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ORIGINAL ARTICLE

Smile Arc Esthetics in Middle-Aged Man from the Layperson's Perspective Via Eye-Tracking

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ABSTRACT

Objective: To evaluate the perceptions of smile esthetics associated with variations in the vertical plane of the maxillary incisors in the smile arc using eye-tracking software. **Material and Methods:** An image of a 59-year-old Caucasian male model was adapted and edited to make three changes in the vertical plane, simulating a convex, straight, and reverse smile arc. Four areas of interest were inserted at the right and left eyes, nose, and mouth. Forty laypeople raters between 18 and 45 years of age participated of the study. Eye-tribe hardware and Ogama software were used to perform eye-tracking. Attractiveness and age-perception questions were also incorporated into the study. ANOVA test and Pearson's correlation coefficient, at $p < 0.05$. **Results:** The most observed AOI in images with convex, straight, and reverse smiles, as assessed using heatmaps and point maps, was the mouth, followed by the right eye. A significant difference for the eye ($p=0.02$) was found when comparing convex and reverse smiles, whereas a significant difference for the mouth was observed between the straight and reverse smiles ($p=0.03$). **Conclusion:** Convex and straight smile arcs were associated with equal levels of attractiveness; the reverse smile was less attractive. No significant difference was noticed regarding age perception and the smile arcs. However, the reverse smile recorded a more complete fixation time.

Keywords: Esthetics; Eye-Tracking Technology; Perception; Smiling.

Introduction

When aging individuals smile, they tend to display less of their maxillary incisors due to soft tissue changes, increasing the upper lip length and increased heights of the lip commissures. These changes are more marked in men than in women [1].

Facial attractiveness is influenced by the smile. Although an attractive face is well-perceived by both laypeople and orthodontists, the addition of a treated malocclusion and an improved smile can contribute to increased facial harmony and attractiveness [2].

The ideal smile arc presents a curvature at the incisal edges of the superior maxillary teeth, parallel to the lower lip's curvature [3]. As an individual age, the dentition wears out, the curvature of the smile arc tends to flatten, and a reverse smile arc can develop. The maxillary central incisors have been described as the noblest area of the smile, and their vertical dimensions should be the primary objective when developing an orthodontic treatment plan to obtain a good esthetic result [4].

The final positions of the maxillary central incisors should be considered among the most important objectives of orthodontic treatment plans [1,3,4], and the smile must be evaluated in each patient using multiple dimensions [frontal, oblique, sagittal, and time-specific] to ensure an optimal esthetic result [5].

Previous studies have used eye-tracking technology to evaluate the visual perceptions of facial and dental structures and differences in how orthodontists and laypeople evaluate smiles, which have suggested that orthodontists tend to be more judicious [6-8]. Eye-tracking technology, combined with the Visual Analog Scale (VAS), may allow a better understanding of the analyses involved in the psychosocial aspects of facial esthetics.

Few studies in the literature have addressed age and the vertical positioning of the maxillary incisor teeth among middle-aged subjects from the perspective of visual perceptions among laypeople. Therefore, this study aimed to apply eye-tracking technology combined with a VAS to identify laypeople's esthetic and age perceptions in response to smile arc simulations featuring modified vertical dimensions of the maxillary incisors in a middle-aged subject.

Material and Methods

Ethical Clearance

This study was approved by the Research Ethics Committee of the Pontifical Catholic University of Paraná (registration number 2,235,302).

Data Collection

An image was selected featuring a 59-year-old caucasian male model with satisfactory esthetics, including normal symmetry, volume, and color. The image was obtained in portrait mode, with the model facing toward the camera and the head oriented with the Frankfurt plane parallel to the ground without lateral tilt or rotation. Images were obtained with the Canon Rebel XTI digital camera (Canon Inc., Tokyo, Japan).

The selected image was adapted and edited using Photoshop CS5® Software (Adobe Systems Inc., San Jose, CA, USA) while retaining real and symmetrical proportions. Layers, sharp contrast, and color correction were adjusted, and imperfections were removed, such as including scars, pigmentation, facial hair, and other features that might interfere with image analysis.

Changes were made to the maxillary smile arc in the vertical dimension of the incisors. No alterations were performed on the mandibular arch, which remained intact. Three clinical aspects were simulated: 1) a convex-consonant smile (Figure 1A), which is considered to be a "perfect smile"; 2) a straight smile (Figure 1B); and 3) a non-consonant, reverse smile (Figure 1C). The resulting three images were saved in JPEG formats at high resolution and used in the eye-tracking software.

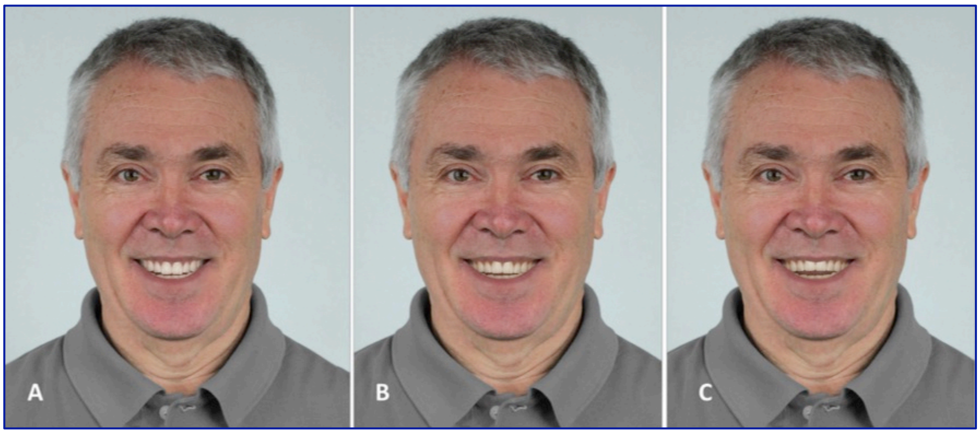

Figure 1. Magnitude of changes: A) Convex smile; B) Straight smile; and C) Reverse smile.

In conjunction with The Eye Tribe Tracker® hardware (The Eye Tribe Aps, Copenhagen, Denmark), Ogama Software (Freie Universität, Berlin, Germany) was used to obtain eye-tracking data, including the ocular movement of each evaluator for a given area of interest (AOI). AOIs were mapped to the images as follows: AOI 1: the eyes; AOI 2: the nose; and AOI 3: the mouth (Figure 2).

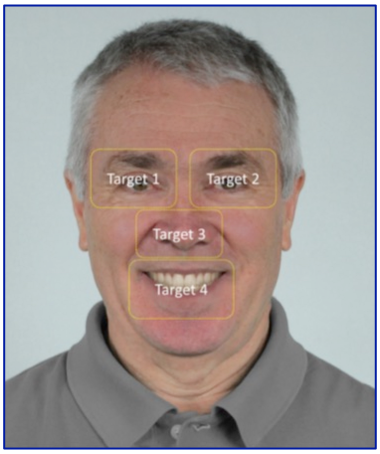

Figure 2. Areas of interest.

Forty participants between 18 and 45 years of age were invited to participate when shopping in two different clothing stores from a countryside city in the state of (omitted), with no limit on educational history or profession. The study population was composed of 60% women (n = 24) and 40% men (n = 16) who were unaware of the study's purpose. After the study evaluation was performed, the laypeople raters signed a consent form in which they affirmed that they had good vision, did not use medication that could interfere with cognitive or motor skills, and did not consume alcohol or drugs 24 hours before the experiment. The mean age of the raters in this study was 35.1 years.

In sequence, the raters were required to perform a single eye-tracking session, provide subjective VAS assessments of the images, and respond to an age perception survey. To obtain correct and reliable tracking data, a 9-point calibration was performed. The observer was allowed to start the experiment when the software considered the results of the calibration to be "perfect".

During the calibration step, the rater was placed in a quiet room containing only one researcher and one rater. Both were seated comfortably, 60 centimeters away from a 17-inch Dell P2317H monitor (Dell Inc., Round Rock, TX, USA), which was placed in an upright position to allow the image to be presented its at actual size. Next, the image ratio was calculated using a ruler and protractor tools, linking height, width, and resolution. Finally, the Eye Tribe equipment was positioned just below the monitor, according to the manufacturer's recommendations for recording eye-tracking data.

The laypeople raters were oriented to allow the free viewing of the images, and all three images were randomly displayed for 7 seconds each. The order of the images was defined before the experiment via the website randomizer.org, and the same sequence was used for all raters. To avoid observation bias, between every image, there were two other random facial images with no changes given a total of 9 images.

Afterward, the VAS and age-perception assessment surveys were administered as printed forms. First, the raters were allowed to view the full-sized images, which were arranged in an album in the order in which they were presented. The rater was then asked to report the perceived age and attractiveness of each image. The VAS scores ranged from 0 to 10, with 0 representing less attractive and 10 representing more attractive, and they could freely give their age perception regarding the images.

Statistical Analysis

Data were obtained from the Ogama Software after the eye-tracking sessions, and the VAS and age-perception survey responses were tabulated in Microsoft Excel and analyzed using SPSS software, version 25 (SPSS Inc., Chicago, IL, USA). To identify differences and interactions in the eye-tracking data and survey responses among the three images, a one-way analysis of variance (ANOVA) was used. The dependent variables were the time until the first fixation, the number of fixations, total fixation time, VAS score, and perceived age. In addition, this study treated the group of observers as the independent variables.

The level of significance adopted was 0.05. Levene's variance homogeneity test was performed to identify heterogeneous or homogeneous results. The Games-Howell, multiple parametric comparison post hoc test was applied when heterogeneous variances were identified. Regardless of whether the results showed homogeneity, Tukey's honest significant difference (HSD) test was used for the comparison. Pearson's correlation coefficient analysis was performed to identify correlations between VAS scores and perceived ages. The power of the test was performed.

Results

The scanning trace of the 40 participants, being women, 60% (n = 24), and 40% men (n = 16), indicated significant differences in complete fixation times between the convex and reverse smiles (p=0.02) for the eye AOI and between the straight and reverse smiles for the mouth AOI.

Significant differences in VAS scores were identified between the convex and reverse smiles (p=0.019) and straight and reverse smiles (p=0.008). No significant differences were observed among the three images for any other variables; however, the mouth AOI of the reverse smile image was associated with the highest mean number of fixations and the longest mean total fixation time (Table 1). In addition, the reverse smile was associated with the longest mean total fixation time (62.793 ms) compared with those for the convex smile (44.336 ms) and the straight smile (39.663 ms) (Figure 3).

Table 1. Comparison between the smiles using ANOVA.

Variables	Convex Smile Mean (±SD)	Straight Smile Mean (±SD)	Reverse Smile Mean (±SD)	p-value
Time until first fixation at Eye (ms)	2543.36 (±427.91)	159.36 (±398.37)	2338.57 (±409.04)	0.056
Time until first fixation at Nose (ms)	2291.14 (±692.72)	935.43 (±398.31)	1008.71 (±364.56)	0.116
Time until first fixation at Mouth (ms)	400.86 (±92.30)	733.00 (±196.21)	1023.14 (±459.60)	0.391
Complete fixation time at Eye (ms)	1722.59 (±172.87)[a]	1809.46 (±236.30)[a]	1173.92 (±167.55)[b]	0.02*
Complete fixation time at Nose (ms)	779.27 (±152.40)	903.85 (±149.38)	580.05 (±97.44)	0.998
Complete fixation time at Mouth (ms)	1462.27 (±249.12)[a]	1898.00 (±302.40)[a]	2755.83 (±434.84)[b]	0.03*
Number of fixations at Eye	4.00 (±0.23)	4.31 (±0.38)	3.50 (±0.38)	0.112
Number of fixations at Nose	2.18 (±0.29)	2.54 (±0.33)	2.08 (±0.26)	0.112
Number of fixations at Mouth	2.55 (±0.45)	3.15 (±0.33)	3.33 (±0.43)	0.826
VAS	7.75 (±1.39)a	7.60 (±1.94)ab	6.80 (±1.38)b	0.003*
Age Perception	57.1 (± 4.21)	57.90 (±4.05)	59.03 (±4.50)	0.126

*Statistical Difference: $p<0.05$

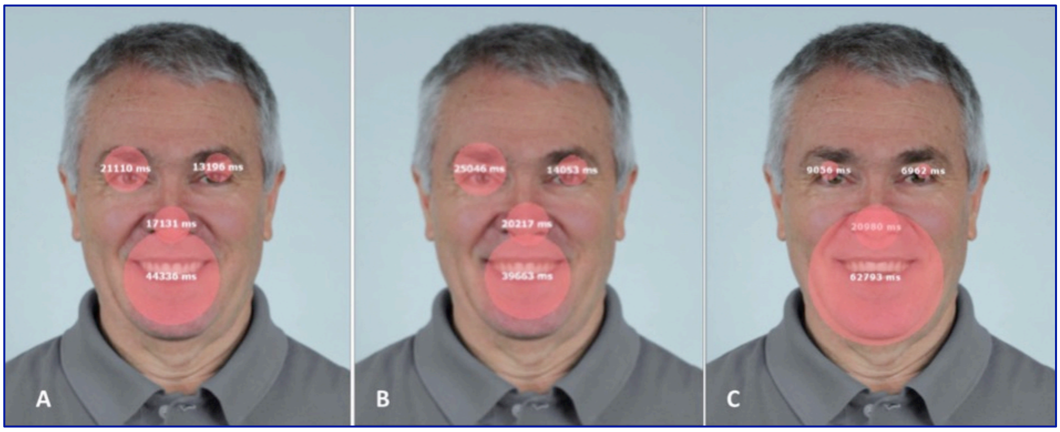

Figure 3. Total fixation time [ms].

The VAS and age-perception surveys revealed similar results for the images featuring convex and straight smiles; however, the image featuring the reverse smile scored fewer points for attractiveness and was perceived as older in the age-perception survey. Pearson's correlation coefficient revealed no significant correlation between the VAS score and perceived for all smile arcs (Table 2).

A power analysis was performed for the VAS. Our population size of 40 volunteers was found to be capable of an alpha value of 0.03 and an effect size of a power of the test of 87.1%, suggesting that our population was large enough to identify significant effects.

Table 2. Descriptive statistics, Pearson Correlation, and p-value

Variables	VAS (±SD)	Age Mean (±SD)	Pearson Correlation	p-value
Convex Smile	7.75 (±1.39)	57.1 (± 4.21)	-0.093	0.569
Straight Smile	7.60 (±1.94)	57.9 (± 4.05)	-0.008	0.959
Reverse Smile	6.80 (±1.38)	59.0 (± 4.50)	-0.117	0.301

SD = Standard Deviation.

Heat maps (Figure 4) were used to analyze which AOIs were associated with the most fixation. Fixations were color-coded, from cold (green) to hot (red), with hotter colors indicating more fixations. The dot maps (Figure 5) show the general tracking order for all raters, represented by dots. When the visualization of a region has been identified, a point is marked on the map until the end of the visualization.

For all images, the heat map and dot map results were concentrated in the mouth and eye AOIs. When visualizing the image featuring a consonant smile, the heat map results (Figure 4A) demonstrated a high level of fixation in the mouth AOI, where a redder coloration was observed. The dot map (Figure 5A) reinforced these results, showing the increased accumulation of points in the mouth AOI, followed by the less dense accumulation in the eye AOI. A similar pattern was observed for the image with the straight smile (Figures 4B and 5B).

The heat map for the reverse smile (Figure 4C) showed a high number of fixations in the mouth AOI, which was also observed on the dot map (Figure 5C), but with greater dispersion, indicating that the smile as a whole and the space between the upper and lower teeth drew more attention from the observers, in contrast with the high density of points observed in the region of the upper incisors for images featuring convex (Figure 5A) and straight smiles (Figure 5B).

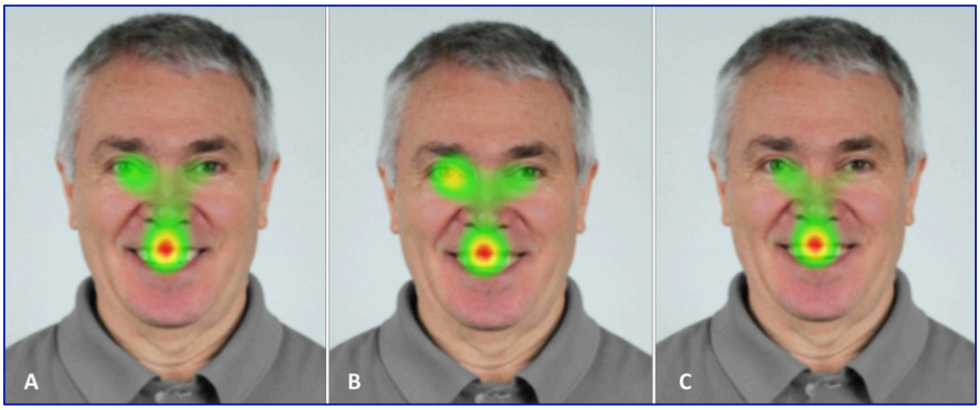

Figure 4. Heatmaps: A) Convex smile; B) Straight smile and C) Reverse smile.

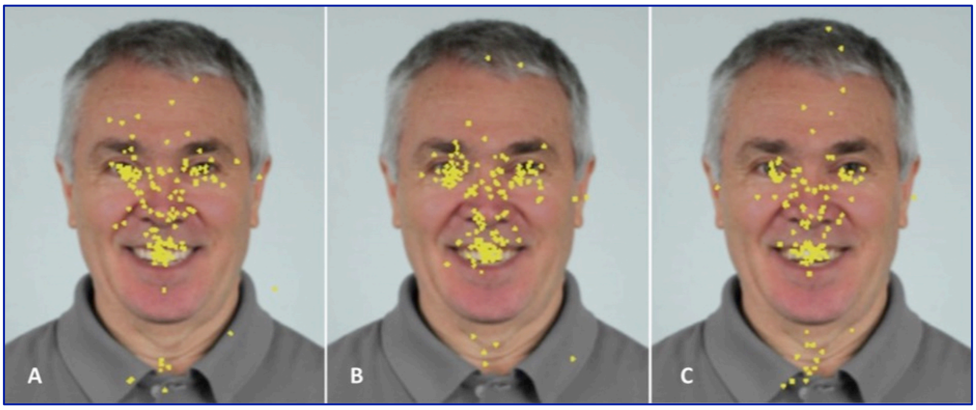

Figure 5. Dot maps: A) Convex smile; B) Straight smile and C) Reverse smile.

In the analysis of Figure 6, significant differences can be observed for the complete fixation times associated with the eye AOI between the convex smile and the reverse smile and the mouth AOI between the flat smile and the reverse smile.

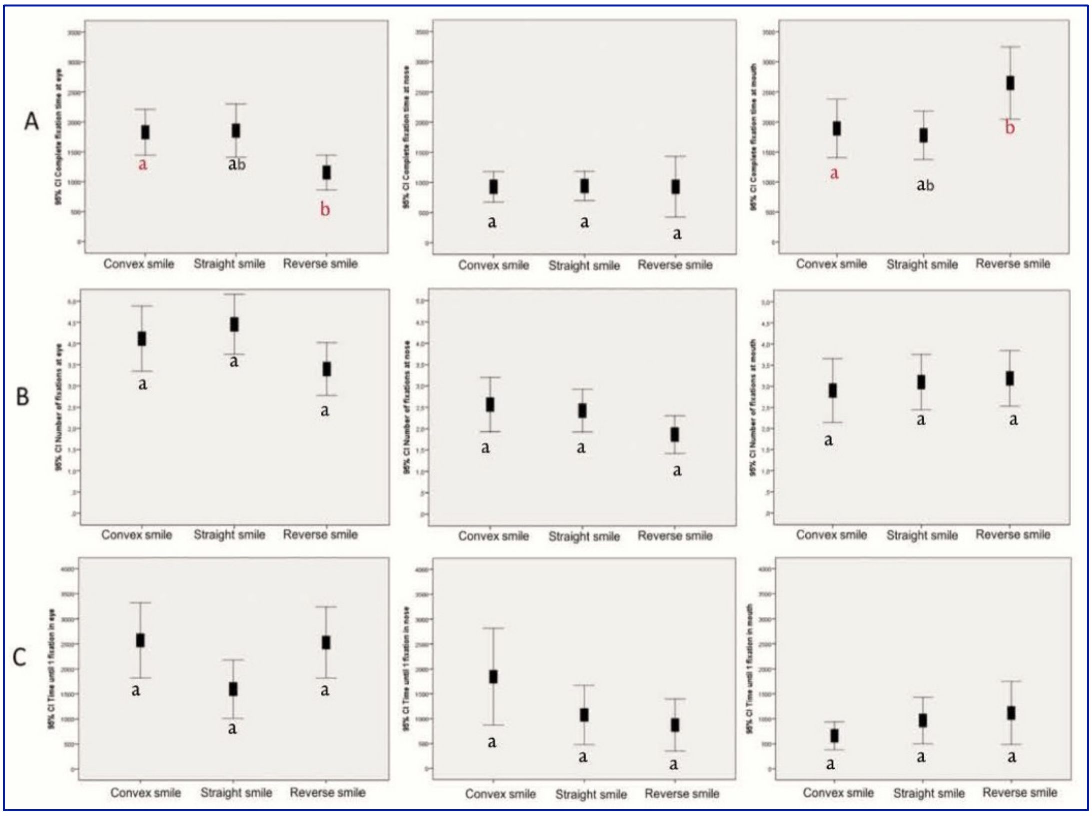

Figure 6. Confidence interval regarding AOIs: A) Complete fixation time; B) Number of fixations; C) Time until first fixation. The same letter do not differ significantly from each other at $p<0.05$.

Discussion

This study evaluated the perceptions of a convex or consonant ideal smile, a straight smile, and a non-consonant reverse smile and found that the smile is affected by variations in the vertical dimension. Most orthodontic treatment is during late childhood and early adolescence, and since time has been introduced as the fourth dimension of treatment planning, long-term knowledge of dentofacial changes are paramount for clinical success [5], and factors such as functional and structural considerations and issues related to the stability of the resulting occlusion must also be considered by the clinicians before active intervention [9]. But the doubt is concerning the laypeople's perspective.

The overbite correction of adult patients should be performed with caution because as dentition gets older, the overbite decreases [10], and the use of intrusion mechanics for the anterior segment to decrease the smile arc and achieve the flattening or straightening of the smile has been associated with negative smile outcomes following orthodontic treatment [11]. Furthermore, the present study showed that reverse smiles were considered to be less attractive by laypeople, in agreement with Machado [4], who identified maxillary central incisor wear as an unesthetic quality.

Due to physiological aging, the exposure of the maxillary teeth tends to decrease in adult patients, especially male patients [1], and this feature has been correlated with a less attractive smile [12]. Therefore, a low smile, in which <75% of maxillary anterior crown height is displayed and an average smile, exposing 75%–100% of the maxillary anterior crown height [13], were used to evaluate the curvature of the smile and the maxillary incisors, which are affected by lip elongation during aging [14].

A straight smile arc is characterized by the maxillary incisal curvature being flatter than the curvature of the lower lip during a smile [3]. Our findings did not show significant differences between convex and straight smiles for a middle-aged man, with similar patterns gaze fixation patterns observed between these two smile types. Parekh et al. [14] found that a straight smile was accepted 50%–60% of the time and not by laypeople, which disagreed with our results. The present study did not evaluate differences between male and female raters because other studies [15,16] have shown no significant differences between these two groups.

The heat map for the reverse smile showed a high number of fixations in the mouth AOI, which was also observed on the dot map, but with greater dispersion, indicating that the smile as a whole and the space between the upper and lower teeth drew more attention from the observers. The existence of cultural reading patterns, such as reading progressively from left to right or from right to left, may have influenced the concentration of visualizations on the left side in the heat maps and dot maps. The same result was observed in studies with Brazilians [16], where the reading pattern occurred from left to right. For this reason, it is advisable to mirror one side of the image, as performed in the present study.

Non-consonant, reverse smile arcs have been associated with less attractive smiles and increased perceived age, which was considered an unacceptable result in other studies [4,14]. Our results confirmed that the reverse smile was perceived as being less attractive, based on the increase in total fixation time associated with the mouth AOI in the reverse smile image, which received a lower VAS value among the layperson raters in our study and showed a statistical difference.

Because esthetic evaluation is subjective in nature, the planned vertical dimension of the incisors must be individually discussed with each patient to ascertain their expectations of treatment [17]. Understanding the perceptions of laypeople can assist clinicians in the achievement of esthetic smiles, particularly because the perceptions of laypeople do not always agree with those of the orthodontist.

This study correlated the age perception of the smile arc with eye-tracking and attractiveness in a male, middle-aged model, and the results suggested that the changes made do not imply more or fewer grades for the subjects evaluated. The similar grades for both variables recorded for the convex and straight smiles may explain this weak correlation. Dentists should pay attention to the smile arc and avoid any treatments that may result in the flattening of the smile.

To aid clinicians when attempting to design an ideal incisal contour within the esthetic zone, the step between the central and lateral incisors must range from 1.0 to 1.5 mm in women and 0.5 to 1.0 mm in men, and convex smile arcs are more suitable for women, whereas either convex or plane arcs are acceptable for men [18].

This study may have limitations, such as the alteration assessed only for a man model. The results may change regarding sex, and further study may be published aiming this important subject. Also, a totally symmetric face may be more reliable for the study, although it is important to point out that it is very difficult or impossible to find a perfect symmetric face. Finally, small distortions may be seen in the graphs regarding the confident interval, although the ANOVA test confirms the statistical difference.

As a person ages, the smile gets narrower vertically and wider transversely, and the dynamic measures indicate that the muscles' ability to create a smile decreases with increasing age [8]; thus, our findings may facilitate conversations with patients regarding facial age perception, particularly as laypeople's perceptions do not always align with those of the clinician. Therefore, clinicians should pay attention to the smile arc and avoid any treatments that may result in a reverse smile. Importantly, treatment should be discussed with patients to individualize any treatment planning and ensure the fulfillment of patients' desires.

Conclusion

Convex and straight smile arcs were associated with equal levels of attractiveness, and the reverse smile was less attractive. No significant difference was noticed regarding age perception and the smile arcs. However, the reverse smile recorded a more complete fixation time.

Authors' Contributions

OMT	https://orcid.org/0000-0002-1052-7872	Conceptualization, Methodology, Writing - Review and Editing, Visualization and Supervision.
VGR	https://orcid.org/0000-0002-1753-5576	Formal Analysis, Investigation and Resources.
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AAR	https://orcid.org/0000-0003-0699-8759	Data Curation and Writing - Original Draft.
IAT	https://orcid.org/0000-0003-2681-5024	Data Curation and Writing - Review and Editing, Visualization, Supervision, Project Administration, Funding Acquisition.
RWFV	https://orcid.org/0000-0003-0861-7243	Conceptualization, Formal Analysis, Data Curation and Writing – Review.

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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