Esthetics and Smile Characteristics Evaluated by Laypersons:
A comparison of Canadian and US data

By

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DEDICATION

To My Family

My full-hearted appreciation to my family for their tremendous love and support without which I would not be where I am today nor the person I am today. Your words of encouragement have always fueled me through my personal and professional challenges. Your belief in me and your prayers for me have given me the strength to reach my goals. Thank you.

Also dedicated to the late Anne McLeod, my Nana, who supported the 'get Catherine braces campaign'. My experience with my orthodontist, Dr.Emanuele, and my transformation from having braces had a profound impact on me and influenced the course of my life more than she knew. Throughout the 36 months of my specialty training, I often thought of the look of pride on her face each time she would ask me to flash her a smile in order to inspect the outcome up close. My confidence sky-rocketed each time she complimented me on my 'perfect smile'. The gratification Nana felt by serving a role in helping to provide me with a 'perfect smile' made me realize I too would like to improve smiles for others. Nana will be greatly missed at my final convocation.

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ABSTRACT

Objective: To collect data regarding Canadian laypersons perceptions of smile esthetics and compare these data to US data in order to evaluate cultural differences.

Methods: Using Adobe® Photoshop® 7, a digital image of a posed smile of a sexually ambiguous lower face was prepared so that hard and soft tissue could be manipulated to alter Buccal Corridor (BC), Gingival display (GD), Occlusal Cant (OC), Maxillary Midline to Face Discrepancy (MMFD) and Lateral Central Gingival Discrepancy (LCGD). Adult Canadian laypersons (n=103) completed an interactive computer-based survey of 29 randomized images to compare smile preferences for these variable. The custom survey was developed to display fluid, continuously appearing modifiable smile variables using MATLAB® R2008 for presentation. These data were compared to previously published data for US laypersons. Statistical inference was determined using Wilcoxon Rank Sum tests.

Results: Canadian laypersons were more sensitive in detecting deviations from ideal and had a narrower range of acceptability thresholds for BC, GD, OC, MMFD and LCGD. Ideal esthetic values were significantly different only for BC.

Conclusions: It appears cultural differences do exist related to smile characteristics. Clinically significant differences in the preference of the smile characteristics were found between Canadian and US laypersons. Canadian laypersons, on average, were more discriminating to deviations from ideal and had a narrower range of acceptability.

Key Words: smile esthetics, acceptability, Buccal Corridor, Gingival display, Occlusal Cant, Maxillary Midline to Face Discrepancy, Lateral Central Gingival Discrepancy.

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CHAPTER 1

INTRODUCTION

Forward

The esthetics of the smile, the relationships between the soft tissues (lips and gingival tissue) and the teeth, are considered fundamental in facial esthetics (Peck, Peck, 1970). It is a common conception that orthodontists are in the 'smile business', and patients have high expectations for the dental profession to evaluate and treat smiles. Improving smile esthetics is a common factor motivating patients to seek orthodontic treatment. Therefore, it is important for orthodontists to control the esthetic effects of their treatment on smile design. Smile design requires an understanding of the principles that manage the balances between teeth and soft tissues while a person smiles (Gul e, Fida, 2008). However, there is limited objective based literature to clarify the important relationship smile characteristics have on smile esthetics.

Facial esthetics and the smile have been researched from a variety of perspectives. Quantifying the perception of smile esthetics is important to both orthodontists and their layperson patients, as this perception can influence the assessment of clinical success and patient satisfaction after treatment. Dental professionals and laypersons are able to identify smile characteristics that both enhance and detract from smile esthetics (Moore, et al., 2005; Parekh, et al., 2006). More importantly, orthodontists and their layperson patients may have different perceptions of smile esthetics. The objective of orthodontics is to create a balance between the skeletal, and dental pattern with the soft tissue drape both dynamically and statically for

individual patients. Of all the possible arrangements of anterior teeth, orthodontists typically

think that one in which the teeth are perfectly aligned is the most esthetic, but laypersons may

not agree (Johnston, 1999). Ackerman *et al* (1999) highlighted the importance of understanding

the relationship between the teeth and the surrounding soft tissue in the design of the smile.

Sarver and Fields (2007) contributed to the widely held view that the smile involves three main

elements – the teeth, the lips and the gingival tissue, and that these elements include many

additional sub elements.

Sarver and Fields (2007) classified the appearance and esthetics into *macroesthetics,*

miniesthetics, and *microesthetics*. *Macroesthetics* are a set of facial esthetics that involves the

profile, vertical proportions, lip fullness, chin projection, nasal projection, etc; *miniesthetics* is a

set of smile parameters which include incisor display, transverse smile, smile symmetry,

crowding, smile arc, and vermillion display; and *microesthetics* is a set of parameters involving

gingival shape and contour, tooth shade, and triangular holes (Sarver, Fields, 2007).

One of the objectives in treating patients orthodontically is to achieve an esthetic smile.

Achieving this objective is the result of the appropriate interaction of different smile components

(Gracco, et al., 2006) and requires an understanding of the principles that manage the balances

between teeth and soft tissues while a person smiles (Gul e, Fida, 2008). To that end,

establishing treatment objectives to enhance smile esthetics based on plaster models alone is

inadequate. Patient expectations are expanded to esthetic smiles that include, but not limited to,

esthetically aligned teeth. The public now expects orthodontists to be 'orthofacists' as well

(Gianelly, 2009).

Individual and ethnic characteristics and perceptions of smile esthetics must be considered in smile design (Mahshid, et al., 2004). By developing a hierarchy of differences in esthetic preferences based on ethnicity / nationality, clinicians can understand the complex inter-relationship of smile characteristics in order to both idealize and limit compromises in smile esthetics.

Identifying differences in perceptions of smile esthetics among orthodontists and laypersons specifically regarding the inter-related elements that make up a smile, is beneficial. Many attempts have been made to objectively evaluate subjective perceptions of smile esthetics amongst dental professionals and laypersons. Kokich Jr, Kiyak, and Shapiro (1999) were the first to systematically quantify orthodontists' and laypersons' perceptions of esthetic smiles by using still photos of posed female smiles adjusted in incremental amounts. Their results indicated that dental professionals recognize specific dental esthetic discrepancies more readily than laypersons, and that laypersons were less critical of discrepancies than dental professionals (Kokich, Kiyak, and Shapiro, 1999). In contrast, Krishnan *et al* (2008) found no difference in the evaluation of overall smile characteristics between specialists and laypersons.

The interactions between smile characteristics and smile esthetics have been described in components of different studies. The dilemma is that the results of studies on ideal and acceptable values for smile characteristics, the results remain speculative or based on artistic interpretation (Sarver, Fields, 2007). The shortcomings of previous studies include confounding variables from lipstick colour, inclusion of full-face views, and larger incremental differences of

1mm or more may have distorted standards of ideal and acceptability. Thus far, Ker *et al* (2008) is the only study which investigated perceptions of smile characteristics along a continuous range where the evaluator digitally modified smiles to select the most ideal and to determine the thresholds of acceptability.

The purpose of this collaborative multicenter study was to incorporate slider technology and advanced digital imaging methods to quantitatively determine and compare ethnic / national differences in smile esthetic preferences of Canadian US laypersons. The smile parameters selected for investigation greatly influence smile esthetics and comprise the key elements in smile design. These data will be compared with published US data. The survey presentation techniques were refined from Ker *et al* (2008).

The aim was to quantify and compare ideal and acceptable ranges of smile characteristics between Canadian and US laypersons through their manipulation of standardized gender ambiguous photos of the lower face along a visually continuous scale. This is the first known collaborative study of both US and Canadian data sets to provide clinically relevant results with adequate statistical power to influence practice patterns. Another purpose was to generate Canadian standards based on an anchored scale of physiologic ranges determined by US Orthodontists.

RATIONAL FOR THE STUDY

The present study investigated an area of the literature with little precedent and minimal empirical evidence, that has the potential to identify quantifiable definitions for, what has until recently been considered, subjectively descriptive characteristics. Smile evaluation and smile design are important yet a comprehensive smile analysis is often ignored in clinical examinations (Krishnan, et al., 2008). Descriptive statistics can be translated into quantitative statistics through the use of a nearly continuous data set rather than using static images of predefined ideals and large incremental deviations from ideal. In this study, laypersons were surveyed because they are the primary consumer of orthodontic services and their satisfaction with the treatment outcome depends on the patient expectations. The definitive preferences of lay people for ideal and acceptable deviations of smile characteristics will be available from the data.

Although there are data from another ethnic group that deal with one aspect of smile esthetics (buccal corridor) (Yang, Nahm, and Baek, 2008) that show similar preferences to US raters, to this point, no study has comprehensively examined whether differences in ethnic background / nationality can alter the perception of smile characteristics. Quantifying potential North American ethnic differences in perception of smile esthetics could reveal important considerations in achieving clinical success and patient satisfaction. Clinicians can use the results of this study as both a guideline toward laypersons expectations, ideal orthodontic finishes and acceptable compromises.

OBJECTIVE

An objective of this collaborative study was to develop a survey to Ker *et al* (2008) in order to administer standardized images for rating by adult laypersons across Canada and to

compare differences in national preferences. The purpose of this study was to quantify and

compare smile characteristic preferences between Canadian and US laypersons.

CHAPTER 2

REVIEW OF LITERATURE

The Re-emergence of the Soft Tissue Paradigm and Smile Esthetics

The paradigm shift towards soft tissues and smile esthetics has re-emerged in orthodontic diagnoses. This shift emphasizes the interaction between soft and hard tissues around the mouth and how they contribute to smile esthetics (Ackerman, Brensinger, and Landis, 2004; Gul e, Fida, 2008). Hulsey (1970) defined *harmony* as the "attractive interrelationship existing between the dentition and the surrounding soft tissue" and provided evidence to support the importance of this feature in an attractive smile.

The objective of orthodontic treatment is to establish a balance between esthetics and function. Establishing ideal function and esthetics may be mutually exclusive and requires detailed consideration during orthodontic treatment planning that should include examination of facial and dental relationships both statically and dynamically. Treatment plan decisions thus include dental and skeletal changes needed to achieve both the esthetic and functional goals (Sarver, Ackerman, 2000). For many patients, the esthetic aspects of treatment are as important as the functional aspects. However, a good occlusion does not always result in an attractive smile (Ackerman, et al., 1998). Norman Kingsley, as cited by Sarver and Ackerman (2000), suggested that the ideal articulation of the teeth was secondary to achieving a good facial appearance. This contradicts Edward Angle's philosophy that harmonious facial form would follow predictably

from the establishment of ideal occlusion; and therefore, specific esthetic objectives were unnecessary (Sarver, Ackerman, 2000). It is critical to appreciate that Angle preceded cephalometric radiography and analysis and marked technological developments in photography (Proffit, 2007). These beliefs, although varied, emphasize that orthodontics increasingly encompasses more than an understanding of how to straighten teeth. Increased attention has been focused on protecting and / or improving the facial soft tissues. This also stresses the importance of a fundamental goal of orthodontics: treat each patient individually including the face and lip curtain by changing lip to teeth relationships. Orthodontic treatment goals encompass three primary objectives: functional efficiency, esthetics and stability (Riedel, 1950). An esthetic smile is the result of the interaction of different components (Gracco, et al., 2006).

Arnett and Bergman (1993) stated: "Facial analysis should be used to identify positive and negative facial traits and therefore how the bite should be corrected to optimize facial change". Orthodontic treatment planning should include an examination of facial and dental relationships statically and dynamically in four dimensions, and treatment plan decisions include dental and skeletal changes needed to achieve the esthetic and occlusal goals (Sarver, Ackerman, 2000).

Opinions regarding esthetics are also a function of perception. The subjective perception of facial and body image and oral function does not necessarily correspond to objective factors, such as millimetre discrepancies from ideal, but may be significant determinants of post treatment satisfaction and may be a predictor of the individual's willingness to undergo a particular treatment (Maxwell, Kiyak, 1991). Quite often, patients see their own faces differently than professionals. It can be clinically observed that when the expectations (esthetic,

function, social) of the patient exceed those of the clinician, the treatment plan and treatment may be doomed to perceived failure (McFadden, 2007). The esthetics of a smile is influenced by different characteristics to varying degrees, which are distinguishable to laypersons (Moore, et al., 2005). Parekh *et al* (2007) reviewed gender differences in the literature and cited studies that have shown that females rate attractiveness higher than their male counterparts and other studies reporting that laypersons to be less critical than orthodontists when rating profiles. Perceptions of esthetics and treatment need, however, may differ between the various groups. Orthodontists, by nature of their training, work, and personalities may be more sensitive to disharmonies in esthetics (Juggins, Nixon, and Cunningham, 2005).

Clinical Implications of this Study

It is important for clinicians to understand the complex inter-relationship of smile characteristics in order to both idealize and limit compromises in smile miniesthetics. The results of this study may produce clinical guidelines that emphasize the importance of achieving esthetic smiles by incorporating the relationship of the teeth to both intraoral and extra-oral soft tissues and avoid the creation of an excessively flat smile arc, for instance, during orthodontic treatment. This concept has been articulated by Sarver (2001). Establishing a consonant smile arc is now an objective in his treatment planning. Just as patients get individualized treatment plans they should also have individualized designs for appliance placement (Sarver, 2001).

Consideration of these results could lead to a more individualized interpretation of smile esthetics in treatment. The results from this study may provide specific clinical recommendations

based on a patient dependent approach to treatment. Bracket placement according to the relationship of the upper incisal edges to the lower lip curvature for each individual case may become a standard treatment objective. When studying dental esthetics it is important for clinicians to consider that although attractiveness may decrease indicating a detrimental result, the perceived change may still fall within the acceptable range to a majority of people. Based on the acceptability ranges, clinicians should be aware of individual preferences for each specific patient. An understanding of the patients' esthetic perception would permit better fulfilment of treatment expectations. This study will provide clinicians with a quantifiable range of deviation in smile parameters that the public may be willing to accept. This would aid the orthodontist in making treatment recommendations, treatment planning, and assessing the success of the esthetic aspect of treatment.

Introduction to Independent Variables of Smile characteristics: Definitions and their interactions with smile esthetics

Buccal Corridor

Buccal corridor is defined as the distance between the teeth and buccal soft tissues. More specifically, Buccal Corridor is the negative space between the buccal surfaces of the posterior teeth and the inner wall of the cheek (Frush, Fisher, 1958). Ackerman and Ackerman (2002) defined an ideal Buccal Corridor by introducing the smile index, width/height smile ratio equal to one.

Tjan, Miller, and The (1984) produced standards of normalcy for Buccal Corridor in an esthetic smile. Their findings showed that an average smile displays six maxillary anterior teeth

and the first or second premolars, has the incisal curvature of the maxillary anterior teeth parallel to the inner curvature of the lower lip, and has the incisal curve of the maxillary anterior teeth touching or slightly touching the lower lip (Tjan, Miller, and The, 1984). Hulsey (1970), and Frush and Fisher (1958) agreed with these standards. Other studies have found the range of ideal Buccal Corridors to vary between 2 percent dark space at the commissures (Moore, et al., 2005) and 19 percent dark space (Ritter, et al., 2006). In addition, Ritter *et al* (2006) found a general trend of preferences for Buccal Corridor towards 19 percent, which compared closely with 16 percent found in the study by Ker *et al* (2008).

There is no consensus on the degree to which Buccal Corridors influence smile esthetics. Some authors found Buccal Corridor does not contribute significantly to perceptions of smile esthetics amongst laypersons (Hulsey, 1970; Ritter, et al., 2006; Krishnan, et al., 2008). In contrast, Moore *et al* (2005) found large Buccal Corridors were associated with less attractive smiles. Laypersons prefer broad smiles with narrow Buccal Corridors to narrow smiles. This group preferred a greater number of teeth displayed during smiling as significantly more attractive than having fewer teeth displayed (Dunn, Murchison, and Broome, 1996; Moore, et al., 2005; Gracco, et al., 2006). Frush and Fisher (1958) disagreed stating that a broad smile with absent Buccal Corridors can give an unnatural prosthetic denture appearance. These results may differ due to the method of measurement, the fact that esthetic values change with time, and the inclusion of more than the lower face area in the images. The inconsistency in methodology is reflected by Hulsey (1970) who measured the ratio intermaxillary canine width with the distance between the corners of the smile, thereby excluding the dentition distal to the maxillary canines.

Gingival Display

Gingival display is defined as the vertical distance between the gingival margin and the nadir of the upper lip during a posed smile (Ker, et al., 2008). Clinically, Gingival Display is a function of upper lip length, upper lip elevation or elasticity during a spontaneous smile, age, gender, and absolute clinical crown length (Proffit, Fields, and Sarver, 2007).

Despite the fact that Gingival Display has been thoroughly investigated, many studies do not agree on the standards. The variability across studies could be the result of different increments of deviation from ideal as opposed to testing continuous data sets. This fact is illustrated in two separate studies by the same authors. In 1999 they suggested that ±4mm of Gingival Display was the threshold of acceptability evaluated by laypersons and dentists collectively (Kokich, Kiyak, and Shapiro, 1999) and later in 2006 tested smaller increments and suggested ±3mm evaluated by laypersons and orthodontists (Kokich, Kokich, and Kiyak, 2006). Continuous data sets have been used most recently and found that the ideal value for Gingival Display was 2.1mm incisor coverage and the acceptable range ± 4mm (Ker, et al., 2008).

Gingival display while smiling is important for pleasing facial esthetics and to the final esthetic outcome of orthodontic treatment (Sarver, 2004). A smile that shows less gingiva is considered more pleasant than a smile with a great display of gingiva (Gracco, et al., 2006). Investigating the acceptability range for Gingival Display has clinical relevance given the changing nature of this smile characteristic. It is important to maintain Gingival Display over the long-term considering that vertical lip changes occur with aging (Zachrisson, 2007). During the

finishing phase of treatment, the long-term aim should be to provide the patient with sufficient Gingival Display that will fall within the acceptability range after treatment, as well as many years after treatment.

Occlusal Cant

Cant is defined as a divergence of the occlusal plane from the transverse (horizontal) axis (Padwa, Kaiser, and Kaban, 1997).

Occlusal Cants have a powerfully detrimental effect on smile esthetics as they are particularly noticeable while smiling (Kokich, Kiyak, and Shapiro, 1999). Levelling the occlusal plane should be a goal of surgical and orthodontic therapy (Padwa, Kaiser, and Kaban, 1997). The etiology of a transverse Occlusal Cant can be differential eruption of the maxillary anterior teeth or a skeletal asymmetry of the nasomaxillary complex and/or mandible (Rosenstiel, Ward, and Rashid, 2000). Careful analysis of the cause of Occlusal Cants and mounted study casts are critical to treatment planning. Proper diagnoses as to the cause requires an accurate clinical examination as Occlusal Cants cannot be seen on intraoral images (Ackerman, et al., 2007). By altering the incisal plane in 1mm increments around a central point at the incisal embrasure between the central incisor crowns, Kokich *et al* (1999) found that dental professionals could detect a 1mm incisal plane asymmetry whereas laypersons could not detect a cant up to 3mm or 4° from true horizontal. Combining results from previous studies, it appeared a range exited from 2° (Geron, Atalia, 2005) to 4° (Peck, Peck, 1995; Padwa, Kaiser, and Kaban, 1997; Kokich, Kiyak, and Shapiro, 1999) was acceptable beyond which asymmetries become noticeable.

Maxillary Midline to Face Discrepancy

Maxillary midline to face is defined by the coincidence of the maxillary dental midline in relation to the facial soft tissue midline, which is established by the center of the philtrum (Tjan, Miller, and The, 1984; Morley, Eubank, 2001) and soft tissue nasion (Tjan, Miller, and The, 1984).

Symmetry is an important component of an esthetic smile (Hulsey, 1970; Brisman, 1980). Midline discrepancies are the most obvious occlusal asymmetries from the patient's perspective and maxillary midline deviations disturb the balance of esthetic smiles (Nanda, Margolis, 1996). The degree of esthetic acceptability depends on the amount of midline deviation in the transverse dimension. However, the literature is inconsistent on the magnitude of the deviation adversely impacting perceptions of dentofacial esthetics when judged by laypersons. Some authors report maxillary midline deviations greater than 2mm are noticeable by laypersons (Frush, Fisher, 1958; Johnston, Burden, and Stevenson, 1999). On the other hand, Kokich Jr. *et al* (1999) found laypersons were less sensitive to the magnitude of deviations, not noticing up to 4mm deviations. These results may differ due to the inconsistent incremental adjustment of each variable tested and therefore may not accurately identify the threshold for perceivable changes in each variable. By manipulating midline deviations along a continuous scale, Ker el al (2008) found that the maximum acceptable value to be 2.9mm.

Lateral Central Gingival Discrepancy

Maxillary lateral incisor gingival height discrepancy is defined by measuring the

difference between the central and lateral incisor gingival zenith, which is the vertical distance

between the apex of the maxillary central incisor gingival margin and the apex of the maxillary

lateral incisal gingival margin (Ker, et al., 2008).

The findings reported in Ker *et al* (2008) corroborated previous results from Kokich Jr. *et al* (1999). Laypersons did not readily notice gingival discrepancies between the maxillary central

and lateral incisors as demonstrated in their broad range of acceptability.

STATEMENT OF PROBLEM and NULL HYPOTHESES

Theories on the development of an esthetic smile remain unsubstantiated. Facial and smile

esthetics have been researched from a variety of perspectives. Until recently, however, the

literature has not clarified the importance of smile characteristics (Kokich, Kiyak, and Shapiro,

1999; Moore, et al., 2005; Wong, Kassim, and Foong, 2005; Parekh, et al., 2006). Clarification

of what is perceived as ideal and the range of what is deemed as acceptable in smile esthetics is

necessary, so that a more individualized approach to meet esthetic preferences can be

incorporated in treatment planning. Clinicians should make clinical decisions based upon as

much objective evidence as possible, instead of being forced to make clinical decisions based on

empirical judgment. Ker *et al* (2008) is the only study reported in the literature investigating

perceptions of smile characteristics along a continuous range where the evaluator digitally

modified smiles to select the most ideal and to determine the thresholds of acceptability.

Null Hypothesis H$_{01}$: There are no statistically significant differences in the perception of

Canadian as compared with US laypersons with respect to defining ideal:

      *1.*1 Buccal Corridor

      *1.*2 Gingival Display

      *1.*3 Occlusal Cant

      *1.*4 Maxillary Midline to Face Discrepancy

      *1.*5 Lateral Central Gingival Discrepancy Gingival Discrepancy

Null Hypothesis H$_{02}$: There are no statistically significant differences in the acceptable

deviations from ideal (mm range) between Canadian and US laypersons perceptions of smile

characteristics.

CHAPTER 3

MATERIALS AND METHODS

Background

This study and its procedures were approved by the University of Manitoba Research

Ethics Board (Appendix 1).

This collaborative research study used identical protocols and digital frontal photographs

as Ker *et al(2008)* and the method of presentation was compatible with that research so

comparison could be made with the results of Ker *et al* (2008). In addition, permission was

obtained from The Journal of the American Dental Association for use of copyrighted images

(Appendix 2).

Objectives, amongst others, were to compare ethnic, and national differences by

comparing Canadian and US laypersons responses, and to also test the reproducibility of

methods and results reported by Ker *et al* (2008).

Assessor Selection

This interactive computer-based survey was administered individually to laypersons in a

manner that was consistent with Ker *et al* (2008). Laypersons were recruited in person at various

locations across Winnipeg, Manitoba, Canada. The recruitment venues were chosen specifically

to draw from a diverse variety of assessors to represent the perceptions of Canadian laypersons. The samples included non dental undergraduate students at The University of Manitoba Undergraduate Student Union Building, and waiting room of The University of Manitoba Orthodontic / Periodontic clinics. Data collection was between August and October 2008, inclusive. Raters were offered an incentive for the 10-15 minutes of their time to complete the survey. The incentive was a chance to win a men's and ladies' watch set, and an electric toothbrush.

Survey Design and Administration

One hundred and three Canadian laypersons years of age and older voluntarily completed an anonymous interactive computer-based survey that consisted of a series of photographs from the lower face region including the lower face of a standardized gender neutral model. The interactive custom survey was developed to compare smile preferences, which displayed fluid, continuously appearing modifiable smile variables using MATLAB® R2008 (MATLAB R2008 (The Mathworks, Inc.,Natick, MA) -- a numerical computing environment and programming language software. The raters selected the ideal and acceptability thresholds of several independent smile variables. Participants were asked to digitally manipulate photographs of smile characteristics in order to appreciate the range of possibilities before selecting the ideal and acceptability thresholds of independent smile variables: Buccal Corridor, Gingival display, Occlusal Cant, Maxillary Midline to Face Discrepancy, Lateral Central Gingival Discrepancy. The survey began with a series of demographic questions followed by instructions on how to complete the questions associated with photographs, emoticon image-based questions.

Evaluators voluntarily and anonymously provided demographic information including Canadian geographical province of residence, age, gender, ethnic background, level of education completed, and dental affiliations. Surveys were individually administered and each rater provided 36 responses: 29 image based responses and seven demographic responses. The 29 images were randomized and standardized gender ambiguous images of the lower face. The survey consisted of 19 unique questions, and 10 repeat questions. The 19 unique questions were presented in random order for each evaluator to minimize bias. The repeat questions were randomly selected for each participant from the twenty three unique questions to test intra-rater reliability. At the completion of the survey, responses were automatically exported into an Excel® file randomly numbered for that individual rater. Once the data collection was completed, the Excel documents were compiled for statistical analysis. Surveys were administered on identically configured laptop computers (Appendix 3, 4, and 5).

Inclusion criteria for laypersons required that the evaluator be over 18 years of age, and must have lived in Canada for the last five years. Exclusion criteria included previous dental professional affiliations.

Model Selection

Digital frontal photographs identical to the images used in Ker *et al* (2008) were provided with permission (Appendix 2). The initial source photographs were selected from the Ohio State University Section of Orthodontics digital archive according to the protocol used by Parekh, *et al*

(Parekh, et al., 2006). These initial digital photographs received IRB ethics approval from the Ohio State University and subsequently from The University of Manitoba.

Image Manipulation

A digital image was adjusted from near ideal dental and lip configurations of a posed smile using Adobe® Photoshop® 7 (Adobe Systems, San Jose, Calif). Hard and soft tissue configurations were manipulated to alter Buccal Corridor, Gingival display, Occlusal Cant, Maxillary Midline to Face Discrepancy, and Lateral Central Gingival Discrepancy following the protocol of Ker *et al*. (2008)   The original JPEG images were digitally manipulated following the protocol of Ker *et al* (2008) on identically configured laptop computers (Ker, et al., 2008).

The facial images were cropped to show only the lips, nasal tip and mentolabial fold. The intraoral photograph was then bisected vertically and mirrored for symmetry. The presentation of standardized gender ambiguous images of the lower face area including the lower face allowed the smile to be seen in a more natural context while limiting confounding or distracting variables. A "hollow" lip curtain was created by erasing the teeth and periodontium from the lip curtain. The ideally treated dentition was then inserted into the "hollow" lip curtain to create a composite ideal photograph which set the standard for all ideal smile characteristics. All smile characteristics were digitally manipulated from a single, original, unique and unidentifiable composite frontal photograph (Ker, et al., 2008).

As in Ker *et al* (2008), the teeth and lip images appearing on the computer monitor were scaled to replicate clinical size at a typical conversational distance of 40cm. The resolution was standardized on all computers at 1024 x 768 pixels, and the images were sized to meet these dimensions. A digital measurement grid, calibrated to Wheeler's Dental Anatomy average value for a central incisor, was used for all smile characteristic digital modification. The size of the maxillary central incisor in the facial model was larger than the average value. Therefore, a correction factor of 0.73 was needed in all variables using metric measurements due to magnification of the intraoral images in Photoshop™. As a result, each variable was altered in 0.1825 mm increments and 0.25 degree increments instead of the originally planned 0.25 mm due to the built-in magnification correction. Figure 1 illustrates an example of the "filmstrip" of maxillary cant changing from severe to less severe. In MATLAB® survey author software, raters scrolled through these images to evaluate all possibilities for this smile characteristic. MATLAB® was developed to quantitatively compare smile esthetic preferences. This method used images to display continuously modifiable smiles across a pre-defined, physiological range.

Figure 1: Example of "filmstrip" of maxillary cant changing from severe to less severe.

Ker AJ, Chan R, Fields HW, and colleagues. *Esthetics and smile characteristics from the layperson's perspective: a computer-based survey study.* JADA 2008 139(10):1318-27. Copyright © 2008 US Dental Association. All rights reserved. Reprinted by permission.

Survey Content

MATLAB® R2008a (Mathworks Inc., Natick MA) custom survey author software was used to develop and administer the survey. MATLAB® survey administration software linked

questions to emoticons which produced a display of continuously modifiable smile characteristics over a pre-defined physiologic range. This interactive interface presented respondents with an animated movie compiled from a series of discrete image "frames". The software allowed raters to move a slider along the film strip of images to adjust each variable (Figure 1). Emoticons, discrete photographs, were coupled to a slider bar that enabled the image to change as the slider was moved. A spectrum of slightly different images was combined into a slowly moving series of images as the rater moves the slider bar. Smile characteristics were manipulated by the raters on a visually continuous scale so they could appreciate the realm of possibilities before they chose what they consider most appealing and the threshold of acceptability (Ker, et al., 2008). Each region along the slider bar corresponds to an emoticon assOcclusal Cant iated with a different data set of smile characteristics predetermined by Ker *et al* (2008). As the raters move the slider bar, an illusion is created of a film strip of continuously changing smile choices. This film strip illusion was created by a series of individual images changing in 0.1825mm incremental amounts. Once the evaluator chose their preferred image, the survey software would then record the emoticon photograph that corresponds to a particular data set of smile characteristics along the slider bar.

Image-based questions were presented with one of two questions: 1) "Select the image you find MOST IDEAL" or 2) "Please move the slider to the left to select the FIRST image that you find UNATTRACTIVE". Question one was designed to determine the ideal value for each smile characteristic. Question 2 was designed to determine the acceptability thresholds before a smile characteristic becomes unattractive (Appendix 3, 4, and 5).

The survey was designed to encompass differing ranges of values for smile characteristics: Buccal Corridor, Gingival Display, Occlusal Cant, Maxillary Midline to Face Discrepancy, Lateral Central Gingival Discrepancy. The range of values was selected based on Parekh's pre-defined physiologic scale which was anchored by US orthodontists' threshold levels, but allowed for increased variation (Parekh, et al., 2006). Ideals were inherent for variables Occlusal Cant and Maxillary Midline to Face Discrepancy and therefore not tested. Table 1 summarizes the method of measurement and the range of possible values.

Table 1: Summary – Range of Values and Measurement of smile variables.

Variable	Range of Values	How Variable Was Measured
Buccal Corridor (Bilateral Total)		Horizontal distance from the facial of the most buccal posterior tooth to a vertical line through the commisure of the lips
Millimetric	0 - 19 mm	
Percentage	0 - 26%	
Gingival Display	-5.1 mm to +5.8 mm	Vertical distance from the gingival zenith of the maxillary central incisors to the nadir of the upper lip above these teeth
Occlusal Cant clusal Cant	0 to 6 degrees	Amount of rotation in the maxillary and mandibular dentition from horizontal plane through the middle of the maxillary central incisors
Maxillary Midline to Face Discrepancy	0 mm - 4.4 mm	Horizontal distance from the middle of the embrasure between the maxillary central incisors to a line representing the midline of the face as determined by the nadir of the cupid's bow and center of the philtrum of the upper lip
Lateral Central Gingival Discrepancy	1.1 mm apical to central incisor to 3.8 mm incisal to central incisor	Vertical distance between the apex of the maxillary central incisor gingival margin to the apex of the maxillary lateral incisor gingival margin

For the independent variables, the image manipulation and range tested is described below as

per Ker *et al* (2008).

Buccal Corridor

The method of Parekh *et al* (2006) was used to create a series of template parabolas. MATLAB®

R2008 (MATLAB R2008 (The Mathworks, Inc.,Natick, MA) was used to generate a nearly

continuous set of possible Buccal Corridors. Buccal corridor spaces were manipulated by

altering the amount of black space between the lip commissure and the most buccal tooth in the

smile by moving the posterior teeth medially or laterally. The ideal, maximum tolerable value

(i.e., upper limit), and minimum tolerable value (i.e., lower limit) was assessed.

Gingival Display

Gingival display on smile was accomplished by modifying the skeletal position of the dental arches in 0.1825 mm increments. The ideal, maximum tolerable value (i.e., upper limit), and minimum tolerable value (i.e., lower limit) was assessed.

Occlusal Cant

The entire dentition was canted in one-quarter degree increments by gradually rotating the occlusal plane in a clockwise direction through a point between the central incisors. The ideal and maximum tolerable value (i.e., upper limit) was assessed.

Maxillary Midline to Face Discrepancy

The ideal maxillary midline was defined with the maxillary midline coincident with the philtrum. The maxillary dentition was moved to the left in 0.1825 mm increments while the posterior dentition was morphed to maintain even Buccal Corridors.

Lateral Central Gingival Discrepancies

A gingival layer overlay allowed apical or incisal movement of the gingival zenith of the maxillary lateral incisors in 0.1825 millimeter increments. The incisal edges will be maintained at their original height. The ideal, maximum tolerable value (i.e., upper limit), and minimum tolerable value (i.e., lower limit) of the difference in gingival heights between maxillary central incisor and maxillary lateral incisor was assessed.

Statistical Analysis

Chi-square and t-tests were used to analyze demographics and test whether the groups were comparable. Confounding variables were controlled by stratifying gender, ethnicity, and educational background. Statistical inference was determined using Wilcoxon Rank Sum tests. The data were subjected to Kruskal Wallis Mann Whitney tests with Bonferroni-Holm correction on the critical significance level (alpha=0.0025) to establish ideal and maximum acceptable ranges. Differences between the published US data[16] and Canadian groups were evaluated with the level of significance established at alpha value <0.05 for all analyses using statistical software (SAS, Version 91.3, SAS Institute, Cary, NC). Differences in attractiveness ratings were analyzed using descriptive nonparametric statistics including median values. For an alpha level of 0.05 and assuming a common standard deviation of 17.42 (Maple, et al., 2005), a sample size of 43 per rater group was necessary to achieve a power of 0.85 to determine statistically significant differences between all variables, as demonstrated by a 1mm or 1 degree difference on the slide scale. Differences in reliability ratings were analyzed using the weighted Kappa statistic at a 95% confidence interval.

RESULTS

Reliability and Reproducibility

Intra-rater reliability was excellent, and assessed by Kappa value (Landis, Koch, 1977) 0.98. The results of this investigation therefore are deemed to be reproducible and reliable.

Frequency Distributions / Rater Demographics

One hundred and three Canadian adult laypersons completed the survey. Distribution by gender, ethnicity, and educational background for the Canadian group and the published US data are presented in Table 2.

Table 2: Frequency distribution of demographic variables by evaluator group.

* Post-Secondary Not Attained = high school, some college, bachelors degree

Evaluator Groups	Gender		Ethnicity		Level of Education Completed	
	Male	Female	Caucasians	Non-Caucasians	Post-Secondary Attained	Post-Secondary Not Attained*
Canadian Laypersons	(61) 59%	(42) 41%	(65) 63%	(38) 36%	(18) 18%	(84) 82%
US Laypersons	(45) 37%	(78) 63%	(200) 83%	(41) 17%	(59) 24%	(184) 76%
Significance	p< 0.0001		p< 0.0003		P<0.0001	

These data indicate the highest proportion of female (63%) evaluators was within the US laypersons group, whereas the highest proportion of male (59%) evaluators was within the Canadian laypersons group. The highest proportion of Caucasian (83%) evaluators was within the US laypersons group, whereas the highest proportion of Non-Caucasians (36%) evaluators was within the Canadian laypersons group. On average, US (24%) laypersons were more highly educated than Canadian (18%) laypersons. After stratifying on gender, ethnicity, and educational background, these three confounding factors were not predictive of the five smile characteristic preferences in either group. Therefore, the Canadian and US groups were comparable as the differences found between the Canadian and US smile preferences were not influenced by these confounders.

Summary Statistics Comparing National Preferences between Canadian and US Laypersons

The descriptive numeric results and corresponding image depiction for each smile characteristic defined as ideal and within acceptable limits are reported using medians.

The most prominent trend throughout the results highlight the ethnic / national differences found

between the Canadian and US perceptions of all smile characteristics investigated (Figure 2).

The hierarchy of differences between the groups at the maximum tolerable limit of acceptability

is illustrated in decreasing order in Figure 8. The findings of the study revealed national

differences between Canadian and US laypersons; they are not equally critical of smile esthetics,

nor necessarily have similar smile esthetic preferences. Groups greatly disagreed at the

maximum tolerable limit of acceptability for OC, BC, and LCGD implying that ethnic

differences would likely result in disagreement on treatment outcomes to a greater degree than

for GD and MMFD (Figure 2).
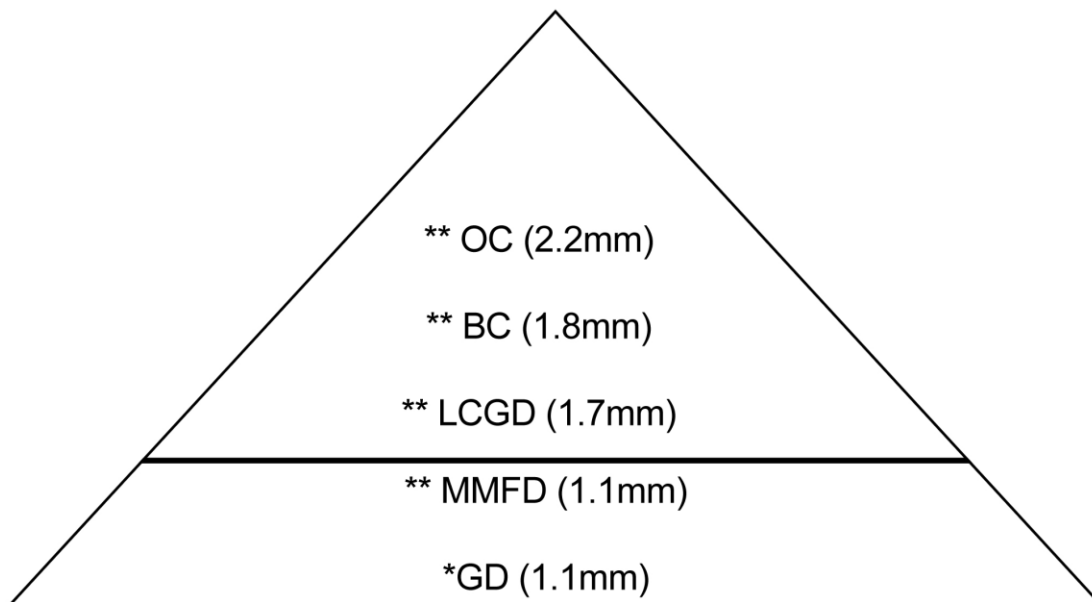
Figure 2: Hierarchy of differences between the groups at the maximum tolerable limit of acceptability
*p<0.05; **p<0.0025

The summary statistics and associated images for ideal and the threshold of acceptability are

illustrated in Figures 3 through 7. Cultural / national differences of less than 1 mm were not

considered clinically significant.

National Differences Defining Ideal and Acceptable Smile Characteristics

Ideal esthetic values were significantly different only for Buccal Corridor (Figure 2) with approximately 7% less dark space (5.3mm) tolerated by the Canadian group (p<0.0025).

Figure 3: Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Buccal Corridor

Ker AJ, Chan R, Fields HW, and colleagues. *Esthetics and smile characteristics from the layperson's perspective: a computer-based survey study.* JADA 2008 139(10):1318-27. Copyright © 2008 US Dental Association. All rights reserved. Reprinted by permission.

Both groups defined Ideal Gingival Display (Figure 3) with limited tooth coverage by the lip (2.7

and 2.1mm) and Lateral Central Gingival Discrepancy (Figure 4) with the lateral gingival zenith

slightly incisal to the central gingival zenith (0.6 and 0.4 mm) similarly and with no clinical

implications.

Figure 4: Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Gingival Display

Ker AJ, Chan R, Fields HW, and colleagues. *Esthetics and smile characteristics from the layperson's perspective: a computer-based survey study.* JADA 2008 139(10):1318-27. Copyright © 2008 US Dental Association. All rights reserved. Reprinted by permission.

Figure 5: Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Lateral Central Gingival Discrepancy

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The ethnic differences between the groups were most evident at the maximum tolerable limit of acceptability. The Kruskal-Wallis test revealed highly statistically significant differences between the groups for the acceptable range for all smile characteristics (Figure 2-7). Canadian laypersons were more sensitive in detecting deviations from ideal and have a narrower range of acceptability thresholds for some variables. For each variable Canadians accepted statistically and clinically less maximum variation from ideal. For BC, the minimum dark spaces were similar, but Canadians liked significantly less dark space for the maximum buccal corridor (22 versus 19.5% or 1.8mm). For GD, the minimum displays were not significantly different, but the maximum display was statistically and clinically less for Canadians by 1.1mm. LCGD was statistically and clinical different with Canadians approving 1.7 mm more incisal gingival position for the lateral incisor gingival. Canadians accepted only a maximum of 1 degree of occlusal cant versus the US 4 degrees and 1.8 mm of MMFD instead of the US 2.9 mm. Again both were statistically and clinically significant.

Figure 6: Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Occlusal Cant

Ker AJ, Chan R, Fields HW, and colleagues. *Esthetics and smile characteristics from the layperson's perspective: a computer-based survey study.* JADA 2008 139(10):1318-27.
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Figure 7: Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Maxillary Midline to Face Discrepancy

Ker AJ, Chan R, Fields HW, and colleagues. *Esthetics and smile characteristics from the layperson's perspective: a computer-based survey study.* JADA 2008 139(10):1318-27. Copyright © 2008 US Dental Association. All rights reserved. Reprinted by permission.

Evaluation of Hypothesis

Null Hypothesis H_{01}

There were no statistically significant differences in the perception of Canadian and

US laypersons with respect to defining ideal:

> *1.*1 Buccal Corridor (BC)

> *1.*2 Gingival Display (GD)

> *1.*3 Occlusal Cant (OC)

> *1.*4 Maxillary Midline to Face Discrepancy (MMFD)

> *1.*5 Lateral Central Gingival Discrepancy (LCGD)

The Null Hypotheses statements were **accepted** for Gingival Display, Occlusal Cant, Maxillary Midline to Face Discrepancy, and Lateral Central Gingival Discrepancy showed no statistically nor clinically significant differences perceived between Canadian and US laypersons when defining ideals ($p>0.0025$). The Null Hypotheses statement was **rejected** for Buccal Corridor as statistically and clinically significant differences were perceived between Canadian and US laypersons when defining ideal Buccal Corridor   ($p<0.0025$).

Null Hypothesis H$_{02}$

There were no statistically significant differences in the acceptable deviations from ideal (mm range) between Canadian and US laypersons perceptions of smile characteristics.

The Null Hypotheses statement was **rejected** for Buccal Corridor, Occlusal Cant, Maxillary Midline to Face Discrepancy, and Lateral Central Gingival Discrepancy ($p<0.0025$) and Gingival Display ($p<0.05$) as there were statistically and clinically significant differences perceived between Canadian and US laypersons about acceptability thresholds.

CHAPTER 5

DISCUSSION

General Evaluator Group Comparisons

This study flushed out unexpected differences between Canadian and US laypersons' perception of ideal smiles and also which smiles fell within a range they considered acceptable. The results demonstrate that laypersons can consistently identify their chosen selection from a series of smiles presented as digital images of the lower face. The participant's reliability strengthens the power of this methodology. Defining laypersons preferences through standardization of image presentation using computer-based slider technology in a realistic context across several smile characteristics is a reliable and accurate method of identifying esthetic perceptions.

These results revealed Canadian and US laypersons' preferences differed statistically and clinically in their perceptions of some individual smile characteristics. With the exception of the ideal BC, this was focused on maximum tolerable differences. Canadian and US orthodontists should not assume that all patients in North America are equally critical of their smile esthetics, nor do they necessarily have similar smile esthetic preferences.

Surprising trends revealed Canadian and US laypersons differed in their acceptance level of esthetic deviations from ideal. Canadian laypersons were more sensitive in detecting deviations from ideal and had a narrower range of acceptability thresholds for all smile characteristics (Figures 2-6).   US laypersons appear to tolerate a wider range of variability because they placed less value on smile esthetics, and/or are more forgiving of imperfections. As a result, US laypersons may be more accepting than orthodontists might expect, whereas Canadians may be less tolerant. As a result, US laypersons may be more accepting than orthodontists might expect, whereas Canadians may be less tolerant. This may have the effect of allowing less latitude for Canadian orthodontists if the values are considered not only from a statistical perspective, but as clinically relevant. Both groups were most critical at the maximum tolerable limit of acceptability for Occlusal Cant, Maxillary Midline to Face Discrepancy, and Lateral Central Gingival Discrepancy (Figure 2-6) compared to Buccal Corridor and Gingival Display (Figure 2-7), revealing that these smile characteristics had an overwhelming clinical impact on smile esthetics. Clinicians might place greater value on idealizing Occlusal Cant, Maxillary Midline to Face Discrepancy and Lateral Central Gingival Discrepancy over Buccal Corridor and when prioritizing treatment objectives in North America. However, previous studies confirmed that only Buccal Corridor (Moore, et al., 2005; Roden-Johnson, Gallerano, and English, 2005; Parekh, et al., 2006; Ritter, et al., 2006) influenced smile esthetics. This study more closely agreed with Hulsey (1970) and Roden-Johnson et al (2005) who found that variations in buccal corridor seemed to have no significance on smile attractiveness. The reason for this inconsistency in the literature may be a function of a few reasons. During the decade that past between this study and the conflicting studies, the ethnic mix in the US has changed dramatically. Such a trend could be redefining the influence of Buccal Corridor on smile

esthetics. In addition, the conflicting study by Ritter (2006) was performed in Brazil, not the US. The conflicting studies may not have examined the true influence of Buccal Corridor on smile esthetics as they did not measure Buccal Corridor consistently.

Ethnic influences also contributed towards differences in Canadian and US laypersons' definition of acceptable clinical results (Figure 2-6). Groups greatly disagreed at the maximum tolerable limit of acceptability for OC, BC, and LCGD implying that national differences would likely result in disagreement on treatment outcomes to a greater degree than for GD and MMFD (Figure 7). Admittedly, statistically significant differences found between the groups do not directly necessarily confer clinically meaningful differences of the same magnitude.

It is a common assumption that Canadians and US laypersons share a generalized value set. It appears this study has demonstrated that different cultures or different mixes of ethnicity can provide different preferences. Other ethnic data exist for one aspect of smile esthetics (Krishnan, et al., 2008), but the current study comprehensively examined whether differences in the cultural / nationality background can alter the perception of smile characteristics. More investigation on cultural influences is warranted so that future studies consider this factor during planning and analysis as it may emerge as a confounding variable.

Statistically significant results do not necessarily infer noticeable therapeutic effects. For this reason, the current study set 1 mm as a lower limit for the threshold of clinical significance. Given substantial sample power, small differences can be unrealistically amplified. The lower face view used in this study may have facilitated the detection of small clinical differences

compared to a full face perspective. As a result, the lower limit of clinical significance threshold was set at 1mm. A similar focusing effect of the slider technology, likewise, may have heightened attention on the variables.

While perspectives are subjective, these results provide significant insights of post treatment satisfaction and may be a predictor of the patients' objectives when undergoing a particular treatment (Maxwell, Kiyak, 1991). Both orthodontist must make a decision in concert with the patient as to what tradeoffs are acceptable in the pursuit of the ideal smile (Sarver, Ackerman, 2003). Discussing the potential limitations of orthodontic treatment with the patient is of utmost importance.

Smile Characteristic Comparisons

Buccal corridor reduction is particularly relevant today with the trend toward broader arch forms and non-extraction treatment (Sarver, Ackerman, 2003; Ioi, Nakata, and Counts, 2009). Substantial variability was reported in the literature on ideal Buccal Corridor size, ranging from 2 percent (Moore, et al., 2005) to 19 percent (Ritter, et al., 2006). Our results showed Canadians defined ideal buccal corridor size (Figure 2) as nine percent, and the acceptability range was 7 to 20 percent. These findings are inconsistent with the conclusions stated by Ker et al (2008) in that US defined ideal buccal corridor size (Figure 2) to be 16 percent dark space at the commissures, and the acceptability range was 8 to 22 percent. Canadians had a narrower range of acceptability thresholds for Buccal Corridor by 1.8mm (p<0.0025) revealing that Canadians are less likely to accept clinical variability in the treatment outcome. This was the only variable where ideal esthetic values were defined as significantly different, statistically and

clinically. This clinically significant difference may not exist if tested with an image illustrating

the entire face. It is important for the clinician to understand that the appearance of buccal

corridors are affected by a number of factors: the antero-posterior position of the maxilla relative

to the lip drape, which is affected by extraction treatment; surgical maxillary advancement; and

the broadness of the arch form (Sarver, 2001). Therefore, orthodontists should consider esthetic

tradeoffs and functional consequences in all smile dimensions (Sarver, Ackerman, 2003). Buccal

Corridor can be controlled by attention to the vertical pattern of the face, amount of upper incisor

exposure, and the sum of tooth material (Yang, Nahm, and Baek, 2008) and improving excessive

buccal corridor, may be an important treatment objective during treatment planning (Dunn,

Murchison, and Broome, 1996; Moore, et al., 2005; Gracco, et al., 2006). Interestingly, buccal

corridor analysis is a clinical finding that is rarely recorded during diagnosis and treatment

planning (Krishnan, et al., 2008). Due to the importance of buccal corridor during treatment

planning, clinical evaluation of the posed smile should be accompanied by a measurement of the

horizontal distance from the facial of the most buccal posterior tooth to a vertical line through the

commissure of the lips in neutral head position at conversational distance (Isiksal, Hazar, and

Akyalcin, 2006) to be compatible with the values in this study.

Finishing orthodontic treatment within an acceptable range of Gingival Display is also a

common treatment objective. There is no consensus on the degree to which Gingival Display

influences smile esthetics (Hulsey, 1970; Rigsbee, Sperry, and BeGole, 1988; Kokich, Spear,

1997; Kokich, Kiyak, and Shapiro, 1999; Sabri, 2005; Kokich, Kokich, and Kiyak, 2006; Ritter,

et al., 2006). National differences found in this study fell within a pre-reported range of

acceptability (Kokich, Kiyak, and Shapiro, 1999; Kokich, Kokich, and Kiyak, 2006). Two

separate studies by Kokich et al (1999) suggested that ±4mm of gingival display was the threshold of acceptability evaluated by laypersons and dentists collectively (1999), whereas the threshold of ±3mm evaluated by laypersons and orthodontists was suggested after testing smaller increments (Kokich, Kiyak, and Shapiro, 1999; Kokich, Kokich, and Kiyak, 2006). The more recent US results represent continuous data sets, as opposed to incremental data sets, and found that the ideal value for gingival display was 2.1mm incisor coverage and reported ±4mm within the range of acceptability (Kokich, Kiyak, and Shapiro, 1999; Ker, et al., 2008). The Canadian data (Figure 3) are consistent with the more recent study by Kokich et al (2006) indicating that a narrower range of ±3mm to be within the range acceptability (Kokich, Kokich, and Kiyak, 2006). Generally, gingival display greater than 4mm is unacceptable and considered excessive (Peck, Peck, 1995; Polo, 2008). Hard tissue contributors to excessive Gingival Display such as anterior maxillary height can be managed with orthodontic treatment, periodontal treatment, and/or orthognathic surgery (Suh, et al., 2009). Van der Geld et al reported that 2mm Gingival Display on smiling was ideal and was a critical factor in self-perception of smile attractiveness (Van der Geld, et al., 2007). Factors such as decreasing gingival display with age should be taken into consideration when treatment planning mechanics to ensure finishing within the acceptability range (Desai, Upadhyay, and Nanda, 2009). If the orthodontist is not cautious, reducing a gummy smile through maxillary incisor intrusion often occurs at the expense of a consonant smile arc.

Studies regarding Occlusal Cant show that a range exists where Occlusal Cant is acceptable to laypeople, and beyond which asymmetries become noticeable. The literature cites 2° (Geron, Atalia, 2005), 3° (Peck, Peck, 1995), and 4° (Padwa, Kaiser, and Kaban, 1997; Ker, et al., 2008)

from true horizontal as being acceptable. The ethnic varieties amongst the Canadian and US samples revealed differences in perceptions of occlusal cants as the most evident of all the smile characteristics investigated. This study found Canadian respondents to be most sensitive in detecting deviations from ideal at 1 degree (Figure 5). With a clinically significant difference between Canadian and US laypersons of 2.3mm, US orthodontists have more latitude in the finishing stages of treatment for OC.

Lombardi (1973) stated that esthetically, midlines are the most important focal spot in the smile. There is substantial variation in the literature reporting noticeable MMFD by laypersons as minor as 2mm (Beyer, Lindauer, 1998; Johnston, Burden, and Stevenson, 1999; Cardash, Ormanier, and Laufer, 2003) or as much as 4mm deviations (Kokich, Kiyak, and Shapiro, 1999; Pinho, et al., 2007). Inconsistencies in the Canadian and US data for midlines also appears to be a function of underlying cultural /nationality differences (Figure 6). Canadians identified 1.8 mm of midline deviation as the limit of acceptability. By manipulating midline deviations along a continuous scale, Ker et al (Ker, et al., 2008) found that 2.9mm of MMFD is the maximum point where US laypersons deemed deviations acceptable (Ker, et al., 2008). Midline discrepancies are the most obvious occlusal asymmetries from the patient's perspective (Nanda, Margolis, 1996). However, perfect bilateral symmetry rarely exists (Bishara, Burkey, and Kharouf, 1994). In clinical terms, it is important for clinicians to know the amount of Maxillary Midline to Face Discrepancy that is acceptable and unlikely to adversely affect smile esthetics. Results may differ due to the inconsistent incremental adjustment of each variable tested and therefore may not accurately identify the threshold for perceivable changes in each variable.

Management of the periodontal tissues that "frame" each tooth is crucial to esthetic smile

design (Bitter, 2007). Differences in ethnic background contributed toward the differences

revealed in perceptibility of Lateral Central Gingival Discrepancy. It appears that -0.5mm is the

maximum point where Canadian laypersons deemed deviations acceptable. However, US

laypersons had great variability in their limit of acceptability and were even willing to accept a

1.2mm deviation where the lateral gingival margin is superior to the central gingival margin

(2008). The US data reported in Ker et al (2008) corroborated previous results by Kokich et al.

(1999). US laypersons did not readily notice gingival discrepancies between the maxillary

central and lateral incisors as demonstrated by the broad range of acceptability. Comparing this

variable amongst the others tested, Canadian and US laypersons placed a higher clinical value on

Lateral Central Gingival Discrepancy than Buccal Corridor and Gingival Display. Indeed,

Canadians were less willing to accept deviations from ideal than their US counterparts (Figure

4). Creating lateral central gingival discrepancies are sometimes an unintended consequence of

proper incisal edge alignment. Preserving esthetic lateral central gingival heights can be achieved

through a number of mechanical techniques and periodontal smile sculpting procedures (Bitter,

2007). This smile characteristic may have an overwhelming clinical impact on smile esthetics

due to the visual prominence in the smile, especially in patients with increased Gingival Display

(Sarver, 2004).

Evaluator Group Characteristics

Considering the demographic variables were significantly different between the samples

for gender, ethnicity and educational background, with the Canadian sample more male, non-

Caucasian and with less post secondary education (Table 2), it was necessary to control these factors in the analysis. The stratified analysis addressed this issue and reduced the probability that these variables confounded the results. The Canadian and US groups were found to be comparable. Therefore, these three confounding factors were not predictive of the five smile characteristic preferences in either group. Furthermore, it may be argued that the Canadian and US groups had a regional bias and may accordingly not accurately represent the entire US and Canadian population. Inherently, there may be a regional sampling bias.

It may be debated whether the Canadian results represent more of a Manitoban sample than an entirely Canadian sample based on the venues chosen for data collection. In that case the Canadian results may be truer of the Prairie Provinces than of Canada as a whole. The US sample compared West, Midwest, and East regional effects on raters' smile preferences and indicated that laypersons in different locations of the US were not significantly different in their assessment of their smile preferences (Ker, et al., 2008).

Patients are becoming more critical of their smile esthetics and are seeking orthodontic treatment with more refined expectations (Gazit-Rappaport, Haisraeli-Shalish, and Gazit, ; Hiemstra, Bos, and Hoogstraten, 2009). Our collaborative study focussed on laypersons because they are the primary consumer of orthodontic services and satisfaction with treatment outcomes depend on patient expectations. Therefore, the esthetic ratings of smile characteristics as evaluated by laypeople are the most appropriate factor as it focuses entirely on the esthetics and is not influenced by biases of the orthodontist. Orthodontists should not impose their ideal values except near the margins of acceptability (Ker, et al., 2008).

Clinical Recommendations

To ensure proper diagnosis and treatment planning, it is important to understand factors that could influence the visual perception of smile esthetics. Current treatment planning approaches incorporate a balance between recent esthetic nuances while still respecting Angle's concepts of using the molar to determine how to treat overjet, and Tweed's concepts of mandibular incisor position as cornerstones of treatment planning. According to Andrews' principles (1972) properly inclined anterior crowns are necessary for anterior and posterior occlusion. He advocated the use of six occlusal characteristics, referred to as the "six keys to normal occlusion", common to naturally optimal occlusions when prioritizing problem lists and as a debond check-list capable of predicting an incomplete orthodontically treated result.

The orthodontist must consider the intentional and unplanned side effects of their mechanics on smile esthetics. Creating a balance between esthetics and function for each individual patient is not always straight forward in clinical practice and may require a compromise to limit the unintended negative side effects for each individual patient. If the orthodontist is not cautious, reducing a gummy smile through maxillary incisor intrusion often occurs at the expense of a consonant smile arc. On the other hand, finishing with level incisal edges, according to the esthetic preferences of some patients, may create detrimental excursive interferences in functional excursions.

Not all interactions between smile characteristics result in esthetic compromises. The orthodontist can use three major components of the smile, smile arc, overbite, and lateral step

harmoniously and establish a more esthetic smile (Ker, et al., 2008). Treatment planning should be sensitive to patients' preferences. Orthodontic treatment recommendations should be in accordance with the patients' treatment expectations rather than the orthodontists' biases. The results of this collaboration of Canadian and US studies may sensitize clinicians to incorporate individualized esthetic treatment mechanics for each patient, and establish patient-centered esthetic considerations while determining multi-disciplinary orthodontic treatment plans (Ker, et al., 2008; Krishnan, et al., 2008).

Study Limitations

Feedback from participants revealed shortcomings in survey design and areas for improvement. In order for raters to more easily distinguish between gingival tissue and lips, shades of pink could have greater contrast. Technical delays in the uploading of a sequence of images occasionally experienced could have affected the results.

In addition, a regional sampling bias may exist in the Canadian group. Although the recruitment venues were chosen specifically to draw from a diverse variety of assessors to represent the perceptions of Canadian laypersons, the results may more accurately represent Manitoban regional-based sampling.

Confounding Factors

It is important for the reader to be understand that, as with any comparison study, even after statistically reducing the influence of confounding variables: gender, ethnicity, and educational background, there is always a possibility that other unrecognized confounders either not investigated or not identified might have impacted the results of this investigation, such as a heightened dental IQ from previous esthetic-based dental treatment. It should be understood that other possible confounding variables not evaluated may account for differences in the response patterns of Canadian and US response groups.

Statistical Limitations

The categorical nature of the variables required that non-parametric statistics be used for many of the calculations. The influence of confounding variables was reduced through stratification. Rather than stratifying, other esthetics studies have used co-variate adjustments to control for confounding variables. Although co-variate analysis would also control for confounding variables, stratification was chosen as a more appropriate analysis as it is suited for categorical variables, and does not risk reducing sample size, unlike the co-variate analysis.

Performing multiple Kruskal Wallis Mann Whitney tests for five smile characteristic preferences between the Canadian and US groups required a Bonferroni correction to maintain the overall alpha at a 0.05 level. While this minimized the likelihood of a type I error (i.e., the risk of obtaining an apparently significant difference purely by accident), using the more conservative critical value of $\alpha = 0.0025$ made it more difficult to identify statistically significant differences.

Also, statistically significant results do not necessarily infer noticeable therapeutic effects.

Future Investigations

It would be interesting to conduct future studies to determine differences in the range of variation found esthetically acceptable according to the attractiveness ratings. Furthermore, to compare these differences in attractiveness ratings at the extremes of the acceptability thresholds and quantify the threshold where deviations begin to impair smile esthetics. It would also be interesting to investigate if laypersons would recommend orthodontic treatment at the thresholds of acceptability. In other words, determine if the acceptability threshold levels are "clinically" significant, defined as requiring treatment. Previous authors have done this through logistic regression analysis to define the Aesthetic Component (AC) of the Index of Orthodontic Treatment Need (IOTN) to recommend the patient for orthodontic treatment. Another opportunity for follow-up studies would be to evaluate the effect of evaluator age, gender, ethnicity, and educational background on attractiveness ratings. Also, to determine if a correlation exists between attractiveness ratings at the acceptability thresholds and the amount of deviations from ideal. Smile characteristics should also be assessed within the context of full facial views in order to determine the smile characteristics of greatest overall clinical impact.

CHAPTER 6

CONCLUSIONS

Laypersons can consistently identify their chosen selection from a series of smiles when defining what they perceive as ideal and within the realm of acceptability. The participant's reliability strengthens the power of this methodology. Defining laypersons preferences through standardization of image presentation using computer-based slider technology in a realistic context across several smile characteristics is a reliable and accurate method of identifying smile esthetic perceptions.

Individual perception of smile esthetics influenced by national / ethnic background must be considered in smile design if comprehensive treatment by today's standards is to be patient, not clinician, centered. National / ethnic background can affect multiple variables in unequal ways and must be considered in research and clinical settings.

Nationality and ethnic differences were revealed in all smile characteristics investigated. Ethnic differences were most evident at the maximum tolerable limit of acceptability for OC, BC, and LCGD compared to GD and MMFD.

Canadian and US laypersons are not equally critical of smile esthetics, nor necessarily have similar smile esthetic preferences.

Canadian laypersons, on average, were more sensitive to deviations from ideal and had a narrower range of acceptability than their US counterparts.

Highly statistically significant differences in the preference of the smile characteristics were found between Canadian and US laypersons.

Statistically significant differences found between the groups do not directly confer clinically meaningful differences of the same magnitude.

The lower face view used in this study may have facilitated the detection of small clinical differences more than if a full facial view had been used.

Perceptions of what constitutes an ideal smile are nearly similar for both groups of laypersons, except for the smile characteristic Buccal Corridor.

Communication is of upmost importance before prioritizing the treatment plan in order to learn the patients' smile preferences and smile characteristic most important to them.

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APPENDICES

Appendix 1: University of Manitoba Health Research Ethics Board (HREB) Approval
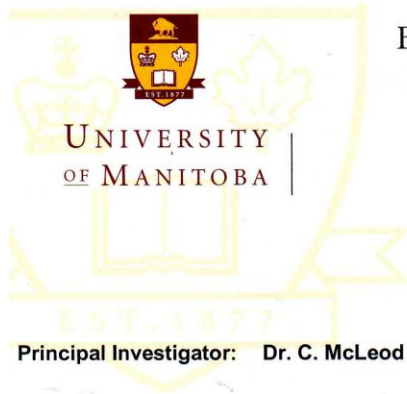
BANNATYNE CAMPUS
Research Ethics Boards

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APPROVAL FORM

Principal Investigator: Dr. C. McLeod

Ethics Reference Number: H2008;196
Date of Approval: August 21, 2008
Date of Expiry: August 21, 2009

Protocol Title: **Esthetics and Smile Characteristics: A Computer Based Study**

The following is/are approved for use:

- **Revised Protocol dated August 17, 2008**
- **Revised Survey submitted August 18, 2008**
- **Participant Information Oral Script to Facilitate the Informed Consent Process submitted May 18, 2008 (received June 16, 2008)**
- **E-mail Invitation to Participate In Research submitted May 18, 2008 (received June 16, 2008)**
- **Flyer Invitation to Participate in Research submitted May 18, 2008 (received June 16, 2008)**

The above underwent expedited review and was **approved as submitted** on August 21, 2008 by Dr. John Arnett, Ph.D., C. Psych., Health Research Ethics Board, Bannatyne Campus, University of Manitoba on behalf of the committee per your letter dated August 18, 2008. The Research Ethics Board is organized and operates according to Health Canada/ICH Good Clinical Practices, Tri-Council Policy Statement, and the applicable laws and regulations of Manitoba. The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the *Food and Drug Regulations*.

This approval is valid for one year only. A study status report must be submitted annually and must accompany your request for re-approval. Any significant changes of the protocol and informed consent form should be reported to the Chair for consideration in advance of implementation of such changes. The REB must be notified regarding discontinuation or study closure.

This approval is for the ethics of human use only. For the logistics of performing the study, approval must be sought form the relevant institution, if required.

Sincerely yours,

John Arnett, Ph.D., C. Psych.
Chair, Health Research Ethics Board
Bannatyne Campus

Please quote the above protocol reference number on all correspondence.
Inquiries should be directed to REB Secretary
Telephone: (204) 789-3883 / Fax: (204) 789-3414

www.umanitoba.ca/faculties/medicine/research/ethics

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July 9, 2008

Dr. Catherine McLeod
Graduate Orthodontic Resident
University of Manitoba
Department of Preventative Dental Science – Orthodontics
D341-780 Bannatyne Avenue
Winnipeg, MB R3E 0W2

Dear Dr. McLeod:

> **Re:**   **H2008:196**
> **"Esthetics and Smile Characteristics: A Computer Based Study"**

In response to your submission dated May 18, 2008 (received June 16, 2008 in the Research Ethics Board office) the above-named study was reviewed in an expedited manner on July 9, 2008 and will be considered for approval conditional to the following:
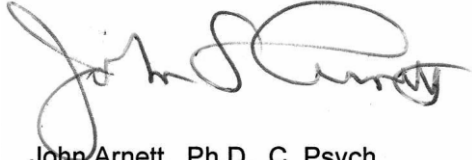
- It does not appear that the orthodontists will be recruited in person at a computer booth set up in the University of Manitoba main campus location as stated in the last paragraph on Page 2 of the protocol. Please clarify how will the orthodontists be recruited.
- It appears that the lay persons (see Page 3) will be recruited in the waiting rooms in the various dental clinics and not on the main campus of the University of Manitoba as stated in the protocol. Please clarify.
- Please expand upon the methodology as it is unclear precisely what procedure will be followed in obtaining the various ratings from the orthodontists and lay participants
- Please describe more completely the dependent variables that will be subjected to data analysis.
- Please clarify whether there are two (2) separate computer-based surveys (i.e. – one for orthodontists and one for lay people) rather than the combined survey attached. It would be more appropriate for each group to be directed to their own survey.

The issue(s) outlined must be met to the satisfaction of the chair of the Board prior to providing a certificate of final approval. When you have completed the requested revisions, **one (1) copy** of the revised portions of your project must be submitted to the Bannatyne Campus Research Ethics Office. **Please summarize your revisions and address the concerns of the board in a cover letter and make sure your revision is highlighted so they can be identified in the text of the revised document. Also, note the Health Research Ethics Board deadlines do not apply to the review of these revisions therefore you may submit them as soon as they are complete.**

Please quote the above protocol reference number on all correspondence. Inquiries should be directed to the REB Secretary. **Telephone:** (204) 789-3255/ **Fax:** (204)789-3414

www.umanitoba.ca/faculties/medicine/research/ethics

Dr. C. Mcleod
H2008:196
Page 2 of 2

Yours sincerely,

John Arnett, Ph.D., C. Psych
Chair, Health Research Ethics Board
Bannatyne Campus

JA/dc

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February 2, 2009 (REVISED APRIL 12, 2010)   via fax: 204-977-5699

Ms. Catherine McLeod
University of Manitoba
D341-780 Bannatyne Ave.
Winnipeg, Manitoba, R3C OW2
Canada

Re: **Request for Permission to Reproduce Tables, Photos, Figures, Illustrations, etc. in Printed Format**

Dear Ms. McLeod:

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Date to be presented: **June, 2010**

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Ms. Catherine McLeod
February 2, 2009 **(REVISED APRIL 12, 2009)**
Page 2

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Sincerely

Karen London
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enclosure

Appendix 3: Complete Multi-Media DVD

Enclosed Back Cover: Canadian Survey: Smile Esthetics: A Computer Based Survey
  Canadian Laypersons Raw Data
  US Laypersons Raw Data
  Data Summary Sheets
  MATLAB execution files
  MATLAB compiler runtime installation file (MCRInstaller.exe)

Appendix 4: Complete Hard Copy Canadian Survey "Smile Esthetics: A Computer Based Survey"

Smile Esthetics - A Masters Research Survey

Please select your ethnicity.

- ● Caucasian/White
- ● Hispanic/Latin American
- ● Asian/Pacific Islander
- ● Aboriginal
- ● Middle Eastern

- ● African American/Black
- ● Other

[Next]

Smile Esthetics - A Masters Research Survey

In which province/territory are you currently living?

- ● Alberta
- ● British Columbia
- ● Manitoba
- ● New Brunswick
- ● Newfoundland and Labrador

- ● Nova Scotia
- ● Ontario
- ● Prince Edward Island
- ● Quebec
- ● Territories

[Next]

Smile Esthetics - A Masters Research Survey

What is your highest level of completed education?

- High School completed
- Some college
- Associates degree
- Bachelor's degree
- Master's
- Professional degree

Next

Smile Esthetics - A Masters Research Survey

Do you have any dental affiliations, past or present (for example, spouse or parent is a dental professional)? Type yes or no. If yes, please list them.

Next

Please read the following questions carefully. They are NOT all the same. Press start to begin.

Back   Start

Select the image you find to be MOST IDEAL. Move the slider to the extreme to see the possible range of options, and then choose the appropriate position.

Back   Next

Select the image you find to be MOST IDEAL. Move the slider to the extreme to see the possible range of options, and then choose the appropriate position.

Back   Next

Please move the slider to the LEFT to select the first image that you find UNATTRACTIVE

Back   Next

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Back   Next

Select the image you find to be MOST IDEAL. Move the slider to the extreme to see the possible range of options, and then choose the appropriate position.

Back   Next

Please move the slider to the LEFT to select the first image that you find UNATTRACTIVE

Back   Next

Please move the slider to the RIGHT to select the first image that you find UNATTRACTIVE

Back   Next

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Back   Next

Select the image you find to be MOST IDEAL. Move the
slider to the extreme to see the possible range of
options, and then choose the appropriate position.

Back   Next

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Back   Next

Please move the slider to rate your chosen smile

Highly UNattractive   Highly
                    attractive

Back   Next

Do you consider the smile you just selected
acceptable? Please move the slider to the left or
right to indicate yes or no.

Yes   No

Back   Next

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Back　　Next

Select the image you find to be MOST IDEAL. Move the
slider to the extreme to see the possible range of
options, and then choose the appropriate position.

Back   Next

Select the image you find to be MOST IDEAL. Move the
slider to the extreme to see the possible range of
options, and then choose the appropriate position.

Back   Next

Select the image you find to be MOST IDEAL. Move the
slider to the extreme to see the possible range of
options, and then choose the appropriate position.

Back   Next

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Back   Next

Please move the slider to rate your chosen smile

Highly UNattractive   Highly
                   attractive

Back   Next

Do you consider the smile you just selected acceptable? Please move the slider to the left or right to indicate yes or no.

Yes   No

Back   Next

Please move the slider to the RIGHT to select the first image that you find UNATTRACTIVE

Back   Next

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

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image that you find UNATTRACTIVE

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Select the image you find to be MOST IDEAL. Move the
slider to the extreme to see the possible range of
options, and then choose the appropriate position.

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Please move the slider to the LEFT to select the first
image that you find UNATTRACTIVE

Back   Next

Please move the slider to the RIGHT to select the first
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Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Back | Next

Please move the slider to the RIGHT to select the first
image that you find UNATTRACTIVE

Back | Next

Select the image you find to be MOST IDEAL. Move the slider to the extreme to see the possible range of options, and then choose the appropriate position.

Back   Next

Experiment Complete

Thank you for completeting the smile survey. Please fill out a ballot for your chance to win many prizes!

OK

Appendix 5: US Survey Illustrated Example Questions

Click on the picture to activate the slider.

Use the slider to select the picture you find
MOST IDEAL

Click on each picture to activate the slider.

Please move each slider to the point where
you feel the smile becomes
UNATTRACTIVE
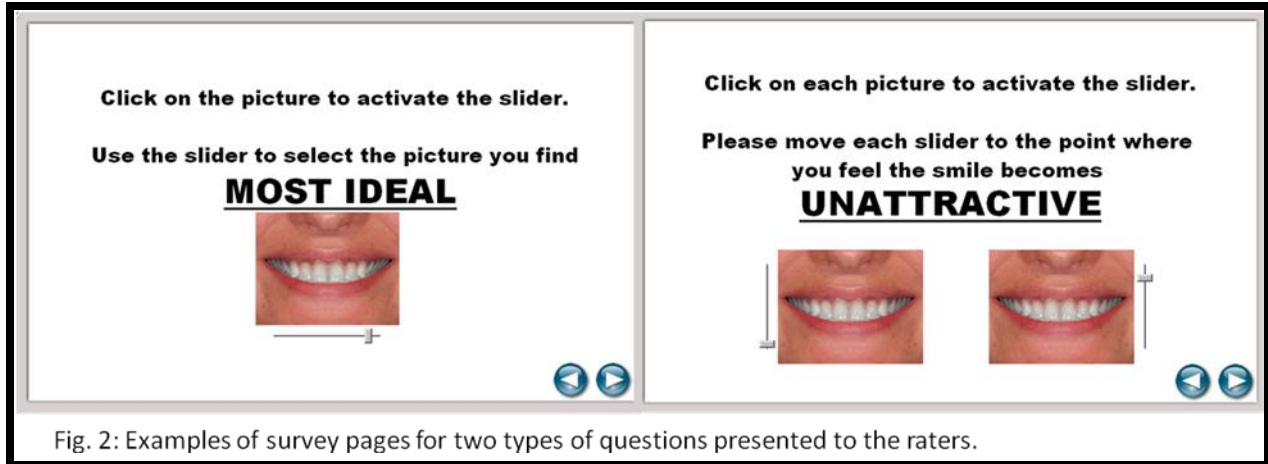
Fig. 2: Examples of survey pages for two types of questions presented to the raters.

Ker AJ, Chan R, Fields HW, and colleagues. *Esthetics and smile characteristics from the layperson's perspective: a computer-based survey study.* JADA 2008 139(10):1318-27.
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ARTICLE

Esthetics and Smile Characteristics Evaluated by Laypersons:
A comparison of Canadian and US data

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[6] Air Force Research Laboratory, Wright-Patterson AFB, OH, USA

Esthetics and Smile Characteristics Evaluated by Laypersons:
A comparison of Canadian and US data

Objective: To collect data regarding Canadian laypersons perceptions of smile esthetics and compare these data to US data in order to evaluate cultural differences.

Methods: Using Adobe® Photoshop® 7, a digital image of a posed smile of a sexually ambiguous lower face was prepared so that hard and soft tissue could be manipulated to alter Buccal Corridor (BC), Gingival display (GD), Occlusal Cant (OC), Maxillary Midline to Face Discrepancy (MMFD) and Lateral Central Gingival Discrepancy (LCGD). Adult Canadian laypersons (n=103) completed an interactive computer-based survey of 29 randomized images to compare smile preferences for these variable. The custom survey was developed to,displayed fluid, continuously appearing modifiable smile variables using MATLAB® R2008 for presentation.   These data were compared to previously published data for US laypersons. Statistical inference was determined using Wilcoxon Rank Sum tests. Results: Canadian laypersons were more sensitive in detecting deviations from ideal and had a narrower range of acceptability thresholds for BC, GD, OC, MMFD and LCGD. Ideal esthetic values were significantly different only for BC.

Conclusions: It appears cultural differences do exist related to smile characteristics. Clinically significant differences in the preference of the smile characteristics were found between Canadian and US laypersons. Canadian laypersons, on average, were more discriminating to deviations from ideal and had a narrower range of acceptability.

Key Words: smile esthetics, acceptability, Buccal Corridor, Gingival display, Occlusal Cant, Maxillary Midline to Face Discrepancy, Lateral Central Gingival Discrepancy.

INTRODUCTION

An esthetic smile is the result of interaction of different smile components[1] and requires an understanding of the principles that manage the balance between teeth and soft tissues.[2] Establishing ideal function and esthetics may be mutually exclusive and requires careful and detailed consideration during orthodontic treatment planning.

Smile esthetics have been researched using a variety of perspectives and methods to help clarify the importance of smile characteristics.[3-6] Kokich et al [4] were the first to systematically quantify orthodontists' and laypersons' perceptions of smiles by using static photos of posed smiles adjusted incrementally. Dental professionals and laypersons had different perceptions of smile esthetics, and were able to identify smile characteristics that both enhanced and detracted from smile esthetics. [3-5] Ker et al [7] comprehensively investigated perceptions of smile characteristics along a continuous range where the evaluator digitally modified smiles using a mouse driven slider to select the most ideal and to determine the thresholds of acceptability.[7]

A number of variables influence the attractiveness of a smile. Buccal corridor minimization is a critical smile feature, [4, 6, 8-10] excessive gingival display does not appear to be well tolerated by raters [4] and maxillary midline deviations can upset the balance of an otherwise esthetic smile. [8, 9] Kokich et al[4] found an occlusal cant to have a detrimental effect on smile esthetics.[4] In addition, the location, shape and contour of the gingiva in the maxillary anterior region also affects smile esthetics.[10]

Individual and cultural characteristics must be considered in smile evaluation.[11] Although there are data from another ethnic group that deal with one aspect of smile esthetics (buccal corridor) [23] and show similar preferences to US raters, to this point, no study has comprehensively examined whether differences in cultural / ethnic background can alter the perception of smile characteristics. Quantifying potential North American cultural differences in perception of smile esthetics could reveal important considerations in achieving clinical success and patient satisfaction.

The purpose of this collaborative multicenter study was to incorporate slider technology and advanced digital imaging methods to quantitatively determine and compare cultural / national smile esthetic preferences of Canadian and US laypersons.

MATERIALS AND METHODS

This collaborative research study was approved by a University Research Ethics Board and used identical digital images as those used by Ker et al [7] (Permission granted by J Am Dent Assoc). The method of presentation was compatible with that research, so the data could be compared.[7]

Model Selection and Image Manipulation

Using Adobe® Photoshop® 7, a digital image of a posed smile of a sexually ambiguous lower face prepared was manipulated to alter Buccal Corridor (BC), Gingival display (GD), Occlusal Cant (OC), Maxillary Midline to Face Discrepancy (MMFD) and Lateral Central Gingival Discrepancy (LCGD) following the protocol of Ker et al. [7] Raters completed an interactive computer-based survey of 29 randomly presented images. The custom survey was developed to

compare smile preferences, which displayed fluid, continuously appearing modifiable smile

variables using MATLAB® R2008 (MATLAB R2008 (The Mathworks, Inc.,Natick, MA) a

numerical computing environment and programming language software. The raters selected the

ideal and acceptability thresholds of several independent smile variables. Figure 1 illustrates an

example of the "filmstrip" of maxillary occlusal cant changing from severe to less severe. The

teeth and lip images appearing on the computer monitor were scaled to replicate clinical size at a

typical conversational distance of 40cm.[7] The resolution was standardized on all computers at

1024 x 768 pixels. A digital measurement grid, calibrated to Wheeler's Dental Anatomy[12]

average value for a central incisor, was used for all smile characteristic digital modification.

Ideals were inherent as zero for variables OC and MMFD and therefore not tested. Table 1

summarizes the range of possible values and the method of measurement.[7]

Survey Design

Adult Canadian laypersons (n=103) voluntarily completed an anonymous interactive computer-

based survey. Surveys were individually administered and each rater provided 36 responses: 29

randomly presented image-based responses (19 unique questions, and 10 repeat questions to

evaluate rater reliability) and seven demographic responses. Demographic information including

Canadian geographical province of residence, age, gender, ethnic background, and level of

education completed. Inclusion criteria for laypersons required that the evaluator must have lived

in Canada for the last five years. Exclusion criteria included previous dental professional

affiliations. Recruitment venues were chosen specifically to increase the diversity of assessors to

represent the perceptions of Canadian laypersons

Image-based questions were presented with one of two questions: 1) "Select the image you find

MOST IDEAL" or 2) "Please move the slider to the left to select the FIRST image that you find

UNATTRACTIVE". Question one was designed to determine the ideal value for each smile

characteristic. Question 2 was designed to determine the acceptability thresholds before a smile

characteristic becomes unattractive.

Statistical Analysis

Demographic variable comparisons were made using Chi-square and t-tests. To control for

demographic differences between the two samples, confounding variables were controlled by

stratifying gender, ethnicity, and educational background. Statistical inference was determined

using Wilcoxon Rank Sum tests. The data were subjected to Kruskal Wallis Mann Whitney tests

with Bonferroni-Holm correction on the critical significance level (alpha=0.0025) to establish

ideal and maximum acceptable ranges. Differences between the published US data[7] and

Canadian groups were evaluated with the level of significance established at alpha value <0.05

for all analyses using statistical software (SAS, Version 91.3, SAS Institute, Cary, NC).

Differences in attractiveness ratings were analyzed using descriptive nonparametric statistics

including median values. Power calculation confirmed the appropriateness of sample size

capable of determining significant differences between all variables, as demonstrated by a 1mm

or 1 degree difference on the slider scale. Differences in reliability ratings were analyzed using

the weighted Kappa statistic at a 95% confidence interval. For an alpha level of 0.05 and

assuming a common standard deviation of 17.42,[13] a sample size of 43 per rater group was

necessary to achieve a power of 0.85 to determine statistically significant differences between all

variables, as demonstrated by a 1mm or 1 degree difference on the slide scale.

RESULTS

Intra-rater reliability was excellent, Kappa value = 0.98. The results therefore were deemed to be reliable. [14]

Frequency Distributions / Rater Demographics

Distribution by gender, ethnicity, and educational background for the 103 Canadian raters and the published US data are presented in Table 2. The Canadian sample was more male, non-Caucasian and with less post secondary education. After stratifying on gender, ethnicity, and educational background, these three confounding factors were not predictive of the five smile characteristic preferences in either group and were considered comparable.

National differences defining ideal and acceptable smile characteristics

The descriptive numeric results and corresponding image depiction for each smile characteristic defined as ideal and their acceptable limits are reported using medians and associated images in Figures 2 through 7. Cultural / national differences of less than 1 mm were not considered clinically significant.

DISCUSSION

Patients are becoming more critical of their smile esthetics and are seeking orthodontic treatment with more refined expectations.[15] This study focussed on esthetic ratings of smile characteristics evaluated by laypersons as they are the primary consumer of orthodontic services and

satisfaction with treatment outcomes depend on patient expectations. The results demonstrate

that laypersons can reliably identify the ideal and the ranges of acceptability when using a lower

face view of models. This finding strengthens the power of this methodology. Considering the

demographic variables were significantly different between the samples for gender, ethnicity and

educational background (Table 2), a stratified analysis was necessary to reduce the probability

that these variables confounded the results.

These results revealed Canadian and US laypersons' preferences differed statistically and

clinically in their perceptions of all smile characteristics tested. With the exception of the ideal

BC, the differences were focused on maximum tolerable differences. Canadian and US

orthodontists should not assume that all patients in North America are equally critical of their

smile esthetics, nor do they necessarily have similar smile esthetic preferences.

This study demonstrated that different cultural / nationalites can provide different smile

preferences. The hierarchy of differences between the groups at the maximum tolerable limit of

acceptability is illustrated in decreasing order in Figure 8. Other ethnic data exist for one aspect

of smile esthetics,[15] but the current study comprehensively examined whether differences in the

cultural /nationality background can alter the perception of smile characteristics. More

investigation on cultural influences is warranted so that future studies consider this factor during

planning and analysis as it may emerge as a confounding variable.

Statistically significant results do not necessarily infer noticeable therapeutic effects. Given

substantial sample power and methodology used, small differences can be unrealistically

amplified. The lower face view used in this study may have facilitated the detection of small clinical differences compared to a full face perspective. As a result, the lower limit of clinical significance threshold was set at 1mm. A similar focusing effects of the slider technology, likewise, may have heightened attention on the variables.

Buccal corridor reduction is particularly relevant today with the trend towards broader arch forms and non-extraction treatment.[16] Canadian raters' definition of ideal Buccal Corridor (Figure 2) agrees with this trend, preferring approximately 7% less dark space (5.3mm) than the US raters. This was the only variable where ideal esthetic values were defined as significantly different, statistically and clinically. Improving excessive BC in Canada, may be a more important treatment objective than in the US.

There is no consensus on the degree to which GD influences smile esthetics.[4, 17, 18] National differences fell within a pre-reported range of acceptability. Two separate studies by Kokich et al[4] suggested that ±4mm of GD was the threshold of acceptability evaluated by laypersons and dentists collectively[4], whereas the threshold of ±3mm evaluated by laypersons and orthodontists was suggested after testing smaller increments.[4, 17] The more recent US results found that the ideal value for GD was 2.1mm incisor coverage, consistent with Van der Geld et al [26] , and reported ±4mm within the range of acceptability.[4, 7] The Canadian data (Figure 3) are consistent with the more recent study by Kokich et al[17] indicating that a narrower range of ±3mm to be within the range acceptability.[17]

Studies regarding OC show that a range exists from 2° [19], 3° [20], to 4° [7] from true horizontal where OC is acceptable to laypeople, and beyond which asymmetries become noticeable. The differences between Canadian and US laypersons perceptions of OC were the most evident of all the smile characteristics investigated. Canadians were the most sensitive, to date, in detecting deviations from ideal at 1 degree (Figure 6). With a clinically significant difference between Canadian and US laypersons of 2.3mm,US orthodontists have more latitude in the finishing stages of treatment.for OC.

Midline discrepancies are the most obvious occlusal asymmetries from the patient's perspective.[8] Noticeable MMFD by laypersons are reported as minor as 2mm [21] or as much as 4mm deviations.[4] Inconsistencies in the Canadian and US data for midlines also appears to be a function of underlying cultural /nationality differences (Figure 6). Canadians identified the threshold of an acceptable midline deviation 1.1mm before the deviation was perceivable to US laypersons.

Management of the periodontal tissues that "frame" each tooth is crucial to esthetic smile design.[22] Differences in ethnic background contributed toward the differences revealed in perceptibility of LCGD. Canadians were less willing to accept deviations from ideal than US raters. The US data [7] corroborated previous results by Kokich et al[4] in that US laypersons did not readily notice LCGD even where the lateral gingival margin is superior to the central gingival margin. US laypersons had great variability in their limit of acceptability as demonstrated by the broad range of acceptability.

Both Canadian and US orthodontists need to discuss the potential limitations of orthodontic treatment in order to make a decision in concert with the patient as to what tradeoffs are acceptable in the pursuit of the ideal smile.[23] These results provide significant insights of post treatment satisfaction and may be a predictor of the patients' objectives when undergoing a particular treatment.

CONCLUSIONS
- Laypersons can reliably identify the ideal and the ranges of acceptability when using a lower face view of models.

- Individual perception of smile esthetics influenced by national / cultural background can affect multiple variables in unequal ways and must be considered in research and clinical settings

- Canadian laypersons, on average, were more sensitive to deviations from ideal and had a narrower range of acceptability.

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FIGURE LEGENDS

Fig 1. Example of "filmstrip" of maxillary cant changing from severe to less severe.

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Fig 2. Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Buccal Corridor.

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Fig 3. Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Gingival Display.

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Fig 4. Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Lateral Central Gingival Discrepancy.

Fig 5. Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Occlusal Cant.

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Fig 6. Summary of Statistics for Defining the Ideal and Acceptable Smile Characteristics: Maxillary Midline to Face Discrepancy.

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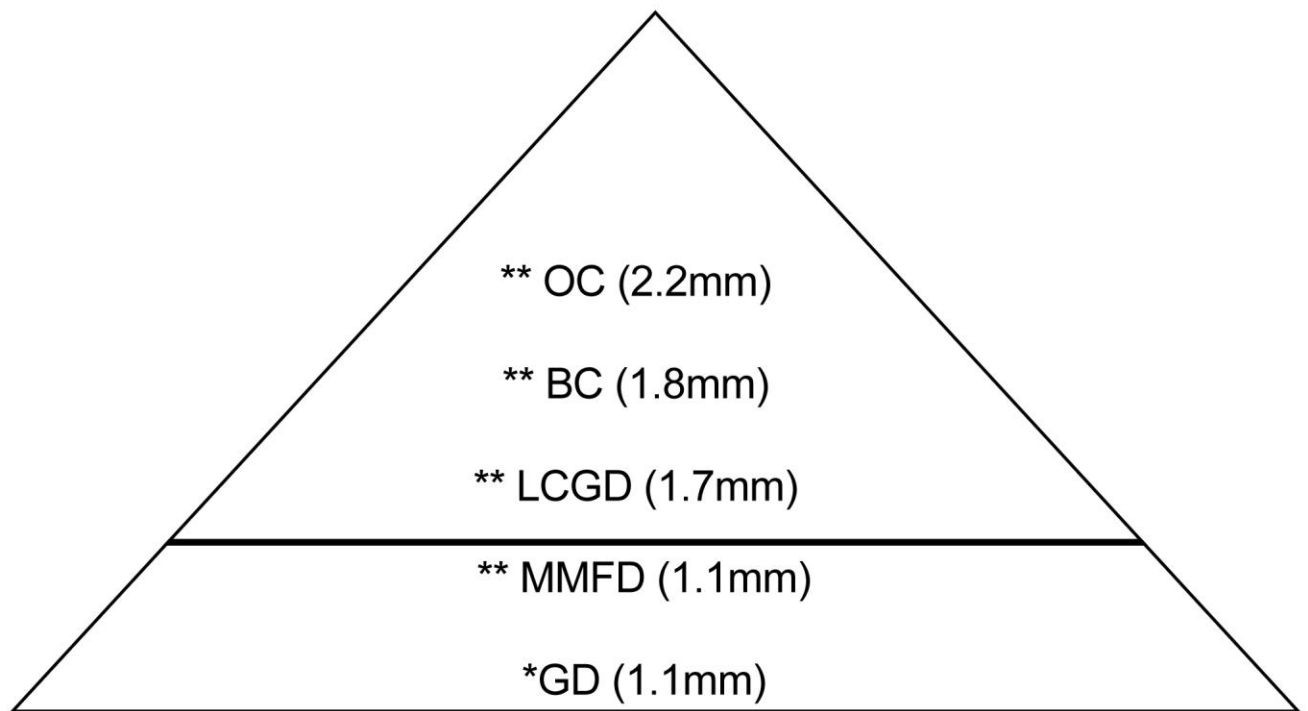
Fig 7. Hierarchy of differences between the US and Canadian median maximum tolerable limit of acceptability. In each case the Canadian raters were less tolerant of deviations from the ideal than US raters.
*p<0.05; **p<0.0025

TABLE LEGENDS

Variable	Range of Values	How Variable Was Measured
Buccal Corridor (Bilateral Total) Millimetric Percentage	0 - 19 mm 0 - 26%	Horizontal distance from the facial of the most buccal posterior tooth to a vertical line through the commisure of the lips
Gingival Display	-5.1 mm to +5.8 mm	Vertical distance from the gingival zenith of the maxillary central incisors to the nadir of the upper lip above these teeth
Occlusal Cant	0 to 6 degrees	Amount of rotation in the maxillary and mandibular dentition from horizontal plane through the middle of the maxillary central incisors
Maxillary Midline to Face Discrepancy	0 mm - 4.4 mm	Horizontal distance from the middle of the embrasure between the maxillary central incisors to a line representing the midline of the face as determined by the nadir of the cupid's bow and center of the philtrum of the upper lip
Lateral Central Gingival Discrepancy	1.1 mm apical to central incisor to 3.8 mm incisal to central incisor	Vertical distance between the apex of the maxillary central incisor gingival margin to the apex of the maxillary lateral incisor gingival margin

Table 1: Summary – Measurement of smile variables

Evaluator Groups	Gender		Ethnicity		Level of Education Completed	
	Male	Female	Caucasians	Non-Caucasians	Post-Secondary Attained	Post-Secondary Not Attained*
Canadian Laypersons	(61) 59%	(42) 41%	(65) 63%	(38) 36%	(18) 18%	(84) 82%
US Laypersons**	(45) 37%	(78) 63%	(200) 83%	(41) 17%	(59) 24%	(184) 76%
Significance	p< 0.0001		p< 0.0003		P<0.0001	

* Post-Secondary Not Attained = high school, some college, bachelors degree
and 243 US
**Ker et al.[16]

Table 2: Frequency distribution of demographic variables by evaluator group.

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