The Eye-Tracking Study of the Impact of the Gingival Margin Height of Maxillary Lateral Incisors

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The objective of this study was to verify differences in eye-tracking metrics and subjective smile esthetic ratings between general practitioners, orthodontists, and laypersons in cases of maxillary lateral incisor gingival margin deviations. Unilateral apical and incisal gingival margin deviations of 1, 2, and 3 mm were digitally produced in pictures of a man and a woman smiling. Specific areas of interest (AOIs) were created in each picture. Eye-tracking metric data included the time to first fixation (TFF) and number of fixations (NF). A specific sensor and software were used to acquire information on the eye movements. Analysis of variance and Pearson correlation were applied. The TFF on the AOIs in the mouth was shorter for general practitioners and orthodontists, signifying that general practitioners and orthodontists rapidly perceived the features in these areas, while for laypersons, the TFF was shorter for the AOIs of the eyes (P < .05). The NF was greater on the AOIs in the mouth for general practitioners and orthodontists, whereas to the laypersons, the NF tended to be greater on the AOIs in the eyes. Mean VAS scores differed between observer groups (P < .05). For the male picture, the 1-mm and 2-mm apical gingival margin deviations received the highest scores from the laypersons, while for both female and male pictures, the 1-mm apical deviation received the highest scores from the general practitioners and orthodontists. Higher VAS scores resulted in longer times that general practitioners and orthodontists spent looking at the gingival margin changes. General practitioners and orthodontists differ from laypersons in their perceptions of smile esthetics. Eye-tracking metrics revealed that the AOIs in the mouth aroused greater interest from the general practitioners and orthodontists, and this interest became greater as the gingival margin deviations increased to 3 mm. Laypersons fixated more on the AOIs of the eyes. The VAS scores indicated that general practitioners and orthodontists were more critical than laypersons, accepting smaller deviations in the gingival margins of the maxillary lateral incisors. Int J Periodontics Restorative Dent 2020;40:261–270. doi: 10.11607/prd.4101

A harmonious smile depends on many factors, such as alignment, tooth shape, color, and gingival level. Therefore, dental professionals should be aware of the factors that influence esthetics to guide their patients towards the best treatment.¹ Treatment must be well planned by the orthodontist and the patient. Details of the lateral incisor’s gingival margin should be observed for its incisal height, and if this is an aesthetic problem for the patient, the orthodontist should consider the possibility of a gingivectomy or an increased clinical crown.²

Most studies of esthetic perception in dentistry and orthodontics use edited photographs of ideal smiles, which are evaluated by general practitioners, orthodontists, and laypersons. Eye-tracking systems have been used in several research fields,³,⁴ but no reports exist in the literature of cases of gingival margin deviation of the maxillary lateral incisor.⁵

Eye-tracking systems can provide orthodontists with a map of what the examiner’s gaze observes, indicating the order of fixations, the intensity and unconscious movements of the eyes, and the areas that the evaluator observes in certain areas of interest (AOIs). Deviations may be less noticeable compared with images that have faces added,¹ and most esthetic perception studies use only the visual analog scale (VAS).
Thus, this study tested the hypotheses that no differences exist with respect to fixation time and number of fixations or in mean scores on the VAS between general practitioners, orthodontists, and laypersons in their eye-tracking of gingival margin height variations of the lateral incisor.

Materials and Methods

Study Population

This was a cross-sectional study and was approved by the Research Ethics Committee of Pontifícia Universidade Católica do Paraná. Thirty observers per group (laypersons not working in dentistry, general practitioners, and orthodontists) evaluated the study images. The observers were between 18 and 70 years of age, with mean ages of 29.5 years for the laypersons (59.2% women and 40.7% men), 25.6 years for the general practitioners (51.8% women and 48.1% men), and 37.0 years for the orthodontists (34.2% women and 65.7% men). The observers were blinded to the study's purpose. Observers who met the age and categorical inclusion criteria were invited to participate in the study after signing the consent form. Exclusion criteria for the observers were neurological alterations, recent drug or alcohol use, and/or taking medications that could interfere with cognitive abilities. Questions were asked regarding gender, age, and dominant laterality.

Picture Edits

Facial and smile images were used, and photographs of a man and a woman were selected by three orthodontists who had been practicing for more than 5 years. Intraoral photographs were adjusted, and the positioning of the gingival margin was simulated using Adobe Photoshop CC (Adobe Systems). The images were edited so that the faces were completely symmetrical, with normal color and shape, and with deviations only in the smile. The smile esthetics were modified by varying the lip. To decrease error variables, the same man and woman were used in all images.

The intraoral images were edited to add to facial features in real
proportions, so that the left half of the face was symmetrical with the right half, and the only asymmetries were on the gingival margin. The gingival margin was adjusted and removed. Skin marks, pigmentation, beards, eyebrows, shirts, excess makeup, and other features that could interfere with the image analysis were removed. The images were saved in high-resolution JPEG format for use in the eye-tracking software.

From the pictures of the man and woman without gingival margin deviations (the ideal smile), the gingival margin of the maxillary right lateral incisor was digitally deviated by 1, 2, and 3 mm in the incisal (Fig 1) and apical (Fig 2) directions in Photoshop CC. The gingival margins were deviated relative to the most superior point of the central incisor’s gingival margin. Thus, the gingival margin of the lateral incisor was positioned 1 mm to the incisal direction of the central incisor’s gingival margin.

Data Collection

In eye-tracking metrics, gaze points indicate what the eyes are looking at. If a group of gaze points is very close (in time and/or area), this gaze group constitutes a fixation and represents a period where the eyes are locked towards a specific zone.

The Eye Tribe tracker hardware in conjunction with OGAMA software (Freie Universität) were used to obtain the eye-tracking data. The time to first fixation, number of fixations, and map of the observer’s eye, with the order of tracking by observer category, were measured as follows:

- AOIs are tools used to select regions of a displayed stimulus and extract metrics specifically for those regions.
- Time to first fixation indicates the amount of time a respondent (or all respondents on average) took to look at a specific AOI from stimulus onset.
- Number of fixations quantifies the amount of time that respondents spent looking at a single AOI.
Maps of the observer’s eye are based on both spatial and temporal information (ie, when and where a participant looked).

Heat maps show the general gaze point distributions. They are displayed as color-gradient overlays on the presented image or stimulus.

The image layout was drawn from the website www.randomizer.org, and its allocation in the VAS software and score was strictly followed.

The eye tracker was positioned horizontally below a Dell P2317H monitor per the manufacturer’s recommendation. The AOIs were identified and positioned in the left hemi-arch, right arch, forehead, cheeks, chin, nose, eyes, ears, and hair. A break occurred between each AOI to avoid fixation errors due to the hardware; therefore, if the participant did not fix their gaze on a certain AOI, the fixation would be considered “other,” thus preventing a fixation from occurring on the edge of two AOIs (Fig 3). After these delimitations, the AOIs were defined as “Searchrect” to obtain the data. “Searchrect” was used to calculate time until first fixation in this special AOI in the statistic module.

The observers were instructed not to move their heads during the test. They were seated comfortably 60 cm from the hardware, as recommended by the manufacturer, and this was calibrated. VAS was also used to judge attractiveness, and the life-size images, which were made available in an album (physical flipbook of images), were the same as those provided on the website (www.randomizer.org). The VAS scores ranged from 0 to 10. The closer to 0, the less attractive the images were perceived to be, and the closer to 10, the more attractive.

The images were randomly arranged, with each observer evaluating each image for 3 seconds. When transitioning between images, a green neutral slide was shown for one second to avoid observer eye fatigue and to notify the participant of the transition to another image so that they focused on viewing the next image.

### Statistical Analysis

The eye-tracking and VAS results were tabulated in Microsoft Excel and analyzed using SPSS software, version 25 (IBM).

The dependent variables studied were time to first fixation, number of fixations, and VAS. The independent variables were the AOI, observer type, and clinical situation.

For the AOIs, right eye, left eye, left hemi-arch, and right hemi-arch were the only used variables. The other AOIs were excluded because they were not statistically significant.

Analysis of variance (ANOVA) was performed when comparing more than two variables. Levene test was used for homogeneity of variances, followed by Tukey’s honestly significant differences parametric multiple comparison test for homogeneous results and Games-Howell multiple parametric comparison test for heterogeneous results. The significance level was set at 5%. Pearson correlation test was used to evaluate the correlations between VAS and AOI.

### Results

Regarding the variables time to first fixation and number of fixations, the areas that generated the greatest interest were the left eye, right eye, left mouth, and right mouth. These variables all differed significantly among the observer groups (P < .05; Table 1).

ANOVA revealed that the times to first fixation on the right mouth and left mouth were lower for general practitioners and orthodontists, indicating that this area aroused greater interest in these groups than in the laypersons. The same pattern was observed for the number of fixations on the mouth, in which general practitioners and orthodontists presented a higher number of fixations. Regarding the time to first fixation on the left and right eyes, the number of fixations on the left and right eyes differed significantly.
P < .05) among evaluators, with laypersons taking less time and fixing their eyes on these areas (Table 1).

The Tukey’s honestly significant difference and Games-Howell tests showed that the differences in time to the first fixation and number of fixations on each hemi-arch of the mouth and left and right eyes differed between general practitioners and laypersons, and between orthodontists and laypersons. The standard of observation for these variables was similar between orthodontists and general practitioners (Table 2).
The heat maps (Figs 4 and 5) and scan paths (Fig 6) of the unchanged and altered images showed that the laypersons scanned the image mainly around the right and left eyes and the right and left hemi-arch mouth, especially the eyes. General practitioners and orthodontists also observed the eyes and mouth more often, but with greater focus on the mouth, especially as the deviation became greater.

For the VAS scores, ANOVA revealed a statistically significant difference in the mean values attributed to the images between evaluator groups ($P < .05$) when the gingival margin deviated by 3.0 mm.

For the laypersons observing the gingival margin deviations, the mean VAS attractiveness scores of the 1- and 2-mm apical deviations in the male photographs were superior to the average of the smile considered ideal for the gingival margin.

In addition, the general practitioners rated the 1-mm apical gingival margin deviation for both women and men above (higher mean VAS scores) the mean values of the images without deviations.

For the orthodontists, the mean VAS score for the 1-mm apical gingival margin deviation in the male photo was higher than that in the image without deviation.
Pearson correlation showed a weak positive correlation between the VAS and time to first fixation in the right hemi-arch of the mouth \((P < .05; \text{Table 3})\). This indicates that when higher VAS score values were assigned to the images, the observers spent more time looking at the side of the mouth where the changes in the smile were located.

**Discussion**

This study evaluated the gingival margin of the maxillary lateral incisors and demonstrated differences in perceived attractiveness among general practitioners, orthodontists, and laypersons in cases of gingival margin deviations of the lateral incisor in men and women. The areas of interest were defined by creating a map of the face, and the mouth was divided into a hemi-arch because it was asymmetric. General practitioners and orthodontists were more rigid in their judgments of attractiveness of the deviations, visually focusing with greater concentration on the mouth area, and thus the study hypotheses were rejected.

The anterior teeth and the gingival margin height can influence attractiveness, and knowledge of the ideal gingival margin height can

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**Fig 5** Heat maps from the (a and b) laypersons, (c and d) general practitioners, and (e and f) orthodontists for images of the 3-mm incisal gingival margin deviations in the male and female photos.
provide professionals with a point of reference for periodontal surgery. In this study, the ideal gingival margin height of the maxillary lateral incisor was evaluated.

In clinical practice, patients, general practitioners, and orthodontists have contrasting opinions of facial attractiveness; thus, images showing deviations in the mouth were evaluated among different observer categories. Most studies use only the lower third of the face to evaluate smile esthetics; however, the present study evaluated the perceived attractiveness of deviations caused by maxillary lateral-incisor treatments relative to the entire face. The observers were unaware that the study’s objective was to obtain quantitative and qualitative measurements of visual attention.

The observers evaluated the images in two sessions; the first session evaluated perception and obtained the eye-tracking data; the second session occurred soon after, when the images were observed again in the same order to obtain a VAS score. This order of data collection was chosen so that observers did not start on the first image by providing a medium VAS score to compare against the following images, thus avoiding possible biases in obtaining true scores.

Fig 6. Scan paths from the (a and b) laypersons, (c and d) general practitioners, and (e and f) orthodontists for images of the 3-mm incisal gingival margin deviations in the male and female photos.
deviations of the apical gingival margin of up to 2 mm in men had a mean score greater than the image without gingival margin deviations, confirming observations from another study, in which subjective scores by the layperson observers did not differ for up to 2 mm of deviation in the canine gingival margin.

Pearson correlation test demonstrated the effectiveness of the results for combining the VAS score with eye tracking, highlighting the utility of combining these methodologies and innovating the study of perception in orthodontics, as previous studies used only eye tracking or the VAS as means of evaluation.

In general, for the male images, gingival margins positioned at the same height as the central incisor yielded VAS scores superior to the images considered ideal by the three categories of observers, indicating that all observers sought smiles that presented gingival margins that were at the same height as the anterior teeth, contrary to what has been recommended in the literature regarding the gingival margin height of the lateral incisors.

Three categories of observers presented VAS scores with few variations between the images they considered ideal and the images with deviations, thus suggesting a pattern between observers when evaluating esthetic perception.

However, general practitioners and orthodontists presented smaller means than the laypersons for the 3-mm deviations, suggesting that their evaluations of the attractiveness of general facial esthetics were more rigorous than those of layperson observers in the presence of deviations in the mouth. In general, layperson observers had difficulty evaluating attractiveness in dentofacial photographs because they lacked adequate training to perceive small deviations in smile esthetics. Furthermore, an ideal smile based on academic considerations may not be perceived as the most attractive by laypersons.

Because Eye Tribe hardware is static but observers can move during eye tracking, the observers are oriented to avoid moving. Movement is sometimes unavoidable, so some of the scan path results may deviate. In addition, in this study, observers were not equally divided into men and women. In previous studies, gender and age distribution for assessing attractiveness did not influence the evaluations.

This study provided information regarding perceptions of gingival margin deviations, which can be applied to the hypotheses, but for well-elaborated treatment plans with esthetically pleasing results, the facial profile, malocclusion type, and lip height must be considered.
The results of this study should be interpreted as an average assessment of different groups of observers using eye-tracking metrics to evaluate gingival margins in maxillary lateral incisors.

Conclusions

The study’s hypotheses were rejected. General practitioners and orthodontists perceived smile esthetics differently than did laypersons. According to the eye-tracking metrics, AOIs in the mouth aroused greater interest among the general practitioners and orthodontists, and this interest increased as the gingival margin deviations increased 3 mm to the gingiva. Laypersons fixated more on the AOIs in the eyes. The VAS scores revealed that general practitioners and orthodontists were more critical than were the laypersons, accepting smaller gingival margin deviations in the maxillary lateral incisors.

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References


