Comparative study between different groups of esthetic component of the Index of Orthodontic Treatment Need and eye tracking

Wagner Leandro de Oliveira,[a] Armando Yukio Saga,[a] Sérgio Aparecido Ignácio,[b] Edson Jose Rodrigues Justino,[c] and Orlando Motohiro Tanaka[a,d]
Curitiba, Brazil, and St Louis, Mo

Introduction: The objective of this study was to determine how different people perceive distinct malocclusions with the use of eye tracking and to compare the results with scores from the subjective visual attractiveness scale (VAS) following 3 grades obtained from the Aesthetic Component of the Index of Orthodontic Treatment Need (AC-IOTN) scale. **Methods:** Ninety participants were equally distributed into 3 groups—dentists, orthodontists, and laypeople—and underwent 1 eye-tracking session. After being positioned and calibrated, they were shown 3 dental images. The images reflected the AC-IOTN grades of 1 (close to ideal), 5 (borderline need for treatment), and 8 (definite need for treatment). During the viewing, eye-tracker data were collected for fixation points, duration, and attractiveness (according to the VAS) for each image. The variables were statistically tested with the use of 2-way analysis of variance and complete factorial model (between groups, grades, and for the interactions between them). **Results:** Grade 1 received the highest subjective score independently from the participant group. This was in contrast to grades 5 and 8, which received similar scores, although the means of fixation points and duration were not significantly different among the grades ($P > 0.05$). The scores obtained from the dentist group were significantly higher than those from the other groups when the comparison was independent from the grade. In terms of fixation points, there were differences between dentists and orthodontists and between orthodontists and laypeople. The fixation point mean was higher for orthodontists than for dentists and was similar to that for laypeople. **Conclusions:** Orthodontists were able to closely analyze the occlusal problems presenting with more severe malocclusions, and the specialists noticed more fixation points. Duration times, however, were not significantly different, because the orthodontists had greater interest, even in situations of unfavorable esthetics. (Am J Orthod Dentofacial Orthop 2019;156:67-74)

Malocclusions are rarely life threatening. However, they do affect physical, social, and psychologic functioning and so may affect a person's quality of life.[1] The Index of Orthodontic

[a]Orthodontics, School of Life Sciences, Pontifícia Universidade Católica do Paraná, Curitiba, Brazil.
[b]Biostatistics, School of Life Sciences, Pontifícia Universidade Católica do Paraná, Curitiba, Brazil.
[c]Informática Aplicada, Pontifícia Universidade Católica do Paraná, Curitiba, Brazil.
[d]Center for Advanced Dental Education, Saint Louis University, St. Louis, Mo.
https://doi.org/10.1016/j.ajodo.2018.07.026

Treatment Need (IOTN) rating system is widely used to determine malocclusion treatment needs owing to its efficiency and practicality.[2]

The concept of beauty is notoriously subjective, with every person having a different perception. A professional's perception is not the same as a patient's.[3] Furthermore, an orthodontist's perception of beauty might differ from that of a layperson in terms of what is attractive and satisfactory.[4,5]

Studies on esthetics and smile attractiveness report subjective assignment of what is perceived visually on the visual analog scale (VAS).[6,7] However, even with the increasing advancements in technology, studies using eye tracking to verify VAS data remain lacking in the literature.

Treatment needs and outcomes for patients with malocclusion are typically evaluated by orthodontists and patients. Orthodontists use cephalometry, model

analysis, and the Index of Complexity, Outcome, and Need (ICON) in their evaluations. The Aesthetic Component of the IOTN (AC-IOTN) scale[2,8] is used in contemporary orthodontics because it represents an evolution in determining subgroups in need of orthodontic treatment.

Some studies have investigated esthetic perception with the use of extraoral[3] and intraoral[9] digitally manipulated photographs. Researchers have proposed a novel method that employs eye tracking to objectively evaluate observer attention.[10,11]

Recent studies on eye tracking have addressed issues such as visual attention to facial structures[11] and the evaluation of orthodontic treatment.[10] It is thought that this method complements the subjective VAS, allowing for a better understanding of the analysis involving the psychosocial aspects of esthetics in cases requiring orthodontic treatment.[11]

Eye movements are an established surrogate for attention. The eye-tracking technique has been widely used in studies of facial expression, sex, and race judgment. The major advantage of this technique is that it can record the movements of the eyeballs while multiple other stimuli compete for attention.

In the present study, visual attention and attractiveness judgment of different observers were analyzed with the use of a subjective attractiveness scale and eye tracking in response to projections of representative clinical images.

The objectives of this study were: (1) to determine whether there are significant differences in the way that different classes of observers perceive occlusal changes in an attractive face, regardless of the severity of the malocclusion; (2) to determine whether all groups evaluate and make the same observations regardless of the severity of the malocclusion; and (3) to determine whether there are interactions between the grades, which represent different malocclusion severities, and the observer.

MATERIAL AND METHODS

This study was approved by the University Committee of Human Ethics and Research. Participants were recruited through an internal notice on the premises of the university and were included, regardless of gender, if they were 18-70 years of age, with no visual impairment or psychologic problems, and had not used drugs or medications that could affect cognitive abilities within 24 hours before the test.

Once recruited, participants were informed of the purpose of the study. They were required to belong only to a single group and participate in a single eye-tracking session while responding to the subjective VAS assessment questionnaire.

All digital images were obtained with the use of a Canon camera model T2i, lens EF-S 60 f2.8 Macro USM, and flash Macro Ring Lite MR-14EX II (Canon, Tokyo, Japan). The standard method used was the following: A frontal facial photo was taken with the camera in the portrait direction, with the head oriented with the Frankfort plane parallel to the floor and without lateral tilt or rotation.

The next step involved the selection of 3 photographs. Three orthodontists each with >5 years of clinical experience selected 3 female facial photographs. The orthodontists assessed the images, considering the symmetry, volume, and color. Features that could have a significant impact (eg, piercings, tattoos, excessive makeup) were avoided.

One month later, classification of the images was again independently performed by the same 3 evaluators, and there was complete agreement among them with the classifications obtained during the first evaluation. Therefore, based on the IOTN, it was demonstrated that there was reliability in the classification of the images. Consequently, there was no need to perform a statistical reliability test, because the same index was given for each image by the 3 orthodontists in the 2 instances of classification 1 month apart. Therefore, reliability testing was not performed in this study.

Three images were thus selected unanimously by the same experts to represent photographic compositions of grades 1, 5, and 8 of the AC-IOTN.[2,8] In addition, all 3 images were standardized and edited with the use of Photoshop CS5 (Adobe, San Jose, Calif) at a resolution of 2560 × 1920 pixels, with resolution of 300 pixels per inch to minimize possible interlayer noise, sharp contrasts, significant color differences, and nonrecognition of individuals.

For this study, images of AC-IOTN grades 1, 5, and 8, composed of the same image cutout of the lower third of the face, were obtained and paired with teeth with the same grades (Fig 1).

For calibration, the EyeProof Ink software (Copenhagen, Denmark) was used and accounted for best/perfect accuracy, ensuring the quality of the observations. This tool allowed for the storage of the scanpaths of the processed eye movements, such as fixation points and duration (in ms; Fig 2).

Ninety participants, divided into 3 groups of 30 each, underwent 1 eye-tracking session. The groups were: (A) newly graduated dentists: 35% men and 65% women, 21-44 years of age; (B) orthodontists; 40% men and 60% women, 25-61 years of age; and (C) laypeople: 50% men and 50% women, 18-53 years of age.

Fig 1. I, Original images of AC-IOTN grades 1, 5, and 8; **II,** representations of AC-IOTN; **III,** composition of the AC-IOTN grades with the same portion of the lower third of the face: **a,** grade 1; **b,** grade 5; **c,** grade 8.
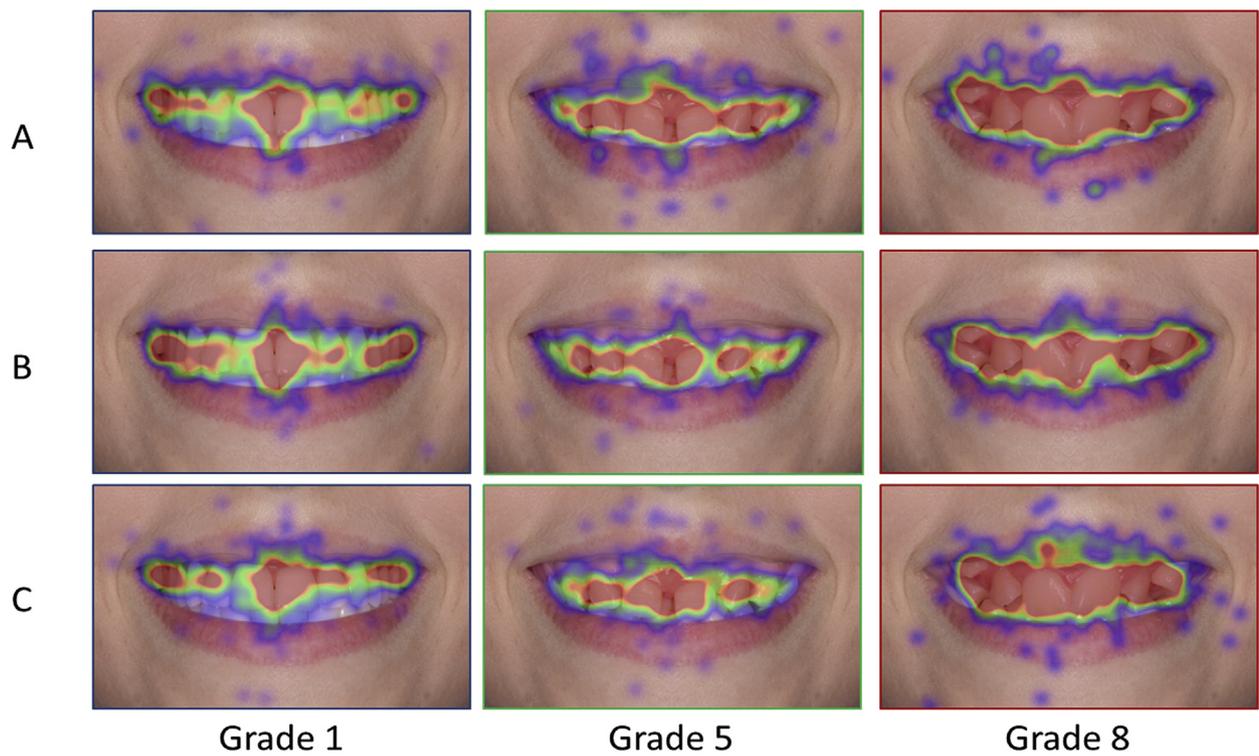

Fig 2. Scanpaths of groups **A, B,** and **C** for AC-IOTN grades 1, 5, and 8.

The participants were oriented to freely view the images, and each image was displayed for 59 seconds. The following were considered: the initial calibration, the interval between the images used for the subjective demarcations in scales (rates), and the exposures of the representative images of grades randomized for 10 seconds each.

The Eye Tribe Tracker sensor (Copenhagen, Denmark) was used in this study. The images were displayed in the middle of a 17-inch high-resolution screen (Samsung, Seoul, South Korea) and an infrared sensor was positioned below the screen. The participants viewed the images at a distance of 60 cm and were instructed to not make any head movements.

Simultaneously, the participants were asked to complete subjective assessments of the same images with the use of the attractiveness scale, wherein 0 corresponded to nonattractive and 10 to attractive.

All participants were informed in advance that, between the intervals and the end of the presentation of the images of the screening session, answers corresponding to the subjective ratings would be requested.

The VAS analysis was applied with the objective of identifying how each group reacted to various occlusal alterations while evaluating the attractiveness of the smile. Data were tabulated for statistical analysis.

Statistical analysis

To identify differences between groups, between grades, and interaction between groups and grades, between the mean values of the subjective rating, and among fixation points and duration for each group and at each grade, a 2-way analysis of variance (ANOVA) was used.

The ANOVA results indicated a significant difference and Levene variance homogeneity test suggested homogeneous variance for each variable according to group and grade factors; therefore, a comparison was performed with the use of Tukey honest significant difference (HSD) test. When heterogeneous variances occurred, a comparison was done with the use of Games-Howell multiple parametric comparison test for heterogeneous variance.

RESULTS

ANOVA was used to compare groups regardless of grade. The analysis indicated a significant difference between groups for the variables subjective rating and fixation points ($P < 0.05$); however, there was no difference between groups for duration.

For the subjective score, Tukey HSD multiple comparisons test showed that group B's (orthodontists) score did not differ from that of group C (laypeople; $P > 0.05$). There was, however, a significant difference between group A (dentists) and groups B and C. The mean score of group A was highest (4.45 ± 2.66), followed by group B (3.26 ± 2.15) and then group C (2.95 ± 3.60; Table).

For fixation points, the Games-Howell test for heterogeneous variances indicated a significant difference between groups A and B and between groups B and C; however, there was no difference between groups A and C. The fixation point means of groups A, B, and C were 18.39 ± 5.35, 20.71 ± 4.97, and 17.08 ± 7.15. Group B (19.67-21.75) was found to have a higher confidence interval (CI) compared with groups A and C (17.26-19.50 and 15.57-18.57, respectively).

For duration, group A had a slightly lower mean than did groups B and C; however, the 3 groups' values remained within the same CI and did not differ significantly from one another.

When comparing the grade independently from group, the ANOVA indicated that there was a difference in the average subjective rating ($P < 0.05$). However, there was no difference in the fixation point means or the duration means ($P > 0.05$; Table).

The subjective variable in Tukey's HSD multiple comparison test for homogeneous variances indicated a statistically significant difference between grade 1 and grades 5 and 8; however, there was not a significant difference between grades 5 and 8 per se.

The mean subjective rating for grade 1 was 6.50 ± 2.19; for grade 5, it was 2.21 ± 1.89; and for grade 8, it was 1.95 ± 2.07. Figures 3-5 show the 95% CIs for AC-IOTN grade 5 independently from group.

Regarding the difference in mean values of the analyzed variables according to group and grade, differences were observed for subjective rating and fixation points ($P < 0.05$). However, there was no significant difference in the mean duration according to group or grade. The comparison between group and grade was performed with the use of the Games-Howell test for heterogeneous variance (Table).

For the subjective rating, tests showed a difference between groups, between grades, and in the interaction between group and grade. The difference was evident from the decline of the subjective rating of group C from grade 1 through 5 and 8, which was greater than those of groups A and B. The behavior of the mean values of the subjective ratings differed significantly for the laypeople as it changed from grade 1 to grade 8 (Fig 3).

For fixation points, there was a difference between groups, but no difference between grades or regarding the interaction between group and grade. Figure 4 shows a significant difference in the fixation point

Table. Descriptive statistics of the crossing of variables between groups, and orthodontists and other groups

| Variable | Orthodontists | | Dentists | | Laypeople | | P value | | |
	Mean	SD	Mean	SD	Mean	SD	B × A	B × C	A × C
Subjective rating	3.25	2.14	4.44	2.66	2.95	3.60	0.00335*	0.76830	0.00515
Fixation points	2.71	4.96	18.38	5.34	17.07	7.15	0.00815*	0.00033*	0.34690
Duration (ms)	401.99	123.14	372.91	105.12	400.51	151.56	0.20687	0.99717	0.33324

*Significant differences ($P < 0.05$; Games-Howell test).
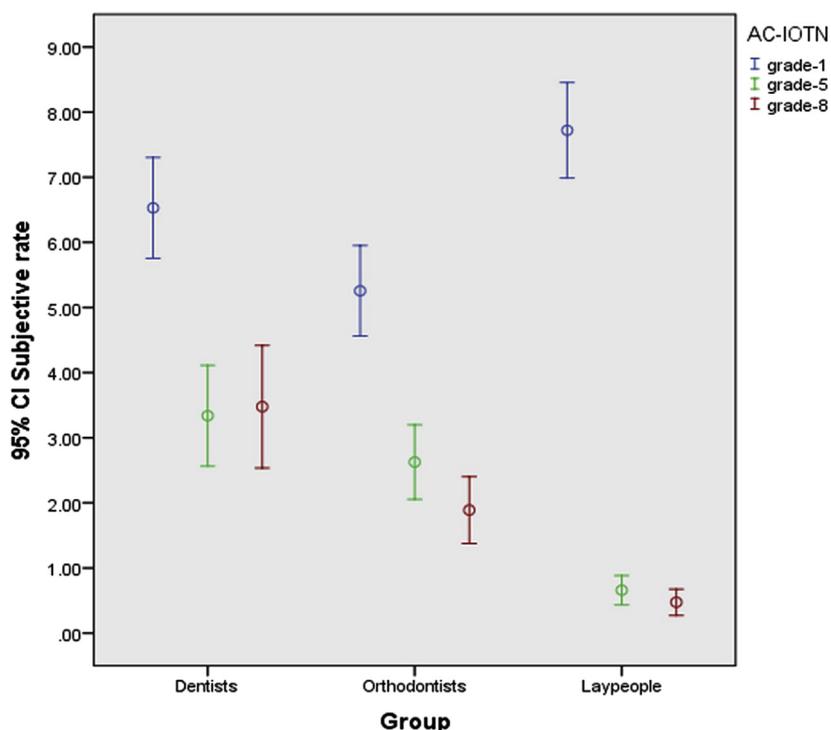

Fig 3. 95% CIs of subjective ratings between AC-IOTN grade and observer group.

mean between groups A and B and grade 8. The fixation points mean of group B was greater than that of group A, independently from grade. We also observed that the fixation points mean of group B in grade 5 was higher than that of a grade-matched layperson. However, the fixation points mean in grade 8, though higher for group B, showed no significant difference that of group C at the same grade. For duration, there was no difference between groups, between grades, or in the interaction between group and grade (Fig 5).

Pearson correlation coefficient did not present a significant correlation between the 3 variables ($P > 0.05$). The above-mentioned evidence suggests that longer duration does not imply more or fewer fixation points or subjective rating.

The scanpaths for each group and grade are shown in Figure 2. The scanpaths demonstrate aspects of visualization, highlighting the areas of concentration and fixation (coloration from blue to red for lower to higher density, respectively). These are good initial indicators of data quality and allow for the analysis of the agreement between design and hypothesis. We observed an increase in foveation through points outside the area of the embedded images (grades 1, 5, and 8) in the visualizations of groups A and C for grades 5 and 8. Group B, however, fixed and maintained the fixation in areas corresponding to the teeth, showed less alteration in the visualization routes, were able to fix more frequently on different points, and presented less focal observation divergence.
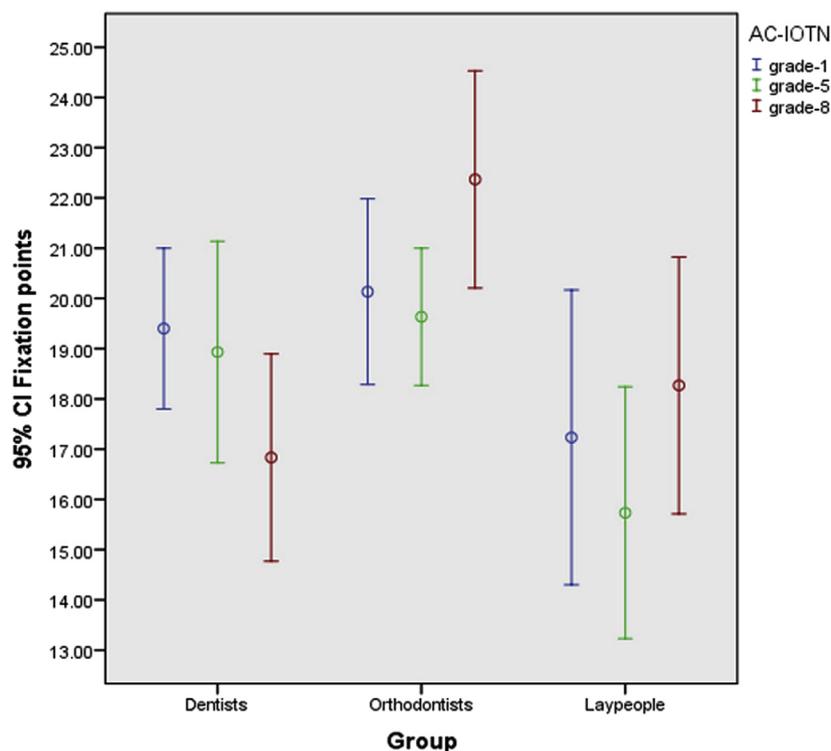
Fig 4. 95% CIs of fixation points between AC-IOTN grade and observer group.

DISCUSSION

This study aimed to evaluate with the use of objective eye-tracking data how different people interpret images reflecting AC-IOTN grades 1 (close to ideal), 5 (borderline need for treatment), and 8 (definite need for treatment), based on viewers' visual attention. The study included 90 participants who were distributed into 3 groups of 30 people each: dentists, orthodontists, and laypeople.

Esthetic appearance has been prioritized with increasingly greater frequency in orthodontic treatment. However, a professional's perception is not the same as that of a patient's. The concept of beauty is notoriously subjective; each person has a different perception. In light of this, researchers are paying more attention to patients' own evaluations of smile esthetics. Therefore, it is necessary to ask: (1) whether there are significant differences in the way that different classes of observers perceive occlusal changes in an attractive face, regardless of the severity of the malocclusion; (2) whether groups evaluate and make the same observations regardless of the severity of the malocclusion; and (3) whether there is an interaction between the degree of malocclusion severity and the observer.

In determining the ways in which smiles are deemed to be socially attractive, studies have identified different perception grades between groups. This suggests that orthodontic treatment recommendations should be based on the specialized professional's observations[12] and that the AC-IOTN does not reflect the esthetic expectations of society.[8]

In this study, the dental esthetic ratings were based on the AC-IOTN, which was chosen as an index, because it is classically used within clinical practice. Furthermore, we focused on the lower face for the evidence of perceptions related to occlusion. For the purposes of this study, we evaluated the esthetic perceptions only from a frontal view to evaluate dental esthetics; we did not seek to directly evaluate dental health treatment needs.

The AC-IOTN proposes 10 graduations (or degrees) of dental characteristics, divided into 3 subgroups, as follows: (1) grades 1-4 suggest little or no need for treatment; (2) grades 5-7 are borderline; and (3) grades 8-10 definitely require orthodontic treatment.[2,13-15] In this study, within-group analyses (independently from grade) suggest that group A had the lowest fixation and assigned the highest subjective rating; group B was more fixed than group A, although it did not differ from group C in terms of duration or subjective rating;
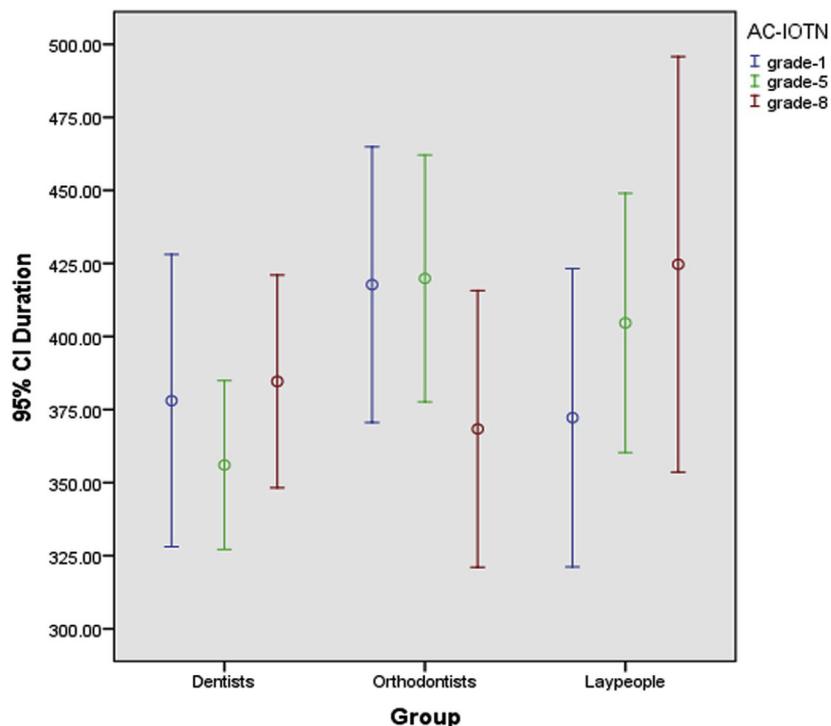
Fig 5. 95% CIs of the duration of fixation between AC-IOTN grade and observer group.

and group C had the lowest fixation points mean and a subjective rating that was equal to group B but with a higher CI.

Among the grades used (1, 5, and 8), independently from group, grade 1 was expected to receive the highest subjective rating because it represents little disharmony and should be more agreeable to general perception, although grades 5 and 8 were subjugated and indiscriminate among themselves because they were more complex and less attractive and remarkable in regard to treatment needs. It is important to note that there were no significant differences between duration or fixation points.

This study sought to deepen the investigations, directing its focus to an evaluation of the understanding of the perceptive faculties of the groups in question, albeit predominantly in group B. This approach is justified because the orthodontist routinely performs detailed assessments of malocclusions in clinical practice. Throughout their training, orthodontists are expected to develop the ability to distinguish between severity of cases, which forms a key component of the orthodontic diagnosis and treatment process. In addition, the orthodontist should develop a perception of the esthetic components of an attractive smile and facial harmony.

Although there was no interaction between group and grade for the 2 more severe malocclusions (grades 5 and 8), there was prudence and caution between the values obtained by dentists (A) and orthodontists (B) compared with those by laypeople (C). Group B fixed more than group A and was significantly different from group C, suggesting that, in the judgment of this group, attractiveness decreases as malocclusion severity increases.

For the subjective variable, the 2-way ANOVA (group × grade) identified a significant difference between groups and between grades, besides identifying group-grade interaction. The presence of interaction can be confirmed in Figure 3. Similar behavior is observed in the subjective rating attributed between dentists and orthodontist for grade 5 and 8 malocclusions. The same did not occur with the layperson, for whom, in addition to the subjective rating being higher in grade 1, the reduction when changing to grade 5 and grade 8 was much higher, confirming that the layperson, owing to lack of experience in the area, gives lower marks to images of more severe malocclusions. This result leads us to reflect to what extent these professionals can understand the perception of their patients on the malocclusions to be treated.

It was suspected that, given the widespread diffusion of esthetic standards by digital and communicative means, it is common to refer to the polarized use of classifications—interesting or uninteresting, attractive or

unattractive—making the judgment of a more severe case of occlusal alteration and facial disharmony trivial.

This study improves the understanding of how distinct groups perceive and understand a range of esthetics. The specialized professional approach seems to be the most relevant one regarding the evaluation of grades 1 (close to normal occlusion), 5, and 8 (higher severity). We determined that there is no common reference point, when taking malocclusion judgments into account, that can be used between the groups. Laypeople (group C) tended to have less cautious observations and a judgment directed toward the extreme, presenting neither weight nor interest in a correct diagnosis of the distinction between severities.

We found that the methodology used in the present study was adequate to evaluate the proposed objectives, because eye tracking provided a good initial indication of the data quality and enabled us to determine the agreement between the research design and hypotheses.

The reliability testing of the results, which requires observers to view the same face twice, because facial memories can affect the pattern of eye movement, was not performed in this study, to prevent the impact of facial memory. Other eye-tracking studies that evaluated pretreatment and posttreatment faces also did not apply reliability testing.[16]

A recent eye-tracking study demonstrated that in people with more severe malocclusions, more attention is directed toward the mouth region.[10] To avoid this, our study was conducted with the use of the lower third of the face. Previous studies of smiling have shown that malocclusions attract so much attention that the time allocated to the eyes and nose is severely decreased.[10,11] Thus, one limitation of our study could be the use of the lower third of the face and static images instead of vivid video.

CONCLUSIONS

In this study, there was a difference in the way different groups observed and evaluated image compositions, both between groups and between grades as well as in relation to groups and grades. The number of fixation points in grade 8 was higher for orthodontists than for dentists, suggesting that the specialists are interested in the more severe occlusions and that the results are clinically relevant. Orthodontists were able to closely analyze the occlusal problems presented, differentiating themselves from both dentists and laypeople.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajodo.2018.07.026.

REFERENCES

1. Brosens V, Ghijselings I, Lemiere J, Fieuws S, Clijmans M, Willems G. Changes in oral health-related quality of life reports in children during orthodontic treatment and the possible role of self-esteem: a follow-up study. Eur J Orthod 2014;36:186-91.
2. Brook PH, Shaw WC. The development of an index of orthodontic treatment priority. Eur J Orthod 1989;11:309-20.
3. Pithon MM, Bastos GW, Miranda NS, Sampaio T, Ribeiro TP, Nascimento LE, et al. Esthetic perception of black spaces between maxillary central incisors by different age groups. Am J Orthod Dentofacial Orthop 2013;143:371-5.
4. Desai S, Upadhyay M, Nanda R. Dynamic smile analysis: changes with age. Am J Orthod Dentofacial Orthop 2009;136:310.e1-10: discussion 310-1.
5. Thomas M, Reddy R, Reddy BJ. Perception differences of altered dental esthetics by dental professionals and laypersons. Indian J Dent Res 2011;22:242-7.
6. Cotrim ER, Vasconcelos Junior AV, Haddad AC, Reis SA. Perception of adults' smile esthetics among orthodontists, clinicians and laypeople. Dental Press J Orthod 2015;20:40-4.
7. Oliveira PL, Motta AF, Guerra CJ, Mucha JN. Comparison of two scales for evaluation of smile and dental attractiveness. Dental Press J Orthod 2015;20:42-8.
8. Hunt O, Hepper P, Johnston C, Stevenson M, Burden D. The Aesthetic Component of the Index of Orthodontic Treatment Need validated against lay opinion. Eur J Orthod 2002;24:53-9.
9. Kokich VO, Kokich VG, Kiyak HA. Perceptions of dental professionals and laypersons to altered dental esthetics: asymmetric and symmetric situations. Am J Orthod Dentofacial Orthop 2006;130:141-51.
10. Richards MR, Fields HW Jr, Beck FM, Firestone AR, Walther DB, Rosenstiel S, et al. Contribution of malocclusion and female facial attractiveness to smile esthetics evaluated by eye tracking. Am J Orthod Dentofacial Orthop 2015;147:472-82.
11. Wang X, Cai B, Cao Y, Zhou C, Yang L, Liu R, et al. Objective method for evaluating orthodontic treatment from the lay perspective: an eye-tracking study. Am J Orthod Dentofacial Orthop 2016;150:601-10.
12. Shaw WC, Rees G, Dawe M, Charles CR. The influence of dentofacial appearance on the social attractiveness of young adults. Am J Orthod 1985;87:21-6.
13. Stenvik A, Espeland L, Linge BO, Linge L. Lay attitudes to dental appearance and need for orthodontic treatment. Eur J Orthod 1997;19:271-7.
14. Siddiqui TA, Shaikh A, Fida M. Agreement between orthodontist and patient perception using Index of Orthodontic Treatment Need. Saudi Dent J 2014;26:156-65.
15. Winnier JJ, Nayak UA, Rupesh S, Rao AP, Reddy NV. The relationship of two orthodontic indices, with perceptions of aesthetics, function, speech and orthodontic treatment need. Oral Health Prev Dent 2011;9:115-22.
16. Dey JK, Ishii LE, Byrne PJ, Boahene KD, Ishii M. Seeing is believing: objectively evaluating the impact of facial reanimation surgery on social perception. Laryngoscope 2014;124:2489-97.