AJO-DO

Influence of optical properties of esthetic brackets (color, translucence, and fluorescence) on visual perception

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Introduction: The aims of this study were to evaluate the optical properties of esthetic brackets and determine their influence on visual perception. **Methods:** Eighty esthetic brackets of 16 commercial brands were tested. The color and translucency of the brackets, as well as the color of the maxillary central incisors of 40 subjects, were measured with a spectrophotometer. The fluorescence of the brackets was determined by duly calibrated appraisers. The color differences between the brands of brackets and the teeth were calculated. Data were analyzed by using 1-way analysis of variance; the Scheffé multiple comparison test was used to establish the difference between brands of brackets, ($\alpha = 0.05$). **Results:** The color parameters L * a * b * of nontranslucent brackets ranged from 49.4 to 86.0, –1.6 to 3.0, and 1.9 to 14.6, respectively. The direct transmission of light ranged from 0.0% to 38.8% transmittance. No bracket showed fluorescence. The color and translucency, as well as the color difference, of the brackets were influenced by brand ($P < 0.01$). **Conclusions:** The optical properties of esthetic brackets have a direct influence on visual perception; translucent brackets and the nontranslucent InVu (TP Orthodontics, LaPorte, Ind) brackets were less visually perceptible. (Am J Orthod Dentofacial Orthop 2012;141:460-7)

Ceramic brackets appeared in the mid-1980s and were better able meet patients' functional and esthetic demands; plastic brackets had left much to be desired, particularly regarding color stability, deformation, torque, friction, tie-wing fracture, and debonding.[1] With improvement in the physical and mechanical properties of esthetic brackets by the incorporation of ceramic or glass particles and a metal channel as reinforcement in plastic brackets,[2-4] in addition to surface preparation of the channel in the ceramic brackets,[5-7] the demand for esthetics became the main target. Less visual perception, to which the term esthetic is related, was desired.

The lingual brackets and transparent orthodontic aligners (Invisalign; Align Technology, Santa Clara, Calif) are the orthodontic appliances that are the least visually perceptible; however, only esthetic brackets allow a conventional orthodontic procedure to be performed.[8,9] Their optical properties (color and stability, translucency, and fluorescence) are unquestionable factors for reducing visual perception. Moreover, the knowledge and careful evaluation of the optical properties of patients' teeth by the orthodontist, especially shade (color), should be considered because they also influence the esthetic performance of brackets.[10]

Esthetic brackets are translucent or nontranslucent, according to their optical properties and availability on the market. The nontranslucent type can be made of plastic or polycrystalline ceramic (machined or injected), and the translucent type is made of plastic or monocrystalline ceramic (popularly called sapphire). For these brackets to have a good esthetic appearance, the nontranslucent type needs to have similar color and fluorescence to the underlying tooth. The translucent type requires a translucency that allows the color and fluorescence of the tooth to appear, and both should have good color stability.

Fluorescence is an optical property inherent to the natural tooth when irradiated by ultraviolet light.[11] This fluorescence, which appears to come from within, makes teeth whiter and lighter in daylight, giving the natural tooth an appearance of vitality.[12,13] When

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Table I. Distribution of the groups according to material, type of bracket, code, brand, composition, and manufacturer

	Type	*Code*	*Brand*	*Composition and manufacturer*
Ceramic	Translucent	RAD	Radiance	Monocrystalline, American Orthodontics, Sheboygan, Wis
	Translucent	PUR	Pure	Monocrystalline, Ortho Technology, Tampa, Fla
	Nontranslucent	CLY	Clarity	Polycrystalline injected, metal slot, 3M Unitek, Monrovia, Calif
	Nontranslucent	INV	InVu	Injected polycrystalline, polymer mesh base, TP Orthodontics, LaPorte, Ind
	Nontranslucent	SIG	Signature	Machined polycrystalline, Rocky Mountain Orthodontics, Denver, Colo
	Nontranslucent	TRL	Translux	Machined polycrystalline, Aditek lmta, São Paulo, Brazil
	Nontranslucent	ICR	Iceram	Machined polycrystalline, Orthometric, São Paulo, Brazil
	Nontranslucent	ILS	Illusion	Machined polycrystalline, Ortho Organizers, Carlsbad, Calif
	Nontranslucent	MYQ	Mystique	Machined polycrystalline, GAC, Central Islip, NY
	Nontranslucent	ALR	Allure	Machined polycrystalline, GAC, Central Islip, NY
	Nontranslucent	TEC	Tecnident	Machined polycrystalline, Tecnident, São Carlos, São Paulo, Brazil
	Nontranslucent	INO	In-ovation	Self-ligating machined polycrystalline , GAC, Central Islip, NY
Plastic	Translucent	SPR	Spirit MB	Polycarbonate reinforced with ceramic Ormco, Glendora, Calif
	Translucent	ELT	Elation	Polycarbonate, metal slot, GAC, Central Islip, NY
	Nontranslucent	SIL	Silkon Plus	Filler reinforced plastic, American Orthodontics, Sheboygan, Wis
	Nontranslucent	COM	Composite	Composite, Morelli, São Paulo, Brazil

anterior tooth restorations (composites or porcelain) and esthetic brackets without this property are exposed to ultraviolet light, either daylight or environments with black light, they become dark, causing esthetic disharmony. Although this property has been studied by dentists and prosthetists and included in their materials, in the orthodontic literature, there are still no reports on it.[14,15]

Although the appearance of orthodontic appliances plays a significant role in the decision of some patients to undergo orthodontic treatment, and this is attributable to the good esthetics of these brackets,[16] few studies have assessed their color and translucence,[17-25] and none have evaluated fluorescence. The purpose of this study was to evaluate the optical properties of esthetic brackets compared with natural teeth and their influence on visual perception according to the Commission Internationale l'Eclairage color scale and the difference in color.

MATERIAL AND METHODS

A total of 80 maxillary right central incisor brackets (slot size, 0.022-in Roth prescription) of 16 commercial brands were obtained. Of these, 12 brackets were ceramic, and 4 were plastic; 5 brackets of each brand were tested (Table I).

After approval from the ethics committee of Federal University of Rio de Janeiro in Brazil, 80 maxillary right and left central incisors in 40 patients who came to the postgraduate orthodontic clinic for the first time were used in the study. There were 16 men and 24 women, aged 20 to 30 years, without distinction as to social and racial groups, with the following characteristics: (1) no previous orthodontic treatment, (2) healthy permanent central incisors (no cavities, fillings, root canal treatments, or patches of decalcification or pigmentation), (3) no smoking habits, and (4) no tooth whitening less than 6 months previously.

The colorimetric readout of the labial surface of the brackets was performed with a digital portable spectrophotometer, Easyshade Compact (model DEASYC220; model DEASYC220; VITA, Bad Säckingen, Germany), positioned perpendicularly to the bracket with a prefabricated positioner (Fig 1, *A*), by using the same luminosity. The brackets were arranged on a mirrored surface, intraoral mirror (No. 5; Barasch Sylmar, São Paulo, Brazil), because the spectrophotometer did not read that kind of surface, but this surface does not influence the color of the brackets as the black and white surface, thus avoiding the influence of background. To exclude any environmental factors, we used a black opaque cardboard mask with a central window the size of the bracket, and measurements were made without moving the position of the spectrophotometer.[18,19] The color was evaluated according to the International Commission l'Eclairage color scale relative to the D65 illumination pattern, which uses the mathematical process based on a colorimetric curve to divide the color into 3 fields: L *, which represents the brightness or color values (from black to white), the axis a *, measuring values from green to red, and axis b *, which measures values from yellow to blue.[20]

Five measurements were made for each bracket without removing the spectrometer from its position. The value obtained for each specimen (L * a * b *) was the mean of these measures.

The spectrophotometer and the measurement system were the same for the teeth as those used for the brackets. All measurements were performed by 1

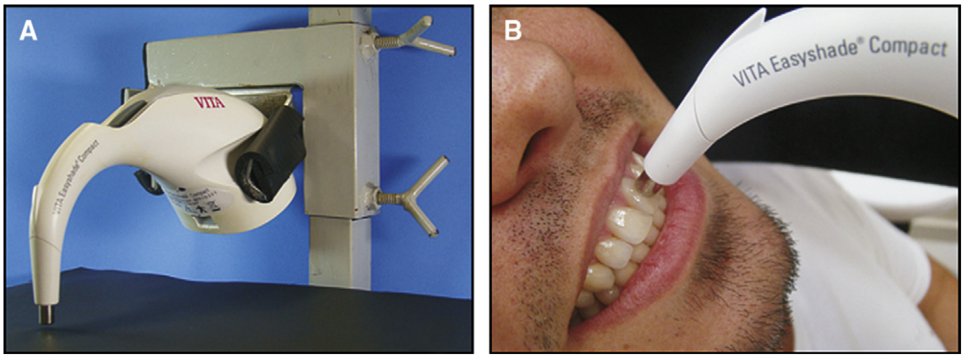

Fig 1. A, Prefabricated positioner; **B,** spectrophotometer in the position to read in vivo.

operator (H.L.F.), under the same light (the same as the brackets), and a standardized protocol had been devised for the subjects for tooth preparation and color evaluation in vivo by using the spectrophotometer.[21] Before the measurements, each subject's teeth were subjected to prophylaxis with pumice and water. Then the teeth to be evaluated were lightly dried with a paper towel before taking the readouts.[22] Immediately after the cleaning and drying procedure, the color of the teeth was measured by the spectrophotometer (Fig 1, *B*). The 3 measurements of each tooth were taken in the middle third region of the labial surface, without removing the spectrophotometer from its place, so that there would be no time for drying and a change in color.[23] The calibration process was performed between each tooth to be measured to compensate for any deviation in the amount of light produced by the internal light.[24]

A microprocessed spectrophotometer especially developed for working under ultraviolet and visible light bands (SP-220; Bioespectro, São Paulo, Brazil) was used to evaluate the translucency of the brackets. An opaque black cardboard mask measuring 1 cm^2 with a central window the size of the bracket was fabricated for each bracket.[25] The mask-bracket set, in turn, was placed on the outer surface of the cubette, facing the light beam at a corresponding height, so that this light beam could only pass through the region of the bracket. Before each bracket was measured, the spectrophotometer was calibrated by using only the cubette, corresponding to 100% transmittance, and the cubette with the mask, without a window, corresponding to no transmittance. The analysis of direct transmission of the brackets was performed 3 times at a wavelength of 400 to 700 nm, corresponding to the wavelength of visible light. The value obtained for each specimen was the mean.

After measuring the color of the subject's teeth and the nontranslucent brackets, the color difference (ΔE) between the means was calculated by using the equation: $\Delta E=[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]^{1/2}$.

To find the difference in color between the teeth and the translucent brackets, a bovine tooth was used for each bracket, and 5 brackets of each brand were tested. The color of the bovine teeth was measured 5 times, and then the bracket was bonded (Transbond XT; 3M Unitek, Monrovia, Calif), and the color of the tooth was measured again 5 times over the bracket. After this, the color difference was calculated by using the same equation as above.

Two properly calibrated examiners (H.L.F. and L.H.M.) qualified the fluorescence of the brackets; in case of disagreement between them, a third examiner qualified the fluorescence, indicating "yes" for those with fluorescence and "no" for those without it, using as the reference the fluorescence of an intact natural tooth (maxillary central incisor) extracted for periodontal reasons. This qualification was performed in a completely dark room, where the samples were exposed to a black light of the Quadriluz black/G-Light, 40 W type (Marschall, Feira de Santana, Brazil), at a distance of 30 cm, perpendicular to the samples.

After bonding the brackets to the bovine teeth, bracket behavior with regard to the visual appearance of tooth fluorescence was observed by an examiner (H.L.F.) to determine whether there was a difference when translucent and nontranslucent brackets had been bonded.

Statistical analysis

Statistical differences were investigated for the parameters of bracket color and translucence by using 1-way analysis of variance (ANOVA) with a level of significance of 0.05. In addition, differences between brands of brackets were investigated with the Scheffé multiple comparison test (post hoc) (α = 0.05). For tabulation and data analysis, we used SPSS software (version 16.0; SPSS, Chicago, Ill).

RESULTS

All color parameters of the nontranslucent brackets were influenced by the brands of materials (P <0.01).

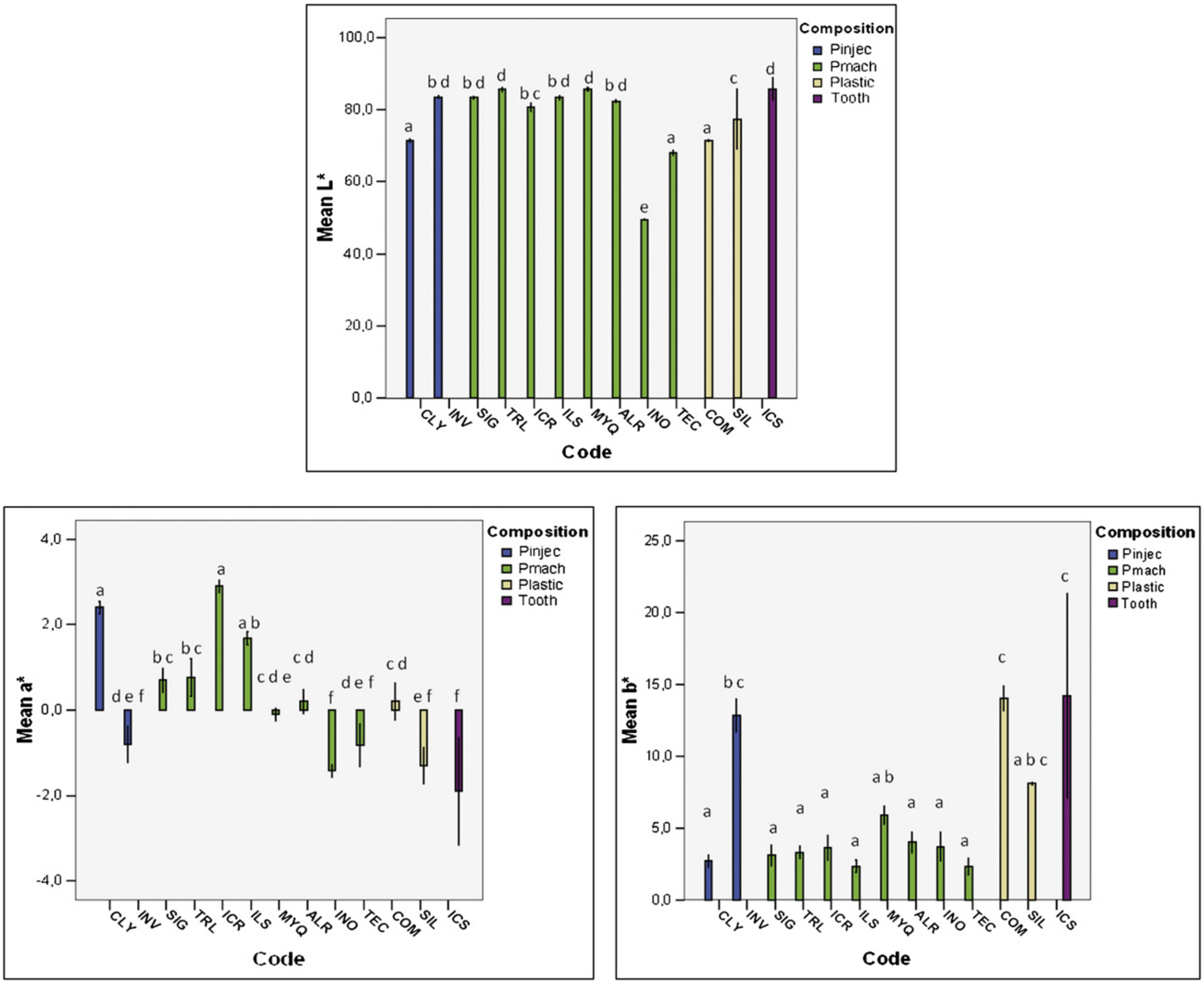

Fig 2. Color parameters (L * a * b *) of nontranslucent brackets and teeth with their standard deviations according to their composition (*Pinjec*, polycrystalline injected; *Pmach*, polycrystalline machined). Same letters indicate no significant statistical difference between groups (multiple comparison test of Scheffé).

Mean color parameters L * a * b * of the brackets and teeth (maxillary central incisors) with their standard deviations are shown in Figure 2.

The differences between the percentages of transmittance obtained between brands of brackets (translucent and nontranslucent) were statistically significant ($P < 0.01$). Figure 3 shows the means and standard deviations of the percentages of transmittance of the brackets according to type and brand. Among the brands, the Radiance translucent bracket showed the greatest amount of direct light transmission, with 38.8% transmittance, and the nontranslucent Tecnident had the least, with 0% transmittance. Among the nontranslucent brackets, Illusion was outstanding with 21.4% transmittance. The color difference between the brands of brackets (translucent and nontranslucent) was statistically significant ($P < 0.01$). The color differences of the teeth with translucent and nontranslucent brackets are shown in Table II.

The brackets tested showed no fluorescence, but, after being bonded, the translucent brackets had a different behavior from the nontranslucent in the visual appearances of the teeth (Fig 4).

DISCUSSION

The color of natural teeth depends on the ability to modify the wavelength of light that falls on them, and several factors involving enamel and dentin interfere in this process.[26]

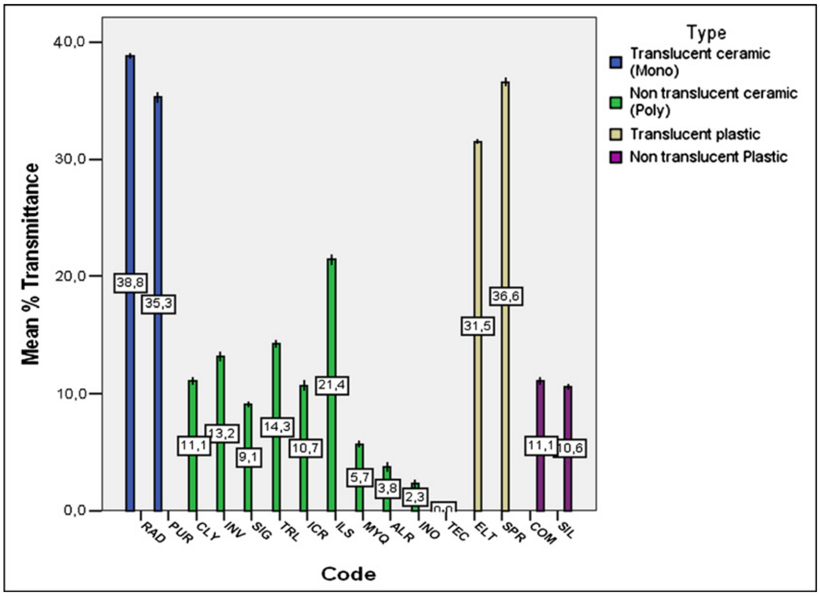

Fig 3. Percentages of transmittance and standard deviations of the brackets according to type.

Enamel has a characteristic translucency, and the more mineralized it is, the more it will allow visualization of the subjacent dentin. The color of the dentin is yellowish, and its thickness acts directly on the final color of the tooth. More mature teeth are more yellow than young teeth as a result of dentin thickness that increases with time from the formation of secondary dentin.[27,28]

The parameters of natural tooth color vary according to the measurement protocol used, race, sex, and age.[19,29] Because of this, color guides or spectrophotometers are used for selecting the most suitable prosthetic and restorative material. Thus, it is easy to say that a brand of bracket of a certain color will not esthetically satisfy the requirements of all patients.

In this study, it was shown that the color parameters (L * a * b *) of natural teeth of our subjects ranged from 81.2 to 88.3, −2.6 to 0.4, and 8.6 to 25.1, respectively, in agreement with other studies.[30] The nontranslucent brackets had the following variations in color: L *, 49.4 to 86.0; a *, −1.6 to 3.0; and b *, 1.9 to 14.6.

The bracket color parameter L *, which represents the color values from black to white (light), had the greatest agreement with that of natural teeth. Of the 14 brands of nontranslucent brackets evaluated, 6 (Mystique, Translux, InVu, Illusion, Signature, and Allure) showed luminosity without a statistically significant difference from that of the teeth ($P > 0.05$).

For the color parameter a *, which measures the axis from green to red, only 4 brands (InVu, In-ovation, Tecnident, and Silkon Plus) had no statistically significant difference from that of the teeth ($P > 0.05$). For b *, which corresponds to the yellow to blue axis, only 2 brands (InVu and Composite) ($P > 0.05$) showed this result.

Table II. Means and standard deviations of color differences between the translucent and nontranslucent brackets with teeth

		Nontranslucent	*Translucent*
	Code	*Mean (SD)*	*Mean (SD)*
Ceramic	RAD	-	5.4 (0.5)
	PUR	-	6.5 (0.3)
	CLY	18.6 (0.2)	-
	INV	3.1 (0.7)	-
	SIG	11.5 (0.4)	-
	TRL	11.1 (0.5)	-
	ICR	13.0 (0.6)	-
	ILS	12.5 (0.5)	-
	MYQ	8.4 (0.6)	-
	ALR	10.8 (0.8)	-
	INO	27.7 (0.7)	-
	TEC	21.2 (0.7)	-
Plastic	ELT	-	7.2 (1.1)
	SPR	-	6.0 (0.4)
	COM	14.4 (1.0)	-
	SIL	8.7 (1.1)	-

Among all the brands tested, only InVu, a polycrystalline ceramic bracket made by means of injection, showed a good relationship with natural teeth regarding the 3 color parameters.

Although 1 or 2 units indicated differences in color,[31] most studies accept the limit of color difference as equal to 3.7 units; these differences are clinically visible.[32]

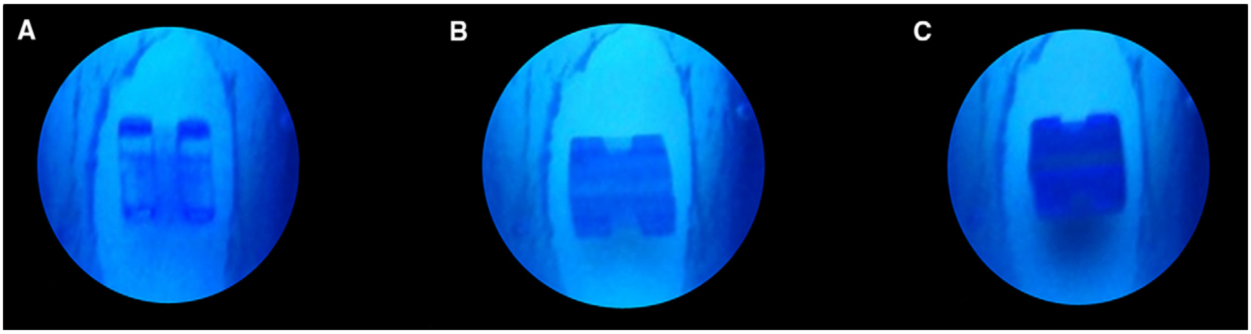

Fig 4. Visual behavior of teeth with translucent and nontranslucent brackets when irradiated with ultraviolet light: **A,** translucent bracket (Radiance); **B,** nontranslucent bracket (Illusion); **C,** nontranslucent bracket (Tecnident).

According to the color difference between the brands of nontranslucent brackets and teeth, INV (color difference, 3.1) was the only brand that was visually imperceptible (color difference, <3.7). However, the difference in color was determined with the mean color of the teeth, and there were considerable variations in the color parameter b* (8.6-25.2). This indicates that, on average, it is imperceptible, but when evaluated individually, it could be perceptible in some cases. Moreover, because the bracket base is made of composite to facilitate debonding after treatment, its color can be changed.

Polycrystalline ceramic brackets made with machining techniques are more commonly used and popular, because of their relative ease of production and cost benefit. However, according to our studies, they did not show a good color relationship with natural teeth (P <0.01), since they are whiter (L*, 77.3 ± 11.9; a*, 0.4 ± 1.3; b*, 3.5 ± 1.1) and visually perceptible (color difference, >3.7). The fact that they are whiter might be related to an emerging trend in American culture for whiter teeth.[33] These brackets are most indicated for patients with a compatible tooth color, because their teeth either were previously bleached or are less calcified. Nevertheless, more clinical studies should be conducted.

Thus, to meet the preestablished requisite of diminished visual perception, manufacturers of both polycrystalline (injected and machined) and plastic nontranslucent brackets need to make available colors and nuances that are more compatible with natural teeth.

According to several studies, structural morphologic (thickness and geometry) and compositional factors of the brackets significantly affect the direct transmission of light and therefore the polymerization of adhesives.[17,25] In this in-vitro study, the direct transmission of light of brackets ranged from 0.0% to 38.8% transmittance, and, as expected, the translucent type had better performance, ranging from 31.5% to 38.8% transmittance; Radiance was the most translucent among the monocrystalline ceramic brackets (38.8% transmittance), and Spirit MB was the most translucent among the plastic brackets (36.6% transmittance), with a statistically significant differences between them (P <0.01).

On average, the nontranslucent brackets showed little direct light transmission: 9.4% ± 5.6% transmittance. Illusion, with 21.4% transmittance, had the greatest, probably due to structural morphologic factors, and Tecnident, with no transmittance, had the least, which was probably due to a compositional factor. According to the manufacturer, Tecnident has zirconia with alumina in its composition, making it more opaque and thus hindering direct light transmission.

However, the percentage of transmittance of translucent brackets did not make them visually imperceptible (color difference, <3.7), because, to achieve this, they would need greater translucency. Nevertheless, it made them less perceptible than the nontranslucent type; it is easier to obtain esthetic success with these brackets, because it is not necessary to correlate the bracket color with that of the tooth. However, translucence alone does not make it the best choice. In addition to this, it should have good physical, mechanical, and bonding properties, and good color stability. Because of this, further studies evaluating these physical properties must be conducted.

To deserve the adjective *esthetic*, these devices must mimic the subjacent tooth, as already reported, and have compatible optical properties, either through the correlation of colors or the translucency of the bracket. However, an optical property inherent to the teeth and important for the esthetic appearance during exposure to ultraviolet light, whether daylight or night-club black light, is fluorescence. A structure is considered fluorescent if it absorbs the light energy from ultraviolet radiation and reemits the visible light spectrum.[34] This property was not found in any bracket evaluated. However, when translucent orthodontic brackets are bonded to teeth and exposed to ultraviolet light, they allow the natural fluorescence of the tooth to pass through (Fig 4). Nevertheless, because the nontranslucent types are not fluorescent and do not allow the fluorescence of the tooth to pass through, the esthetic appearance of the tooth is damaged (Fig 4). This is why it is necessary to incorporate this property into nontranslucent brackets, to make them less perceptible when they are exposed to ultraviolet light. However, further studies are necessary to quantify the fluorescence of teeth with these brackets and clinically evaluate their esthetics.

It is important to know the optical properties of both the teeth and the brackets, so that orthodontists can achieve better results in esthetic appearance when selecting the brackets. The color of the patient's tooth is the most important factor; before installing the esthetic bracket, one should make a careful evaluation of color, especially on the maxillary anterior teeth, since they are the most visible. When the color of the patient's teeth is not similar to the color of nontranslucent bracket, the selection of a translucent bracket is most proper, but a good bonding material, with its color matching and color stability, is essential for not interfering with the final results. Further studies on this issue need to be undertaken.

The purpose of this study was to evaluate only the influence of the optical properties of esthetic brackets in visual perception. More studies evaluating the optical properties of the wires and elastics are important because they can influence the esthetic performance of brackets. The clinical combination of bracket, wire, and ligation is also important to achieve the best esthetic result.

CONCLUSIONS

From this study, the following can be concluded.

1. The optical properties of esthetic brackets have a direct influence on visual perceptions.
2. Translucent brackets in addition to the nontranslucent InVu were less visually perceptible in natural light, but color stability must be considered.
3. Although they showed no fluorescence, after being bonded to the teeth and exposed to ultraviolet light, translucent brackets showed better behavior regarding the visual appearance of the teeth.

Further clinical studies are necessary to evaluate the influence of the optical properties of these brackets on esthetics and the distance at which these brackets are not visually perceptible.

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