woman in which the dental midline was altered digitally 1.0, 2.0, 4.0, 6.0 or 8.0 mm to the right or left of the facial midline; photographs	No sex differences in sensitivity to midline discrepancy; discrepancies greater than 2.0 mm predicted to be rated as less attractive by more than 56% of randomly selected laypeople;	19

		presented randomly; judges not allowed to rereview photographs; no mention of reliability testing; scoring on a 10-level Likert aesthetic scale	discrepancies of 4.0 mm predicted to be rated as less attractive by 93% of randomly selected laypeople	
Ker and Colleagues,[28] 2008	243 laypeople from four U.S. cities	Judges evaluated frontal perioral photographs of smiling people in which numerous aesthetic parameters were modified continuously by a computer program; judges manipulated photographs by using a slider bar; reliability testing done via use of weighted κ values; judges scored images by selecting the arrangement of parameters that was most acceptable and by selecting the minimum and maximum tolerable values	Maximum tolerable maxillary midline deviation 2.9 mm from facial midline, ideal deviation coincident with facial midline; maximum tolerable gingival display 3.6 mm, ideal incisal coverage 2.1 mm, maximum tolerable incisal coverage 4.0 mm; maximum tolerable maxillary central incisor gingival height discrepancy 2.0 mm, ideal 0 mm; maximum tolerable maxillary lateral incisor gingival height 1.2 mm apical to central incisor gingival zenith, ideal 0.4 mm coronal to central incisor gingival zenith, minimum tolerable 2.9 mm coronal to central incisor gingival zenith; maximum tolerable smile arc is second molars 8.5 mm and canines 3.3 mm above the central incisal edge, ideal smile arc consonant with lip, minimum smile arc is second molars 2.3 mm and canines 1.2 mm apical to central incisal edge; maximum tolerable buccal corridor 16.0 mm (22% of smile), ideal buccal corridor 11.6 mm (16% of smile), minimum tolerable buccal corridor 5.8 mm (8% of smile)	18
Kerns and Colleagues,[29] 1997	57 non-orthodontic dental patients	Judges evaluated post treatment frontal perioral photographs of six smiling people; all photographs presented simultaneously; no mention of reliability testing; scoring on a seven-level Likert aesthetic scale; judges also noted which factor contributed most to the score (that is, amount of teeth showing, lips or chin)	Amount of teeth showing had greater influence (58.43%) on scores than did lips (33.71%) or chin (7.87%)	13

Kim and Gianelly,[30] 2003	50 laypeople (no mention of source)	Judges evaluated frontal perioral photographs of 12 smiling patients who underwent extraction of premolars and of 12 smiling patients who did not undergo extraction of premolars; judges allowed to rereview photographs and revise scores; no mention of reliability testing; evaluation on a 10-level Likert aesthetic scale; judges also asked to indicate the factors they considered when arriving at scores	Study results showed no significant difference in mean aesthetic score between extraction and nonextraction groups	13
Kokich and Colleagues,[8] 1999	74 laypeople from the community	Judges evaluated 40 frontal perioral photographs of smiling people that had been altered digitally in terms of maxillary central incisor crown length, maxillary lateral crown width, maxillary incisor crown angulation, maxillary midline deviation, open gingival embrasure, gingival margin, incisal plane, incisal coverage/display and gingival display; judges viewed more than one photograph at a time; no mention of reliability testing; scoring by visual analog scale (VAS) for attractiveness	Judges did not note a maxillary midline deviation of 4.0 mm (maximum deviation); gingival display threshold of 4.0 mm; judges did not note an absence of gingival display; open gingival embrasure threshold of 3.0 mm between central incisors; judges did not note a gingival height deviation of 2.0 mm at the maxillary lateral incisors	15
Kokich and Colleagues,[9] 2006	66 laypeople from the community	Judges evaluated 35 frontal perioral photographs of smiling people that had been altered digitally in terms of crown length (asymmetrically), crown width (asymmetrically without altered crown length and with proportionally altered crown length), midline diastema, papillary height (with unilateral asymmetry and bilateral symmetry) and gingiva to lip distance; more than one photograph visible at once; no reliability testing; scoring by VAS for attractiveness	Gingival display threshold of 3.0 mm; judges did not detect unilateral decreased papillary height of 2.0 mm (maximum discrepancy) between a central incisor and a lateral incisor; bilateral papillary height threshold 1.5-mm decrease between all maxillary anterior teeth	15
Krishnan and Colleagues,[31] 2008	10 laypeople (people accompanying	Judges evaluated frontal perioral photographs of 30 smiling untreated men and 30 smiling untreated women; photographs presented	All 14 of the highest ranked photographs of women had consonant smile arcs; high correlation between right and left buccal	14

	dental patients)	randomly; judges not allowed to rereview photographs during scoring; no reliability testing; scoring by VAS for attractiveness	corridor spaces but low correlation between attractiveness ratings in photographs of men and women	
LaVacca and Colleagues,[32] 2005	50 laypeople (25 orthodontic patients, 25 prosthodontic patients)	Judges evaluated frontal perioral photographs of smiling people that had been altered digitally in terms of interdental papilla height and crown shape anterior to and exclusive of the first premolars in a symmetrical fashion; photographs viewed one at a time in several different sequences; judges not allowed to rereview photographs; photographs repeated during test for reliability; scoring on a six-level Likert aesthetic scale	Judges did not identify increases in papilla length of 3 mm or decreases of 2.0 mm as being unaesthetic compared with control images	19
Mackley,[33] 1993	Six parents (whose children had not received orthodontic treatment)	Judges evaluated 168 pre-treatment and post treatment frontal and three-fourths profile full-face photographs of smiling patients for attractiveness of smile, maxillary incisor torque and protrusiveness of teeth; frontal photograph viewed before profile photograph (otherwise not described); no mention of reliability testing; scoring on a five-level Likert aesthetic scale	Images that were judged as having the most attractive smiles had lip lines close to or at the gingival margin of the maxillary central incisors	9
Martin and Colleagues,[10] 2007	94 laypeople (patients from dental school waiting room, people at airports, friends and family)	Judges evaluated frontal perioral photographs of smiling women in which the number of teeth displayed and buccal corridors were altered digitally (symmetrically and asymmetrically); more than one photograph viewed at a time; photographs repeated for reliability testing; scoring by VAS for attractiveness	Judges preferred small or no buccal corridors; buccal corridor ratio was more important than was symmetry in determining smile attractiveness; no differences in buccal corridor ratings between sex or age groups; judges rated smiles displaying second premolar to second premolar as most attractive, but ratings did not differ significantly from those for smiles displaying first molar to first molar	17
McNamara and Colleagues,[34]	30 laypeople from a public	Judges evaluated 60 frontal perioral pre-treatment photographs of smiling people	No significant correlation between incisogingival display and smile esthetics; upper	14

2008	space	obtained from video footage; all photographs were viewed simultaneously; no reliability testing; scoring by VAS for attractiveness	lip height correlated positively with smile esthetics; height of upper lip one of two variables that accounted mostly for discrimination between smiles rated as pleasant or unpleasant; lower lip height correlated positively with smile esthetics; no significant correlation between smile arc and smile esthetics; no significant correlation between size of buccal corridors and smile esthetics	
Moore and Colleagues,[6] 2005	30 university staff members	Judges evaluated paired frontal full-face photographs of a smiling person in which the buccal corridors had been altered digitally; photographs presented in pairs; reliability testing conducted by presenting identical pairs; scoring by adding or subtracting points depending on judge's preference for a given image when paired with another image	2% buccal corridors (broad smile fullness) rated highest, followed by 10% buccal corridors (medium broad), 15% buccal corridors (medium) and 22% buccal corridors (medium narrow); 28% buccal corridors (narrow) rated least attractive; no significant differences in judges' evaluations of smile attractiveness according to varying levels of smile fullness between photographs of men and women or between male and female judges	19
Parekh and Colleagues,[7] 2006	115 laypeople from the general public	Judges evaluated digitally altered frontal perioral photographs of smiling people in which combinations of three smile arc variations (flat, ideal, excessive) and buccal corridor variations (none, ideal, excessive) were used to create nine female and nine male images; photographs were distributed randomly; judges did not rereview photographs; photographs repeated during test for reliability; scoring by VAS for attractiveness	Excessive buccal corridors and flat smile arcs in images of men and women rated as less attractive; flat smile arcs received overwhelmingly lower attractiveness ratings regardless of buccal corridors	21
Parekh and Colleagues,[35] 2007	115 laypeople from the general public	Judges evaluated digitally altered frontal perioral photographs of smiling people in which combinations of three smile arc variations (flat, ideal, excessive) and buccal corridor variations	Excessive buccal corridors rated as less acceptable than ideal and absent buccal corridors but still acceptable more than 70% of the time; flat smile arcs, regardless of buccal	21

		(none, ideal, excessive) were used to create nine female and nine male images; photographs distributed randomly; judges did not rereview photographs; photographs repeated for reliability testing; scoring by VAS for attractiveness and whether the smile was acceptable or not	corridor display, acceptable only 50% to 60% of the time; ideal and excessive smile arcs, regardless of buccal corridor display, acceptable 84% to 95% of the time	
Pinho and Colleagues,[36] 2007	50 university students	Judges evaluated three frontal perioral photographs of smiling women altered digitally to simulate several degrees of asymmetry of the gingival margin of a maxillary central incisor, wear of a maxillary canine cusp and a dental midline shift; photographs presented randomly; judges not allowed to rereview photographs; no reliability testing; scoring by VAS for attractiveness	Judges did not perceive midline shifts (maximum 4.0 mm) but perceived discrepancies in gingival height of 2.0 mm or greater	16
Ritter and Colleagues,[37] 2006	Two laypeople from a public space	Judges evaluated 60 frontal perioral photographs of 30 smiling men and 30 smiling women; no rereviewing of photographs; photographs repeated for reliability testing; scoring by VAS for attractiveness	Buccal corridors did not influence judges' aesthetic evaluations of photographs	15
Roden-Johnson and Colleagues,[38] 2005	20 laypeople (no mention of source)	Judges evaluated frontal perioral photographs of 20 smiling women after treatment and 10 smiling untreated women altered digitally to include buccal corridors (if absent) or not to include buccal corridors (if present) for a total of 60 images; presented randomly; judges not allowed to rereview photographs; no mention of reliability testing; scoring by VAS for attractiveness	Presence or absence of buccal corridors had no effect on judges' smile ratings	16
Rodrigues and Colleagues,[39] 2009	20 patients and companions of patients	Judges evaluated perioral and full-face photographs of one man whose teeth were altered digitally to create four variations (3-mm maxillary midline deviation, 10° distal axial	No significant differences in judges' evaluations of full-face and perioral photographs of maxillary midline deviation and reverse smile arc compared with those of the ideal control	16

		inclination of maxillary lateral incisors, 1-mm maxillary midline diastema and reverse smile arc); random selection of photograph set (perioral or full face) presented first; all photographs within each set presented simultaneously; no mention of reliability testing; scoring by rank ordering followed by use of a 10-level Likert aesthetic scale	smile	
Rosenstiel and Rashid,[5] 2002	1,934 laypeople (contacted via mass unsolicited e-mail)	Judges evaluated frontal perioral and full-face photographs of teeth altered digitally to create five variations (absence of incisal embrasures, midline diastema, increased tooth whiteness, altered anterior tooth proportion and midline discrepancy); photographs presented in pairs; no mention of reliability testing; scoring by comparing paired images and selecting the preferred image	Almost 80% of judges preferred the image without the 3-mm midline deviation	17
Wagner and Colleagues,[40] 1996	63 laypeople (mostly dental patients)	Judges evaluated five sets of images in which full frontal photographs of a man and woman had been altered digitally in terms of tooth size, tooth form, tooth color, smile line or presence of diastema; all photographs in each set presented simultaneously; no mention of reliability testing; judges asked to select the variation they liked best within each set of photographs	Eighty-three percent of judges preferred a consonant smile arc in photographs of women, 11% preferred a flat smile arc; 64% of judges preferred a consonant smile arc in photographs of men, 34% preferred a flat smile arc	15

DISCUSSION

Midline deviation. Investigators in eight of the studies[4,5,8,17,22,28,36,39] assessed midline deviation. The methodological scores were relatively high in these studies; the studies by Beyer and Lindauer[17] and Johnston and colleagues[4] received 19 points each. The findings of these studies appeared to be influenced substantially by the methods and materials; in studies in which the researchers used full-face photographs, laypeople were more sensitive to midline deviations. This is not surprising, because the position of the nose, eyes and chin are important cues for perception of the facial midline with which the dental midline is compared. Researchers in one study[39] presented both a full-face photograph and a perioral photograph to participants and found that they were not sensitive to midline deviations with either framing method.

In three of the studies in which investigators used perioral photographs, laypeople did not detect a maximum maxillary midline deviation of 3.0 to 4.0 millimeters.[8,36,39] Ker and colleagues[28] also used a perioral photograph; however, the participants were able to modify a computer generated maxillary midline by using a slider bar and, thus, were aware of the deviation. In that study, laypeople tolerated a maximum deviation of 2.9 mm, but they preferred a maxillary midline that was coincident with the facial midline. Similarly, for the mandibular midline, laypeople tolerated a maximum deviation of 2.1 mm, but they preferred a midline that was coincident with the maxillary midline.

In contrast to the studies by Kokich and colleagues,[8,9] Pinho and colleagues[36] and Rodrigues and colleagues,[39] investigators in studies that presented full-face photographs with maxillary midline deviations found that laypeople were able to identify midline discrepancies of less than 4.0 mm. Laypeople in three studies[4,5,17] reported that they found midline discrepancies between 2.0 and 3.0 mm to be unaesthetic. In one study, participants were even able to detect midline discrepancies of less than 2.0 mm.[22] However, in another study,[39]

laypeople were unable to detect a midline discrepancy of 3.0 mm in a full-face photograph. It appears that a 3.0-mm maxillary midline deviation is near the threshold of aesthetic acceptance, which may explain why participants in the study by Rodrigues and colleagues[39] did not notice the deviation.

It is important to note that Johnston and colleagues[4] assessed midline deviations in increments of 1.0, 2.0, 4.0, 6.0 and 8.0 mm, which arguably are too large in light of the fact that previous study results have shown that laypeople are able to identify a 3.0-mm deviation when presented in a full-face photograph.[4,17]

Nevertheless, studies in which researchers used full-face photographs tended to receive higher methodological scores than did those in which researchers used perioral photographs; thus, the findings of the former studies likely are a more accurate representation of laypeople's tolerances to midline deviations.

Although laypeople appeared to be able to detect dental midline deviations of less than 3.0 mm, they were not necessarily aware of deviations of up to 4.0 mm when shown images of only the immediate perioral region. However, when made aware of midline deviations, they preferred those that were coincident with each other and with the facial midline.

Gingival display and architecture. Gingival display during smiling is of particular interest to researchers, with investigators in nine of the studies examining these parameters.[8,9,20,22-24,28,33,34] Ker and colleagues[28] reported the greatest aesthetic range, with laypeople tolerating between 4.0 mm of incisal coverage by the upper lip and 3.6 mm of maxillary gingival display. Aesthetic ranges reported in other studies varied from 0 to 2.0 mm of upper incisor coverage (that is, no maxillary gingival display)[20] and from 2.0 mm of upper incisor coverage to 2.0 mm of maxillary gingival display.[8,24] Researchers[34] in only one study found no correlation between gingival display and smile esthetics.

The study by Ker and colleagues[28] was the only one in which modifications to gingival and incisal displays were continuous (that is, via digital manipulation with a slider bar). Investigators in other studies either did not present the same range of gingival and incisal display or did so by using larger increments that the participants rejected.

The effect of increment size is demonstrated in the studies by Kokich and colleagues.[8,9] In one study, laypeople identified a gingival display of 4.0 mm as unaesthetic; the gingival display varied in increments of 2.0 mm above and below the labial gingival margin of the central incisors.[8] In a follow-up study, laypeople identified a gingival display of 3.0 mm as unaesthetic; the gingival display varied in increments of 1.0 mm above the labial gingival margin of the central incisors.[9] This gingival display threshold of 3.0 mm is in agreement with the findings of Hunt and colleagues.[24] However, laypeople in one study graded a gingival display of greater than 1.0 mm as outside the aesthetic range.[20]

Investigators in three studies[22,23,33] described laypeople as preferring the upper lip height to be at the gingival margin of the maxillary central incisors. This description is in agreement with the study findings of Hunt and colleagues,[24] who reported that participants rated photographs with zero gingival display and zero incisal coverage as most attractive. It is important to note that researchers in three of these studies[23,24,33] used photographs of patients and those in one of these studies[22] used digitally altered photographs with non-ideal dentitions (as opposed to digitally altered “ideal” dentitions). It is possible that the dentition had some influence on laypeople’s perceptions of gingival display, resulting in their stated preference for zero gingival display.

Ker and colleagues[28] conducted a study in which laypeople used a slider bar to modify the image. The authors reported an ideal incisal coverage of 2.1 mm. This value is greater than that reported by investigators in most other studies. For example, in the study by Geron and Atalia,[20] participants gave the highest score

to an image with 0.5 mm of lip coverage of the maxillary central incisors. It is unlikely that this difference was due to the effects of incremental values, because Geron and Atalia[20] included an image with incisal coverage of 2.0 mm. However, the laypeople in their study preferred the image that demonstrated approximately 0.5 mm of gingival display. Again, it is possible that the dentition used in each study influenced the outcomes, because the teeth in the study by Ker and colleagues[28] differed from those in the study by Geron and Atalia[20] in terms of such variables as shape, size and proportion. For example, if the gingival margin architecture in the photographs presented by Geron and Atalia[20] did not appeal to the participants, they may have preferred that this feature be covered by the upper lip.

Gingival morphology. Researchers in six studies investigated variations in the morphology of gingivae and their influence on a layperson's perception of dental esthetics.[8,9,16,28,32,36] Most laypeople accepted a discrepancy in gingival heights between central incisors of up to 2.0 mm, but they preferred an absence of gingival height discrepancy.[28,36]

Researchers reported that most laypeople preferred the gingival zenith of the lateral incisor to reach a point 0.4 to 0.5 mm coronal to the gingival zenith of the central incisor.[16,28] However, they tolerated lateral gingival zeniths that lie between a point 1.2 mm above and 2.9 mm below the gingival zenith of the central incisor.[28] This finding is reinforced by the results of a study by Kokich and colleagues,[9] who demonstrated that most laypeople did not notice a bilateral 2.0-mm decrease in gingival height at the lateral incisors. These results may indicate that laypeople are less sensitive to changes that are symmetrical and farther away from the midline.

Kokich and colleagues[8] reported that laypeople noticed a 3.0-mm open embrasure (a so-called black triangle) between the maxillary central incisors. However, they did not notice a discrepancy in interdental papillary height of 2.0

mm between a central and a lateral incisor.[9] In the same study,[9] participants rated a 1.5-mm decrease in papillary height between all anterior teeth as unaesthetic. It is difficult to explain why participants in this study were more sensitive to a symmetrical decrease in papillary height than they were to a unilateral decrease in papillary height, because laypeople tend to be more critical of unilateral alterations than of bilateral alterations.[9] Perhaps this finding is due to the fact that the decrease in bilateral papillary height between all anterior teeth altered the shape of the teeth mesially and distally, giving them an unaesthetic square emergence profile, whereas in the case of the unilateral decrease in papillary height, only the mesial aspect of the lateral incisor and the distal aspect of the central incisor were altered, and this change may have been much less obvious.

In a study by An and colleagues,[16] laypeople expressed a preference for papillary heights that were two-thirds of the crown length. However, these findings are contradicted by those of a study that received a higher methodological score; LaVacca and colleagues[32] concluded that laypeople were unable to identify bilateral alterations in papillary heights as unaesthetic.

We found only one study in which investigators assessed the actual contour of the gingival zenith; the results showed that laypeople preferred a gingival zenith with intermediate flatness, which was not too broad or too narrow.[16]

Gingival display is related intimately to the shape and position of the lips that frame the teeth and gingivae. Thus, it is important to note the ways in which lips affect dental esthetics. Investigators in four studies[19,23,26,34] commented on the influence of lips on laypeople's perception of dental esthetics. The results of two of these studies[23,34] indicate that the height of the upper and lower lips are correlated positively with smile esthetics, and the upper lip curvature was most attractive when the corners of the mouth were above the midline of the upper lip. These findings are in contrast to those of Dunn and colleagues,[19] who

reported that the variables of symmetry and height of the lip line were least important in predicting perceived attractiveness. It is possible that the relatively small number of photographs presented in this study[19] (16, versus 60 photographs in the study by McNamara and colleagues[34]) did not allow for enough variation in lip morphology to show any correlation with dental esthetics. Investigators in another study,[26] in which only two laypeople evaluated images, found that upper lip thickness had no effect on the smile ratings. However, owing to the small number of evaluators, the study's conclusions are questionable with regard to laypeople's preferences.

The majority of evidence from our literature review suggests that laypeople prefer no gingival display, with the upper lip height at the gingival margin of the maxillary central incisors. However, they seem to tolerate a range of values—from 4.0 mm of maxillary central incisor coverage to 3.6 mm of maxillary gingival display. Our review of the literature also revealed that laypeople are sensitive to some, but not all, changes to gingival architecture. It seems that laypeople's perception of the ideal gingival display may be influenced by the dentition with which the gingivae are displayed, as well as by the lips that frame them.

Smile arc. Authors of nine of the included articles investigated laypeople's evaluation of the smile arc.[7,18,22,23,28,34,35,39,40] In most of these studies, the researchers found that laypeople preferred smile arcs that are consonant with the contour of the lower lip to those that are "reverse" or "flat." However, participants were more likely to accept flat smile arcs in men than in women.[18,40] Reverse smile arcs appear to be least attractive to laypeople.[18,39,40]

The results of two studies did not show a preference among laypeople for consonant smile arcs. McNamara and colleagues[34] found no significant correlation between the smile arc and smile esthetics, whereas Gul-e-Erum and Fida[22] reported a preference for flat smile arcs in men and an almost equal preference for flat and consonant smile arcs in women.

Ker and colleagues[28] described a range of smile arcs that were acceptable to laypeople. They found that the maximum tolerable smile arc was one in which the second molars were 8.5 mm above the central incisor edge and the canines were 3.3 mm above the central incisor edge. The minimum tolerable smile arc was one in which the second molars were 2.3 mm above the central incisor edge and the canines were 1.2 mm apical to the central incisor edge.

The data also suggest that the smile arc has a greater impact on esthetics than do buccal corridors; a flat smile arc can decrease attractiveness ratings overwhelmingly, regardless of the buccal corridors, and an ideal smile arc appears to be acceptable regardless of the buccal corridors.[7,35] Given the level of agreement in the literature, it is apparent that laypeople prefer consonant smile arcs in both men and women, but they tolerate flat smile arcs in men more than they do in women.

Buccal corridors. Authors in 12 of the articles investigated laypeople's preferences for buccal corridor size.[6,7,10,21-23,28,31,34,35,37,38] Most authors defined the buccal corridors or visible dentition as a percentage of the oral aperture width; however, some simply described the buccal corridors or smile width (for example, broad, medium, narrow). As a result of these differences in descriptions of buccal corridors given to laypeople, it is somewhat difficult for us to compare the study results. As a result of this lack of standardization across studies with respect to buccal corridor size, narrow buccal corridors in one study may have been the same size as broad buccal corridors in another study.

The majority of study findings indicated a preference among laypeople for small or absent buccal corridors.[6,7,10,21,22,35] This correlates with the finding that the number of teeth displayed is an important factor in predicting perceived dental attractiveness.[19,29] Although it appears that laypeople preferred small or absent buccal corridors, Parekh and colleagues[35] reported that more than 70 percent of laypeople found "excessive" buccal corridors (that is, 14 percent of the smile

width in photographs of women and 19 percent in photographs of men) acceptable. This finding is not surprising given that laypeople in other studies did not consider a 14 or 19 percent buccal corridor excessive.[6,10,21] Because of the variability across studies in the definition of minimal buccal corridors, the preferred minimal values among laypeople ranged from 0 percent to approximately 18 percent of the smile width.[10,21]

Ker and colleagues[28] defined the maximum tolerable, minimum tolerable and ideal buccal corridors as 22 percent, 8 percent and 16 percent of the smile width, respectively, on the basis of participants' preferences. Sex may have an influence on laypeoples' perception of buccal corridors, as researchers in one study[22] found that laypeople preferred no buccal corridors in a photograph of a man and 10 percent buccal corridors in a photograph of a woman. In contrast, Moore and colleagues6 and Parekh and colleagues[7,35] found no significant difference in laypeople's evaluations of photographs of men and women with varying levels of smile fullness.

Researchers in five studies found no influence of buccal corridors on laypeople's perceptions of smile esthetics.[23,31,34,37,38] Investigators in four of these five studies used patients' photographs rather than a digitally altered photograph.[23,31,34,37] It is possible that these patients' buccal corridors were not sufficiently large to have affected the judges' opinions. With digitally altered photographs, however, it is possible to exaggerate buccal corridors to elicit a response from the evaluators. In addition, it is possible that the variability inherent in patients' photographs (such as differences in soft tissues and tooth shape) may have affected the judges' perceptions of the buccal corridors.

Furthermore, the sample in one of these studies consisted of only two judges and, thus, it is unlikely that the results reflect the opinions of the general public.[37] Another study was conducted 40 years ago, and aesthetic preferences may have changed across time.[23] Roden-Johnson and colleagues[38] conducted a

study in which laypeople compared a collection of images consisting of one digitally altered and one unaltered photograph of 20 women who underwent orthodontic treatment and of 10 women who did not undergo treatment. The results showed no influence of buccal corridors on the judges' smile ratings. Again, it may be that the buccal corridors were not sufficiently large to have elicited a response from the judges. Although the purpose of this study was to compare altered and unaltered photographs of the same patient, it is possible that the variability among the photographs of 30 patients (for example, differences in tooth shape) was enough to affect the judges' ability to perceive changes in the buccal corridor.

Researchers in three studies investigated the effect of premolar extraction on a layperson's perception of buccal corridors and dental esthetics.[25,27,30] All of the researchers reported that they observed no predictable relationship between premolar extractions, perception of buccal corridors and smile esthetics as rated by laypeople.

The data obtained from our review of the literature suggest that laypeople prefer minimal buccal corridors, rating images that showed the least lateral negative space as most attractive. However, the definition of minimal varies from study to study (from 0 to 18 percent of the smile); thus, it is difficult to define quantitatively. Premolar extraction does not appear to predictably affect laypeople's perception of buccal corridors or dental esthetics.

Authors' note. Some factors such as ethnicity, sex, viewer's perspective and facial attractiveness in the full-face images have not been explored fully to date, and they may play a significant role in laypeople's preferences regarding frontal dentofacial esthetics.

CONCLUSIONS

The results of this systematic review show that laypeople appeared to be able to detect dental midline deviations of less than 3.0 mm, but when made aware of midlines, they preferred those that are coincident with each other and with the facial midline. The majority of laypeople preferred no gingival display, with the upper lip height at the gingival margin of the maxillary central incisors. The study results indicate an aesthetic range—from 4.0 mm of maxillary central incisor coverage to 3.6 mm of gingival display—that laypeople tolerated. Most judges preferred that the gingival zeniths of the lateral incisors be positioned 0.4 to 0.5 mm coronal to the gingival zeniths of the central incisors. They also were sensitive to some changes to the gingival architecture. The ideal gingival display and architecture from a layperson's perspective may be influenced by the dentition with which the gingivae are displayed, as well as by the lips that frame them. Laypeople preferred consonant smile arcs in photographs of both men and women, but they tolerated flat smile arcs in men more than they did in women. They also preferred minimal buccal corridors, rating images that showed the least lateral negative space as most attractive. Extraction of premolars does not appear to predictably affect laypeople's perceptions of buccal corridors or dental esthetics.

Laypeople have varying degrees of sensitivity to certain aesthetic issues. Consequently, clinicians can expect their patients to be more attentive to some dental aesthetic factors than they are to others.

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Chapter 4: Analysis of Anterior Dentofacial Aesthetic Characteristics and their Association to Post-Phase I Orthodontic Treatment Decisions

INTRODUCTION

Non-compliance correction of Class II malocclusions is a technique of growing interest in orthodontics[1]. The Xbow (pronounced "crossbow", a patented appliance design by Duncan W. Higgins from Delta, BC) consists of a maxillary expansion appliance, a Triple "L" mandibular arch, the Forsus Fatigue Resistant Device (3M Unitek, Monrovia, CA), and Gurin locks. It is indicated for Phase I treatment in the late mixed dentition or early permanent dentition. Treatment during this Phase I may also include fixed orthodontic appliances across the maxillary incisors (i.e., a "2x4" treatment) if alignment of these teeth is desired or necessary to provide overjet for Class II correction.

Flores-Mir et al[2] found that Phase I treatment with the Xbow appliance in Class II patients resulted in favorable dental and skeletal changes in the direction of Class II correction. Skeletal changes included a decrease in maxillary protrusion without a mandibular advancement; whereas dental changes included an increase in mandibular incisor protrusion without maxillary incisor movement as well as distalization of the upper molars with mesialization of the lower molars. Treatment length with this approach usually only takes a few months and it is not deemed to fully correct all the skeletal and dental occlusal and aesthetic imbalances.

Phase I treatment with the Xbow may or may not be followed by a Phase II treatment with conventional braces. It appears that a number of patients and parents are satisfied with the occlusal and aesthetic results of the Phase I Xbow treatment and do not opt for Phase II treatment despite a recommendation to continue with treatment. This recommendation is usually based on a goal of attaining final occlusal and aesthetic details. Previous studies[3-6] have shown that the lay public is able to identify factors that detract from an aesthetic smile; however, they are far less critical than dental professionals with regards to some of those elements[7-9].

Tooth shape[10-13], tooth size and proportion[5, 7, 8, 12-15], incisor position (including tooth angulation and presence of a diastema)[5, 7, 8, 12, 13, 16-22], midline deviation[4, 5, 7, 17, 18, 22-24], gingival display[7, 8, 16-18, 25-28] and morphology[7, 8, 24, 29, 30], smile arc[3, 12, 13, 17, 18, 22, 25, 28, 31], buccal corridors[3, 6, 9, 17, 18, 25, 28, 31-35] are important factors for frontal dentofacial aesthetics from the layperson perspective. Studies investigating these factors are typically survey-based, with laypeople ranking or scoring a number of frontal photographs of smiling patients. In the majority of cases, photographs are either selected or modified such that only one parameter varies between the different photographs presented as survey stimuli. Only a few studies[25, 28, 31] have attempted to analyze multiple factors simultaneously to determine their relative influence on the layperson's perception of dental aesthetics. Moreover, there is limited research investigating how these various factors influence a patient's decisions regarding orthodontic treatment.

It can be hypothesized that patients that decide not to undergo a Phase II orthodontic treatment may be completely satisfied with the final attained occlusion even though the treating orthodontist suggests otherwise. Therefore, it would be valuable to investigate if there are identifiable dentofacial and perioral aesthetic factors that bias laypeople towards discontinuing treatment after Phase I treatment.

METHODS

Study Sample

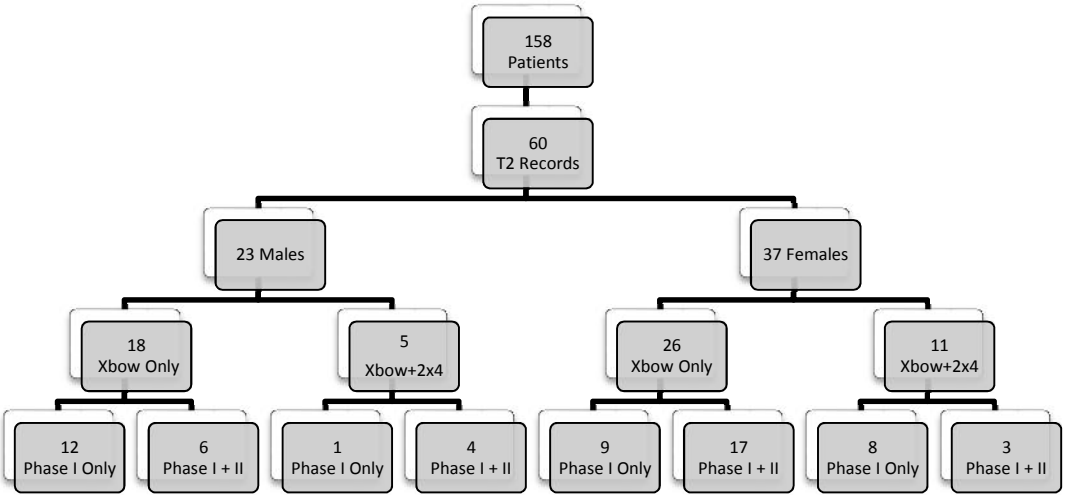
The treatment sample was obtained from the private practice of Dr. Duncan W. Higgins and included all patients consecutively treated with the Xbow appliance that had dental casts and post-treatment (T2) digital frontal photographs of their smiles.

Photographs were taken at f-stop 9.5 and ISO 200 using a Fuji Fine Pix S3 Pro (Fujifilm Canada, Mississauga, ON, Canada) equipped with a Nikon 60mm lens and SU-800 Nikon Wireless Speedlight Commander (Nikon Canada, Mississauga,

ON, Canada). Ideally, the patient photographs would be taken in maximum smile but there was no way to retroactively determine if the smiles captured in the photographs were demonstrations of maximum smile, a natural smile, or a forced smile. Patients were excluded from the study if their smiling photographs depicted smiles that did not display the majority of the maxillary incisors because measurements of the teeth and gingiva would not be possible. For each patient, it was noted if a 2x4 fixed appliance was used during Phase I and if Phase II treatment was administered, however no information regarding age, treatment time, or reason for not continuing treatment was recorded.

A total of 158 patients had been treated with the Xbow appliance. Unfortunately, only 60 of the 158 patients in this pool had T2 records available. The private practice from which the records were obtained does not routinely take post-Phase I photographs of patients that are proceeding to Phase II treatment. Furthermore, a number of patients not proceeding with Phase II treatment did not show up for their post-Phase I treatment records. The final sample included 30 patients that did undergo Phase II orthodontic treatment and 30 that did not. Details of the study sample population are illustrated in Figure 4-1 (note that this is a description of the sample, not an allocation tree).

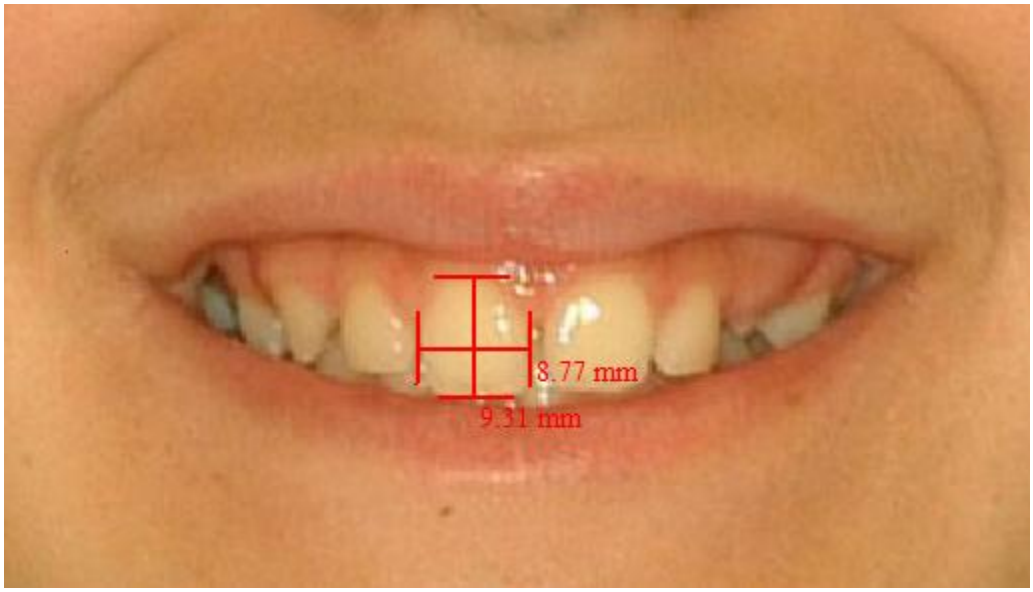
Figure 4-1: Study Sample Details



The width of the patients' maxillary right central incisors were measured on dental casts using a Max-Cal electronic digital caliper (Fowler Canada, Brantford, Ontario, Canada) for the calibration of measurements performed in the photographs. Patient photographs were cropped vertically (between the columella and the superior portion of the mental protuberance) and horizontally (between the inferior portions of the nasiolabial sulci) without distorting the proportions of the teeth and lips.

Using Kodak Orthodontic Imaging Software (Carestream Dental LLC, Atlanta, Georgia, USA) a number of easily measured and previously reported aesthetically important[36, 37] dental and peri-dental factors were measured from both the T1 and T2 photographs of each patient. The width of each patient's maxillary right central incisor was input into the software to calibrate the measurements. Measurements taken using the imaging software were recorded as continuous variables in mm or degrees with two decimals. Distribution histograms for each measurement can be found in Appendix 7.

Figure 4-2: Width and height measurements for tooth 1.1



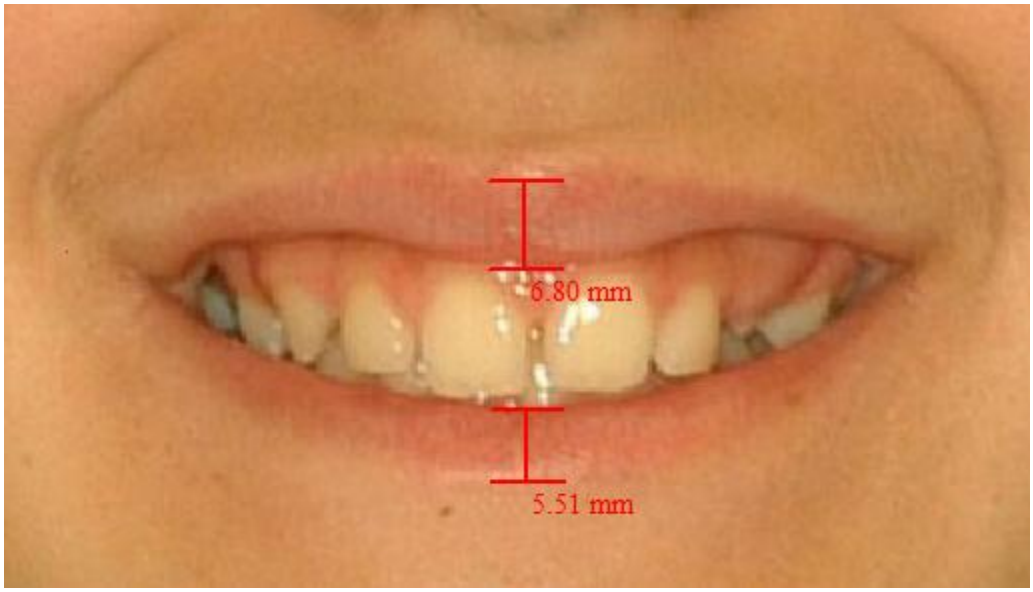
Height and Width Measurements

Using the calibrated photographs, height (H) and width (W) measurements were taken for the upper right and left central and lateral incisors (Figure 4-2). These values are identified as "1.2 W", "1.2 H", "1.1 W", "1.1 H", "2.1 W", "2.1 H", "2.2 W", and "2.2 H".

Tooth Proportions

Using the height and width measurements of the upper incisors (Figure 4-2), the width:height ratios were determined for each incisor. These values are identified as "1.2 WH", "1.1 WH", "2.1 WH", and "2.2 WH". Tooth width:width proportions between the central and ipsilateral lateral incisors were also determined. These values are identified as "1.2/1.1" and "2.2/2.1".

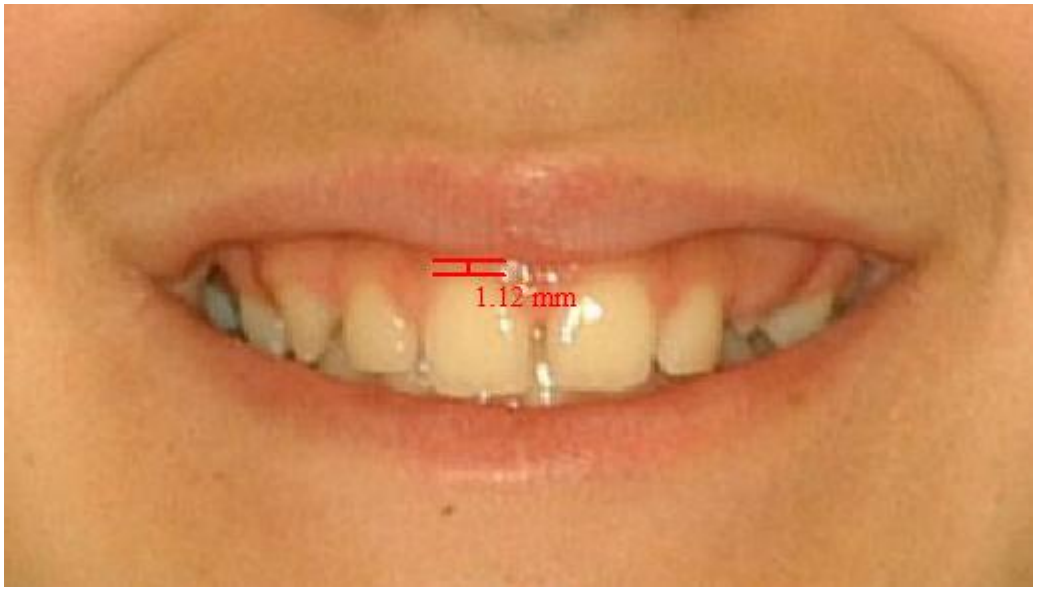
Figure 4-3: Vertical thickness measurements for the upper and lower lip



Vertical Lip Thickness

The vertical thicknesses of the upper and lower lip were measured in the facial midline (Figure 4-3). These values are identified as "U Lip" and "L Lip".

Figure 4-4: Gingival display measurement

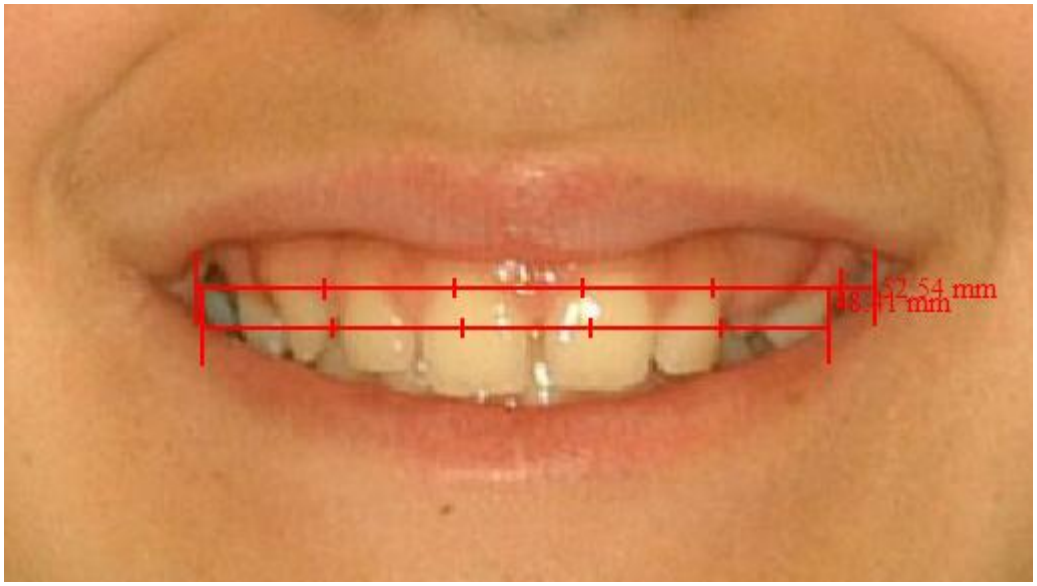


Gingival Display or Incisal Coverage

The vertical height of the gingiva between the zenith of the gingival margin of the central incisors and the lower border of the upper lip was measured and recorded as a positive value (Figure 4-4). If the zenith of the gingival margin was

covered by the lower border of the upper lip, an estimated negative value representing the distance covered was recorded. In cases where one central incisor was covered and the other was exposed, the positive value was recorded. Regardless of whether there was positive or negative gingival display, the value is identified as "Gingiva".

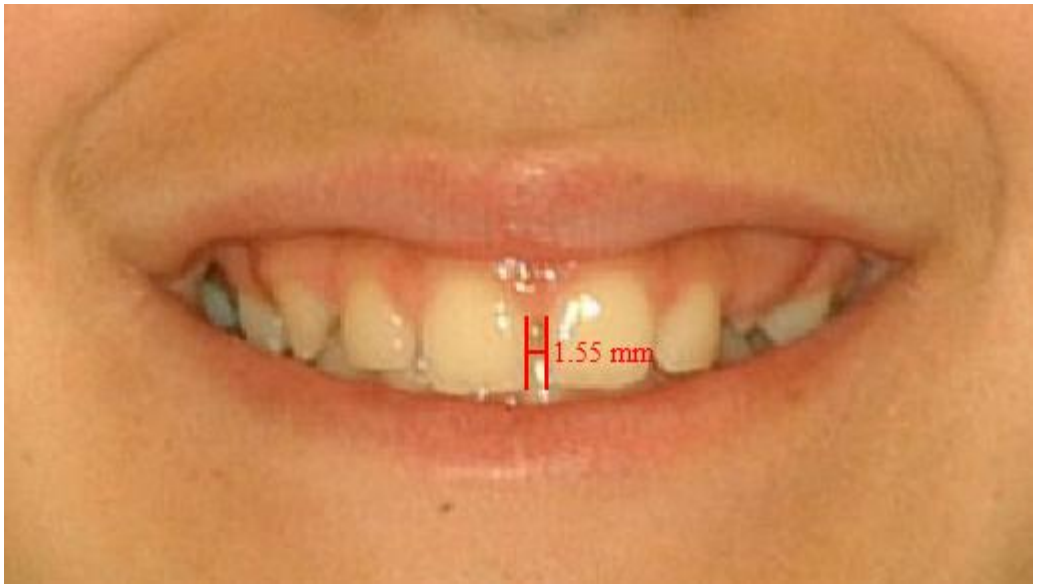
Figure 4-5: Oral aperture width (top) and smile width (bottom) measurements



Smile Width Percent

The distance between the inner aspects of the commissures of the lip was measured to give the oral aperture width (OAW) as measured from the inner aspect of the buccal mucosa (Figure 4-5). The distance between the buccal aspects of the most laterally situated teeth in the smile was measured to give the smile width, identified as "SmW" (Figure 4-5). The smile width percent was obtained by dividing the SmW by OAW. This value was identified as "Sm%" and is a measure of buccal corridor size.

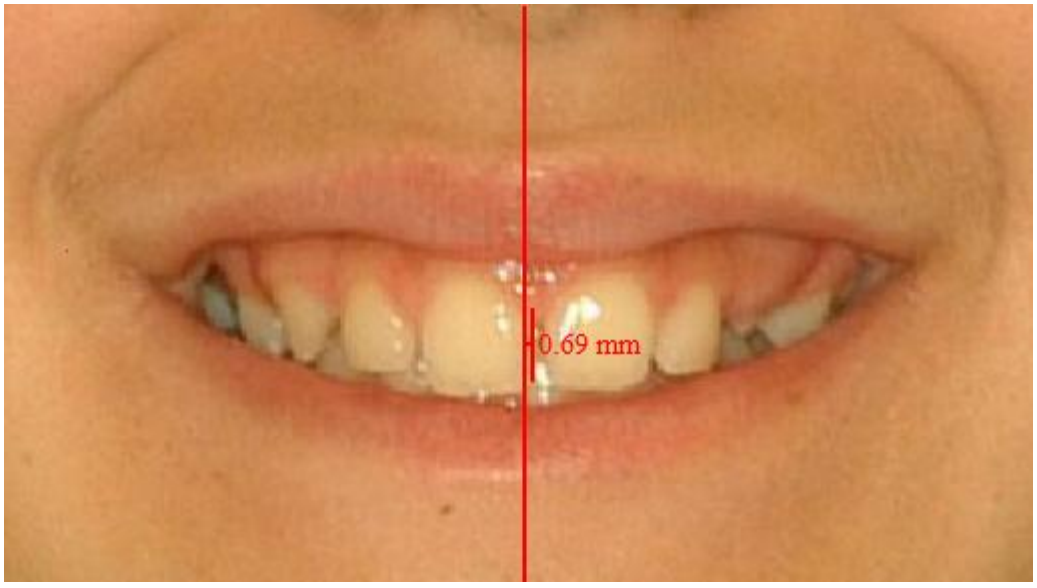
Figure 4-6: Measurement of maxillary midline diastema



Diastema

If present, the maxillary midline diastema was measured (Figure 4-6). This value is identified as "Diast" and was given a value of 0 if no diastema was present.

Figure 4-7: Measurement of midline deviation

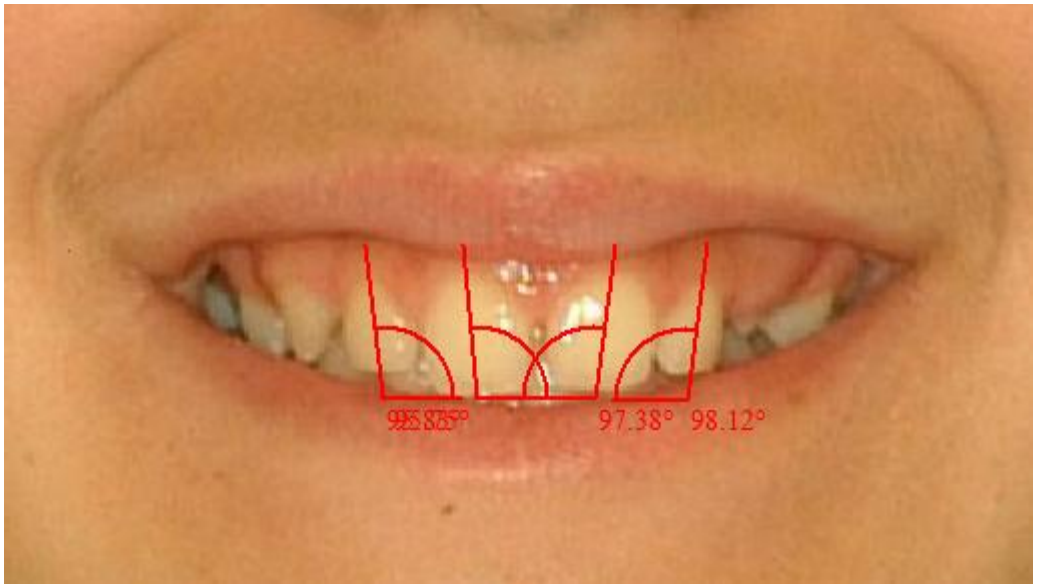


Midline Deviation

The deviation of the midline was measured (Figure 4-7). The midline was determined by drawing a vertical line through the middle of the tip of the nose

and through the middle of the philtrum of the lip. No indication of the direction (right or left) was given. This value is identified as "MLDev".

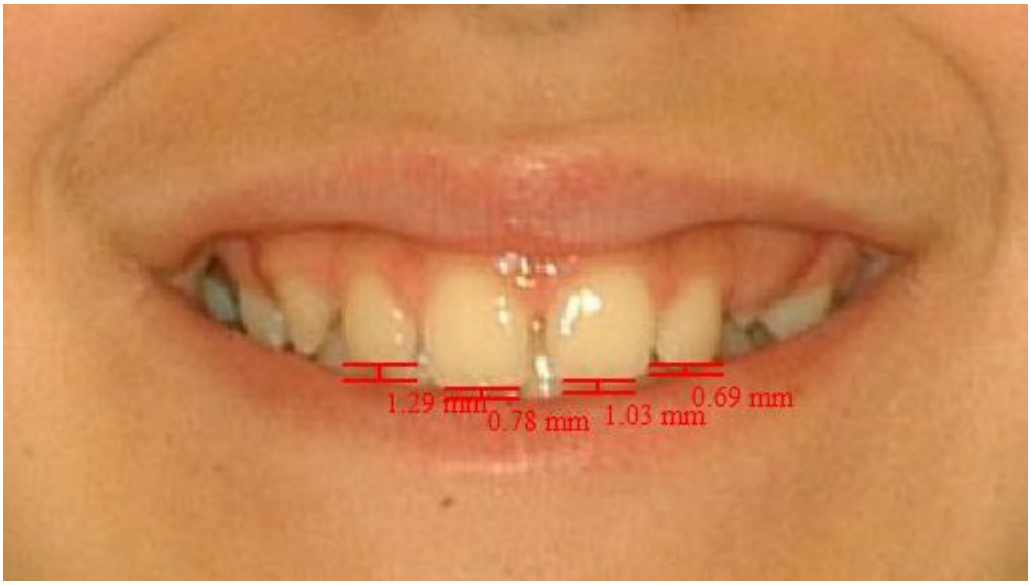
Figure 4-8: Measurement of the angulation of the maxillary incisors



Tooth Angulations

The angulations of the four upper incisors were measured with respect to the horizontal plane of the image (Figure 4-8). These values are identified as "1.2 A", "1.1 A", "2.1 A", and "2.2 A".

Figure 4-9: Measurement of distances between maxillary incisal edges and lower lip superior border



Smile Arc

As an approximate measure of the smile arc (i.e., the degree to which the incisal edges of the maxillary teeth follow the superior border of the lower lip), the vertical distance between the incisal edges of the four upper incisors were measured (Figure 4-9). These values are identified as "1.2 E-L", "1.1 E-L", ”2.1 E-L", and "2.2 E-L". It is important to recognize that an increase in these values indicates a decrease in the consonance of the smile arc with the contour of the lower lip.

Oral Hygiene, Gingival Inflammation, and Tooth Shape

The level of oral hygiene/gingival inflammation was also considered in the analysis but was not included due to difficulty in assessing this factor on smiling photographs. Tooth shape and tooth were also considered, however due to the degree of variation between patient photos these factors could not be easily assessed.

Statistical Analysis

The analysis of the data involved three main elements: 1) reliability analysis (intraclass correlation coefficient – ICC), 2) principal component analysis (PCA), and 3) logistic regression.

Due to the large number of variables measured and limited sample size, it was not considered appropriate to carry out a logistic regression analysis with all the variables included. Therefore, the number of variables was reduced using principal component analysis (PCA), a statistical procedure that combines correlated variables into a set of variables called principal components while retaining most of the information in the original variables.

All statistical tests were performed using The Statistical Package for the Social Sciences (SPSS) 19.0 (International Business Machines Corp, Armonk, NY, USA).

RESULTS

Reliability Analysis

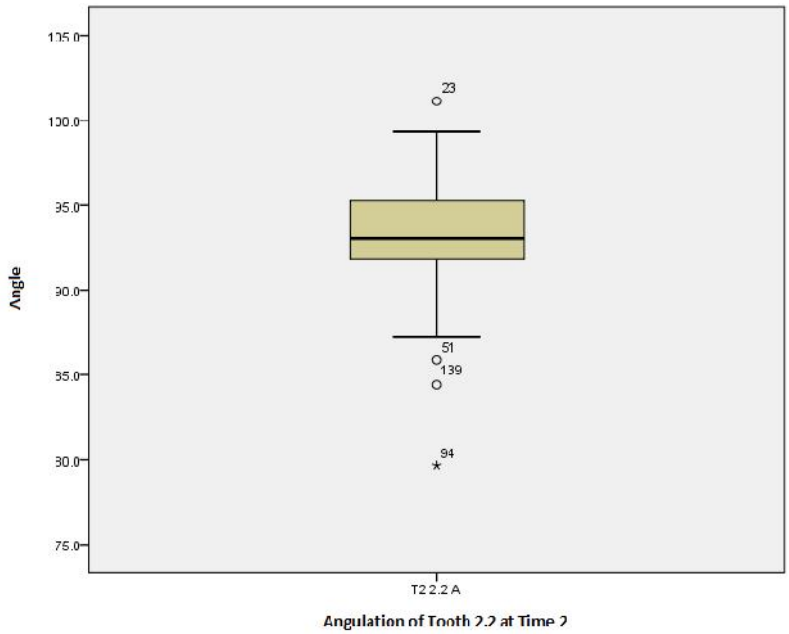
As part of a reliability analysis, each measurement was repeated five times (at intervals of one week) by a single evaluator for ten randomly selected patients. Reliability testing suggested high intraclass correlation coefficients, indicating strong intra-rater reliability and agreement for 1.2 H, U Lip, L Lip, Gingiva, OAW, SmW, Diast, 1.1 A, 2.1 A, and the E-L series of variables (Table 4-1). The 1.2 W, 1.1 W, 1.1 H, 2.1 W, 2.1 H, 2.2 H, MLDev, 1.2 A, and 2.2 A variables demonstrated adequate reliability, though the lower limits for the confidence intervals on these variables were less than desirable. The variable 2.2 W had poor reliability.

Table 4-1: Intra-rater reliability for variable measurements		
VARIABLE	ICC*	95% CONFIDENCE INTERVAL
1.2 W	0.856	(0.683, 0.956)
1.2 H	0.879	(0.739, 0.963)
1.1 W	0.770	(0.554, 0.925)
1.1 H	0.844	(0.674, 0.951)
2.1 W	0.847	(0.668, 0.953)
2.1 H	0.838	(0.666, 0.949)
2.2 W	0.362	(0.110, 0.710)
2.2 H	0.756	(0.534, 0.919)
U Lip	0.966	(0.909, 0.990)
L Lip	0.959	(0.874, 0.989)
Gingiva	0.949	(0.881, 0.985)
OAW	0.965	(0.915, 0.990)
SmW	0.941	(0.863, 0.983)
Diast	0.982	(0.956, 0.995)
MLDev	0.810	(0.618, 0.939)
1.2 A	0.821	(0.633, 0.943)
1.1 A	0.916	(0.793, 0.976)
2.1 A	0.893	(0.764, 0.968)
2.2 A	0.802	(0.598, 0.937)
1.2 E-L	0.985	(0.964, 0.996)
1.1 E-L	0.992	(0.980, 0.998)
2.1 E-L	0.980	(0.952, 0.994)
2.2 E-L	0.988	(0.971, 0.997)
*. ICC, Intraclass Correlation Coefficient		

Principal Component Analysis

First, two sets of data were produced: one in which extreme values (i.e., outliers) were removed and one in which they were kept in the dataset. Outliers were identified as starred values (*) on a boxplot graph designating a value further than 3 interquartile ranges from the nearer edge of the box. An example of an outlier is demonstrated in Figure 4-10; the same approach was used for all other variables. Outliers were not removed for any of the midline discrepancy data, as any nonzero value was an outlier on the boxplot.

Figure 4-10: Box plot of angulation (in degrees) of tooth 2.2



The principal component analysis (PCA) was conducted with and without these extreme values to determine the best theoretically fitted set of new variables to employ in a future logistic regression.

The diastema variable was left out of the PCA so that it could be re-introduced independently for the subsequent logistic regression. This was done to ensure that the diastema variable was not precluded from the logistic regression due to elimination during PCA if it did not correlate well to any of the principal components. The rationale behind this special handling of the diastema variable is based on the strong consensus in the literature that laypeople are particularly critical of diastemas[5, 8, 12, 13, 22] and thus this variable is very likely related to the decision to continue onto Phase II orthodontic treatment.

A cross-tabulation between Diastema and Phase II treatment was performed (Table 4-2). In the population of patients without diastemas, there is a nearly even split between patients that did not go on to Phase II treatment and those that did (17 versus 21, respectively), whereas in the population of patients with

diastemas, there was over twice as many patients that sought Phase II treatment versus those that did not (15 versus 7, respectively).

Table 4-2: Cross-tabulation of Diastema and Phase II Treatment

		Phase II		Total
		No	Yes	
Diastema	No	17	21	38
	Yes	7	15	22
Total		24	36	60

Four principal component analyses procedures were performed in attempt to find the best model: 1) no rotation PCA with outliers, 2) varimax rotation PCA with outliers, 3) no rotation PCA without outliers, and 4) varimax rotation PCA without outliers. Of these four analyses, the varimax rotation PCA with the outliers produced the model with the most coherent results (Table 4-3). Due to the sample size limitations in this study, only those loading values (i.e., correlation between PC and each variable) that were greater than or equal to |0.600| were interpreted as significant, since components loadings above |0.600| are considered reliable regardless of sample size. A total of five principle components (PC1 - PC5) were derived from the PCA. Five of the variables (Gingiva, Sm%, MLDev, and 2.2 A, 2.1 A,) did not appear to belong to any principle component.

Table 4-3: Correlation between PC and Each Variable Based on Varimax Rotation (with Outliers)					
VARIABLE	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
1.2 E-L	**0.926**	0.111	-0.019	0.000	-0.065
1.1 E-L	**0.926**	-0.048	0.107	0.139	0.156
2.1 E-L	**0.940**	0.047	0.117	0.069	0.159
2.2 E-L	**0.855**	0.181	0.080	-0.248	0.059
1.2 WH	0.259	**0.628**	0.550	0.153	0.164
1.1 WH	0.202	**0.878**	-0.203	-0.121	0.097
2.1 WH	0.010	**0.919**	-0.156	-0.103	-0.100
2.2 WH	-0.031	**0.796**	0.404	-0.043	-0.014
1.2/1.1	0.210	-0.020	**0.824**	0.034	0.110
2.2/2.1	-0.067	-0.041	**0.846**	0.115	-0.064
1.2 A	-0.079	-0.108	0.004	**0.833**	-0.008
1.1 A	0.131	0.033	0.271	**0.823**	0.072
U Lip	0.181	-0.039	-0.123	0.067	**0.810**
L Lip	0.132	0.052	0.063	0.072	**0.852**
Gingiva	0.168	-0.015	-0.188	0.408	-0.563
Sm%	0.216	0.221	0.496	-0.488	-0.011
MLDev	0.019	0.068	0.014	-0.362	0.303
2.2 A	0.054	-0.049	-0.061	0.108	-0.105
2.1 A	-0.026	-0.102	0.497	0.453	-0.113

Table 4-4: Coefficient of Each Variable in PCs					
VARIABLE	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
1.2 E-L	**0.283**	-0.013	-0.056	-0.003	-0.106
1.1 E-L	**0.265**	-0.069	-0.013	0.049	0.016
2.1 E-L	**0.265**	-0.040	-0.009	0.024	0.014
2.2 E-L	**0.248**	-0.010	0.002	-0.115	-0.047
1.2 WH	0.002	**0.212**	0.165	0.088	0.063
1.1 WH	0.006	**0.341**	-0.141	0.038	0.035
2.1 WH	-0.037	**0.363**	-0.109	0.038	-0.055
2.2 WH	-0.075	**0.289**	0.128	0.017	-0.018
1.2/1.1	0.015	-0.065	**0.330**	-0.047	0.020
2.2/2.1	-0.046	-0.059	**0.356**	-0.019	-0.044
1.2 A	-0.028	0.034	-0.053	**0.383**	0.044
1.1 A	0.012	0.059	0.039	**0.371**	0.064
U Lip	-0.001	-0.013	-0.087	0.076	**0.435**
L Lip	-0.033	0.016	-0.014	0.075	**0.457**
Gingiva	0.093	0.035	-0.103	0.175	-0.298
Sm%	0.031	0.006	0.222	-0.253	-0.065
MLDev	-0.050	0.019	0.009	-0.150	0.124
2.2 A	-0.006	0.017	-0.043	0.047	-0.077
2.1 A	-0.043	-0.012	0.176	0.161	-0.066

Principal scores are obtained as the weighted sum of 19 dental aesthetic variables and the weights are called coefficients (Table 4-4). For example, a subject's score for PC1 is calculated thusly:

PC1 = 0.283(1.2 E-L) + 0.265(1.1 E-L) + 0.265(2.1 E-L) + 0.248(2.2 E-L) + 0.002(1.2 WH) + 0.006(1.1 WH) - 0.037(2.1 WH) - 0.075(2.2WH) + 0.015(1.2/1.1) - 0.046(2.2/2.1) - 0.028(1.2A) + 0.012(1.1 A) - 0.001(U Lip) - 0.033(L Lip) + 0.093(Gingiva) + 0.031(Sm%)- 0.050(MLDev) - 0.006(2.2 A) - 0.043(2.1 A),

where 1.2 E-L, 1.1 E-L, 2.1 E-L, 2.2 E-L, 1.2 WH, 1.1 WH, 2.1 WH, 2.2 WH, 2.2/1.1, 2.2/2.1, 1.2 A, 1.1 A, U Lip, L Lip, Gingiva, Sm%, MLDev, 2.2 A, and 2.1 A represent the standardized values of those variables for that individual. The larger values of the 1.2 E-L, 1.1 E-L, 2.1 E-L, and 2.2 E-L beta scores reflect the heavier contribution of these variables to PC1.

The total variance explained by each principle component (i.e., the degree to which each component contributes to the description of the smiles) is shown in Table 4-5. Note that each subsequent factor is responsible for progressively less variation. Table 4-5 also lists the names given to the components.

Table 4-5: Total Variance of Smile Explained (Rotation Sums of Squared Loadings)

COMPONENT	COMPONENT NAME	EIGENVALUE	% OF VARIANCE	CUMULATIVE %
PC1	Smile Arc	4.398	23.149	23.149
PC2	Intratooth	2.867	15.091	38.240
PC3	Intertooth	2.495	13.132	51.372
PC4	Right Angle	1.915	10.080	61.451
PC5	Lips	1.583	8.331	69.782

PC1 is dominated by four variables (1.2 E-L, 1.1 E-L, 2.1 E-L, and 2.2 E-L) and can be considered as the average of these four variables that represent the vertical distance between the incisal edges of the four upper incisors and the superior border of the lower lip and thus was labelled "Smile Arc".

PC2 is dominated by four variables (1.2 WH, 1.1 WH, 2.1 WH, and 2.2 WH) and can be considered as the average of these variables that represent the tooth width:height ratios (i.e., the proportionality within each tooth). This principal component was labelled "Intratooth".

PC3 is dominated by two variables (1.2/1.1, 2.2/2.1) and can be considered as the average of these variables representing the width:width ratios between the central and ipsilateral incisors (i.e., the proportionality between teeth). This principal component was labelled "Intertooth".

PC4 is dominated by two variables (1.2 A and 1.1 A) and can be considered as the average of these variables representing the angulation of the right maxillary central incisor and the right maxillary lateral incisor. This principal component was labelled "Right Angle".

PC5 is dominated by two variables (U Lip and L Lip) and can be considered as the average of these variables representing the vertical dimension of the upper and lower lips. This principal component was labelled "Lips".

Independent t-tests were used to examine whether significant differences existed in any of the principal components existed between (1) boys and girls and (2) those with and without 2x4. Results indicated that those with 2x4 were significantly lower in the Right Angle score than those without 2x4, ($t(51) = 2.572$, $p = 0.013$) (Table 4-6). No other significant differences for 2x4 or sex were revealed.

Table 4-6: Independent samples t-test of 2x4 and the principal components*

COMPONENT	T-SCORE	DEGREES OF FREEDOM	P-VALUE**	MEAN DIFFERENCE
Right Angle	-2.572	51	.013	0.780
Smile Arc	-0.448	51	0.628	0.322
Intratooth	0.038	51	0.970	0.322
Intertooth	1.700	51	0.095	0.314
Lips	-0.841	51	0.404	0.320

*equal variances assumed
**2-tailed

Logistic Regression

First, an exploratory logistic regression was performed with the Sex, 2x4, and the diastema variable as covariates in order to test the hypothesis that these three variables are strong contributors to the decision to proceed to Phase II treatment. None of the factors were significant (Table 4-7).

Table 4-7: Exploratory Logistic Regression Model with Sex, 2x4, and Diastema Covariates

VARIABLE	COEFFICIENTS (B)	S.E.	P-VALUE	EXP(B)	95% C.I. FOR EXP (B)
Sex	0.699	0.579	0.228	2.011	(0.646, 6.261)
2x4	0.457	0.629	0.467	1.580	(0.461, 5.419)
Diast	0.564	0.457	0.217	1.758	(0.717, 4.308)

A second exploratory logistic regression was run including the Sex, 2x4, and diastema variable as covariates with the five principal components (Table 4-8). Again, none of the variables were significant, although Right Angle approached significance.

Table 4-8: Exploratory Logistic Regression Model with Sex, 2x4, and Diastema Covariates

VARIABLE	COEFFICIENTS (B)	S.E.	P-VALUE	EXP(B)	95% C.I. FOR EXP (B)
Sex	0.747	0.719	0.299	2.111	(0.516, 8.630)
Right Angle	0.722	0.392	0.065	2.060	(0.956, 4.439)
2x4	0.659	0.790	0.404	1.933	(0.411, 9.090)
Diast	0.448	0.468	0.339	1.565	(0.625, 3.916)
Intratooth	0.146	0.312	0.640	1.157	(0.627, 2.134)
Intertooth	-0.085	0.364	0.817	0.919	(0.450, 1.877)
Lips	-0.239	0.324	0.460	0.787	(0.418, 1.484)
Smile Arc	-0.384	0.319	0.230	0.681	(0.364, 1.274)

The coefficient of each variable indicate the degree to which each variable increases (or decreases) the odds of proceeding to Phase II, with all other factors held fixed. For example, Diast has a coefficient(B) of 0.448, therefore Exp(B) is $e^{0.448}$ = 1.565. Thus the odds of proceeding to Phase II treatment are 56.5% greater with a one standard deviation increase in the value of Diast (as calculated using the formula derived from Table 4-3). However, it is important to

note that this is merely for the exploratory logistic regression model and that none of the coefficients were significant in this preliminary analysis.

In light of this result, a backward conditional logistic regression was performed with the Sex, 2x4, and Diast covariates with Smile Arc, Intratooth, Intertooth, Right Angle, and Lips principal components (Appendix, Table 4-9). Results indicated that at the seventh and penultimate step, both Sex and Right Angle remained, but were both non-significant.

At the eighth and final step of the logistic regression, only Right Angle remained significant (B = 0.735, SE(B) = 0.339, p = 0.030, exp(B) = 2.085, 95% C.I. = 1.074, 4.049). A factor that neither decreases or increases the likelihood of going to Phase II treatment would have an exp(B) = 1.00. The increase in the odds ratio for a given factor can be calculated as that factor's exp(B) - 1.00, multiplied by 100%. Therefore, with a one standardized value increase in the value of the Right Angle principal component, there would be an a 109% increase in the odds of proceeding to Phase II treatment.

DISCUSSION

The goal of this study was to determine which aesthetic factors were related to a patient's likelihood to proceed with Phase II orthodontic treatment after receiving Phase I Xbow orthodontic treatment. In this situation, the decision to continue to Phase II treatment was viewed as an indicator of the aesthetic result following Phase I treatment. The sample was a set of frontal smiling photographs of 60 children (23 males, 37 females from a private orthodontic practice) taken after a Phase I treatment with the Xbow appliance.

Nine frontal dentofacial aesthetic factors were chosen based on previous research:[36, 37]

- width to height ratios for the maxillary incisors

- width to width ratios between ipsilateral maxillary lateral and central incisors
- vertical thickness of the upper and lower lips
- maxillary gingival display or incisal coverage
- smile width
- size of maxillary midline diastema, if present
- maxillary dental midline deviation, if present
- angulation of the maxillary incisors
- smile arc

Two additional factors were included, for a total of eleven factors in the analysis:

- sex
- the use of fixed orthodontic appliances across the maxillary incisors (i.e., a "2x4" treatment)

The results of a principal component analysis and logistic regression indicate that increased angulations of the maxillary right lateral and central incisor are related to increased odds that a patient will proceed to Phase II treatment. Specifically, a one standard deviation increase in the value of the Right Angle variable is related to a 109% increase in the odds of Phase II treatment. Unfortunately, since the standardized scoring of the Right Angle variable does not translate easily back to an angular value, this finding cannot easily be applied clinically. The primary value is the finding that increasing angulations of the maxillary right lateral and central incisor appears to be (for the sample of patients in this study) the most significant predictor of proceeding to Phase II treatment.

The standardized scores from this study's sample population would likely differ from those of another population, therefore it is unlikely that a one standard deviation increase in the value of the Right Angle variable in another population

would have the same relationship with the likelihood of Phase II treatment. Thus the external validity of this study is limited.

Previous studies have shown that laypeople are sensitive to changes in the angulation of the anterior dentition (either as an occlusal plane cant or as individual teeth).[7, 16-20] However none of these studies have determined how noticeable changes to the angulation of the anterior dentition are in the presence of other aesthetic defects.

Angulations of the left maxillary central and lateral incisors did not appear to be a significant contributor to the decision to proceed with Phase II treatment. The variables representing the angulations of tooth 2.1 and 2.2 did not correlate well with any of the principal components during dimension reduction (Table 4-3). Thus, they were not included in the logistic regression. The poor correlations of 2.1 and 2.2 angulations to the principal components may be due to the lower reliability of these measurements (Table 4-1).

To put this into a clinical perspective, however, during the intra-rater reliability testing the largest discrepancy between measurements of the angulation of tooth 2.1 was approximately 5 degrees (with the average discrepancy of approximately 3 degrees). The largest discrepancy between measurements of the angulation of tooth 2.2 was approximately 9° (with the average discrepancy of approximately 4 degrees). One study[22] has shown that laypeople are not sensitive to a 10° distal angulation of the lateral incisor. Thus, the discrepancy in measurements due to the decreased intra-rater reliability is probably not of significance to the layperson.

Geron and Atalia[16] have demonstrated that laypeople are more sensitive to counterclockwise cants (versus clockwise cants), which in a sense result in the increase in angulation of the maxillary right incisors (and concurrent decrease in angulation of the maxillary left incisors). However, there is research that

suggests that right-handed people are more sensitive to details in the right side of an asymmetric image[38]. This would not explain the apparent increased sensitivity to increases in angulation of the maxillary right incisors, but may have been a factor during the measurement process and perhaps could explain increased variability on the left incisors as mentioned above. Interestingly, handedness appears to be neuropsychologically linked to right-versus-left aesthetic preferences, diminishing the effects of cultural cues[39]. It is important to keep in mind that people demonstrate an overall preference for symmetry over asymmetry[15, 25, 39].

Although the other factors entered into the logistic regression were not found to be of significance, there are additional trends that can be interpreted from the results (Table 4-8). Females and patients who received 2x4 orthodontic appliances were more likely to continue to Phase II treatment. Presence of a diastema or an increase in the width:height ratio of the maxillary incisors (i.e., wider, shorter teeth) also was related to an increased likelihood of receiving Phase II treatment.

Conversely, an increase in the width:width ratios of the maxillary central and lateral incisors (i.e., lateral incisors that more closely matched the central incisors in terms of width), and an increase in the vertical thickness of the lips appear to decrease a subject's odds of proceeding to Phase II. It appears that an increase in the value of smile arc (which in this study indicates an increased distance between the lower border of the lip and the maxillary incisal edges, and thus a decrease in smile arc consonance) is associated with a decreased likelihood of continuing to Phase II treatment.

Patients that received a 2x4 treatment were significantly lower in the Right Angle score than those without, demonstrating the expected relationship between these two variables (Table 4-6). It is interesting to note that incisor angulation was a significant factor but the use of orthodontic brackets on the incisors (2x4)

was not, as the two should be intimately related. This indicates that although the two variables are related, Right Angle is a more precise variable than 2x4 when predicting a patient's likelihood of proceeding to Phase II treatment.

The decreased ability of 2x4 to predict Phase II treatment may be due to the way in which 2x4 treatment is allocated. In some cases, 2x4 is given to patients with retroclined maxillary incisors in order to create enough overjet for anteroposterior correction of the Class II malocclusion. In other cases, 2x4 would be given to patients that had a diastema, or had severely malpositioned teeth, or simply because the parents or patients desired alignment of the incisors early in treatment (rather than waiting until Phase II). Therefore the situations in which 2x4 was used were not uniform and likely decreased this variable's predictive power.

It was unexpected that the presence of a diastema would not be significantly predictive of a patient's likelihood to receive Phase II treatment, as laypeople react strongly to the presence of diastemas[5, 8, 12, 13, 22]. Although a diastema is almost universally unacceptable by laypeople, it is generally not noticeable unless it is of a certain size, probably larger than 1-2 mm[8, 22]. Although 22 of the 60 patients had measurable diastemas, only 10 of these patients had diastemas larger than 1 mm, and only 3 of those patients had diastemas larger than 2 mm. Therefore, it is likely that including patients with diastemas smaller than 1 mm wide (which were likely not aesthetically impairing) in the analysis overshadowed the effects of patients with larger aesthetically impairing diastemas.

Tooth shape is an important factor in the layperson's perception of frontal dentofacial aesthetics[10-13]. Investigations of the aesthetics of tooth shape are best suited to study designs in which a limited number of tooth shapes are presented to laypeople. Unfortunately, each of the 60 patients used in this study had different tooth shapes. Since tooth shape is highly variable between individuals it was deemed too difficult to classify each of the 60 individuals' tooth

shapes and include it as a parameter in the current study. However, it is important to note that although tooth shape was not included as a variable, there are ways in which tooth shape may have influenced the other variables used in this study. For example, the shape of a tooth can influence the perception of its angulation or its mesiodistal dimensions. Similarly, a pair of central incisors that taper towards the incisal edges can produce a diastema. Although there is no simple way to compensate for these sorts of effects, it is important to realize that they may be present.

There are only two previous studies[25, 28] that are similar in design to the present study. Research by McNamara et al[28] investigated laypeople's preferences in posed smiles of 60 growing patients seeking orthodontic treatment, and concluded that vertical lip thickness proved to be the most influential variable in smile aesthetics. Buccal corridors, smile arc, and incisogingival display were not significant contributors to smile aesthetics. Although McNamara et al did not include incisor angulation as one of their aesthetic factors, it was expected that lip thickness would also be a significant factor for this current study. It is possible that the inclusion of tooth angulation in the present study overwhelmed the effects of lip thickness on smile aesthetics such that they were statistically insignificant (although still observable as a trend in the logistic regression).

Research by Hulsey[25] in 1970 investigated laypeople's preferences in photographs of posed smiles of 20 pre-treatment and 20 post-treatment adult subjects. Laypeople rated the most attractive smiles based on gingival display, upper lip curvature, symmetry, and smile arc. Buccal corridors were of no significance with respect to aesthetic smiles. Again, incisor angulation was not included as one of the aesthetic factors, which in the present study may have overwhelmed the effects of smile arc on smile aesthetics such that they were statistically insignificant (but were still observable as a trend in the logistic regression).

Thus, the present study has some similar results to the two previous comparable studies. In all three studies, buccal corridors appear to be of no significance. However, the present study and the McNamara study showed that smile arc was of no significance, which is in contradiction to the study by Hulsey. It is possible that these differences are due to the use of adult subjects in the Hulsey study or the changes in what is considered aesthetic over the decades since the 1970s.

Unlike the present study, most research on frontal dentofacial aesthetics assesses the importance of only one or two factors at a time.[4, 9, 15, 20, 21, 23, 26, 30-32] The advantage of that approach is the ability to remove confounding factors and focus on the effects of altering a single aesthetic parameter. With the advent of computer imaging, the trend in has been towards digital editing ("photoshopping") of sample photographs that are presented to study subjects.[5, 7, 8, 10, 12-22, 24]

For example, the contribution of smile arc to dentofacial aesthetics has been one relatively recent area of interest[37]. In the majority of these studies,[12, 13, 17, 18, 22] the smile arc is altered (flat, reverse, or consonant) while all other aspects are held constant (e.g., tooth proportion, tooth angulation, lip thickness, buccal corridor, etc.). From these studies, it appears that laypeople prefer a consonant smile arc, which is an important piece of information for the dental practitioner. However, the disadvantage of these studies and others of similar design is their inability to ascertain which aesthetic factors are most important, which are least important, or how they interact.

The ability of the present study to analyze multiple aesthetic factors simultaneously is both an advantage and disadvantage. Discerning the relative importance of multiple aesthetic factors is valuable, but the large number of factors needed to fully describe each photograph weakens the statistical analysis. It is tempting to include every imaginable aesthetic parameter for fear of excluding an important one. Even if a large number of factors are included, it

is still possible that laypeople are discriminating between photographs based on some unaccounted parameter.

It is possible that the sample used for this study was a source of bias. The records used in this study came from a sample of 158 patients that was reduced due to a lack of T2 (post-Phase I) records. Most of the patients that received only Phase I treatment had T2 records, but the majority of the patients that received Phase II treatment did not have T2 records. It is unclear why T2 records were taken for only some of the patients receiving Phase II treatment. It is possible that these cases represented exceptional cases that made them desirable for documentation. Furthermore, there is a difference in the proportions of patients receiving Phase II treatment between the study sample and the original sample. In the study sample, 30 of the 60 patients proceeded with Phase II treatment whereas in the original sample, 107 of the 158 patients proceeded with Phase II treatment.

There are two possible sources of bias related to the upper lip position. Firstly, the sample of patients was further reduced because patients were excluded from this study if their smiling photographs depicted smiles that did not display the majority of the maxillary incisors. In most cases, it appears that poor display of the maxillary incisors was due to a poorly posed smile rather than anatomical limitations and could have been remedied by retaking the photograph. Secondly, for those cases in which the posed smile was adequate but the maxillary incisors were partially covered by the upper lip the degree of incisal coverage was estimated. Therefore the measurements for gingival display are more accurate than those for incisal coverage. The degree of estimation could have been reduced by taking incisogingival caliper measurements of the incisors on the patient models rather than just the mesiodistal measurements.

There was a difference in the proportion of males to females in the sample (38% male, 62% female) versus the private practice from which the sample was taken

(42% male, 58% female). Previous research conducted in the neighbouring American state of Washington shows that there is a sex distribution of orthodontic patients (36% male, 64% female) that is more reflective of the ratio found in the current study population[40]. Still, it is unclear why the discrepancy exists between the gender ratio of the study population and the private practice from which it was obtained and thus indicates a possible source of bias.

For this study, the decision regarding Phase II orthodontic treatment is treated as a proxy for the patient's (and likely their family's) feelings about the aesthetic result of Phase I treatment. Perhaps the most obvious shortcoming of this approach is that it attempts to assign frontal dentofacial aesthetics as the single reason for family's orthodontic treatment decisions, when these decisions are often made in a psycho-socio-economic context that includes the patient and caregiver burnout, peer pressures, and financial pressures. It was not possible to contact the patients in this study to find out the reasons they did or did not continue on to Phase II treatment; even if it were possible, the actual truth may not be disclosed by the patient or their family (recall bias or fear to answer the truth). There is one advantage to using a treatment decision as an indicator of dental aesthetics, however. Unlike survey-based aesthetic research, it allows for the testing of large numbers of cases. To illustrate -- a survey using all 60 of the photographs in this study including repeated photographs for reliability analysis would likely result in survey respondent fatigue.

This study is the first in a pair of studies. The follow-up study will use a selection of the photographs from this first study to create a layperson survey in which the photographs are given a score based on the smile aesthetics. A similar analysis can then be repeated to determine if there are identifiable dentofacial aesthetic factors that bias laypeople towards giving a photograph a high or low score.

A modified version of this experiment could be repeated using records collected at an academic institution. The patient pool needs not be constrained by a

particular treatment modality (e.g., Xbow) as the focus should be on frontal dentofacial aesthetics as they relate to Phase I treatment. This would yield a much larger set of records to analyze and should diminish the effects of poorly posed smiles or missing post-Phase I records. Patients declining Phase I treatment could also fill out a survey to investigate their reasons for discontinuing treatment to improve the quality of information. Alternatively, the focus could be solely on dentofacial aesthetics rather than on dentofacial aesthetics as they relate to orthodontic treatment decisions, since there is a dearth of studies that investigate multiple frontal dentofacial aesthetic factors in a single image. This would also prevent non-aesthetic reasons for discontinuing orthodontic treatment (i.e., social, economic, and psychological reasons) from skewing the data.

CONCLUSIONS

- the angulations of the maxillary right central and lateral incisors were the most significant factor related to a patient's likelihood of receiving Phase II treatment following Phase I treatment with the Xbow appliance; a one standard unit increase in angulation of these teeth increases the odds of proceeding with Phase II by 109%
- although the pattern lacked statistical significance, the results of this study demonstrate that females and patients who received 2x4 orthodontic appliances were more likely to continue to Phase II treatment, as were those patients with a diastema or an increase in the width:height ratio of the maxillary incisors (i.e., wider, shorter teeth)
- although the pattern lacked statistical significance, the results of this study demonstrate that males and patients with an increase in the width:width ratios of the maxillary central and lateral incisors (i.e., lateral incisors that more closely matched the central incisors in terms of width), an increased vertical thickness of the lips, and decreased smile arc consonance were less likely to continue to Phase II treatment

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Chapter 5: General Discussion and Conclusions

Contemporary dental patients are arguably more educated and more discerning than ever, with a keen focus on aesthetic procedures. This is understandable given the influence that physical attractiveness may have on a patient's personal success in life.[1-3] The decision to seek orthodontic treatment is largely driven by a desire to improve dental aesthetics.[4] A such, the field of orthodontics has also undergone a paradigm shift towards aesthetically-driven treatment[5] with the understanding that patients are more concerned about their appearances than the function of their occlusions.

It is assumed that many of the orthodontic treatment decisions patients and their families make are based upon their perceptions of dental aesthetics. It appears that the lay public is able to identify factors that detract from an aesthetic smile;[6-9] however, they are far less critical than dental professionals with regards to some of those factors.[10-12] A systematic search of electronic databases (MEDLINE, PubMed, Embase, Cochrane Library and Web of Science) was conducted in order to gain an appreciation for the layperson's perspective on dental aesthetics.[13, 14]

It appears that most laypeople do not discriminate between square, square-round and round incisors or canine shapes when displayed in photographs of female models, but they prefer square-round incisors to square incisors and flat canines (when paired with round incisors) when displayed in photographs of male models. In addition, laypeople prefer unworn dentitions and small teeth in images of female models and large teeth in images of male models. Most laypeople appear to prefer width-to-length ratios of between 75 and 85 percent in the central incisors and tooth-to-tooth proportions of between 50 and 74 percent between the lateral and central incisors. They also detect variations in crown width or height among individual teeth, especially when the variation is unilateral. Laypeople’s sensitivity to variations in crown width or height appears

to be diminished when the variation maintains ideal crown proportions and when the variation is not in the midline.

Studies also show that laypeople discern a 10° angulation of one or both central incisors as being less attractive than a 2° angulation. The majority of laypeople prefer a 1.4-mm step between the incisal edges of maxillary central and lateral incisors, but they tolerate a maximum step of 2.9 mm. However, many laypeople prefer even incisal-edge relationships. In addition, according to the results of one study,[15] they preferred an overbite of 2.0 mm and tolerated maximum and minimum overbites of 5.7 mm and 0.4 mm, respectively. They also preferred no diastemas and tended to notice a diastema larger than 1 mm.

Laypeople appear to be able to detect dental midline deviations of less than 3.0 mm, but when made aware of midlines, they prefer those that are coincident with each other and with the facial midline. The majority of laypeople prefer no gingival display, with the upper lip height at the gingival margin of the maxillary central incisors. Results of the literature review indicate an aesthetic range — from 4.0 mm of maxillary central incisor coverage to 3.6 mm of gingival display — that laypeople tolerate. Most judges prefer that the gingival zeniths of the lateral incisors be positioned 0.4 to 0.5 mm coronal to the gingival zeniths of the central incisors. They also are sensitive to some changes to the gingival architecture. The ideal gingival display and architecture from a layperson's perspective may be influenced by the dentition with which the gingiva are displayed, as well as by the lips that frame them. Laypeople prefer consonant smile arcs in photographs of both men and women, but they tolerate flat smile arcs in men more than they do in women. They also prefer minimal buccal corridors, rating images that show the least lateral negative space as most attractive. Extraction of premolars does not appear to predictably affect laypeople's perceptions of buccal corridors or dental esthetics.

Following the literature review, it became apparent that many studies investigated the effects of altering a single aesthetic factor, but few investigated the effects of altering multiple aesthetic factors.[6, 16-18] This is largely borne out of an attempt by researchers to determine the layperson's thresholds and preferences each individual aesthetic factor, and the importance of this type of research should not be understated. However, the result of this trend in the literature is that there is little data regarding the relative importance of each aesthetic factor when viewed as the composite "picture" of a patient's smile. Factors that appear important in "single factor" studies may in fact be insignificant when these factors are displayed with other aesthetic defects.

For example, research by Parekh et al suggests that smile arc has a greater impact on esthetics than do buccal corridors; a flat smile arc can decrease attractiveness ratings overwhelmingly, regardless of the buccal corridors, and an ideal smile arc appears to be acceptable regardless of the buccal corridors.[6, 18] Hulsey described attractive smiles as those with symmetry, an upper lip height at the gingival margin of the upper incisor, an upper lip curvature above the midline of the upper lip, and a consonant smile arc; buccal corridors appeared to be of no significance[17]. A study by McNamara et al[16] found that the vertical thickness of the upper and lower lips was a significant aesthetic factor while incisogingival display, smile arc, and buccal corridor were not.

Thus the research investigating multiple aesthetic parameters is not only limited, but also somewhat contradictory. Clearly, further research into this area of dentofacial aesthetics is required.

The present study attempted to determine the relative importance of a multiple dentofacial aesthetic factors as they relate to a patient's likelihood of proceeding with Phase II orthodontic treatment after receiving Phase I orthodontic treatment. Thus, the decision regarding Phase II treatment acted as an indicator of the aesthetics following Phase I treatment. The sample was a set of frontal

smiling photographs of 60 children (23 males, 37 females from a private orthodontic practice) taken after a Phase I treatment with the Xbow appliance. Nine frontal dentofacial aesthetic factors were chosen based on the literature review:

- width to height ratios for the maxillary incisors
- width to width ratios between ipsilateral maxillary lateral and central incisors
- vertical thickness of the upper and lower lips
- maxillary gingival display or incisal coverage
- smile width
- size of maxillary midline diastema, if present
- maxillary dental midline deviation, if present
- angulation of the maxillary incisors
- smile arc

Two additional factors were included, for a total of eleven factors in the analysis:

- patient gender
- the use of fixed orthodontic appliances across the maxillary incisors (i.e., a "2x4" treatment)

The results of a principal component analysis and logistic regression indicate that increased angulations of the maxillary right lateral and central incisor increase the odds that a patient will proceed to Phase II treatment. A number of other trends were also observed in the data, although these trends were not statistically significant. The odds of proceeding to Phase II are increased in female patients, patients with an increase in the width:height of the maxillary incisors, and patients who had been treated with a 2x4 orthodontic appliance. Conversely, the odds of proceeding to Phase II are decreased in male patients, patients with a decrease in smile arc consonance, patients with an increase in

the width:width ratios between the maxillary central and lateral incisors, and patients with an increase in the vertical thickness of the lips..

The effect of the angulations of the right incisors in the present study may be due to the effects of neuropsychological linkage between left-versus-right aesthetic preferences during the measurement stage[19, 20]. This could have led to increased variability during the measurement of the left incisor angulations which ultimately resulted in the exclusion of this factor from the statistical analysis.

The current study had a number of other possible biases that may have influenced the result: the sample size was relatively small in comparison to the large number of factors analyzed, the use of Phase II treatment decisions as a means of measuring dentofacial aesthetics is inaccurate, and the photographs used in the study were not of a uniform quality.

This type of dental research is important in light of society's focus on aesthetics. Further research in the field of dentofacial aesthetics would further clarify the relative importance of the various factors that comprise an aesthetic smile. Such a study could be performed using the scores of patient records available at an academic institution, and should be administered to laypersons in the form of a survey. The obstacle to this technique will be creating a long enough survey to determine the differences between the highly variable patient photographs but short enough to avoid the effects of survey respondent fatigue.

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Appendices

Appendix 1
Search strategy for Ovid MEDLINE, 1950 to May 31, 2010

No.	Searches	No. of Results
1	exp Public Opinion/ or general public.mp.	17,206
2	laymen [including related terms]	588
3	lay men [including related terms]	595
4	lay person*.mp.	436
5	layperson*.mp.	563
6	laypeople*.mp.	166
7	lay people*.mp.	564
8	lay public [including related terms]	13,566
9	exp Attitude to Health/ or lay opinion*.mp.	222,840
10	lay attitude*.mp. or exp Public Opinion/	12,974
11	lay perception*.mp.	73
12	exp Peer Group/ or peer assessment*.mp.	10,389
13	nonprofessional*.mp.	812
14	non-professional*.mp.	736
15	exp Patient Satisfaction/ or patient* opinion*.mp.	44,350
16	patient* attitude*.mp.	1,462
17	patient* perception*.mp.	4,045
18	patient* assessment*.mp.	3,020
19	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18	265,546
20	buccal corridor*.mp.	20
21	buccal corridor [including related terms]	5,050
22	dent* midline*.mp.	54
23	dental midline [including related terms]	10,150
24	diastema.mp. or exp Diastema/	1,174
25	exp Gingiva/ or gingiva* display*.mp.	12,449
26	gingival display [including related terms]	9,717
27	incisor* position*.mp.	123
28	incisor position [including related terms]	9,070
29	smil* arc*.mp. [mp = title, original title, abstract, name of substance word, subject heading word, unique identifier]	14
30	smile arc [including related term	5,616
31	tooth proportion*.mp.	7
32	tooth proportion [including related terms]	11,884
33	tooth shape*.mp.	176
34	tooth shape [including related terms]	11,844
35	tooth form*.mp.	618
36	tooth form [including related terms]	10,359
37	tooth morpholog*.mp. [mp = title, original title, abstract, name of substance word, subject heading word, unique identifier]	192
38	tooth morphology [including related terms]	10,568
39	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38	67,851
40	19 and 39	971

Appendix 2
Search strategy for PubMed

No.	Searches	No. of Results
1	general public	34,989
2	laymen	343
3	laymen	4,633
4	layperson	145
5	lay person	5,800
6	layperson*	581
7	lay person*	427
8	laypeople	158
9	lay people	1,244
10	laypeople*	175
11	lay people*	587
12	lay public	1,811
13	lay opinion	330
14	lay opinion*	18
15	lay attitude	1,357
16	lay attitude*	21
17	lay perception	560
18	lay perception*	76
19	lay perceptions	842
20	peer assessment	4,223
21	peer assessment*	280
22	nonprofessional	713
23	nonprofessional*	830
24	non-professional	626
25	non-professional*	755
26	patient opinion	16,024
27	patient* opinion*	12,724
28	patient attitudes	90,303
29	patient* attitude*	69,040
30	patient perception	73,369
31	patient perceptions	85,016
32	patient* perception*	25,443
33	patient assessment	288,815
34	patient* assessment*	144,257
35	patient satisfaction	62,747
36	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35	533,651
37	buccal corridor	14
38	buccal corridors	11
39	dental midline	656
40	dental midline*	56
41	diastema	1,306
42	midline diastema	92

43	maxillary midline diastema	57
44	median diastema	63
45	gingival display	127
46	excessive gingival display	25
47	gingiva* display*	515
48	incisor position	1,044
49	incisor* position*	1,779
50	smile arc	14
51	smil* arc*	95
52	tooth proportion	1,170
53	tooth proportion*	7
54	tooth shape	1,723
55	tooth shape*	189
56	tooth form	3,875
57	tooth form*	615
58	tooth morphology	42,126
59	tooth morpholog*	186
60	#37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 OR #48 OR #49 OR #50 OR #51 OR #52 OR #53 OR #54 OR #55 OR #56 OR #57 OR #58 OR #59	48,420
61	#36 AND #60	1,139

Appendix 3
Search strategy for Cochrane database of systematic reviews, 2005 to April 2010

No.	Searches	No. of Results
1	exp Public Opinion/ or general public.mp.	37
2	laymen [including related terms]	0
3	lay men [including related terms]	0
4	lay person*.mp.	24
5	layperson*.mp.	5
6	laypeople*.mp.	0
7	lay people*.mp.	14
8	lay public [including related terms]	89
9	exp Attitude to Health/ or lay opinion*.mp.	1
10	lay attitude*.mp. or exp Public Opinion/	0
11	lay perception*.mp.	0
12	exp Peer Group/ or peer assessment*.mp.	1
13	nonprofessional*.mp.	3
14	non-professional*.mp.	21
15	exp Patient Satisfaction/ or patient* opinion*.mp.	27
16	patient* attitude*.mp.	19
17	patient* perception*.mp.	73
18	patient* assessment*.mp.	103
19	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18	377
20	buccal corridor*.mp.	0
21	buccal corridor [including related terms]	4
22	dent* midline*.mp.	1
23	dental midline [including related terms]	249
24	diastema.mp. or exp Diastema/	0
25	exp Gingiva/ or gingiva* display*.mp.	0
26	gingival display [including related terms]	30
27	incisor* position*.mp.	2
28	incisor position [including related terms]	3
29	smil* arc*.mp. [mp = title, original title, abstract, name of substance word, subject heading word, unique identifier]	0
30	smile arc [including related term	0
31	tooth proportion*.mp.	0
32	tooth proportion [including related terms]	385
33	tooth shape*.mp.	2
34	tooth shape [including related terms]	113
35	tooth form*.mp.	6
36	tooth form [including related terms]	856
37	tooth morpholog*.mp. [mp = title, original title, abstract, name of substance word, subject heading word, unique identifier]	0
38	tooth morphology [including related terms]	116
39	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38	1,245
40	19 and 39	104

Appendix 4
Search strategy for Embase, 1980 to 2010 (Week 21)

No.	Searches	No. of Results
1	exp Public Opinion/ or general public.mp.	8,437
2	laymen [including related terms]	357
3	lay men [including related terms]	364
4	lay person*.mp.	322
5	layperson*.mp.	422
6	laypeople*.mp.	110
7	lay people*.mp.	475
8	lay public [including related terms]	10,577
9	exp Attitude to Health/ or lay opinion*.mp.	5,253
10	lay attitude*.mp. or exp Public Opinion/	4,767
11	lay perception*.mp.	62
12	exp Peer Group/ or peer assessment*.mp.	2,652
13	nonprofessional*.mp.	482
14	non-professional*.mp.	579
15	exp Patient Satisfaction/ or patient* opinion*.mp.	41,847
16	patient* attitude*.mp.	24,191
17	patient* perception*.mp.	3,171
18	patient* assessment*.mp.	9,917
19	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18	102,035
20	buccal corridor*.mp.	1
21	buccal corridor [including related terms]	9,072
22	dent* midline*.mp.	8
23	dental midline [including related terms]	238,739
24	diastema.mp. or exp Diastema/	84
25	exp Gingiva/ or gingiva* display*.mp.	2,903
26	gingival display [including related terms]	6,302
27	incisor* position*.mp.	14
28	incisor position [including related terms]	3,990
29	smil* arc*.mp. [mp = title, original title, abstract, name of substance word, subject heading word, unique identifier]	1
30	smile arc [including related term	12,464
31	tooth proportion*.mp.	0
32	tooth proportion [including related terms]	18,595
33	tooth shape*.mp.	73
34	tooth shape [including related terms]	18,593
35	tooth form*.mp.	237
36	tooth form [including related terms]	10,033
37	tooth morpholog*.mp. [mp = title, original title, abstract, name of substance word, subject heading word, unique identifier]	44
38	tooth morphology [including related terms]	10,447
39	20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38	287,945
40	19 and 39	3,824

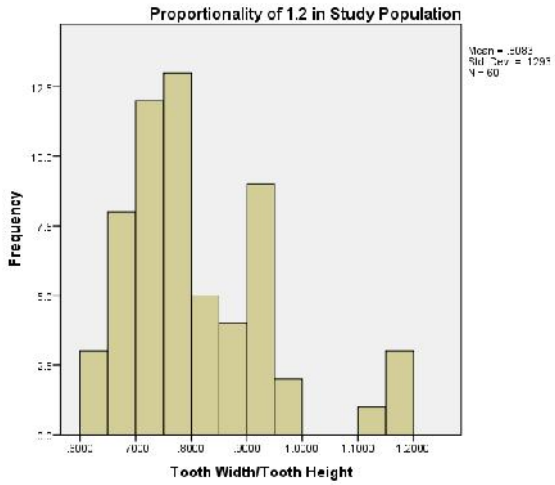
Appendix 5
Search strategy for Web of Science

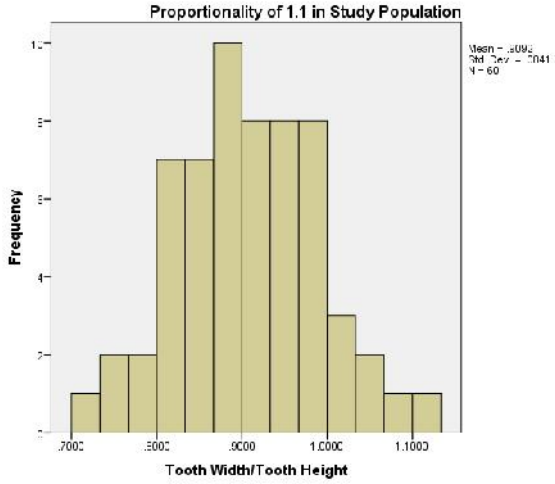
NO.	SEARCHES	NO. OF RESULTS
1	Topic = (general public) OR Topic = (laymen) OR Topic = (lay men) OR Topic = (lay person*) OR Topic = (layperson*) OR Topic = (lay people*) OR Topic = (laypeople*) OR Topic = (lay public) OR Topic = (lay opinion*) OR Topic = (lay attitude*) OR Topic = (public opinion*) OR Topic = (lay perception*) OR Topic = (peer assessment*) OR Topic = (nonprofessional*) OR Topic = (non-professional*) OR Topic = (patient* opinion*) OR Topic = (patient* attitude*) OR Topic = (patient* perception*) OR Topic = (patient* assessment*)	>100,000
2	Topic = (buccal corridor*) OR Topic = (dent* midline*) OR Topic = (dental midline) OR Topic = (diastema) OR Topic = (gingiva* display*) OR Topic = (gingival display) OR Topic = (incisor* position*) OR Topic = (incisor position) OR Topic = (smil* arc*) OR Topic = (smile arc) OR Topic = (tooth proportion*) OR Topic = (tooth proportion) OR Topic = (tooth shape*) OR Topic = (tooth shape) OR Topic = (tooth form*) OR Topic = (tooth form) OR Topic = (tooth morpholog*) OR Topic = (tooth morphology)	14,684
3	#1 and #2	276

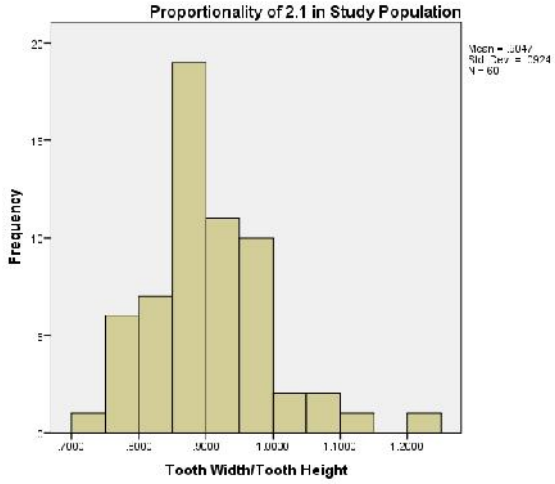
Appendix 6
Search results from five databases and manual search

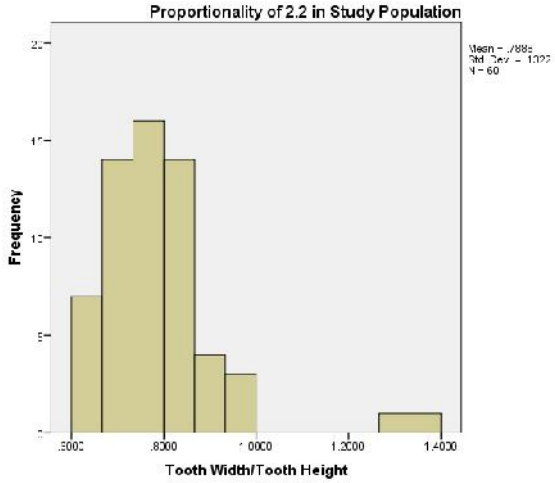
DATABASE	NO. OF RESULTS	NO. SELECTED	NO. REJECTED	NO. OF DUPLICATES	NO. OF ARTICLES INCLUDED
Ovid MEDLINE	971	28	0	26	28
PubMed	1,139	34	3	28	3
Cochrane	104	0	0	0	0
Embase	3,824	3	1	2	0
Web of Science	276	23	0	23	0
Manual Search	21	8	0	0	8

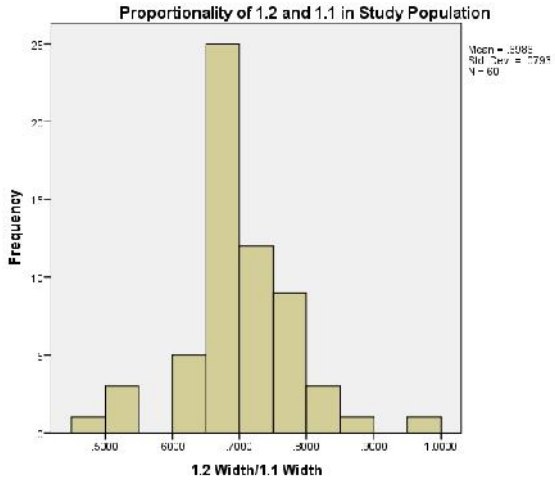
Appendix 7
Histograms of Variables

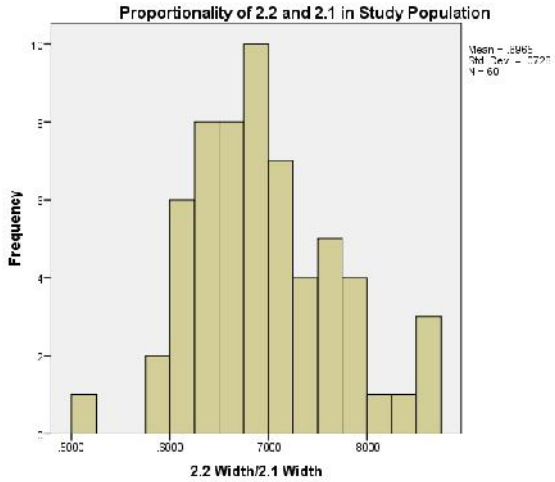


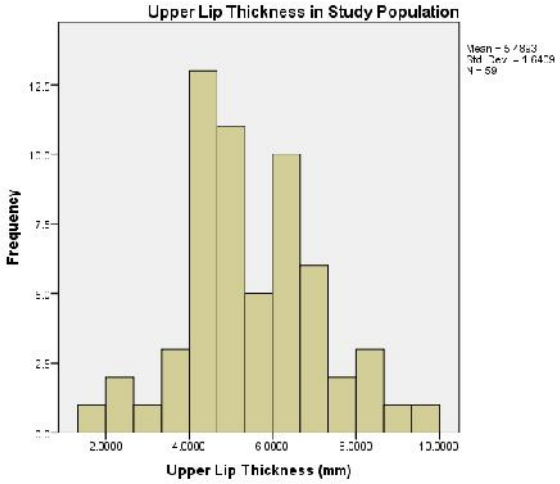


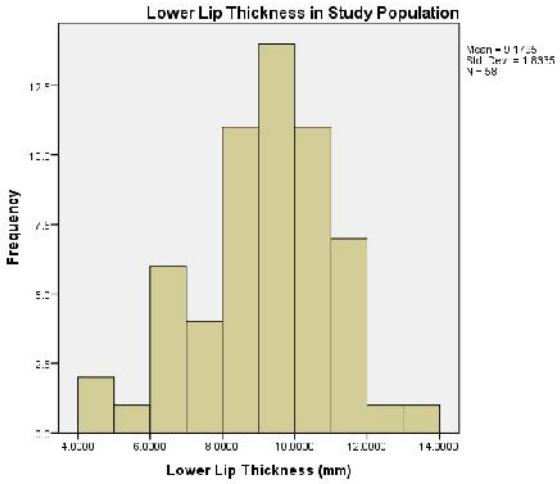


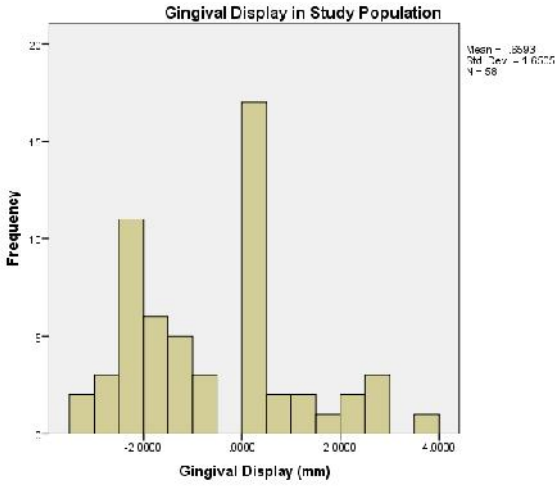

Proportionality of 2.2 in Study Population
Frequency
Tooth Width/Tooth Height

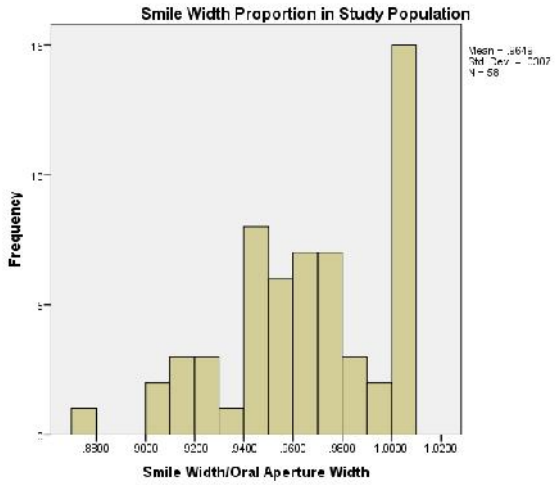

Proportionality of 1.2 and 1.1 in Study Population
Frequency
1.2 Width/1.1 Width

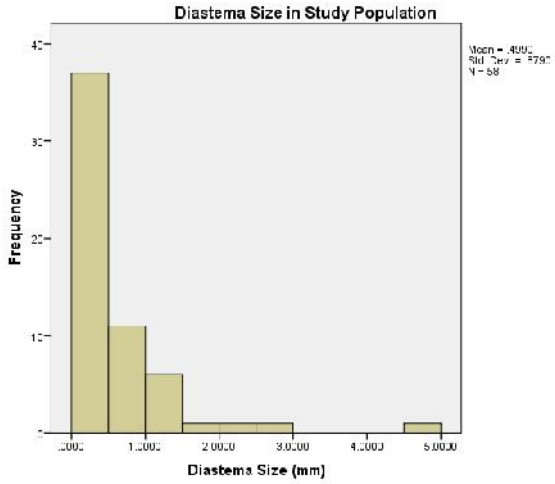

Proportionality of 2.2 and 2.1 in Study Population
Frequency
2.2 Width/2.1 Width

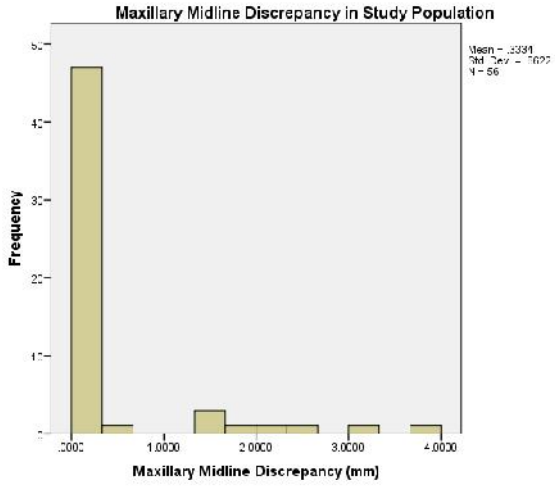

Upper Lip Thickness in Study Population
Frequency
Upper Lip Thickness (mm)

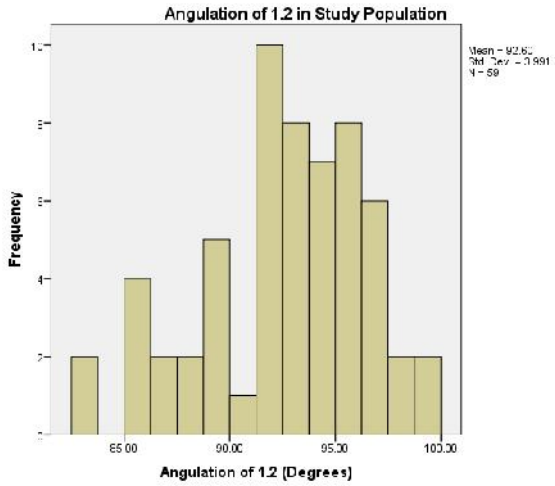

Lower Lip Thickness in Study Population
Frequency
Lower Lip Thickness (mm)

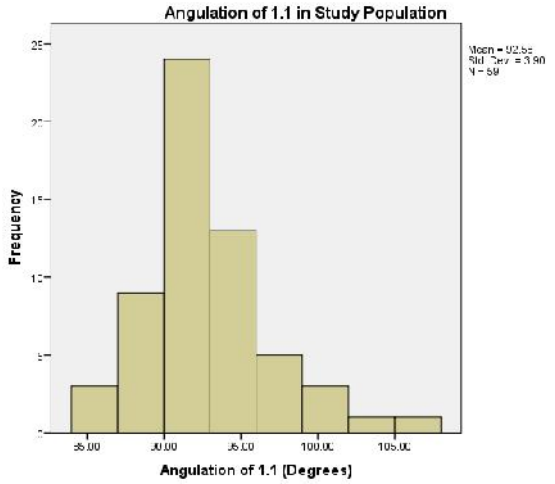

Gingival Display in Study Population
Frequency
Gingival Display (mm)

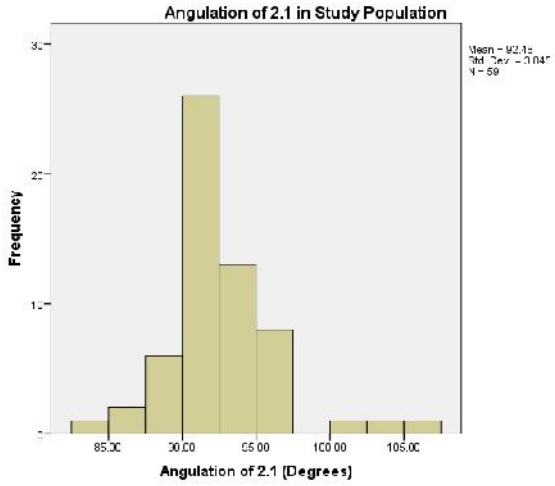

Smile Width Proportion in Study Population
Frequency
.8800
.9000
.9200
.9400
.9600
.9800
1.0000
1.0200
Smile Width/Oral Aperture Width

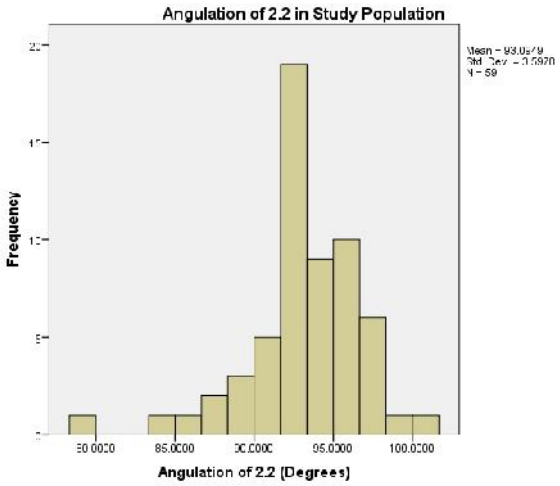

Diastema Size in Study Population
Frequency
1.0000
2.0000
3.0000
4.0000
5.0000
Diastema Size (mm)

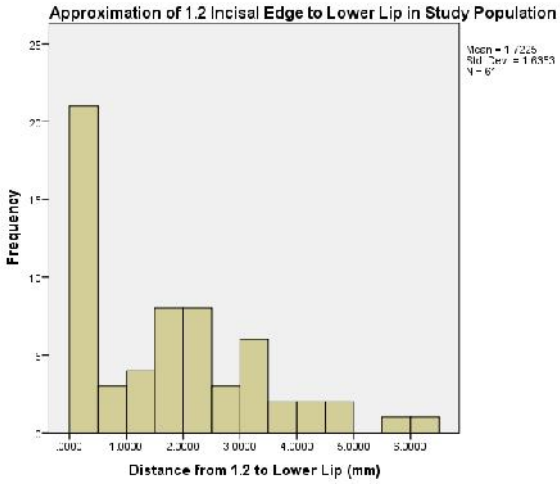

Maxillary Midline Discrepancy in Study Population
Frequency
1.0000
2.0000
3.0000
4.0000
Maxillary Midline Discrepancy (mm)

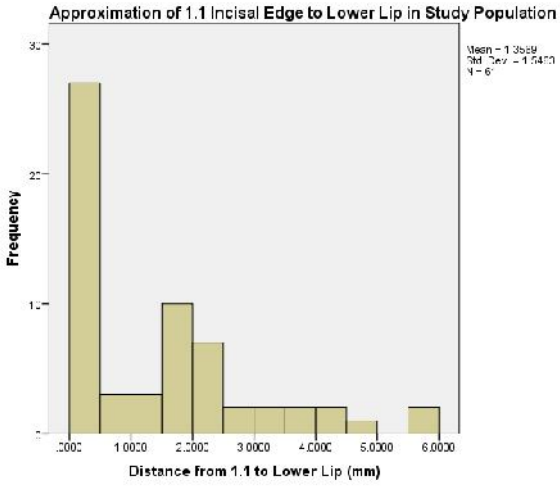

Angulation of 1.2 in Study Population
Frequency
85.00
90.00
95.00
100.00
Angulation of 1.2 (Degrees)

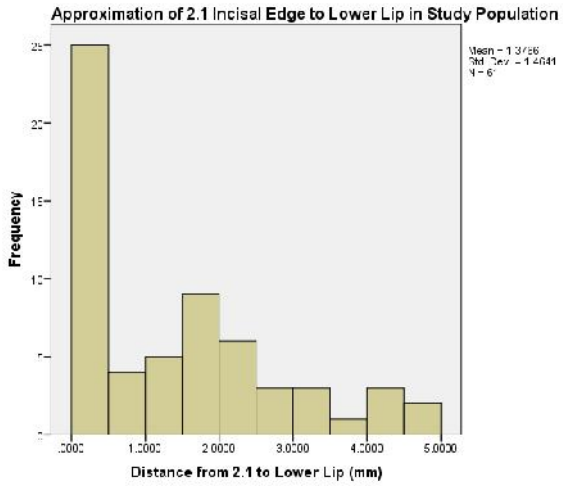

Angulation of 1.1 in Study Population
Frequency
Angulation of 1.1 (Degrees)

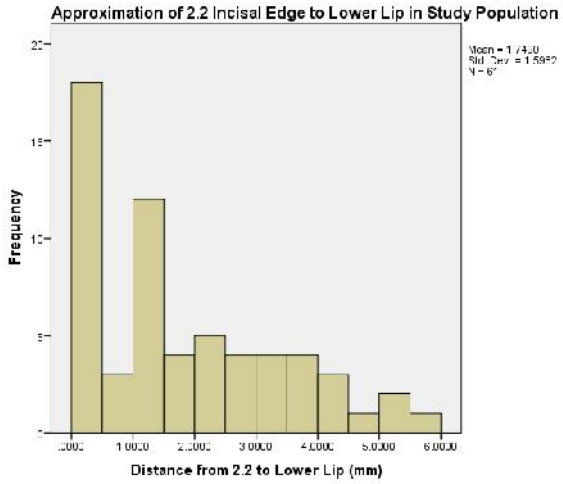

Angulation of 2.1 in Study Population
Frequency
85.00
90.00
95.00
100.00
105.00
Angulation of 2.1 (Degrees)


Angulation of 2.2 in Study Population
Frequency
80.0000
85.0000
90.0000
95.0000
100.0000
Angulation of 2.2 (Degrees)


Approximation of 1.2 Incisal Edge to Lower Lip in Study Population
Frequency
Distance from 1.2 to Lower Lip (mm)


Approximation of 1.1 Incisal Edge to Lower Lip in Study Population
Frequency
1.0000
2.0000
3.0000
4.0000
5.0000
6.0000
Distance from 1.1 to Lower Lip (mm)


Approximation of 2.1 Incisal Edge to Lower Lip in Study Population
Frequency
Distance from 2.1 to Lower Lip (mm)


Approximation of 2.2 Incisal Edge to Lower Lip in Study Population
Frequency
Distance from 2.2 to Lower Lip (mm)

Appendix 8
Logistic regression variables in the equation

	Variable	Coefficient (B)	S.E.	P-value	Exp(B)	95% C.I. for Exp (B)
Step 1	Sex	0.747	0.719	0.299	2.111	(0.516, 8.630)
	2x4	0.659	0.790	0.404	1.933	(0.411, 9.090)
	Diast	0.448	0.468	0.339	1.565	(0.625, 3.916)
	Smile Arc	-0.384	0.319	0.230	0.681	(0.364, 1.274)
	Intratooth	0.146	0.312	0.640	1.157	(0.627,2.134)
	Intertooth	-0.085	0.364	0.817	0.919	(0.450, 1.877)
	Right Angle	0.722	0.392	0.065	2.060	(0.956, 4.439)
	Lips	-0.239	0.324	0.460	0.787	(0.418, 1.484)
	Constant	-0.542	0.681	0.426	0.581	
Step 2	Sex	0.700	0.687	0.309	2.013	(0.524, 7.736)
	2x4	0.715	0.755	0.343	2.045	(0.466, 8.977)
	Diast	0.460	0.469	0.327	1.585	(0.632, 3.975)
	Smile Arc	-0.387	0.320	0.226	0.679	(0.363, 1.271)
	Intratooth	0.148	0.313	0.635	1.160	(0.628, 2.141)
	Right Angle	0.711	0.388	0.067	2.037	(0.952, 4.356)
	Lips	-0.244	0.324	0.452	0.784	(0.416, 1.478)
	Constant	-0.570	0.670	0.395	0.565	
Step 3	Sex	0.726	0.684	0.288	2.068	(0.542, 7.895)
	2x4	0.713	0.749	0.341	2.040	(0.470, 8.850)
	Diast	0.426	0.460	0.354	1.531	(0.622, 3.774)
	Smile Arc	-0.383	0.319	0.229	0.681	(0.365, 1.274)
	Right Angle	0.712	0.388	0.066	2.037	(0.953,4.356)
	Lips	-0.242	0.324	0.455	0.785	(0.416,1.480)
	Constant	-0.560	0.664	0.400	0.571	
Step 4	Sex	0.756	0.676	0.263	2.129	(0.566, 8.006)
	@2x4	0.635	0.738	0.389	1.888	(0.444, 8.026)
	Diast	0.456	0.498	0.360	1.578	(0.595, 4.189)
	Smile Arc	-0.381	0.316	0.227	0.683	(0.368, 1.267)
	Right Angle	0.717	0.383	0.061	2.048	(0.967, 4.337)
	Constant	-0.518	0.668	0.438	0.596	
Step 5	Sex	0.800	0.663	0.228	2.225	(0.606, 8.169)
	Diast	0.509	0.495	0.304	1.664	(0.630, 4.392)
	Smile Arc	-0.360	0.312	0.249	0.698	(0.379, 1.286)
	Right Angle	0.804	0.368	0.029	2.234	(1.086, 4.596)
	Constant	-0.085	0.437	0.845	0.918	
Step 6	Sex	0.914	0.657	0.164	2.494	(0.688, 9.046)
	Smile Arc	-0.354	0.309	0.252	0.702	(0.383, 1.287)
	Right Angle	0.848	0.362	0.019	2.335	(1.148, 4.749)
	Constant	0.117	0.392	0.764	1.125	
Step 7	Sex	0.801	0.639	0.210	2.229	(0.637, 7.792)
	Right Angle	0.819	0.355	0.021	2.269	(1.131, 4.554)
	Constant	0.146	0.389	0.708	1.157	
Step 8	Right Angle	0.735	0.339	**0.030**	2.085	(1.074, 4.049)
	Constant	0.463	0.302	0.125	1.589	
	Variables entered on step 1: Sex, 2x4, Diast, Smile Arc, Intratooth, Intertooth, Right Angle, Lips.					