Differences in Mandibular Dentogingival Exposure as a Function of Age and Type of Facial Expression

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Differences in Mandibular Dentogingival Exposure as a Function of Age and Type of Facial Expression

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ABSTRACT

**Statement of Problem:** The need to accurately and reliably assess the maximum mandibular dentogingival display is essential during the planning of dental treatment, and inaccuracies in capturing a patient’s genuine border movements in the mandible can result in a faulty treatment outcome.

**Purpose:** Maximum smile as an expression is a frequently used to establish the extent of dentogingival display in the dental practice. In this study, the facial expressions “maximum smile,” (MS) “eyes closed smile,” (EC) and enunciation of the word “church” (CH) was used to evaluate the effect of facial expression on mandibular dentogingival display, and to assess the applicability of these findings in a clinical setting. The primary purpose of this study was to know, among the 3 stated facial expressions, the horizontal and apical differences in mandibular dentogingival display in the anterior and posterior regions. The secondary purpose of this study was to know, within each facial expression, whether age or gender is a factor in the horizontal and apical mandibular dentogingival display in the anterior and posterior regions.

**Material and Methods:** One hundred and thirty-eight subjects were recruited to participate in the study. The group studied consisted of 85 females and 53 males. Additionally, there were 6 age groups in each study with the following subjects in each group: Age 21-30 consisted of 32 subjects, Age 31-40 consisted of 20 subjects, Age 41-50 consisted of 21 subjects, Age 51-60 consisted of 20 subjects, Age 61-70 consisted of 24 subjects, and Age 71-80 consisted of 21 subjects. After obtaining UCHC IRB approval, digital photographs of the lower half of the face of 138 dentate subjects were taken during the following three expressions: “Maximum smile” (MS) “Maximum smile with eyes closed” (EC), and saying the word “church” (CH) while holding the “ch” sound. Subjects completed a standardized demographic sheet to be statistically
categorized by age, gender, and ethnicity. Photographs and the subject’s information were de-identified, and the digital photographs were analyzed. Statistical analysis used the categorical data to compare the differences in dentogingival display among the three facial expressions, and then as a function of age and gender of the subjects within each facial expression.

**Results:** The overall presence of mandibular tooth display differed significantly between the facial expressions MS, EC and CH with respect to the number of teeth visible, calculated as a percentage ($p < 0.001$). In the anterior mandible, expressions EC and CH showed 93% of mandibular anterior teeth, whereas MS showed 76% of mandibular anterior teeth. In the posterior mandible, EC showed 86% of the mandibular teeth, with MS showing 55% and CH showing 14% of mandibular teeth.

Analysis also showed a statistically significant difference between apical extent display between facial expressions MS, EC and CH ($p < 0.001$). In the anterior mandible, CH had the most display with an average score of 2.08, followed by EC with a score of 1.67, and lastly MS with a score of 0.93. For amount of display in the posterior mandible, EC had the most display with a score of 1.38, then MS with a score of 0.62, and CH had a minimal amount of posterior vertical display with a score of 0.19. No evidence of a statistically significant trend in percent presence value or mean score was found with respect to effect of gender and age.

**Conclusions:** The results of this study illustrated that additional diagnostic tools such as expressions EC and CH can predictably capture a broader extent of mandibular dentogingival display. Findings from this study suggest that multiple facial expressions should be used to diagnose mandibular display, as each facial expression provides a different diagnostic element.
INTRODUCTION

Review of Literature

The smile is dynamic, changing with multiple factors including age, gender and ethnicity.\textsuperscript{15} The desire for an esthetic and functional smile via implant-supported prosthesis is not limited to the elderly, and incorporates patients with a wide array of clinical characteristics.\textsuperscript{16} The complications from incorrect calculations have dire consequences on the patient’s esthetic outcome, oral hygiene, and implant success,\textsuperscript{20} and should not be underestimated. Hence, the importance in understanding the factors involved in accurately assessing dentogingival display.

It is advantageous for clinicians to establish an objective, available method to evaluate facial esthetics and expressions. Panossian et al emphasized the importance of a consistent, repetitive and objective examination, and evaluated patients using a protocol that divided the face into proportions and formed diagnoses using a decision tree.\textsuperscript{21} Numerous studies discuss using action units (AU), an anatomically based measurement corresponding to the contraction of different facial muscles, to measure the complexity of facial expressions.\textsuperscript{8,22} An et al attempted to narrow down a smile as involving two parts of facial movements, the cheek raiser (AU6), and the lip corner puller (AU12).\textsuperscript{23} While Girard et al noted that during pleasant circumstances, a smile is more likely to involve the orbicularis oculi muscle (AU6) and the buccinators muscle (AU14) during active depression of the mouth.\textsuperscript{22} While action units is a thorough method to analyze facial expressions, it is impractical in clinical settings. Girard et al believed smile intensity to be an additional clue into facial expression, which could not be measured using AU.\textsuperscript{22}

Using classifications based on careful visual judgment, rather than mathematical measurements, Tjan et al categorized differences in smile types, defining a high smile line as revealing a contiguous band of gingiva with a total cervicoincisal length of maxillary teeth.\textsuperscript{6}
The study found an average smile revealed 75-100% of the maxillary anterior teeth and interproximal gingiva, while a low smile was termed as displaying less than 75% of the anterior teeth. The survey found that 10.57% of subjects were classified as having a high smile, 68.4% as having an average smile, and 20.48% were quantified as having a low smile.

While lips and musculature may evolve and affect anterior tooth display, Oh et al observed that the incisive papilla is a relatively constant landmark. Hochman et al discerned that in a study of 420 patients from the ages of 10 to 89, the maxillary interdental papillae during smiling was present 91% of the time, even if patients were classified as having a low smile line. The maxillary interdental papilla is present in the majority of patients, and is an important feature in esthetics.

Smile and mouth movements during speaking are of utmost concern to a dentist when treatment planning, but psychology becomes a guiding factor in contributing to an accurate assessment. Despite all efforts to consistently capture the Duchenne smile in the dental office, it is difficult for a dentist to provoke spontaneous movements from a patient. Facial expressions present from a complex neurological response that incorporates sensory feedback from multiple cranial nerves and the cerebral cortex. Patients seeking prosthodontic treatment are usually unhappy with their current smile or looking for improvement and, subconsciously or not, do not display as much teeth when smiling or speaking. Matthews et al explains that patients often come to the dental office with dental pathology such as missing or carious dentition, what they feel as an unsightly condition. With practiced restraint, consciously or unconsciously, patients cover their teeth with their lips. Due to insecurities commonly intensified by the backdrop of a medical office, it is difficult for a dentist to elicit a genuine smile from a patient. As Hess et al found, “participants displayed the most facial expression intensity when experiencing strong
emotions in the company of friends”. If eliciting a natural smile in a dental office is not predictably achievable, the question arises whether a posed maximum smile is sufficient to represent a comparable lip line height, tooth, and gingival exposure? Because dentists cannot simulate social settings in order to elicit the greatest intensities of facial expression, multiple techniques have been attempted to accurately record the range of lip movements necessary for diagnosis.

The eye musculature has been a notable clue into whether a smile is genuine, and are active in pulling the corners of the lips upward to create a smile. Current literature has repetitively found the importance of the eye musculature in creating a Duchenne smile, which has been shown to exhibit maximal dentogingival display. Mandal et al also observed that the aperture of the eyes was an important clue to the value of a smile. Matthews explains that a smile is conveyed mainly in the oral region and the eyes. The spontaneous smile, termed the Duchenne smile, has been studied and distinguished from a posed smile by the activation both the zygomaticus major muscle with the orbicularis oculi. The complex series of neurological events contract multiple facial muscles, which all insert at the muscle around the eye, the orbicularis oris. Hulsey noted that the main effectors of the smile are the zygomaticus major muscles, which insert into the orbicularis oris as a mode to raise the corners of the mouth up and out, curving the lips into a smile. The Duchenne smile utilizes all of the muscles in the face, but primarily involves the zygomaticus major, levator labii superioris, and levator anguli oris, along with the periocular muscles for greatest lip elevation.

Walter et al concluded that images captured of an intense grimace of disgust and a funnel-shaped expression showed a statistically significant greater height of gingiva at the maxillary central; whereas a statistically significant greater height of gingival tissue at the
maxillary canines occurred with a Duchenne smile. While the study used verbal instructions and an image of the Duchenne smile for subjects to imitate, which disregards the emotion and spontaneity behind a Duchenne smile, it found that multiple facial expressions should be used to evaluate the maximum gingival display.

Many studies have assessed maxillary anterior display; yet far less have investigated mandibular display. Vig et al noted the neglect of mandibular incisors in denture esthetics, a viewpoint that can also be applied to fixed dentition. Muller et al emphasized the importance of mandibular esthetics, especially in older adults, and stressed that a clinician should consider assessment and restoration of mandibular teeth with the same attention that is given to maxillary teeth. In a study of one hundred ten sets of diagnostic casts from persons 35 to 70 years of age, Lorton et al assessed the arrangement of mandibular anterior teeth as viewed anteriorly. Seventy-five percent or more of the facial surface of the mandibular canines was visible in 78% of all casts when viewed on the level of the occlusal plain. Lorton’s study, along with Vig et al and Muller et al, enforced the importance of considering esthetic factors regarding mandibular anterior fixed prostheses.

Some studies have assessed facial expressions relative to mandibular display. Cade found that mandibular anterior teeth were displayed in multiple facial expressions including resting, smiling and speaking. Drummond et al found the greatest display of both the maxillary and mandibular central incisor arrived from the pronunciation of the sound “chee” after Ackerman et al determined that the phrase “Chelsea eats cheesecake by the Chesapeake” provoked the greatest amount of incisal display during speech. Similarly, Sackstein concluded that speech could reveal mandibular anterior teeth “to a significant extent,” and study subjects pronounced the Hebrew word for six, “shesh” to reveal mandibular anterior teeth. Muller et al
noted that a posed smile or many of the traditional phonetic testing are not effective in assessing mandibular display. Instead, mandibular display was found to be more visible when an “A” sound was made, used the word “mam” as a phonetic test in order to expose the lower anterior teeth.\textsuperscript{12}

Mandibular display has also been seen to change with variables such as age and gender. Sackstein found that mandibular anterior tooth display increased with age, tended to be greater in men, and was greater during speech than during smiling.\textsuperscript{14} Vig et al and Cade’s studies concluded an increase in the mandibular tooth exposure corresponding with an increase in age.\textsuperscript{11,17} Muller et al explained that as patients age, soft tissues changes cause increased mandibular anterior tooth exposure.\textsuperscript{12} In regards to factors of gender and race, men were found to display more mandibular anterior tooth surface than women, while no variance in mandibular or maxillary incisor exposure was found among races.\textsuperscript{11} Likewise, Cade’s data showed that men displayed mandibular anterior teeth more than women during facial expressions.\textsuperscript{17} Cade’s study suggested that when fabricating esthetic dentures in patients over 40 years of age, dentists should consider mandibular anterior teeth as much as they would maxillary anterior teeth.\textsuperscript{17}

Dentists rely on correct assessment of lip position during smiling and speech in order to plan for optimal esthetic results.\textsuperscript{25} Currently, there is no agreed-upon method to evaluate lip movements, and many dentists depend on a photograph or clinical measurement of a posed smile to obtain information. A photograph of the patient has been described as the gold standard in patient care, being that it is reliable, reproducible, and invaluable to dentists in analyzing a patient’s smile and recording clinical needs.\textsuperscript{26} Sarver clarifies: “The posed smile is voluntary and need not be elicited or accompanied by emotion. A posed smile is static in the sense that it can be sustained. The lip animation is fairly reproducible, similar to the smile that may be rehearsed
for photographs or school pictures”.\textsuperscript{27} While the posed smile is idyllic in that it is reproducible, it is not reliable to capture the full extent of dentogingival display during expressive facial movements.

Previous studies have used ear rods to standardize the head position, but it has been argued that this is not conducive when attempting to produce a spontaneous smile of joy.\textsuperscript{5} To overcome the shortcomings of the posed smile, dynamic videography was established as a way to better capture the greatest movements during spontaneous facial expressions. Maulik et al asserted that using video (about 30 frames per second) could attain a more predictable and standardized smile when likened to static photographs.\textsuperscript{28} With this method, the spontaneous Duchenne smile could be captured at the exact moment.\textsuperscript{29} Sackstein studied anterior display using a digital video technique and found it convenient to record speech with the video function of a digital camera.\textsuperscript{14}

Van der Geld et al used videography to capture authentic spontaneous smiles, and used digital measurements to compare with posed smiles. Duchenne smiles were incited by videotaping subjects in front of a television playing clips of practical jokes. The study found an increased display in spontaneous smiles compared with posed smiles. When the spontaneous smiles were compared to the posed smiles, the posed smiles showed reduced smile heights.\textsuperscript{30} Van der Geld et al concluded that videography with digital measurements appeared reliable, reproducible, and valid for clinical practice, and recommended for capturing a spontaneous smile for records.\textsuperscript{29} The study does acknowledge that the application of digitalized methods in order to measure the smile line, while perhaps ideal, may not be clinically feasible.\textsuperscript{30}

In assessing facial expressions for fixed prosthesis, the dentist must be cognizant of the prosthetic-tissue-junction (PTJ). Bidra et al emphasizes that it is crucial the PTJ not be visible
during maximum smile\textsuperscript{19} or other speech movements for optimal esthetic considerations. Bidra et al discussed the magnitude of correctly assessing facial expression in order to correctly plan for implant supported fixed prostheses,\textsuperscript{19} applicable in maxillary and mandibular situations. During implant rehabilitations, the bony platform is recommended to be 4-5mm below the lip position during maximum smile in order to safely conceal the PTJ.\textsuperscript{19}
RATIONALE

The desire for an esthetic and functional smile via implant-supported prosthesis is not limited to the elderly, and incorporates patients with a wide array of clinical characteristics.\textsuperscript{16} During treatment planning, especially critical when planning for fixed implant-supported prosthesis, it is essential that the dentist accurately calculate that the prosthetic-tissue-junction (PTJ) will not be visible when a patient is in an everyday situation, speaking or laughing with friends and family. The detriment of incorrect assessment of the PTJ is calamitous, and includes extremely poor esthetics and patient dissatisfaction; modifications to correct this after implant placement would be reduced to implant removal, or fabricating an unhygienic prosthesis occasioning in implant failure.\textsuperscript{31} Patients with excessive gingival display require more complex treatment planning.

In addition to difficulties in obtaining a genuine smile in an office setting, a smile is not the appropriate means to assess mandibular display. Walter et al found that multiple facial expressions should be used to evaluate the maximum gingival display.\textsuperscript{24} Drummond et al found the greatest display of both the maxillary and mandibular central incisor arrived from the pronunciation of the sound “chee”,\textsuperscript{13} after Ackerman et al determined that the phrase “Chelsea eats cheesecake by the Chesapeake” provoked the greatest amount of incisal display during speech. Sackstein concluded that speech could reveal mandibular anterior teeth “to a significant extent,”\textsuperscript{14} and in his study subjects pronounced the Hebrew word for six, “shesh” to reveal the mandibular anterior teeth. There have been no studies analyzing the facial expression with the greatest mandibular dentogingival display as a means to photograph and analyze for treatment planning purposes.
Through requesting various facial expressions, a practitioner could use a posed expression to capture the dynamic nature of the mouth, providing a consistent, reliable, and applicable method to capture maximum mandibular dentogingival display. A photograph of the patient has been described as the gold standard in patient care, being that it is reliable, reproducible, and invaluable to dentists in analyzing a patient’s smile and recording clinical needs. Being able to correctly assess the extent of facial movements during treatment planning will help practitioners understand the complexity of their case, providing guidance of whether to refer the case to a prosthodontist, or the need for pre-prosthetic procedures. An accurate, repeatable, and recordable diagnostic tool to assess dentogingival display will improve patient satisfaction and help prevent unforeseen esthetic, hygienic, and restorative failures and medical-legal issues.

It is advantageous for clinicians to establish an objective, available method to evaluate facial esthetics and expressions. This is the first study on mandibular dentogingival display to be done on this topic and based on empirical and preliminary observations, results are anticipated to show a significantly increased mandibular dentogingival and papillary display when comparing the pronunciation of the word “church” and smile with eyes closed to the more common maximum smile. Photographs of the facial expression of maximum smile with eyes closed and the pronunciation of “church” are expected to assist the dentist in more accurately defining the extent of mandibular dentogingival and papillary display, mimicking the spontaneous movements of a patient’s everyday speaking and laughing.
OBJECTIVES AND HYPOTHESIS

Objectives

This study investigated digital photographs of the lower half of the faces of 138 dentate subjects and analyzed the magnitude of dentogingival exposure among three facial expressions:

1. Maximum smile with eyes opened (MS)
2. Maximum smile with eyes closed (EC)
3. Pronunciation of the word “church” (CH)

The objectives were:

1. To know, among three facial expressions, horizontal (width) differences in mandibular dentogingival display in the anterior and posterior regions.
2. To know, among three facial expressions, apical (height) differences in mandibular dentogingival display in the anterior and posterior regions.
3. To know, within each facial expression, whether age is a factor in the horizontal and apical mandibular dentogingival display in the anterior and posterior regions.
4. To know, within each facial expression, whether gender is a factor in the horizontal and apical mandibular dentogingival display in the anterior and posterior regions.

Hypothesis

The null hypotheses of this study were as follows.

There is no difference between:

1. the horizontal (width) extent of mandibular dentogingival exposure amongst 3 different facial expressions (maximum smile (MS), smile with eyes closed (EC) and while elucidating the “church” sound (CH) in anterior and posterior regions.
2. the apical (height) extent of mandibular dentogingival exposure amongst three different facial expressions MS, EC and CH in anterior and posterior regions.

3. mandibular dentogingival exposure as a function of age within each facial expression MS, EC and CH

4. mandibular dentogingival exposure as a function of gender within each facial expression MS, EC and CH.
MATERIALS AND METHODS

Overview

The study was approved by the University of Connecticut Institutional Review Board (16-230-I). A total of 138 study participants from UConn Health Center read the informed consent, filled out a demographic form (Appendix A) and were digitally photographed. Photographing only the lower half of the face preserved anonymity, along with collecting only pertinent demographic information. Subjects for this study responded to flyers posted around the main building at the University of Connecticut Health Center, and included patients, visitors, medical and dental students and employees. Volunteers were required to meet the following criteria, outlined on the demographic form (Appendix A), in order to have qualified for the study:

- Age range of 21-80 years
- No history of congenital conditions or trauma affecting facial movements
- No history of orthognathic or facial plastic surgery
- No missing mandibular anterior teeth
- No mandibular diastemas
- No active orthodontic treatment in the mandibular arch
- Ability to understand English in written informed consent documents as well as verbal communication

The exclusion criteria for eliminating a selected digital photograph were:

- Images with rotations around the horizontal axis and vertical axis
- Inaccurate clinical markings
- Images without a good resolution
**Photographs**

Before digital photographs were taken, each participant filled out the demographic form as well as the IRB dictated consent forms. Participants for the study were asked to remove any distracting accessories, including glasses, hats, or masks, before being photographed.

A digital camera (Canon EOS Rebel T5i DSLR Camera; Canon USA, Lake Success, NY) with a Canon EF 100mm f/2.8 Macro USM and a Canon MR-14EX II Macro Ring Lite was used in the 12 o'clock position. The Camera had an aperture setting of F4.5 and was mounted on a tripod (Canon Deluxe 200 Tripod; Canon USA, Lake Success, NY) with a standardized focus and at a standardized distance of 2 feet from the subject (Fig 1). A black background was placed behind the seated participant, and the researcher guided the subject’s head position in order to assist subjects in assuming a straight and natural posture to true horizontal. Lighting conditions remained constant for all photographs. The procedure was similar to the protocol described by Bidra et al.³¹

Digital photographs were taken of the lower half of the subject’s face. No full-face photographs were taken. When subjects were ready and seated in front of the black background in the adjusted position (Fig 1), the following specific instructions were read from a script in order to ensure consistency between volunteers and researchers: “I am going to take a photograph of your biggest smile. Here is an example of what this smile looks like.” While the script was being read, each subject was shown the same 8”x10” color photograph of a person performing the biggest smile with eyes opened (Fig 2). The following was then read: “Before you smile, I want you to say, “Emma, emma, emma,” relax, and then give me your biggest smile like the person in the picture I showed you.” The subject could practice the movements, and adjustments were made to ensure the correct expression. When the subject
successfully completed the phrase, a photograph was taken of the lower half of the face during the climax of the subject’s biggest smile with eyes opened. The above methods were similar to the protocol described by Desai et al, Walter et al and Muller et al.\textsuperscript{1,2,4,12} The same protocol was used for the other two facial expressions. For the “smile with eyes closed” expression, all subjects were shown the same 8”x10” color photograph of a person smiling their biggest smile, this time with eyes closed tightly (Fig 2). The following phrase was read:

“Now I am going to take a photograph of your biggest smile with your eyes closed tightly. Here is an example of what this smile looks like. Before you smile, I want you to say, “Emma, emma, emma,” relax, and then give me your biggest smile with your eyes closed tightly like the person in this picture I showed you.”

When the subject successfully completed the phrase, a photograph was taken of the lower half of the face during the climax of the subject’s biggest smile with eyes closed tightly. Finally, the last facial expression was captured using the same methods as the previous two expressions. All subjects were shown the same 8”x10” color photograph of a subject pronouncing the word “church” (Fig 2). The following phrase was read:

“Now I am going to take a photograph of you saying “church” while holding the “ch” sound at the end. Here is an example of what this smile looks like. Before you smile, I want you to say, “Emma, emma, emma,” relax, and then say, “church” and hold the “–ch” sound.”

When the subject successfully completed the phrase, a photograph was taken of the lower half of the face during the climax of the subject saying “church” while holding the “ch” sound.

Photographs were then digitally analyzed. To qualify maximum mandibular dentogingival display, reference points (Fig 3) were labeled and scored as follows (Table 2 and Fig 4):
• Mandibular interdental embrasures were labeled using consecutive letters a-k, in alphabetical order, beginning with the incisal embrasure between tooth #30 and #29, moving across the arch, and ending with the incisal embrasure between tooth #20 and #19 (i.e. the embrasure between tooth #24 and #25 is labeled as “f”). (Fig 3)

• If an embrasure was not visible, it maintained its corresponding letter (i.e. the incisal embrasure between tooth #24 and #25 is always labeled as “f”, regardless of whether it was visible or not). (Fig 3)

• If the most apical level of the visible level of the embrasure was equal to or apical to the mucogingival junction, it was recorded with a score of 4. (Table 2 and Fig 4)

• If the visible level of the embrasure was equal to or apical to the gingival margin level of the adjacent teeth, it was recorded with a score of 3. (Table 2 and Fig 4)

• If the interdental papilla was visible, the corresponding letter was recorded with a score of 2. (Table 2 and Fig 4)

• If the embrasure was present in any capacity along the tooth surface, the corresponding letter was recorded with a score of 1. (Table 2 and Fig 4)

• If no tooth is visible, the corresponding letter was recorded with a score of 0. (Table 2 and Fig 4)

**Data subjected to statistical analysis:**

Comparing expressions MS, EC and CH this study analyzed:

• Anterior/posterior presence or absence of tooth display

• Horizontal (width) differences of dentogingival display in the anterior or posterior mandible
• Apical (height) differences of dentogingival display in the anterior or posterior mandible
• Age effect on mandibular display
• Gender effect on mandibular display

**Statistical Analysis:**

Data was recorded for statistical analysis in Microsoft Excel data sheets. Each subject had three sets of scores, one for each facial expression MS, EC and CH. The present status and score were summarized by expression separately for anterior and posterior dentition, and the percent present status and mean scores were compared among age groups and between genders, given an expression and anterior or posterior teeth. (Fig 5-13, Table 3-8) All the between-group comparisons were conducted under generalized linear mixed effects models assuming subject-specific random effects. A p-value smaller than 0.05 was deemed to be statistically significant.

All of the statistical analyses were performed with the statistical software R 3.5.1 (R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org/). The analysis included calculated mean values and standard deviations. Differences in the mean of the scores used to evaluate apical extent of mandibular dentogingival display in the anterior and posterior during MS, EC and CH were evaluated for significance.

The horizontal scope of mandibular display, analyzed by calculating the percentage of the amount of visible mandibular dentition during MS, EC and CH, was evaluated for significance. A repeated measures general linear mixed modeling analysis (GLMM) was used when inferences to gender and age were made. Trends of mean scores within age groups and the trend mean score differences between MS, EC and CH, were tested in the framework of generalized linear mixed
effects model. Similarly, the differences between genders mean scores within each facial expression were tested in the framework of generalized linear mixed effects model.
RESULTS

A total of 138 subjects were recruited to participate in the study. The group studied consisted of 85 females and 53 males. Additionally, there were 6 age groups in each study with the following subjects in each group: Age 21-30 consisted of 32 subjects, Age 31-40 consisted of 20 subjects, Age 41-50 consisted of 21 subjects, Age 51-60 consisted of 20 subjects, Age 61-70 consisted of 24 subjects, and Age 71-80 consisted of 21 subjects (Table 2).

The overall presence of mandibular tooth display differed significantly between the facial expressions MS, EC and CH with respect to the number of teeth visible, calculated as a percentage (p < 0.001) (Fig 5, Table 3). In the anterior mandible, expressions EC and CH, showed 93% of mandibular anterior teeth, whereas MS showed 76% of mandibular anterior teeth. In the posterior mandible, EC showed 86% of the mandibular teeth, with MS showing 55% and CH showing 14% of mandibular teeth respectively.

Using the scoring system for apical extent of mandibular display, analysis also showed a statistically significant difference between apical extent display between facial expressions MS, EC and CH (p < 0.001) (Fig 7, Table 4). In the anterior mandible, CH had the most display with an average score of 2.08, followed by EC with a score of 1.67, and lastly MS with a score of 0.93. (Fig 6) Scores for CH in the anterior mandible reached 4 in at least one location in 34 patients, whereas only 3 participants had a score of 4 at EC and none with MS. (Fig 7) For amount of display in the posterior mandible, EC had the most display with a score of 1.38, then MS with a score of 0.62, and CH had a minimal amount of posterior vertical display with a score of 0.19. (Fig 7)

No evidence of a statistically significant trend in percent presence value or mean score was found with respect to effect of gender and age. (Fig 8-13, Tables 5-6) For both
measurements regarding the amount and extent of mandibular dentogingival display in the anterior and posterior regions, a conclusion could not be established relating to the effects of gender or age.
DISCUSSION

The null hypothesis of this study was that there was no difference between the horizontal (width) or apical (height) extent of mandibular dentogingival exposure amongst 3 different facial expressions (maximum smile (MS), smile with eyes closed (EC) and while elucidating the “church” sound (CH) in anterior and posterior regions. Additionally, the null hypothesis for this study stated neither age nor gender was a factor in mandibular dentogingival exposure within each facial expression MS, EC and CH. The study rejected the null hypothesis relating to the magnitude of mandibular dentogingival display among the facial expressions MS, EC and CH. (Fig 5-7, Tables 3-4) However, there was a failure to reject the null hypothesis relating to a statistical significance of age or gender’s effect on mandibular dentogingival display (Fig 9-13).

The results of this study illustrated that additional diagnostic tools such as photography of capturing expressions EC and CH can predictably diagnose a broader extent of mandibular dentogingival display (Fig 6-8, Table 3). Incorporating analysis of photographs of patients performing EC and CH is a diagnostic tool that is easily obtainable and valuable for dentists. As Muller et al, Sackstein and Janzen noted in their studies, a photograph is the gold standard in patient care due to its reliability, reproducibility, and ease of use.26 This study assessed multiple requested facial poses and by-passed the limitations photography otherwise presented, specifically the difficulty in capturing a natural and spontaneous smile for diagnosis.

By photographing multiple facial poses, we effectively evaded relying on the patient’s psychological state to capture the extreme extent of mandibular dentogingival display otherwise necessary in videography or other forms of documentation. Requesting the patient smile with their eyes closed activates the zygomaticus major muscle with the orbicularis oculi,8 which has been shown to be an essential part of a spontaneous smile. Hulsey noted that the main effectors
of the smile are the zygomaticus major muscles, which insert into the orbicularis oris as a mode to raise the corners of the mouth up and out, curving the lips into a smile. The complex series of neurological events contract multiple facial muscles, which all insert at the muscle around the eye, the orbicularis oris. The zygomaticus major, levator labii superioris, and levator anguli oris, along with the periocular muscles have been shown to provide greatest lip elevation.

The use of CH to diagnose mandibular display proved essential when assessing the amount of apical display in the anterior mandible (Fig 7, Table 4). This facial expression activates the buccinator, mentalis muscles, risorius, depressor anguli oris and depressor labii inferioris muscles, causing lip depression. Muller et al found mandibular display to be more visible when an “A” sound was made, used the word “mam” as a phonetic test in order to expose the lower anterior teeth. Drummond et al found the greatest display of both the maxillary and mandibular central incisor arrived from the pronunciation of the sound “chee” after Ackerman et al determined that the phrase “Chelsea eats cheesecake by the Chesapeake” provoked the greatest amount of incisal display during speech. Similarly, Sackstein concluded that speech could reveal mandibular anterior teeth “to a significant extent,” and study subjects pronounced the Hebrew word for six, “shesh” to reveal mandibular anterior teeth.

The study analyzed an empirical technique for simulating a patient’s extreme border movements through photographic specific facial expressions so accurate assessment of mandibular display can address treatment needs and limitations. Similar to the classification system for maxillary smile line by Tjan et al, the scoring system was devised in this study to rank mandibular dentogingival display using visual judgment rather than a measurement. Gingival display was then able to be measured in two ways: by the presence of visible teeth in the horizontal direction using a binary qualification of whether the tooth is present, and by
calculating the percent present for both anterior and posterior segments of the mouth for each expression. In this study, the movement EC was found to best illustrate the horizontal range of mandibular display, recording a mean of 93% visible teeth in the anterior, and 86% visible teeth in the posterior (Fig 5, Table 3).

The apical amount of display, crucial in assessing the vertical height of a future prosthesis, was measured by the devised scoring system which ranked display on a scale of 0-4, with 0 being no display, 1 showing only tooth at the specific location, 2 having papillary display, 3 showing apical display equal to or below the cervical margin of the tooth, and 4 showing equal to or apical to the mucogingival junction. The scoring system is effective in describing what is being seen in the mouth. Scores for CH in the anterior mandible reached 4 in at least one location in 34 patients, whereas only 3 participants had a score of 4 at EC and none with MS, effectively describing the greater scope that CH can produce. (Fig 7) Additionally, the apical amount of display in the posterior was largest with EC (Fig 7, Table 4). This study can provide a valuable tool in diagnosing mandibular display, and can lay importance on mandibular esthetic diagnoses.

Cade found that mandibular anterior teeth were displayed in multiple facial expressions including resting, smiling and speaking.¹⁷ Findings from this study agree in suggesting multiple facial expressions be used to diagnose mandibular display, as each facial expression was shown to provide a different diagnostic element. Muller et al noted that a posed smile or many of the traditional phonetic testing are not effective in assessing mandibular display.

This study did not find any significant differences when assessing the factors of age and gender (Fig 8-13, Tables 5-8). This was an interesting result, as previous studies have found that both age and gender have an effect on the magnitude of mandibular display. Sackstein found that mandibular anterior tooth display increased with age, tended to be greater in men, and was
greater during speech than during smiling.\textsuperscript{14} Vig et al and Cade’s studies concluded an increase in the mandibular tooth exposure corresponding with an increase in age.\textsuperscript{11,17} Muller et al explained that, as patients age, soft tissues change over time which causes increased mandibular anterior tooth exposure.\textsuperscript{12} In regards to factors of gender and race, men were found to display more mandibular anterior tooth surface than women, while no variance in mandibular or maxillary incisor exposure was found among races.\textsuperscript{11} Likewise, Cade’s data showed that men displayed mandibular anterior teeth more than women during facial expressions.\textsuperscript{17} The findings with respect to age and race could possibly be affected by limitations in sample size. Additionally, this study did not measure the height of teeth, but rather the presence of teeth and the apical extent of display. Muller et al noted that often mandibular teeth are extruded with age, leading to increased mandibular display. This trend would not be seen with the measurements in this study, which do not quantify the coronal extent of tooth display. Cade’s data showing an increased mandibular display in men over women may differ from the results found in this study because of the methods used to elicit patient movements. In Cade’s study, participants were asked to answer questions and recite a poem while the researcher observed the amount of visible display in the mandible. This study requested participants to express specific poses to their extreme effect, and to hold at this position. The methods used in this study may have neutralized the variations between men and women during speaking, causing both genders to express the requested facial positions to the more exaggerated extent.

**Study limitations**

This study attempted to study the maximum dentogingival exposure in the mandible across 3 facial expressions. In studying a 3-dimensional movement using 2-dimensional methodology,
certain challenges were encountered: 1) mandibular movement caused changes in vertical dimension, eliminating the ability to relate a steady point on the mandible to a point on the maxilla. For this study relating to mandibular display, during the 3 facial expressions subjects were not required or requested to maintain teeth in a maximum intercuspal position. Often, teeth were not in maximum intercuspation when speaking. For each expression, the amount of mandibular movement varied, thus changing the distance of any reference point used on the mandible when related to the maxilla; 2) there was a lack of a fixed mandibular point of reference. A point on the chin was attempted to be used in combination with a point on a tooth, but not every subject displayed mandibular teeth in images. There were also instances when the maxillary teeth overlapped, and thus covered, the mandibular incisal edges, masking a reliable point of reference. The chin point changed between images and also could not be used; 3) minor movements affected measurements: Thought of using the base of the chin (Gnathion) as a reference was attempted, but this became unreliable with any head movements by the subject. Soft tissue points were also found to be inaccurate, for similar reasoning. Using videography as advocated by Desai et al was considered, but not advocated due to the loss of resolution in the images for measurements.\(^1\) Due to the listed limitations that arose when attempting to standardize and quantify mandibular dentogingival display as a size, a binary scoring system was chosen instead to qualify the data (Table 2, Fig 4).

Limitations regarding the sample size are acknowledged in this study, and further analysis is necessary for a more accurate assessment of factors such as age, gender and race. After analyzing the data, it was found that not enough samples were obtained to accurately analyze race as a factor. All observations and measurements were made by 1 observer, which may
introduce bias in the data collection; However, it can be argued that this may also strengthen the study as it eliminated errors and heterogeneity.
CONCLUSIONS

This study investigated digital photographs of the lower half of the faces of 138 dentate subjects and analyzed the magnitude of dentogingival exposure among three facial expressions:

1. Maximum smile with eyes opened (MS)
2. Maximum smile with eyes closed (EC)
3. Pronunciation of the word “church” (CH)

Within the limitations of the study, the following conclusions were made:

1. Among 3 facial expressions there was significant horizontal (width) differences in mandibular dentogingival display in the anterior and posterior regions. (Fig 5, Table 3)
   a. In the anterior mandible, EC and CH expressions had equal amounts of tooth display, with MS showing less display.
   b. In the posterior mandible, the movement EC best illustrated the horizontal range of display in the posterior mandible, with MS eliciting the second highest number of teeth displayed in the posterior mandible and lastly CH which showed little teeth in the posterior mandible.

2. Among three facial expressions there was significant apical (vertical) differences in mandibular dentogingival display in the anterior and posterior regions. (Fig 6, Table 4)
   a. In the anterior mandible, CH was most effective in eliciting dentogingival display in the apical direction, with MS showing the least amount.
   b. In the posterior mandible, the movement EC demonstrated the most apical extent of dentogingival display, with CH showing the least amount of vertical display.
3. Age was not established as a factor in the horizontal and apical mandibular dentogingival display in the anterior and posterior regions among the facial expressions MS, EC, and CH (Fig 10-13, Table 5-6).

4. Gender was not established as a factor in the horizontal and apical mandibular dentogingival display in the anterior and posterior regions among the facial expressions MS, EC, and CH. (Fig 8-9, Table 7-8).

The authors suggest using photographs of smile with eyes closed and saying “church” are more preferable than simply an image with maximum smile to fully capture the magnitude of mandibular dentogingival display for accurate diagnosis, and multiple facial expressions are required to most accurately assess mandibular dentogingival display.
**TABLES**

Table 1: Age and Gender Demographic Table.

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<td>31-40</td>
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<td>41-50</td>
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<td>51-60</td>
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<td>4</td>
<td>20</td>
</tr>
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<td>61-70</td>
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<td>8</td>
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</tr>
<tr>
<td>71-80</td>
<td>11</td>
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<td>21</td>
</tr>
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Table 2: Scoring System to quantify apical extent of mandibular dentogingival display.

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<tr>
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<td>2</td>
</tr>
<tr>
<td>Mandibular gingival display equal to or apical to cervical level of tooth, coronal to mucogingival junction</td>
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<tr>
<td>Gingival display equal to or apical to mucogingival junction</td>
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Table 3: Percent mandibular display among facial expressions MS, EC and CH in the anterior and posterior.

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<th>Posterior</th>
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<td>Standard Deviation</td>
<td>P-value</td>
<td>Percent present</td>
</tr>
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<td>Maximum smile</td>
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<td>0.39</td>
<td>reference</td>
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<tr>
<td>Eyes closed</td>
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<td>0.24</td>
<td>&lt; 0.001</td>
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<tr>
<td>Church</td>
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<td>0.17</td>
<td>&lt; 0.001</td>
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Table 4: Mean score of anterior and posterior mandibular apical display across facial expressions MS, EC and CH.

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<td>P-value</td>
</tr>
<tr>
<td>Maximum smile</td>
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<tr>
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<tr>
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Table 5: Effect of age on percent anterior and posterior mandibular display among facial expressions MS, EC and CH.

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<td>P-value</td>
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Table 6: Age as a factor of apical extent of anterior and posterior mandibular display.

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Table 7: Effect of Gender on percent of anterior and posterior mandibular display.

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<th></th>
<th>Posterior</th>
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<tbody>
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<td>SD</td>
<td>P-value</td>
<td>Percent present</td>
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<td>Percent present</td>
<td>SD</td>
<td>P-value</td>
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<td>church</td>
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<td>Percent present</td>
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Table 8: Gender as a factor of apical extent of anterior and posterior mandibular display.

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FIGURES

Fig 1: Photograph Set-up for making standardized images
Fig 2: Images of the three facial expression examples shown to subjects.

“Maximum smile”  
“Biggest smile with eyes closed”  
“Say “Church” and hold the –“Ch”
Fig 3: Examples of labeling among the facial expressions MS, EC and CH. Locations are labeled with designated letters, and analyzed values were categorized as anterior or posterior.
Fig 4: Scoring Criteria for apical extent of mandibular display at designated locations among facial expressions MS, EC and CH. Levels correlate to scoring system (Table 2)
Fig 5: Percent Mandibular Display Among Facial Expressions in the Anterior and Posterior
Fig 6: Apical Extent of Mandibular Display Across Facial Expressions in the Anterior and Posterior

![Chart showing apical extent of mandibular display across facial expressions in the anterior and posterior. The chart includes mean scores for different facial expressions and regions.](chart.png)
Fig 7: Apical Extent of Mandibular Display in the Anterior and Posterior

Range of Apical Extent of Mandibular Display

Facial Expression

Mean Score

Anterior

Posterior

smile
eyes closed
church
smile
eyes closed
church
Fig 8: Gender effect on anterior and posterior mandibular display

<table>
<thead>
<tr>
<th>Gender</th>
<th>Anterior</th>
<th>Posterior</th>
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<tr>
<td>MS</td>
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<td>0.86</td>
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<tr>
<td>EC</td>
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<tr>
<td>CH</td>
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<td>0.86</td>
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</tbody>
</table>

- Male (MS): 0.75, 0.86
- Female (EC): 0.78, 0.86
- Female (CH): 0.92, 0.86

[Graph showing gender effect on mandibular display]
Fig 9: Gender Effect on apical extent of mandibular display
Fig 10: Age as a function of apical extent of anterior mandibular display
Fig 11: Age as a function of apical extent of posterior mandibular display
Fig 12: Effect of Age on Anterior Mandibular Display
Fig 13: Effect of Age on Posterior Mandibular Display
Appendix A

Demographic sheet:

Subject ID# ________________________ .
Date __________ Time __________ .
Age: 21-30, 31-40, 41-50, 51-60, 61-70, 71-80
Gender: male/female
Ethnicity:
  • African American
  • Asian
  • Caucasian
  • Other ________________________ .

Inclusion Criteria (circle “yes” or “no”):

Yes/No - Age is between 21-80 years old
Yes/No - No history of congenital conditions or trauma affecting facial form and appearance
Yes/No - No history of orthognathic or facial plastic surgery
Yes/No - No missing front teeth (upper or lower jaw)
Yes/No - No open spaces/gaps between front teeth
Yes/No - No active orthodontic treatment (braces)
Yes/No - Ability to understand English in written documents as well as verbal communication
LITERATURE CITED


7. Mandal B, Ouarti N. Spontaneous vs. Posed smiles - can we tell the difference? Can be accessed at: https://arxiv.org/abs/1605.07026


