The Contribution of Malocclusion and Female Facial Attractiveness to Smile Esthetics
Evaluated by Eye Tracking

THESIS

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Abstract

There is disagreement in the literature concerning the importance of the mouth and teeth in overall facial attractiveness. Eye tracking provides an objective method to evaluate what individuals view when shown a face for the first time. **Objectives:** To objectively determine which area of the face (eyes, nose, mouth, chin, ears, or other), are viewed first, viewed the greatest number of times, and viewed for the greatest total time (duration) using eye tracking. **Methods:** Seventy-six viewers underwent one eye tracking session. After being positioned and calibrated they were shown 24 unique female composite images repeated twice for reliability. These images reflected a repaired unilateral cleft lip or three levels of malocclusion, similar to those of levels 1, 7, and 10 of the Aesthetic Component of the Index of Orthodontic Treatment Need (AC-IOTN), which were embedded in faces of three levels of attractiveness: attractive, average, unattractive. During viewing, data were collected for the first location, frequency, and duration of the viewers' gaze. **Results:** Observer reliability ranged from ICC .44 to .89, but was .00 to .31 for the chin, which should be interpreted cautiously. Repeated-measures ANOVA showed a significant effect ($p < 0.001$) for level of attractiveness by malocclusion by area of the face. For both number of fixations and duration of fixations the eyes overwhelmingly were most salient. In all but 13 of 452 combinations of malocclusion and attractiveness levels that included the eyes, the eyes received significantly more visual attention than the second most observed area, the mouth. As the

malocclusions became more severe the visual attention increased on the oral/circumoral area, sometimes approaching that of the eyes. AC-IOTN level 10 gained the most attention followed by both AC-IOTN level 7 and the cleft. AC-IOTN level 1 received the least amount of visual attention. Also, the more severe malocclusions (AC-IOTN 7 and AC-IOTN 10) received more visual attention as facial attractiveness increased.

Conclusions: Eyetracking and not self-reports indicate that malocclusion, repaired unilateral cleft lip, and facial attractiveness affect the areas of the female face viewed by layperson. Further work studying smile esthetics and facial attractiveness using eye tracking is needed

Dedication

This document is dedicated to my wife, parents, children, and the rest of my family.

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Table of Contents

Abstract	ii
Dedication	iv
Acknowledgments	v
Vita	vi
List of Tables	viii
List of Figures	ix
Chapter 1: Introduction	1
Chapter 2: Materials and Methods	16
Chapter 3: Manuscript	31
Chapter 4: Conclusions	59
Appendix: Tables and Figures	60
Complete References	74

List of Tables

Table 1. Combinations of composite images	61
Table 2. Reliability.....	61
Table 3. ANOVA summaries.....	62
Table 4. Means and standard deviations for sum of total duration of fixations.....	63
Table 5. Means and standard deviations for number of fixations.....	64

List of Figures

Figure 1. Example of a rating sheet for malocclusions.....	65
Figure 2. Examples of composite images	66
Figure 3. Composite image showing how interest areas were defined.....	67
Figure 4. Adult positioned in table mounted eye tracker.....	67
Figure 5. Mean sum of total duration of fixations for all areas of interest	68
Figure 6. Mean number of fixations for all areas of interest	69
Figure 7. Viewing attention the eye received by AC-IOTN level	70
Figure 8. Viewing attention the mouth received by AC-IOTN level	71
Figure 9. Viewing attention the mouth received by level of facial attractiveness	72
Figure 10. Sex differences of viewing attention	73

Chapter 1: Introduction

Humans devote a lot of time and resources trying to improve their facial appearance and attractiveness according to what their culture views as attractive. In the Mayan culture artificial cranial deformation, which involved strapping a board to the cranium of infants to flatten their heads, was considered desirable.¹ In traditional Chinese culture, the practice of foot binding in females was viewed as attractive.²

Many consider improving facial attractiveness as cosmetic, superficial, and of no true social or tangible value or importance. Jokela³ presented evidence that facial attractiveness has evolutionary importance, and it has been associated with reproductive success in humans living in an industrial setting during the late 20th century.

Facial attractiveness has been linked to greater interpersonal success in school and in the workplace, which leads to more favorable judgments, performance, and academic reviews for attractive adults and children compared with their unattractive counterparts.⁴ In a study, grade school boys who were rated as attractive received significantly higher report card grades than did their unattractive peers.⁵ Elovitz and Salvia⁶ performed a study in which 324 practicing school psychologists received a fictitious case study with an attached photograph of an attractive boy, unattractive boy, attractive girl, or unattractive girl and then they were asked to make several decisions concerning the fictitious students. The results indicated that the psychologists believed that the attractive pupils would be more successful at integrating into normal classes. Attractive individuals are judged to be more intelligent and competent. They are even perceived to be more

competent in unrelated, specific tasks such as piloting an airplane.⁷ Attractiveness has also been shown to affect hiring success for job applicants.⁸

Infants have been shown to spend a greater amount of time viewing attractive faces than unattractive faces. Infants as early as four months of age showed similarity to adults in ‘aesthetic perception’ of attractiveness.⁹ It seems infants have an innate ability to recognize attractiveness.

There has been much dispute in the literature concerning the importance of the mouth and teeth in facial attractiveness. Some assign major importance to the mouth and teeth in facial attractiveness;¹⁰ however, others disagree saying that it does not depend on any single facial feature. Edward H. Angle, considered to be the father of orthodontics, claimed: “The mouth is the most important factor in making or marring beauty and the character of the face.”¹¹ Those that disagree suggest that among these features, the teeth and nose are the least associated with facial attractiveness.¹² One study suggested that dental esthetics only made up 25% of overall facial attractiveness.¹³ This essentially proposed that background or overall facial attractiveness was more important than any single facial feature including the teeth.¹⁴

Shaw¹⁵ produced a hierarchy showing how dental features affect facial attractiveness. He accomplished this by taking photographs of an unattractive boy and girl and of an attractive boy and girl. These photographs were then modified so that for each face there were five different versions. The faces were standardized but the dentofacial appearance was altered. Forty-two adults and forty-two children viewed each photograph. Following each photograph they recorded their impressions of the child’s

social attractiveness using a visual analogue scale. The results from Shaw's study showed that a repaired unilateral cleft lip most negatively affected facial attractiveness; followed by a missing incisor, crowded incisors, and prominent incisors. Background attractiveness was also important. Attractive male and female models received more generous ratings than did their unattractive counterparts with the same dental feature.

Shaw also showed that dental features affect how viewers assign personal characteristics. Individuals with a missing incisor or repaired unilateral cleft lip were believed to be most likely to pick on others and start fights. Individuals with crowded incisors or a repaired unilateral cleft lip were least desirable as a friend. Shaw concluded, "The central hypothesis, that children with normal dental appearances would be judged to be better looking, more desirable as friends, more intelligent, and less likely to behave aggressively was upheld."¹⁵

In yet another study, Shaw showed that individuals with a repaired unilateral cleft lip were judged to be the least friendly, of the lowest social class, least compliant, least popular, possessing the lowest intelligence, and had the lowest sexual attractiveness when compared with other dental conditions such as crowding, missing incisor, prominent incisors, and normal incisors. Again, background attractiveness affected personal characteristics.¹⁴

In 2011 Olsen and Inglehart¹⁶ performed a study similar to those of Shaw.^{14,15} They found that ratings of attractiveness, intelligence, conscientiousness, agreeableness, and extraversion differed significantly depending on occlusal status. Subjects with normal occlusion were rated the most positively.

In addition, it has been documented that facial and dental esthetics have an impact on some forms of quality of life. Kiyak¹⁷ in a review paper dealing with oral health related quality of life (OHRQoL) stated that patients seek orthodontic treatment primarily to improve the esthetic and social aspects of OHRQoL. She then mentioned that the severity and visibility of the malocclusion is of more importance in a lowering OHRQoL than the type of malocclusion. The severity and visibility doesn't seem to affect the functional aspects of OHRQoL. Orthodontic treatment improves the esthetic aspects of OHRQoL, but seems to have little effect on long-term psychological well-being, this being measured primarily by self-esteem. She concluded, "The evidence from the available OHRQoL research suggests that esthetic and functional improvement is realistic, but the patient should not anticipate that treatment will enhance their self-esteem or prevent future caries, periodontal disease, or temporomandibular disorder (TMD)."

A recent article from ABC News reported that based on a survey conducted by USA Today of 5,500 unattached adults 21 years of age and older, both women and men judged teeth as the most important thing on which they judged the opposite sex. This was ahead of other items such as hair, clothes, shoes, grammar, and the car they drive.¹⁸

Despite the debate concerning the relative importance of the mouth and teeth in facial attractiveness, most individuals seek orthodontic treatment primarily to improve esthetics.¹⁹ According to Baldwin²⁰ 80% of adults who are seeking orthodontic treatment for themselves or for their children are solely motivated by the desire to improve appearance. A study showed that parents believed that malocclusion negatively affected their child's appearance and this was their primary reason for seeking orthodontic

treatment for their children. All other factors such as improving health and function were of secondary importance.²¹

Several recent studies documented that individual variables can reliably affect the smile's attractiveness or acceptability taking into account nationality, ethnicity, sex, and facial attractiveness.²²⁻²⁸ This work on smile characteristics has progressed with time. Initially, the studies on this subject had different versions of the same photograph cropped to the circumoral area, with each version representing different levels of severity of a certain characteristic. The raters were then asked to rate the images using a visual analog scale.^{26,27} Ker et al.²⁸ focused on the lower face and introduced a slider that altered the magnitude of individual smile characteristic being evaluated on an almost continuous scale. In other words they eliminated the large jumps between different levels of severity.

Springer et al.²² showed the entire face to viewers as smile characteristics were altered using the digital slider technology. In a similar study using digital slider technology it was shown that facial attractiveness impacted smile characteristics.²³

These studies reliably outlined the ideal and the range of acceptable variation from the norm for a number of dental features that are part of smile esthetics. They also reliably demonstrated the impact of facial attractiveness and the constellation of features that were and were not affected by the full-face context. This work also made it apparent that nationality, ethnicity and sex affect how we regard the smile. This provided some guidance for clinicians when selected esthetic issues arise with patients.

A shortcoming of these studies is that they directed the raters to focus on the mouth or selected oral features.^{14,15} This quite possibly biases the results and does not determine whether or how people spontaneously view the mouth of a smiling individual. This is of concern because self-report data from those viewing facial images report that the eyes and mouth are important, while others find that other facial features are viewed first and most frequently.²⁹

Another approach is to determine what viewers actually look at when presented with different facial images. Such an approach provides a direct and objective method for evaluating what facial features are important to a viewer.

Eye movement involves a series of quick, jerky movements known as saccades between stops known as fixations. It is possible through the use of computer hardware and software to record eye movement through a pupillary-corneal reflection technique. This technique is often called eye tracking. The brain records information during the fixations of eye movement.³⁰ Research has shown that the retina needs about 80 ms of seeing a new image before that image is registered by the brain. These fixations also can indicate awareness of central and peripheral information.³¹ Thus, by recording the location and duration of fixations one can get some idea of what features or characteristics the brain considers the most interesting. In a classic study, Berlyne presents evidence that if an object or feature is of great interest to the viewer their eyes will be drawn to this particular object or feature.³² Similarly, multiple studies have shown that regions or objects that are considered informative may not influence the initial fixation but do influence the fixation density (number of fixations) and the total duration

of the fixations. Objects or regions with high informativeness receive greater fixation density.³³⁻³⁵

Mackworth and Morandi³⁶ found using eye tracking that viewers were as likely to fixate on informative regions of scene in the first two seconds of scene viewing as in other two second intervals. This finding suggests that region informativeness could be detected relatively early during scene viewing. The implications for longer term viewing are not clear.

If a viewer is presented with a face free of anomalies and with a neutral expression they will tend to fixate on certain features of the face, like the eyes, nose, and mouth.³⁷

Despite the widespread use of eye tracking in optometry research, psychology research, psychophysics research, and other disciplines there has been surprisingly little use of it in dental research. Over thirty years ago it was suggested that the most direct and simple method of assessing the relative importance of different facial features to a viewer was by examining their eye movements.³⁸ This is accomplished by using modern eye trackers, which record and synthesize both corneal and pupillary reflection.³⁹

Meyer-Marcotty et al.⁴⁰ used eye tracking technology to provide evidence that persons with cleft lip and palate (CLP) were looked at differently than persons who do not have CLP. Thirty participants viewed photographs of 18 adults with complete, unilateral CLP and 18 age matched controls (no CLP). All faces viewed had neutral facial expressions. As the participants viewed the photographs an eye tracker recorded

eye movements. They were then asked to rate each of the faces in the photographs for appearance, symmetry, and facial expression. Their results showed that the CLP faces had significantly more initial and longer fixations in the mouth and nose regions compared to the control faces. The CLP faces were also rated more negatively overall. This study indicated that an abnormality in the region of the oral cavity can draw a viewers' visual attention. However, it did not indicate if the teeth, with or without a significant malocclusion, could attract the viewers' attention.

Hickman et al.²⁹ conducted a study to determine the location, order, and duration of viewers' visual fixations on facial features using eye tracking. Their subjects were shown images of 20 different individuals with average facial appearance post-orthodontic treatment. They were shown 3 images (smiling, non-smiling, and profile) for each individual. These individuals were judged to have good facial proportions, their jaws related well to each other and the face (Class I skeletally), and their teeth were well aligned. As they were shown these images their eye movements and fixations were being tracked and recorded using an eye tracking camera. The area of first fixation, the area of greatest number of fixations, and the area with greatest duration of fixation time (recorded in milliseconds) were recorded for each image. Essentially, they were examining whether individuals, when first viewing normal facial and dental images would look at their teeth/mouth or some other facial structure. They quantified eye fixations for six areas of interest: eyes, ears, nose, mouth, chin and other. Following the eye tracking they asked the subjects, how long they believed they looked at the different facial features, and in what order. What they found was that there is no single facial feature that viewers' eyes preferentially fix upon in well-balanced faces and "other"

received the most visual attention. The mouth only attracted a small percentage of first fixations (2.7%), fixation time (3.5%), and number of fixations (1.7%). There was also extremely low reliability for the three measures of eye tracking. On the other hand, fourteen percent of the raters' in this study reported that the mouth was the location of their first gaze. These findings suggest the mouth and teeth do not receive a lot of visual attention in "well-balanced faces" with near ideal occlusions.

The above study²⁹ was an important initial step for the use of eye tracking in dental research. However, it had several limitations. One limitation of this study was that all of the images were of individuals following orthodontic treatment. Thus, the images contained no or very minor malocclusions and the overall facial attractiveness of the individuals in the images was not quantified or controlled.

The questions still remain: Do observers who are not directed to the mouth and teeth spontaneously look at this area as quantified by eye tracking methodology and do the background attractiveness and level of malocclusion (when quantified) affect this viewing? Under these circumstances do the viewers report what the eye tracking methodology confirms they are viewing?

The purpose of the current study is to determine if and when a circumoral feature or malocclusion becomes severe enough that it will attract a viewers' attention using quantified levels of malocclusion and facial attractiveness.

Hypotheses:

Ho1: The level of malocclusion or the presence of a repaired, unilateral cleft lip will not significantly affect how participants view photographs of faces measured by the area of first fixation, the area of the most number of fixations, and the area with the maximum duration of fixations using eye tracking.

Ho2: The facial attractiveness will not affect how the photographs of faces with a repaired unilateral cleft lip or different levels of malocclusion are viewed. The area of first fixation, the area of the most number of fixations, and the area with the maximum duration of fixations using eye tracking will measure this.

Ho3: The rater gender will not affect how the photographs of faces with a repaired unilateral cleft lip or different levels of malocclusion are viewed. The area of first fixation, the area of the most number of fixations, and the area with the maximum duration of fixations using eye tracking will measure this.

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Chapter 2: Materials and Methods

Preliminary work to assemble images

Several preliminary steps were completed before the actual study was completed. These steps made it possible to create composite images that had varying levels of facial attractiveness and varying levels of malocclusion. This was accomplished by obtaining facial images of consenting models and developing sets of comparable malocclusions to those provided by IOTN. Once these images were created it was possible to have subjects view them as their eye movements were recorded.

Facial images

Facial images were obtained by seeking individuals (18-30 years of age) on an availability basis in high traffic areas on a university campus. Potential models provided their written consent via a model release form, authorizing the researchers to use their facial image in research, education, and any future publications or presentations. To encourage participation, all models were entered into random drawings for \$50 gift cards at a general merchandise/grocery store --one drawing for the female models and one for the male models. Two frontal facial portraits of each individual were taken using a DSLR camera (Nikon D60, Tokyo, Japan) mounted on a tripod. The first portrait was of the individual smiling with their lips together showing no teeth and for the second portrait they were smiling showing their teeth. This was the classic posed smile, which has been judged to be reliable.¹⁻³

Any individual that approached the researchers wanting to participate was allowed to do so. Models that were judged by the researchers to have a significant distraction, such as a facial tattoo, extreme hairstyle, extreme facial hair, facial asymmetry, facial piercing, etc. had their facial images eliminated from the study. For the current study only Caucasian models were used in an attempt to eliminate the variable of ethnicity. Different ethnicities have varied facial features, for both hard and soft tissue relationships.⁴⁻⁶ It has been documented that smile characteristics vary by ethnicity.⁷

Once all of the facial images were collected, young adults rated the smiling images showing no teeth. The raters judged the facial attractiveness of the models as “unattractive,” “average attractiveness,” or “attractive” without further definition. The raters had no experience with facial or oral esthetics. The images were projected and the raters recorded their judgments on a response sheet as 1, 2, and 3, respectively. Thirty-six raters were shown 199 images; of these 41 images (25.9%) were repeated images in order to determine reliability. The repeated images were selected by using a random number generator (Random.org ©). The images were also presented in a random order determined using the same random number generator. If a model had a mean score of 3 that meant that all raters rated the model as attractive. A mean score of 2 would indicate the model was considered average, and a 1 would be possible if all rates rated the individual as unattractive. The models were then sorted based on mean attractiveness rating. The ratings of eighteen raters were used to determine reliability because they rated an average of 97.3% of the images. For all models the intra-rater reliability was fair and the inter-rater reliability was poor. Reliability was then determined for a subset of the model images. The subset included only female model images, and included cluster

groups -- the first cluster group had mean facial attractiveness ratings ≥ 2.5 , the second cluster group with ratings near average attractiveness (2) (1.875-2.41), and the third cluster group with ratings < 1.5 . This new subset included 42 model images; 22 of which or 52% were rated twice for intra-rater reliability. The intra-rater kappa statistic was 0.66 and the inter-rater kappa statistic was 0.51.

Malocclusion images

The next step involved collecting images of malocclusions. These were obtained by searching the records of a graduate orthodontic clinical archive. Only non-identifiable frontal intraoral photographs were used (these images showed only the teeth and associated intraoral structures).

The Aesthetic Component (AC) of the Index of Orthodontic Treatment Need (IOTN) provides 10 levels of malocclusion based on esthetic impairment. Level 1 represents the least treatment need and level 10 the greatest treatment need. The 10 levels have been reduced to 3 subgroups; levels 1-4 are considered to have little or no treatment need, levels 5-7 borderline treatment need, and 8-10 definite treatment need.^{8,9} Each of the images was rated and assigned an AC-IOTN level (1-10) by the researchers. The goal was to obtain multiple similar malocclusions for 3 of the 10 levels (levels 1, 7, and 10) of malocclusion as defined by the Aesthetic Component of the IOTN. The esthetic level was matched, not the malocclusion or position of the teeth as prescribed by the developers of IOTN. All images were then evaluated by experienced orthodontists (15 full and part-time university faculty) to confirm the level of malocclusion as defined by the AC of the IOTN. To accomplish this, the raters viewed printed pages of the frontal

intraoral photographs. At the top of each page was the IOTN standard photograph for each level to be rated. Below the standard, were placed the six images to be rated (five images that the researchers believed were representative of that level and one image that did not belong to the level of malocclusion). The experienced orthodontists were then asked to put an “X” or “?” through any of the images that they felt were not representative of the standard. For each of the 10 levels there were 2 pages of malocclusions to be judged against the standard. In other words, the raters saw 12 malocclusions for each level, 10 were selected to be similar to the standard and 2 were non-similar distractors. All images were rated twice to determine reliability. Each rater had their pages in a different, random order determined using a random number generator (Random.org ©). The intra-rater reliability was 0.72 with 91.7% agreement and the inter-rater reliability was 0.56 with 83.1% agreement for all images.

In addition to the three levels of malocclusion an additional “level” was used in attempts to establish the validity of the eye tracking method for the oral region of the face. Because Shaw¹⁰ showed that individuals with repaired unilateral cleft lip were judged as the most unattractive when compared with other oral characteristics studied such as missing incisor, crowded incisors, prominent incisors, and normal incisors this facial anomaly was used to verify that it was possible to draw visual attention to the oral area. This was especially important as it could establish the validity of attraction of visual attention to the oral area in the event that none of the malocclusions attracted visual attention.

Only the malocclusions that most closely resembled the standard for their specific level were used. If a malocclusion received more than 3 marks of disagreement from the

experienced orthodontist raters it was not used. Another way to look at it is that the malocclusion was only used if it received $\geq 90\%$ approval by the raters.

We again searched the records of the orthodontic department's clinical archive at Ohio State University for poorly repaired unilateral cleft lips, as judged by the researchers. The images were cropped to only include the lower third of the nose to the cervical gingiva of the maxillary dentition. No identifying information was associated with these cropped images.

Composite images

The rated malocclusion images were combined with the rated smiling images of different levels of facial attractiveness to form composite images. These composite images were created using Adobe® Photoshop® Elements 7.0 software (Adobe Systems; San Jose, CA).

The three levels of malocclusion plus the unilateral repaired cleft lip were placed in each of the three levels of facial attractiveness. This provided 12 possible combinations of malocclusion and facial attractiveness. However, to provide more data, two different images were created for each combination. Thus, there were 24 unique composite images.

As the cleft images were created the models' teeth were replaced with IOTN level 1 teeth. This assured us that the viewers were looking at the oral or circumoral region and not the dental features. In other words, for the cleft images we attempted to eliminate a confounding variable of dental malocclusion.

Often, in facial esthetic studies the faces are bisected and mirrored to eliminate any asymmetry, producing a bilaterally symmetric face. In many instances this produces an image in which the hair or another facial feature does not look natural. In this study this was not done. It has been shown that individuals are primarily unaware of the existence of mild facial asymmetries. Observers do not judge symmetrical faces any differently than faces with minor asymmetry.¹¹ This may be because the facial asymmetry in physically normal, healthy people is minor and most people are unaware of mild facial asymmetries.^{11,12} Usually, in normal everyday encounters, shadows or the viewing angle hide any asymmetry. When faces are viewed from a direct frontal perspective it is most likely to show an asymmetry but even when viewed in this manner ocular exploration is usually limited to one hemiface.¹³ Visible differences between symmetrical composite images and original images are slight, if not unnoticeable, in young individuals, like those used in this study.^{11,14,15}

Experiment Builder® software (SR Research Ltd., Katana, Ontario, Canada) was then used to construct the program to run the study on the eye tracker. Using this software, interest areas of the face were defined for each subject; in essence, creating a map of the face. The interest areas used were: head, hair, eyebrows, nose, eyes, mouth, cheeks, cleft (if present), chin, and ears. These interest areas made it possible for us to quantify what area of the face the subject was viewing (Figure 1). A small gap was left between interest areas to ensure accuracy of a fixation. If a fixation landed on a gap between areas of interest it was recorded as other. This eliminated the potential problems of assigning a fixation to an interest area if it landed on border of two

interest areas and also dealt with the 0.25-0.50° of viewing angle error of the eye tracker.

The University Behavioral and Social Sciences IRB approved the study.

Participants were recruited through the Psychology Department's Research Experience Program (REP) and by posting flyers on the main campus. All flyers were placed away from the medical center to eliminate recruitment of dental professionals. Subjects recruited through the flyers received \$10.00 for participating. REP participants and paid participants were not recruited or tested at the same time. Our inclusion criteria consisted of the following items:

- 18-30 years of age
- Able to understand English
- No prior neurological condition
- Normal to corrected-to-normal, color vision (no hard contact lenses)
- Not recently consumed alcohol or other drugs
- Not currently using any medication that may affect cognitive abilities
- Not wearing mascara or willing to remove it

To prevent subjects from being biased as they viewed the images, deception was used. They were told that the title of the study was, "Visual exploration of faces recorded from an eye-tracking system." They were also told that the purpose of the study was to "help us understand how individuals view other people." The consent form reflected the deception used. After the subjects completed the study they received a debrief form explaining the actual title and purpose of the study and why deception had been used.

After filling out an informed consent form the participants were positioned in the eye tracker (EyeLink 1000®, SR Research Ltd., Katana, Ontario, Canada) and it was calibrated to them. They were given the instructions to simply look at the images shown on the computer screen. The eye tracking session began by showing the participant five

sample images to make sure the instrumentation was working properly. They were then shown all 24 images in random order; each participant had a different random order. Each image was displayed for 3 seconds. Between each image a blank screen with a randomly placed X was displayed for 1 second. After all 24 images had been displayed they were shown again in a new random order to determine intra-rater reliability. As these images were shown, data were being collected concerning what area of the face they looked at first, what area they viewed the most frequently, and what area of the face they viewed for the greatest duration.

Following the eye tracking the subjects were then asked to fill out a short questionnaire asking what facial feature they looked at first and then second when meeting someone for the first time and what facial feature they looked at the longest when meeting someone for the first time. They were also asked for demographic data including age, sex, and ethnicity. Their final experimental task was to fill out a personality test developed by Colin DeYoung entitled, Big Five Aspects Scales (Minneapolis, Minnesota).^{16,17}

In summary the independent variables were:

- Level of malocclusion – The Aesthetic Component (AC) of the Index of Orthodontic Treatment Need (IOTN) provides 10 levels of malocclusion based on esthetic impairment. It represents standards from 1-10 by way of color, intraoral, frontal photographs. Level 1 is the most esthetic level and level 10 the most non-esthetic level. The levels represent three treatment recommendations: ‘no treatment need’ (levels 1-4), ‘borderline treatment need’ (levels 5-7), and ‘greatest treatment need’ (levels 8-10).¹⁸ Multiple studies have verified the reliability of

the IOTN scale and its use on international populations.^{8,19-22} In addition to the IOTN levels a more noticeable circumoral feature, a poorly repaired unilateral cleft lip, was included to verify that oral features can attract visual attention. This is based on the previous work of Shaw who showed that repaired unilateral cleft lip had the most significant negative impact on attractiveness.^{10,23} Only levels 1, 7, and 10 of the AC of the IOTN and repaired unilateral cleft lips were used in this study. This was done to limit the amount of data and simplify the experiment for interpretational and statistical purposes. The levels chosen represent each of the categories (no, borderline, and greatest treatment need) of the AC of the IOTN.¹⁸ Additionally levels 1 and 10 represent the extremes of the spectrum of malocclusions depicted by the AC of the IOTN. Level 7 was chosen because it represents the most severe malocclusion in the borderline treatment need category.

- Facial attractiveness – Frontal, extraoral photographs of models were classified in one of three categories: unattractive, average, or attractive as described above.
- Model sex – Only female models were used in the current study. This was to reduce the number of variables in the study in an attempt to make it more likely to interpret a true interaction between malocclusion and background attractiveness. In other studies model sex has been shown to impact smile attractiveness characteristics.^{22,24,25}
- Subject/rater sex – Subject/rater sex was recorded, male or female. Both sexes rated the models. We examined this variable to determine if the sex of the rater

was a factor, which may have produced different study results. In other studies rater sex has made no difference in how smile characteristics were rated.²⁶⁻²⁸

- Subject/rater ethnicity – Subject rater ethnicity was recorded. Sharma et al. showed ideal smile characteristics vary by ethnicity.⁷ In this study we attempted to determine if ethnicity affected how individuals view faces, specifically the teeth and circumoral area.

Our dependent variables were as follows:

- Location of first fixation – As described above the face was broken up into interest areas. The areas evaluated were eyes, mouth, chin, ears, nose and “other.” “Other” included any location that was not one of the former five areas and was subdivided into hair, eyebrows, cheeks, and forehead. The location of the first fixation was recorded as one of these six areas.
- Area of greatest number of fixations – The area of the face that received the greatest number of fixations was recorded.
- Area of longest duration of the summed fixations – The area of the face that received the most fixation time was determined by summing up the fixation times over the viewing period of an image for each area.
- Amount of time (milliseconds) spent in the area which was viewed for the longest duration was recorded.
- Responses to the Big Five Aspects Scales (BFAS) personality test – The responses to the BFAS were recorded and scored as defined by the instrument.¹⁷

A power analysis was performed to determine an appropriate sample size. With an alpha risk of 0.05 and an effect size of 0.4, a total sample size of 118 subjects was determined would be needed to achieve a power of 0.8 for the dependent variable of first fixation, area receiving the greatest number of fixations, and area of maximum duration. Also, with an alpha risk of 0.05 and assuming a standard deviation of 800 milliseconds,²⁹ it was determined that a sample size of 118 subjects was needed to yield a power of >.99 to detect a difference of ± 500 milliseconds in maximum duration time. A preliminary statistical analysis, including a post-hoc power analysis, was performed on the data obtained from the first 32 viewers. From this post-hoc power analysis it was determined that with a non-directional alpha risk of 0.05 and assuming a standard deviation of 2.54,²⁹ a sample size of 75 viewers was required to demonstrate a difference of ± 1.5 fixations with a power of 0.996. Again, with non-directional alpha risk of 0.05 and assuming a standard deviation of 793 milliseconds,²⁹ a sample size of 75 would yield a power of 0.998 to detect a difference of ± 500 milliseconds in total duration time.

Statistical analysis

It was our intention to determine the area of first fixation. However, it became quickly apparent that viewer reliability was poor. Overall reliability calculated with the first 32 viewers was $\kappa=0.08$ for intra-rater reliability and $\kappa=-0.03$ for the inter-rater reliability. For this reason area of first fixation was dropped from the study.

Both dependent variables (area of greatest fixation density and area of maximum total duration) were analyzed by a repeated-measures, factorial analysis of variance (ANOVA). Independent variables were level of malocclusion, perceived model

attractiveness, area of the face, and rater sex. Post hoc testing was done using the Tukey-Kramer procedure.

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Chapter 3: Manuscript

The Contribution of Malocclusion and Female Facial Attractiveness to Smile Esthetics Evaluated by Eye Tracking

Abstract

There is disagreement in the literature concerning the importance of the mouth and teeth in overall facial attractiveness. Eye tracking provides an objective method to evaluate what individuals view when shown a face for the first time. **Objectives:** To objectively determine which area of the face (eyes, nose, mouth, chin, ears, or other), are viewed first, viewed the greatest number of times, and viewed for the greatest total time (duration) using eye tracking. **Methods:** Seventy-six viewers underwent one eye tracking session. After being positioned and calibrated they were shown 24 unique female composite images repeated twice for reliability. These images reflected a repaired unilateral cleft lip or three levels of malocclusion, similar to those of levels 1, 7, and 10 of the Aesthetic Component of the Index of Orthodontic Treatment Need (AC-IOTN), which were embedded in faces of three levels of attractiveness: attractive, average, unattractive. During viewing, data were collected for the first location, frequency, and duration of the viewers' gaze. **Results:** Observer reliability ranged from ICC .44 to .89,

but was 00 to .31 for the chin, which should be interpreted cautiously. Repeated-measures ANOVA showed a significant effect ($p < 0.001$) for level of attractiveness by malocclusion by area of the face. For both number of fixations and duration of fixations the eyes overwhelmingly were most salient. In all but 13 of 452 combinations of malocclusion and attractiveness levels that included the eyes, the eyes received significantly more visual attention than the second most observed area, the mouth. As the malocclusions became more severe the visual attention increased on the oral/circumoral area, sometimes approaching that of the eyes. AC-IOTN level 10 gained the most attention followed by both AC-IOTN level 7 and the cleft. AC-IOTN level 1 received the least amount of visual attention. Also, the more severe malocclusions (AC-IOTN 7 and AC-IOTN 10) received more visual attention as facial attractiveness increased.

Conclusions: Eyetracking and not self-reports indicate that malocclusion, repaired unilateral cleft lip, and facial attractiveness affect the areas of the female face viewed by layperson. Further work studying smile esthetics and facial attractiveness using eye tracking is needed

Introduction

People devote a lot of time and resources trying to improve their appearance and attractiveness. Many may even accept and endure pain and discomfort to obtain this improvement based on what their culture views as attractive.¹

While some consider improving facial attractiveness as cosmetic, superficial and of no true social, tangible value or importance, studies have shown it to provide greater interpersonal success in school and the workplace.^{2,3}

There is disagreement in the literature concerning the relative importance of the mouth and teeth in overall facial attractiveness. Some investigators assign the mouth and teeth major importance.⁴ Other investigators have found that the teeth and mouth contribute little to facial esthetics and background or that overall facial attractiveness is more important than any single facial feature.^{1,5,6} However, some of the same investigators have shown dental features affect how viewers assign facial attractiveness and personal characteristics such as desirability as a friend, intelligence, aggressiveness, and popularity.^{6,7}

Despite the uncertainty concerning the relative importance of the teeth in facial attractiveness, most individuals seek orthodontic treatment primarily to improve esthetics.⁸ According to Baldwin⁹ eighty percent of adult who are seeking orthodontic treatment for themselves or their children are solely motivated by the desire to improve appearance. Parents also seek orthodontic treatment for their children primarily to improve the child's appearance.¹⁰

Several recent studies documented that individual variables can reliably affect the smile's attractiveness or acceptability taking into account nationality, ethnicity, sex, and

facial attractiveness.¹¹⁻¹⁷ A shortcoming of all of these studies is that they directed the raters to focus on the mouth or selected oral features. This possibly biases the results and does not determine whether or how people spontaneously view the mouth of a smiling individual. This is of concern because self-report data from those viewing facial images indicate that the eyes and mouth are most important, while others find that other facial features are viewed first and most frequently.¹⁸ The question of what role the teeth and circumoral features play in overall facial attractiveness remains unanswered by these studies.

Another approach is to determine what viewers actually look at when presented with different facial images. Such an approach provides a direct and objective method for evaluating what facial features are important to a viewer. The premise is that features that attract the viewer's gaze are informative or have salience in determining what is viewed including its relative attractiveness.

It is possible through the use of computer technology to record eye movement through a pupillary-corneal reflection technique. This technique is called eye tracking. Eye movements involve a series of quick, jerky movements known as saccades between stops known as fixations. The brain records information only during the fixations of eye movement.¹⁹ By recording the location and duration of fixations it is possible to learn what features the individual considers the most pertinent. If a feature is of great interest to the viewer their eyes will be drawn to this particular feature.²⁰ Similarly, multiple studies have shown that regions or objects that are considered informative may not influence the initial fixation but do influence the fixation density (number of fixations) and the total duration of the fixations. Objects or regions with high informativeness

receive greater fixation density.²¹⁻²³ If a viewer is presented with a face free of anomalies and with a neutral expression they will tend to fixate on certain features of the face, like the eyes, nose, and mouth.²⁴

Despite the widespread use of eye tracking in other disciplines there has been surprisingly little use of this technology in dental research. Meyer-Marcotty et al.²⁵ used eye tracking to provide evidence that persons with cleft lip and palate (CLP) are looked at differently than persons who do not have CLP.

Hickman et al.¹⁸ conducted a study to determine the location, order and duration of viewers' visual fixations on facial features using eye tracking. Their viewers were shown images of 20 different individuals with non-quantified facial attractiveness, post-orthodontic treatment. They reported that there was no single facial feature that viewers' eyes preferentially fixed on in well-balanced faces. The findings from this study suggest that the mouth and teeth receive little reliable visual attention in "well-balanced faces" with near ideal dentitions.

The purpose of this study was to determine if and when a circumoral feature or malocclusion can attract viewers' visual attention using quantified levels of malocclusion and female facial attractiveness.

Materials and Methods

A university-based institutional review board approved the study. Preliminary steps were necessary to create the composite images with varying levels of facial attractiveness and malocclusion used in this study.

Facial images:

Facial images were obtained by seeking individuals (18-30 years of age) on an availability basis in high traffic areas on a university campus. Potential models provided written consent authorizing the researchers to use their facial images in the research and were compensated with a gift card lottery chance. Two frontal facial portraits of each individual were taken using a digital SLR camera (Nikon D60, Tokyo, Japan) mounted on a tripod. The first portrait was of the individual smiling with their lips together showing no teeth and the second portrait was the classic posed smile, which has been judged to be reliable.²⁶⁻²⁸

Any individual that approached the researchers wanting to participate was allowed to do so. Models who were judged by the researchers to have a significant distraction, such as a facial tattoo, extreme hairstyle, extreme facial hair, asymmetry, abnormal piercing, etc. were eliminated from the study. Only Caucasian models were used in an attempt to eliminate the variable of ethnicity. Different ethnicities have varied facial features, for both hard and soft tissue relationships.²⁹⁻³¹ Also, it has been shown that smile characteristics vary by ethnicity as well.¹⁴

Once all of the facial images were collected, thirty-six young adults rated one hundred ninety-nine smiling facial images revealing no teeth. The raters had no

experience with facial or oral esthetics. They rated the facial attractiveness of the images as “unattractive,” “average attractiveness,” or “attractive;” 1, 2, or 3, respectively without further definition. The images were projected (approximately 5x magnification) in random order on a screen. Forty-one images (25.9%) were repeated in random order to determine reliability. The images were then sorted based on mean attractiveness ratings. The ratings of eighteen raters were used to determine reliability because they had rated an average of 97.3% of the images. For all the models the intra-rater reliability was fair and the inter-rater reliability was poor³². Reliability was then determined for a subset of the model images. The subset included only female models, and included cluster groups based on attractiveness – the first cluster group had a mean facial attractiveness <1.5, the second cluster group with ratings close to 2 (1.875-2.41), and the third cluster group with ratings ≥ 2.5 . This new subset included 42 model images; 22 (52%) were rated twice for reliability. The intra-rater kappa statistic was 0.66(CI 95%: 0.58-0.74) and the inter-rater kappa statistic was 0.51 (CI 95%: 0.49-0.52).

Malocclusion images:

The next step involved collecting images of malocclusions. These were obtained by searching the records of a university orthodontic clinical archive. Only non-identifiable frontal intraoral photographs were used (these images showed only the teeth and associated intraoral structures).

The Aesthetic Component (AC) of the Index of Orthodontic Treatment Need (IOTN) provides 10 levels of malocclusion based on esthetic impairment. The 10 levels are often broken into 3 subgroups; levels 1-4 are considered to have little or

no treatment need, levels 5-7 borderline treatment need, and levels 8-10 definite treatment need.³³⁻³⁵ Malocclusion images were assigned an AC-IOTN level (1-10) by one of the researchers. The goal was to obtain multiple similar malocclusions for 3 of the 10 levels (levels 1, 7, and 10) as based on the AC of the IOTN. The esthetic level was matched, not the malocclusion or position of the teeth. All images were then evaluated by experienced orthodontists (15 full and part-time university faculty) to confirm the level of esthetic impairment based the AC of the IOTN. Each rater was given printed pages of the frontal intraoral images to rate (Figure 1). There were 2 pages for each level as based on the AC of the IOTN. At the top of each page was the gold standard photo for a level and below that were six images to be rated (five were believed to similar to the representative level and one was obviously different). The raters were asked to put a mark, such as an “x,” through any image that they felt did not match the standard. Each rater had their printed pages in a random order determined using a random number generator (Random.org ©). They rated all images twice for reliability purposes. The intra-rater reliability was 0.72(CI 95%: 0.64-0.80) with 91.7% agreement and the inter-rater reliability was 0.56(CI 95%: 0.53-0.59) with 83.1% agreement for all images.

In addition to the three levels of malocclusion an additional “level” was used in attempts to establish the validity of the eye tracking method for the oral region of the face. Based on the work of Shaw⁷ individuals with repaired unilateral cleft lip were judged as the least attractive when compared with other oral characteristics studied such as missing incisor, crowded incisors, prominent incisors, and normal incisors. This facial feature was used to verify that it was possible to draw visual attention to the oral area.

We again searched the records of a university orthodontic archive for multiple poorly repaired unilateral cleft lips, as judged by one of the researchers. Selected images were cropped to only include the area between subnasale and the cervical gingiva of the maxillary dentition. No identifying information was associated with these cropped images.

Composite images:

After obtaining and rating the malocclusion images, they were combined with the rated smiling images of different levels of facial attractiveness to form a composite image (Figure 2). Only the malocclusions that most closely resembled the standard for their specific level were used. A malocclusion image was only used if it received $\geq 90\%$ agreement from the raters. Similarly, only the images that had the most agreement for the level of facial attractiveness were used. All of the unattractive models had a mean attractiveness rating of less than 1.40. The average models mean attractiveness ratings ranged from 1.90-2.11 and the attractive models were rated greater than 2.60. These composite images were created using commercial image processing software (Adobe® Photoshop® Elements 7.0, Adobe Systems; San Jose, CA).

The three levels of malocclusion plus the unilateral cleft lips were placed in each of the three level of facial attractiveness. This provided 12 possible combinations of malocclusion and facial attractiveness (Table I). However, to provide more data, two different images were created for each combination resulting in 24 unique images.

For the cleft images the teeth were AC-IOTN level 1 teeth to standardize the variable of dental malocclusion. The faces of the models were not bisected and mirrored to produce bilaterally symmetric faces based on evidence that this was not necessary.³⁶⁻⁴⁰

Software (Experiment Builder®, SR Research Ltd., Katana, Ontario, Canada) was used to construct the program to run the study on the eye tracker. Areas of interest of the face were defined for each composite image, in essence creating a map of the face (Figure 3). The interest areas defined were: head, hair, eyebrows, eyes, nose, mouth (if a cleft was present it was grouped with the mouth), cheeks, chin, and ears. These interest areas defined where the participant/viewer was viewing. A small gap was left between interest areas to ensure accuracy of a fixation. If a fixation landed on a gap between areas of interest it was recorded as other. This eliminated the potential problems of assigning a fixation to an interest area if it landed on the border of two interest areas and also dealt with the 0.25-0.50° of viewing angle error of the eye tracker.

Viewers were recruited using the Psychology Department's Research Experience Program (REP) and by posting flyers on the main campus of the university. Dental professionals (including dental and dental hygiene students) were excluded from the study. As an incentive to encourage participation REP viewers received a partial credit hour and the flyer-recruited viewers received a monetary incentive. REP viewers and paid viewers were not recruited or tested at the same time. The inclusion criteria consisted of the following items: 18-30 years of age; able to understand English; no prior or existing neurological condition; normal or corrected-to-normal, color vision (no hard contacts); not recently consumed alcohol or other drugs; not currently using any

medication that may affect cognitive abilities; and not wearing mascara or willing to remove it.

Deception was used in order to avoid the viewers from being biased as they were shown the images. They were told the title of the study was, “Visual exploration of faces recorded from an eye-tracking system,” and that the purpose of the study was to “help us understand how individuals view other people.” Upon completion of the study a debriefing form was provided to explain the reason for the deception.

After obtaining consent, the viewers were positioned in the eye tracker (EyeLink 1000®, SR Research Ltd., Katana, Ontario, Canada) and it was calibrated to them (Figure 4). For the study they were instructed to simply look at the images shown on the computer screen. The eye tracking session began by showing the viewers five sample images to make sure the instrumentation was working properly, and then all 24 images in random order. Each image was displayed for 3 seconds. Between each image a blank screen with a randomly placed “X” was displayed for 1 second. After all 24 images had been displayed they were shown all 24 images again in a new random order to determine intra-rater reliability. As the images were shown, data were being collected concerning: what area of the face the viewer looked at first, what area of the face they viewed the most frequently (fixation density), and what area of the face they viewed for the longest duration (recorded in ms).

Following the eye tracking, the viewers were asked to fill out a short questionnaire asking them what facial feature they looked at first and then second and for the longest duration when meeting someone for the first time. They were also asked for demographic data including age, sex, and ethnicity.

Statistical Analysis and sample size determination

With a non-directional alpha risk of 0.05 and assuming a standard deviation of 2.54,¹⁸ a sample size of 75 viewers was required to demonstrate a difference of ± 1.5 fixations with a power of 0.996. Again, with non-directional alpha risk of 0.05 and assuming a standard deviation of 793 milliseconds,¹⁸ a sample size of 75 would yield a power of 0.998 to detect a difference of ± 500 milliseconds in total duration time.

It was our intention to determine the area of first fixation. However, it became quickly apparent that viewer reliability was poor. Overall reliability calculated with data from the first 32 viewers was $\kappa=0.08$ for intra-rater reliability and $\kappa=-0.03$ for the inter-rater reliability. For this reason the area of first fixation was dropped from the study.

Both remaining dependent variables (area of greatest fixation density and area of maximum total duration) were analyzed by a repeated-measures, factorial analysis of variance (ANOVA). Independent variables were level of malocclusion, perceived model attractiveness, area of the face, and rater sex. Post hoc testing was done using the Tukey-Kramer procedure.

Results

Seventy-eight viewers participated in this study, of those seventy-six (n=76) finished the study. The two viewers who did not finish the study were disqualified because of difficulty calibrating the eye tracker and not being able to keep it calibrated throughout the duration of the eye tracking session. Of the viewers who finished the study 51% were male and 49% were female. The mean age of the viewers was 20.1 years (range 18-29 years); four viewers did not provide their age. The ethnicity of the viewers was 69% Caucasian, 8% African-American, 5.5% Hispanic, 10% Asian, 1% Middle-Eastern, 1% Native-American, and 5.5% other. Two viewers did not provide their ethnicity.

Viewer reliability ranged from ICC .44 to .89, but was 00 to .31 for the chin. Because of the poor to fair reliability the chin area should be interpreted with caution. (Table II).

Repeated-measures ANOVA showed a significant effect ($p < 0.001$) for level of attractiveness by malocclusion by area of the face. This was seen for both the fixation density (total number of fixations) and total duration of fixations. For both fixation density and total duration of fixations, the eyes overwhelmingly were most salient. In all but 13 of 452 combinations of malocclusion and attractiveness levels that included the eyes, the eyes received significantly more visual attention than the second most observed area, the mouth. The nose was the third most observed area. For the location of greatest total duration of fixations the eyes received 29-41%, the mouth 13-30%, and the nose 10-17% of the total viewing time (Figures 5 & 6). As the malocclusions became more severe the visual attention increased on the oral/circumoral area, sometimes approaching that of

the eyes (Figures 7 & 8). In one instance, attractive + AC-IOTN 10, the mouth received greater mean total duration of fixation time than did the eyes; however, this finding was not statistically significant. At AC-IOTN level 10 the mouth gained the most attention followed by both AC-IOTN level 7 and the cleft. At AC-IOTN level 1 the mouth received the least amount of visual attention (Figure 8). Also, the more severe malocclusions (AC-IOTN 7 and AC-IOTN 10) received more visual attention as facial attractiveness increased (Figure 9). For the average and the attractive levels of facial attractiveness there was a significant difference ($p < 0.001$) in fixation density and total duration of fixations between AC-IOTN level 1 and AC-IOTN level 7, but not between AC-IOTN 7 and AC-IOTN 10. However, the opposite was true for the unattractive level of facial attractiveness; there was not a significant difference in fixation density and total duration of fixations between AC-IOTN level 1 and AC-IOTN level 7, but there was between AC-IOTN 7 and AC-IOTN 10 ($p < 0.001$) (Figure 8, see asterisks).

The repeated-measures ANOVA also showed a significant effect ($p < 0.001$) between viewer sex and area of the face for both fixation density (total number of fixations) and total duration of fixations (Figure 10). Female viewers had a significantly greater ($p < 0.001$) fixation density and total duration of fixations on the area of the eyes and significantly less fixation density and total duration of fixations on the area of nose than the male viewers.

When viewers were asked what facial feature they looked at first when meeting someone for the first time 79% of viewers selected the eyes, 18% reported the mouth, and 3% selected a different area. When asked where they look second, 16% reported the eyes, 62% the mouth, 10% the nose, and 12% other areas. When asked about what facial

feature they viewed for the longest duration when meeting someone for the first time
78% reported the eyes, 16% reported the mouth, 1% the nose, and 5% other areas.

Discussion

Reliability for the area of first fixation was poor and therefore eliminated from the analysis and reporting. Similarly, in a previous dental eye tracking study¹⁸ it was found that the location of first fixation for smiling images was not reliable ($\kappa = 0.09$). In other research there has been much more use of eye tracking and it has been reported that first fixation is not reliable because initial fixations are controlled by visual, not semantic analysis.^{41,42} The earlier dental study also reported there was poor reliability for the measures of area of maximum number of fixations (fixation density) and area of maximum fixation duration.¹⁸ In the current study, reliability for area of fixation density and area of maximum fixation duration was moderate to very good, most likely due to the more visually varied information presented. Another possible reason for the difference in reliability from the previous eye tracking dental study and this study was the difference in time between viewing sessions. In the former study the viewers had a 2-week interval between viewing sessions. However, in the current study the viewers began the second session immediately following a three second pause, less than 2 minutes after beginning the initial viewing session.

We found a significant interaction between interest area of the face, level of attractiveness, and malocclusion. The eyes were the most salient facial feature followed by the mouth. In another eye tracking study evaluating the importance of the eyes and mouth when viewers examine a face for the first time, they found that the eyes received almost four times more visual attention than did the mouth.⁴³ This study did not specify the malocclusion of their models. Our results indicate that the eyes received

approximately three times the amount of visual attention depending on the level of malocclusion and facial attractiveness.

However, as the malocclusion became more severe the mouth received greater visual attention and the eyes less (Figures 7 & 8). In fact, the mean total duration for the mouth was greater than that for the eyes in the combination of AC-IOTN 10 + attractive. This finding suggests that viewers when looking at someone for the first time default the majority of their visual attention to the eyes but if there is a facial feature that is discordant it is possible to draw their visual attention away from the eyes to that facial feature. This is supported by the results of a study in which a repaired cleft also drew increasing attention in average and attractive faces.²⁵

In the current study we were testing whether decreasing the esthetic value of the occlusion would draw visual attention. As the AC-IOTN level increased, meaning the malocclusion became more non-esthetic, more visual attention was directed towards it. We found a significant difference between AC-IOTN level 1 and level 7 for the average attractiveness and attractive models (Figure 8, see asterisks). Interestingly, we did not see the same significant difference for the unattractive models. However, there was a significant difference between AC-IOTN level 7 and 10 for unattractive models that was not seen for the average attractiveness and attractive models (Figure 8, see asterisks). This finding suggests a couple of interesting and related ideas. First, it appears that the level of background facial attractiveness affects how noticeable similarly non-esthetic malocclusions are to a viewer. The more attractive the model is, the more visual attention the viewer spends on a discordant malocclusion (Figure 9). Chang et al.¹² also found that facial attractiveness affects smile characteristics. Second, it seems that there is

an esthetic level of malocclusion somewhere between AC-IOTN levels 1 and 7 where the malocclusion becomes non-esthetic enough to attract the viewers attention away from the eyes when the background facial attractiveness is average or attractive. For the unattractive level of facial attractiveness this point seems to be somewhere between AC-IOTN level 7 and 10. Essentially this confirms the findings of Chang et al.¹² data that different levels of facial attractiveness are seen as consonant with different levels of malocclusions.

Further studies are needed to determine exactly where this tipping point is in the AC-IOTN spectrum. The AC of the IOTN is often divided into three subgroups; levels 1-4 little or no treatment need, levels 5-7 borderline treatment need, and levels 8-10 definite treatment need. Our findings are similar to the definitions of these subgroups, but the threshold for attention to the malocclusion from an esthetic point of view, most probably in the level 5-7 area, remains undefined.³³⁻³⁵ Similarly, somewhere in the definite treatment need group, levels 8-10, the malocclusion becomes severe enough from an esthetic point of view to draw the viewers visual attention to it for all models, independent of the level of their facial attractiveness.

Our self-report data were similar to that found by Hickman et al.¹⁸ These data are certainly situation specific. For the area of the face receiving the greatest duration of total fixation time our objective data showed in 11 of 12 (91.7%) combinations of attractiveness and malocclusion the eye received a greater mean duration than any other facial feature, including the mouth. In only 1 of 12 (8.3%) combinations of attractiveness and malocclusion, AC-IOTN 10 + attractive, did the mouth have a mean total duration

greater than the eyes. However, this difference was not statistically significant. This finding supports the results of the self-reports.

Previous work on smile esthetics found no differences based on the viewers' sex.^{11,12,17} In the current study there was a significant difference ($p < 0.001$) in viewers' sex and how they viewed areas of the face (Figure 10). Female viewers devoted significantly more visual attention to eyes than did male raters. Conversely, male viewers directed more visual attention to the nose than did the female viewers. This finding was unexpected and interesting. However, the absolute differences were small and need to be confirmed by other investigators.

Initially, we were uncertain if we would be able to reliably draw visual attention to the mouth or circumoral region of the face. Based on the work of Shaw^{6,7} we added images with a poorly repaired unilateral cleft lip as an extreme oral feature to test the salience of an oral feature.

Unexpectedly, AC-IOTN level 10 received more visual attention than did the cleft. AC-IOTN level 7 and the cleft received similar amounts of visual attention (Figures 8 & 9). Our findings are different than those of Shaw^{6,7}, who found the cleft most negatively affected facial and sexual attractiveness. This difference may be due to the fact that malocclusions similar to that of AC-IOTN 10 may appear to an observer to be a combination of multiple oral features such as prominent incisors, crowded incisors, and it may even appear that an incisor is missing. Shaw tested these dental features independently of each other.

Another possible factor to account for the cleft not drawing as much visual attention in the current study as was expected may be the fact that we combined the clefts

with AC-IOTN level 1 teeth; in other words the models had a poorly repaired unilateral cleft lip but had little or no dental malocclusion. Shaw's cleft models had dental malocclusions. In both studies the cleft did not affect the nose.

Our results also differ from Meyer-Marcotty et al.²⁵ who reported that persons with CLP were viewed more negatively overall than non-CLP persons. However, their models were showing no teeth and their clefts affected the nose. Meyer-Marcotty et al. also found that the viewers spent more initial fixations on the mouth and longer fixations on the mouth and nose in CLP persons. Results with a modified protocol, such as combining appropriate malocclusions in the AC-IOTN range of 7-10 with the cleft, might yield similar results.

We found that the eyes received 29-41% of total viewing time and the mouth received 13-30% of total viewing time depending on the level of malocclusion and level of facial attractiveness. Only in extreme cases did the mouth rival the importance of the eyes in determining visual attention. Other researchers have reported that both the eyes and the mouth are important in facial attractiveness and that the eyes are secondary to the oral region in determining overall facial attractiveness.⁴⁴ More commonly the mouth has not been ascribed major significance.¹ Tatarunaite et al.⁵ present evidence that dental attractiveness seemed to be less influential on overall facial attractiveness than the rest of the face.

From the current study we conclude that more non-esthetic dental malocclusions receive more visual attention. This adds weight in favor of improving dental esthetics for individuals with a high level AC-IOTN malocclusion.

Our viewers only saw each image for three seconds. It is unknown whether a short viewing time such as this reflects what would occur over a longer viewing period, such as minutes, with regard to the visual attention and eye movements.^{45,46} However, viewers are likely to fixate on informative regions in the first two seconds of scene viewing as in other two second intervals, suggesting that region informativeness could be detected relatively early during scene viewing.⁴¹ In addition, facial attractiveness is determined within the first two seconds.⁴⁷

Our results for area of greatest fixation density and area of greatest total fixation duration were very similar. Fixation density and fixation durations are both used to evaluate informativeness of an object. Most studies have shown that areas with high informativeness or that are semantically inconsistent receive greater fixation density and fixation duration. This does not seem to change over viewing time.⁴⁸ The severe malocclusions in average and attractive models could be considered inconsistent or discordant and partially explain why the mouth received greater fixation density and duration than similar malocclusions in unattractive models.

In the current study the viewers saw static images. It is unknown what effect varying levels of malocclusion and varying levels of facial attractiveness would have on eye movements and facial exploration if the models were not in a static state. In addition, we do not know what affect the self-perceived level of facial and dental attractiveness of the viewers has on their interaction with the images.

Conclusions

Eye tracking provides a reliable and objective method for evaluating the visual attention paid to facial features, including the mouth.

The eyes were the most salient facial feature in 92% of the time, followed by the mouth.

As the AC-IOTN level increased the mouth received more visual attention, at times approaching and in one instance surpassing the eyes.

Facial attractiveness affected the amount of visual attention received by the varying levels of malocclusion. As facial attractiveness increased the higher AC-IOTN levels drew more visual attention.

Poorly repaired unilateral cleft lip images received greater visual attention than did images with no cleft but less than those with no cleft and AC-IOTN level 10.

Viewer sex had an effect on how faces were viewed.

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Chapter 4: Conclusions

Conclusions

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Poorly repaired unilateral cleft lip images received greater visual attention than did images with no cleft but less than those with no cleft and AC-IOTN level 10.

Viewer sex had an effect on how faces were viewed.

Appendix: Tables and Figures

Legend

Table 1.	Combinations of composite images
Table 2.	Reliability
Table 3.	ANOVA summaries
Table 4.	Means and standard deviations for sum of total duration of fixations
Table 5.	Means and standard deviations for number of fixations
Figure 1.	Example of a rating sheet for malocclusions
Figure 2.	Examples of composite images
Figure 3.	Composite image showing how interest areas were defined
Figure 4.	Adult positioned in table mounted eye tracker
Figure 5.	Mean sum of total duration of fixations for all areas of interest
Figure 6.	Mean number of fixations for all areas of interest
Figure 7.	Viewing attention the eye received by AC-IOTN level
Figure 8.	Viewing attention the mouth received by AC-IOTN level
Figure 9.	Viewing attention the mouth received by level of facial attractiveness
Figure 10.	Sex differences of viewing attention

Occlusion Face	AC-IOTN 1	AC-IOTN 7	AC-IOTN 10	Cleft +AC-IOTN 1
Unattractive	IOTN 1 + Unattractive	IOTN 7 + Unattractive	IOTN 10 + Unattractive	Cleft + Unattractive
Average	IOTN 1 + Average	IOTN 7 + Average	IOTN 10 + Average	Cleft + Average
Attractive	IOTN 1 + Attractive	IOTN 7 + Attractive	IOTN 10 + Attractive	Cleft + Attractive

Table 1. Combinations of malocclusion level and facial attractiveness used to create the composite images

AREA	Intra-rater reliability			AREA	Inter-rater reliability		
	ICC	LCB	UCB		ICC	LCB	UCB
Mouth	0.85	0.84	0.86	Mouth	0.77	0.74	0.80
Eye	0.89	0.88	0.90	Eye	0.83	0.81	0.85
Ear	0.65	0.62	0.68	Ear	0.46	0.40	0.51
Nose	0.86	0.85	0.87	Nose	0.77	0.74	0.80
Chin	0.58	0.55	0.61	Chin	-0.18	-0.24	-0.11
Other	0.67	0.64	0.70	Other	0.52	0.47	0.57

A.

AREA	Intra-rater reliability			AREA	Inter-rater reliability		
	ICC	LCB	UCB		ICC	LCB	UCB
Mouth	0.85	,84	0.86	Mouth	0.77	0.74	0.80
Eye	0.88	0.87	0.89	Eye	0.80	0.77	0.82
Ear	0.64	0.61	0.67	Ear	0.44	0.38	0.49
Nose	0.81	0.79	0.83	Nose	0.62	0.58	0.66
Chin	0.31	0.27	0.35	Chin	-0.22	-0.28	-0.15
Other	0.65	0.62	0.68	Other	0.49	0.44	0.54

B.

Table 2. Reliability. A, Total duration of fixations by area of the face; B, fixation density by area of the face; Reliability is designated as follows: <0.20 poor, 0.21-0.40 fair, 0.41-0.60 moderate, 0.61-0.80 good, and >0.80 very good³²

	Num	Den		
Effect	DF	DF	F Value	Pr > F
ATTRACT	2	148	0.07	0.9325
OCCLSN	3	222	1.46	0.227
ATTRACT*OCCLSN	6	444	0.64	0.7015
AREA	5	370	1635.41	<.0001
ATTRACT*AREA	10	740	4.69	<.0001
OCCLSN*AREA	15	1110	26.26	<.0001
ATTRACT*OCCLSN*AREA	30	2220	4.57	<.0001
RGEND	1	74	0.65	0.4234
ATTRACT*RGEND	2	148	0.13	0.8808
OCCLSN*RGEND	3	222	0.03	0.9923
ATTRACT*OCCLSN*RGEND	6	444	0.11	0.9954
AREA*RGEND	5	370	41.96	<.0001
ATTRACT*AREA*RGEND	10	740	0.84	0.5924
OCCLSN*AREA*RGEND	15	1110	0.69	0.7952
ATRA*OCCL*AREA*RGEND	30	2220	0.85	0.6967

A.

	Num	Den		
Effect	DF	DF	F Value	Pr > F
ATTRACT	2	148	0.18	0.8392
OCCLSN	3	222	3.43	0.018
ATTRACT*OCCLSN	6	444	0.08	0.998
AREA	5	370	1734.53	<.0001
ATTRACT*AREA	10	740	3.92	<.0001
OCCLSN*AREA	15	1110	26.61	<.0001
ATTRACT*OCCLSN*AREA	30	2220	5.2	<.0001
RGEND	1	74	1.29	0.2594
ATTRACT*RGEND	2	148	0.85	0.4295
OCCLSN*RGEND	3	222	0.44	0.725
ATTRACT*OCCLSN*RGEND	6	444	0.46	0.8411
AREA*RGEND	5	370	31.21	<.0001
ATTRACT*AREA*RGEND	10	740	0.55	0.8517
OCCLSN*AREA*RGEND	15	1110	0.51	0.938
ATRA*OCCL*AREA*RGEND	30	2220	0.9	0.6209

B.

Table 3. ANOVA summary tables. A, total duration of fixations; B, fixation density

						Std							
ATTRACT	OCCLSN	AREA	N	Mean	Dev								
AVE	CLEFT	CHIN	152	2.08	13.89			OTHER	152	223.30	277.85		
		EAR	152	36.32	122.91			IOTN10	CHIN	152	0.19	2.35	
		EYE	152	1039.86	662.08			EAR	152	26.45	96.12		
		MOUTH	152	507.19	503.34			EYE	152	882.45	658.24		
		NOSE	152	336.46	426.06			MOUTH	152	897.64	643.15		
		OTHER	152	235.45	274.15			NOSE	152	331.63	426.85		
	IOTN1	CHIN	152	1.07	13.14			OTHER	152	201.89	288.35		
		EAR	152	98.24	174.92			IOTN7	CHIN	152	2.80	25.37	
		EYE	152	1043.04	606.19			EAR	152	76.59	193.70		
		MOUTH	152	398.93	354.65			EYE	152	899.38	588.19		
		NOSE	152	498.72	418.06			MOUTH	152	773.69	592.32		
		OTHER	152	188.07	290.11			NOSE	152	356.98	385.35		
	IOTN10	CHIN	152	75.27	99.59			OTHER	152	164.01	243.95		
		EAR	152	16.76	109.35			Unattract	CLEFT	CHIN	152	1.67	15.44
		EYE	152	868.24	634.97			EAR	152	26.13	89.69		
		MOUTH	152	830.62	604.03			EYE	152	903.38	687.30		
		NOSE	152	305.52	326.89			MOUTH	152	704.66	619.73		
		OTHER	152	125.23	228.36			NOSE	152	373.56	480.52		
	IOTN7	CHIN	152	0.99	12.00			OTHER	152	207.43	281.10		
		EAR	152	8.65	51.72			IOTN1	CHIN	152	13.13	56.58	
		EYE	152	967.10	649.15			EAR	152	19.26	87.06		
		MOUTH	152	738.38	570.61			EYE	152	1225.16	655.07		
		NOSE	152	412.92	478.76			MOUTH	152	420.43	449.95		
		OTHER	152	183.26	198.77			NOSE	152	322.32	331.98		
Attract	CLEFT	CHIN	152	0.15	1.87			OTHER	152	263.59	245.28		
		EAR	152	50.20	176.19			IOTN10	CHIN	152	4.93	47.13	
		EYE	152	824.83	607.49			EAR	152	36.89	120.01		
		MOUTH	152	743.49	556.75			EYE	152	838.91	660.29		
		NOSE	152	361.73	450.10			MOUTH	152	780.91	565.65		
		OTHER	152	123.49	251.73			NOSE	152	402.45	390.05		
	IOTN1	CHIN	152	0.00	0.00			OTHER	152	224.47	278.49		
		EAR	152	70.03	169.48			IOTN7	CHIN	152	12.45	95.87	
		EYE	152	1116.35	611.24			EAR	152	105.93	179.37		
		MOUTH	152	404.18	372.44			EYE	152	1000.09	616.33		
		NOSE	152	354.53	384.36			MOUTH	152	509.79	465.02		
								NOSE	152	299.60	361.15		
						OTHER	76	271.61	297.52				

Table 4. Mean total duration and standard deviations of fixations by level of attractiveness (ATTRACT), level of malocclusion (OCCLSN), and area of interest

ATTRACT	OCCLSN	AREA	N	Mean	Std Dev						
AVE	CLEFT	CHIN	152	0.033	0.213	Unattract	IOTN10	CHIN	152	0.007	0.081
		EAR	152	0.191	0.572			EAR	152	0.118	0.398
		EYE	152	3.586	2.151			EYE	152	3.178	2.091
		MOUTH	152	1.888	1.634			MOUTH	152	2.934	2.093
		NOSE	152	1.289	1.221			NOSE	152	1.362	1.199
		OTHER	152	1.164	1.039			OTHER	152	0.967	1.100
							IOTN7	CHIN	152	0.013	0.114
	IOTN1	CHIN	152	0.007	0.081			EAR	152	0.362	0.802
		EAR	152	0.467	0.797			EYE	152	3.368	2.061
		EYE	152	3.704	2.077			MOUTH	152	2.520	1.711
		MOUTH	152	1.467	1.255			NOSE	152	1.520	1.173
		NOSE	152	2.086	1.531			OTHER	152	0.934	1.053
		OTHER	152	0.967	1.498						
	IOTN10	CHIN	152	0.474	0.563		CLEFT	CHIN	152	0.020	0.140
		EAR	152	0.059	0.310			EAR	152	0.112	0.356
		EYE	152	3.171	2.121			EYE	152	3.125	2.178
		MOUTH	152	2.796	1.903			MOUTH	152	2.493	2.062
		NOSE	152	1.454	1.156			NOSE	152	1.414	1.076
		OTHER	152	0.612	1.168			OTHER	152	1.020	1.253
	IOTN7	CHIN	152	0.020	0.181		IOTN1	CHIN	152	0.079	0.316
		EAR	152	0.039	0.227			EAR	152	0.105	0.384
		EYE	152	3.487	2.046			EYE	152	4.224	2.011
		MOUTH	152	2.474	1.884			MOUTH	152	1.474	1.419
		NOSE	152	1.711	1.325			NOSE	152	1.368	1.222
		OTHER	152	1.033	1.100			OTHER	152	1.355	1.082
Attract	CLEFT	CHIN	152	0.007	0.081		IOTN10	CHIN	152	0.020	0.140
		EAR	152	0.217	0.680			EAR	152	0.164	0.494
		EYE	152	3.020	2.070			EYE	152	2.796	2.104
		MOUTH	152	2.592	1.653			MOUTH	152	2.783	1.863
		NOSE	152	1.526	1.552			NOSE	152	1.770	1.299
		OTHER	152	0.559	1.034			OTHER	152	1.020	1.130
	IOTN1	CHIN	152	0.000	0.000		IOTN7	CHIN	152	0.046	0.266
		EAR	152	0.289	0.677			EAR	152	0.507	0.846
		EYE	152	3.987	2.153			EYE	152	3.579	2.005
		MOUTH	152	1.507	1.317			MOUTH	152	1.928	1.696
		NOSE	152	1.638	1.350			NOSE	152	1.296	1.190
		OTHER	152	1.118	1.097			OTHER	152	1.329	1.356

Table 5. Mean number and standard deviations of fixations by level of attractiveness (**ATTRACT**), level of malocclusion (**OCCLSN**), and area of interest (**AREA**)

Figure 1. Example of a sheet the raters would have seen when rating the malocclusions against the standard (at the top to the sheet), they were asked to place an “X” through any image they felt was not similar to the standard.

Figure 2. Examples of composite images created for this study. A, unattractive + AC-IOTN 1; B, average attractiveness + AC-IOTN 1; C, attractive + AC-IOTN 1; D, unattractive + AC-IOTN 10; E. average attractiveness + AC-IOTN 10; F. attractive + AC-IOTN 10

Figure 3. Composite image (attractive + cleft) showing the demarcation of interest areas

Figure 4. An adult (not a study participant) positioned in a table-mounted, eye-tracking device

Figure 5. Mean sum of total duration of fixations for areas of interest by level of malocclusion. A, Unattractive; B, Average Attractiveness; C, Attractive

Figure 6. Mean number of fixation for areas of interest by level of malocclusion. A, Unattractive; B, Average Attractiveness; C, Attractive

Figure 7. Mean total duration of fixations and mean number of fixations received by the eyes by AC-IOTN level; * indicates an intra-attractiveness level significant difference ($p < 0.05$) between malocclusion levels, † indicates an inter-attractiveness significant difference at the given malocclusion level.

Figure 8. Mean total duration of fixations and mean number of fixations received by the mouth by AC-IOTN level; * indicates an intra-attractiveness level significant difference ($p<0.05$) between malocclusion levels, † indicates an inter-attractiveness significant difference at the given malocclusion level.

Figure 9. Mean total duration of fixations and mean number of fixations received by the mouth by level of facial attractiveness * indicates an intra-malocclusion level significant difference ($p < 0.05$) between attractiveness levels; see Figure 8 for intra-attractiveness level significant differences.

Figure 10. Mean total duration of fixations and mean number of fixations for different areas of the face by sex; † indicates an inter-sex significant difference ($p<0.05$) at the given facial area.

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