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Perceptibility and Acceptability of Surface Gloss Variations in Dentistry

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Clinical Relevance

The surface gloss of esthetic restorations is a determinant in accurately mimicking dental structures in terms of tooth proportion and visual perception. Restorative protocol choices might be guided by understanding the threshold of perceptibility and acceptability of gloss differences.

SUMMARY

Objective: To assess the visual perception of observers regarding perceptibility and acceptability of surface gloss variations of resin composites and to determine the limit of perceptibility and acceptability of gloss variations.

Methods: Eight resin composite specimens and one human tooth specimen were fabricated. The resin specimens were polished to reach a surface gloss, in gloss units (GUs), of 10 GU, 20 GU, 30 GU, 40 GU, 50 GU, 60 GU, 70 GU, and 80 GU, and the human tooth specimen had a surface gloss of 80 GU. Sixty observers were selected to compare the surface gloss of the specimens in a light booth. For the perceptibility assessment, specimens were randomly displayed two at a time. Each observer performed a total of 144 observations. Observers answered two specific questions for determining the level and limit of perceptibility of gloss variations. The acceptability limit of gloss was determined by comparing the resin specimens with the tooth specimen. The observations were performed with dental practice scenarios (illuminant conditions, visualization field, and observers' education). Data were submitted to a nonlinear probit model and nonlinear regression estimation probit (5%).

Results: Differences in perceptibility and acceptability were observed for surface gloss variations (ΔGU) ($p<0.001$). Perceptibility in-

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creased with ΔGU (10<20<30<40<50=60=70), while acceptability decreased with ΔGU (0=10>20>30>40>50>60=70). Acceptability and perceptibility limits were 6.4 GU and 35.7 GU, respectively.

Conclusions: Perceptibility and acceptability of surface gloss are influenced by gloss variations. A variation of 6.4 GU was required for 50% of observers to notice gloss variations. Concerning acceptability, observers required a variation of 35.7 GU to consider differences in gloss not acceptable.

INTRODUCTION

Esthetic restorative treatments strongly rely on the material's optical properties for accurate tooth mimicking. Besides the color of resin composites, it has also been reported that translucency, fluorescence, and surface gloss strongly affect the final result of esthetic restorations.[1-3] Esthetic issues might be noticed when the resin gloss is different from dental enamel or other restoratives present in the mouth.[4] Still, specularity (gloss) is capable of altering color perception,[5] which may favor restoration optical outcomes. Thus, the study of surface gloss of resin composites is of great relevance in dentistry.[6]

In clinical practice, accurate restoration finishing and polishing might affect the way light reflects on the tooth surface, generating larger areas of reflection. This alters esthetics, especially the perception of tooth size and shape.[7-9] It is also known that restorations with increased roughness, besides causing esthetic problems, might also lead to greater biofilm retention.[10]

Objective gloss (measured by a glossmeter) is the amount of light reflected on an object's surface at a determined angle (20°, 60°, or 85°) and presenting the same angulation toward light incidence, but in the opposite direction,[11] compared with a polished standard. Although the objective gloss information is of extreme relevance to perform *in vitro* studies, in clinical practice, objective gloss eligibility is unfeasible, given that teeth and/or restorations do not possess a perfectly flat surface (an important attribute for objective gloss interpretation). Furthermore, the subjective qualification of this property is routine in the dental field.

Although it is common to find a variety of studies regarding surface gloss in the dental literature, limited data address the visual perception of gloss of dental materials by observers. Some data support a positive correlation between surface gloss perception and surface roughness.[12] However, most studies in that field are limited to presenting a decrease in gloss value related to artificial aging and/or surface gloss obtained through finishing and polishing equipment, with gloss variations assessed in percentage[13] or in gloss units.[14-17] Other than the studies highlighting this feature, the real impact of gloss variations in clinical practice is poorly explored, considering the fact that the human eye's capability to perceive gloss intensity and optical variations is unknown. This supports the need for studies assessing the perception of surface gloss of dental materials.

Thus, if surface gloss perception is targeted, various aspects should be considered. The visualization field, type of illuminant, surface characteristics of materials, color, and color of background may affect the perception of gloss.[11,18] It is also known that gloss perception is not only influenced by the material's intrinsic characteristics, surface features, and illuminants but also by the observer's educational level.[11]

Within the reported context, considering dental practice peculiarities such as illuminating type, visualization field, and observers' instruction, the present study aims to evaluate the observers' visual perceptions in relation to the perceptibility and acceptability of surface gloss variations of resin composites. The null hypothesis of the present study, considering the included parameters, is that there is no difference in the levels of perceptibility and acceptability according to the studied gloss differences.

METHODS AND MATERIALS

The study was approved by the local Institutional Review Board under protocol #1.824.169. Methodology will be divided into two sections for facilitated comprehension.

Perceptibility Analysis

Resin Specimen Fabrication—Eight specimens were fabricated with the nanofilled resin composite Filtek z350 XT (3M ESPE, St Paul, MN, USA). Stainless steel matrices with 6-mm-diameter orifices and of varying thicknesses, were used. First, a 1-mm-thick matrix was used for fabricating the dentin shade (A2D) portion of the specimen. Resin was inserted into the cylindrical orifice in a single increment and light activated for 40 seconds, using light-emitting diode light (Radii-Cal, SDI, Victoria,

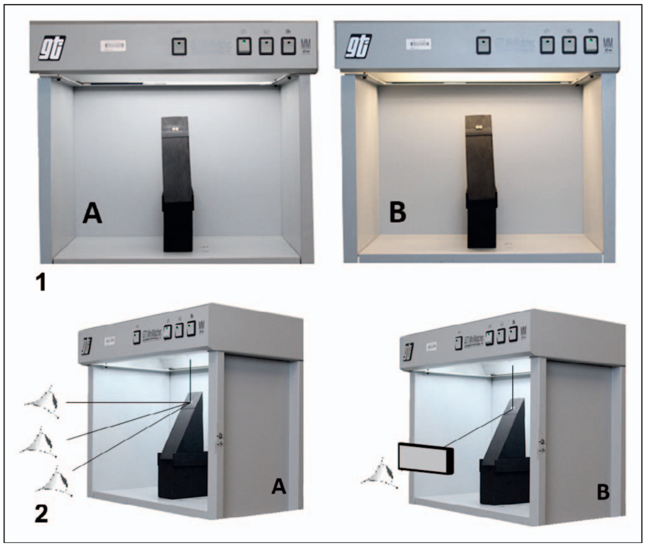


Figure 1. *Light booth with different illuminant exposures. (A): D65 light; (B): Fluorescent light.*

Figure 2. *Representative figure of the visualization field for the light booth. (A): Nonfixed visualization field; (B): Visualization field at 60°.*

Australia) at 900mW/cm^2 and assessed by a radiometer.

Next, a 1.5-mm matrix was used. Dentin resin specimens (A2D) were inserted into the orifices, leaving a 0.5-mm space free of restorative material. A2E resin was then inserted in a single increment, covered with a Mylar strip, and pressed with a glass slide. The resin composite was light activated for 40 seconds. Specimens 1.5 mm thick were obtained with 1 mm in the A2D shade and 0.5 mm in the A2E shade.

Specimen Polishing Assessment

All specimens received an initial surface polishing (A2E resin surface) with abrasive disc grits #1200 and #2400 (Fepa-P, Extec, Enfield, CT, USA). The specimens were mounted in a polishing machine (DP-10, Panambra, São Paulo, SP, Brazil) at 300 rpm under distilled water cooling for 30 seconds for each abrasive disc. Then the specimens received different polishing protocols using abrasive disc grits #1200, #2400 and/or #4000 according to the surface gloss to be achieved. Abrasive discs were fixed to a flat surface and used under water irrigation. Polishing was performed with circular movements (resembling a number 8) holding the specimen by the thumb with no pressure, following a previously described protocol.[19] Such movement allowed the surface to be polished leaving no surface scratches.

Following the polishing procedure, the specimens were immersed in an ultrasonic bath to remove residues. Then, the surface gloss was measured. The accepted variation considering each target group was ±0.9. Polishing was repeated in cases where the surface gloss did not match the specimen's group. Gloss was measured using Novo-Curve (Rhopoint Instrumentation, East Sussex, UK) with a 2 × 2 mm square area and 60° of geometry (light incidence), with values expressed in gloss units (GU).[20-22] A metallic positioner was used to block and eliminate possible environment light interference.[23] Three random measurements were performed for each specimen on the A2E resin surface, and the average obtained was used as the final gloss value. The 60° of geometry was chosen considering the targeted gloss values were within the medium gloss range.[24,25]

Specimens were allocated according to surface gloss into 10 GU, 20 GU, 30 GU, 40 GU, 50 GU, 60 GU, 70 GU, or 80 GU groups.

Selection of Observers—Sixty observers between 18 and 50 years old were selected: 20 laypeople (no graduation and no relation to dentistry), 20 undergraduate dental students (fifth and sixth semester students who have initiated clinical practice), and 20 dentists (with more than two years of practice).[26] The sample size considered previous studies on the perceptibility and acceptability of color, in which 20 observers per groups were required.[23] Participants were included after written consent was signed.

To participate, observers could not have visual impairment. If they did, then participants were required to have visual correction near 10/10 (or 10/3 on the metric scale) according to the Snellen visual graph.[27] This means participants should be able to visualize at least 80% of letters in line 10 at a distance of 3 m from the graph. Participants were also questioned about stereoscopic vision and asked to report possible differences in vision between the two eyes, which was expected to be normal.[27]

Assessing Gloss Perception—Specimens were randomly arranged in the light booth (Elcometer 6300 MM-4E, Gti, New Jersey, USA), two at a time. Specimens were positioned so to allow light incidence of different illuminants (D65 and fluorescent light; Figure 1A,B) on the specimen's surface at a light reflection angle of 60°.

Of the observers, 50% first observed the specimens' surfaces at a nonfixed angle of visualization during gloss qualification, followed by one of the selected illuminants. After those observations, the booth was closed and observers performed gloss qualifications at a 60° angle (Figure 2A,B).

The other 50% of the observers started with the gloss qualification at a 60° angle, followed by observations in a nonfixed angle of visualization.

All observers performed assessments with a nonfixed angle of visualization and a predetermined angle of visualization at 60° under the two illuminants (D65: daylight and fluorescent light), for a total of 28 combinations of specimen evaluations under each condition. Observers performed random observation of specimens. To avoid eyestrain, observers were given five-minute breaks after each 30 minutes of analysis.[28] Any combination of specimens observed always presented gloss differences. Observers were given no previous explanation about surface gloss.

Perceptibility of surface gloss was collected from the answers of the following questions: (1) Do both specimens present the same surface gloss? and (2) If no, which one presents the greater surface gloss?).

Acceptability Study

For acceptability, all resin composite specimens (used in the perceptibility study) were randomly compared with a polished human tooth specimen.

Fabrication of the Human Tooth Standard Specimen—An anterior human tooth in the A2 shade, assessed with Vita Classical scale (Vita Zahnfabrik, Bad Säckingen, Germany), was selected and observed by three observers at different periods. The tooth was sectioned 2 mm below the cementoenamel junction. Afterward, an enamel/dentin disc with a 6.0 mm diameter was cut with a trephine diamond bur connected to a drilling bench machine.

Then, the dentin surface was exposed and ground with abrasive disc grit #800 (Fepa-P, Extec) and mounted in a polishing machine (DP-10, Panambra) at 300 rpm with a load close to 100 g under irrigation until the dentin thickness reached approximately 1.0 mm. Thereafter, the flat part was placed inside a metallic device with a depth of 1.5 mm and ground, resulting in a 1.5 mm specimen (0.5 mm enamel and 1 mm dentin).

Polishing Human Tooth Specimen—The human tooth specimen was polished to 80 GU using abrasive disc grits #1200, #2400, and #4000 (Fepa-P, Extec). The specimen was coupled to a polishing machine (DP-10, Panambra) at 300 rpm with an approximate load of 100 g under distilled water cooling for 30 seconds per disc. After the polishing procedure, the specimen was immersed in an ultrasonic bath to remove residues. The specimen's gloss was measured, using the Novo-Curve, right after polishing and immediately before the observations took place. Three measurements were performed, and the average obtained was used as the final value (80 GU, variation of ± 0.90 at most).

Surface Gloss Assessment in Relation to Acceptability—For the acceptability study, the resin specimens (10 GU, 20 GU, 30 GU, 40 GU, 50 GU, 60 GU, 70 GU, and 80 GU) were randomly and individually arranged in the light booth (Elcometer 6300 MM-4E, Gti) together with the human tooth specimen (80 GU). Specimens were adapted to a device that allowed light incidence (D65 and fluorescent light) toward the specimen's surface at a 60° angle.

All observers performed their observations with nonfixed and 60° angles of visualization under both illuminants. To avoid eyestrain, observers were given five-minute breaks after each 30 minutes of analysis.[28]

Observers answered two questions. First: Do both specimens present the same surface gloss? In case of a positive answer, there were no further questions and the possible gloss difference was considered acceptable. However, in case of a negative answer, the second question was asked: Would this difference be clinically accepted in an anterior restored tooth?

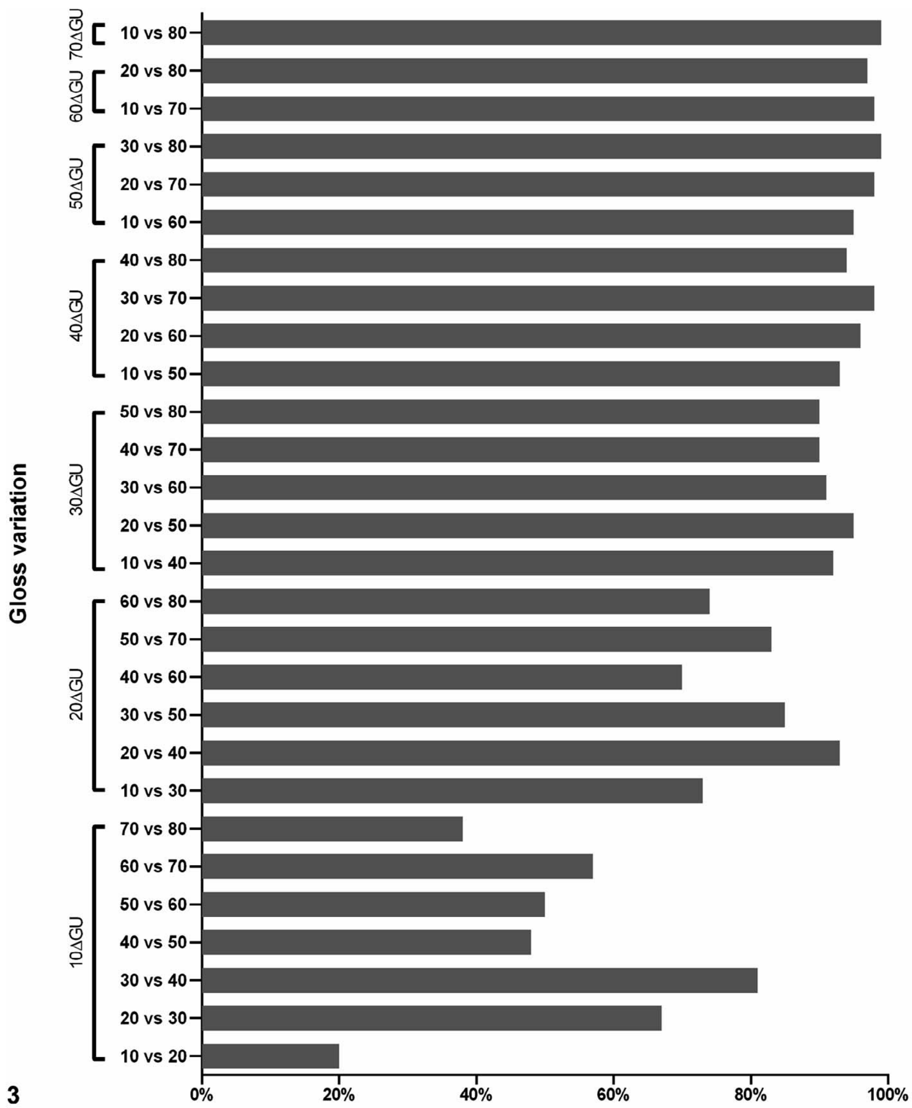
Analysis of Variables—Perceptibility and acceptability data were submitted to a linear/nonlinear regression probit model (5%),[29] which presents the binary response as the dependent variable (right or wrong answer on surface gloss assessment) and the frequency variable (number of right and wrong answers) and gloss variations as the independent variables.

RESULTS

Each observer assessed 112 perceptibility combinations and 32 acceptability combinations, with two illuminants and two visualization field methods, totaling 144 observations per observer.

Perceptibility and acceptability descriptive analyses are presented in Figures 3 and 4, respectively, by means of the percentage of obtained right answers.

The percentage of gloss perceptibility and acceptability, considering the observers, resulted in differences among gloss variations (ΔGU) ($p<0.001$), according to probit regression analysis. For perceptibility, increased gloss variations (ΔGU) resulted in an increased perception by observers, with no differences among ΔGUs 50, 60, and 70 (ΔGU $10<20<30<40<50=60=70$). For acceptability, in-



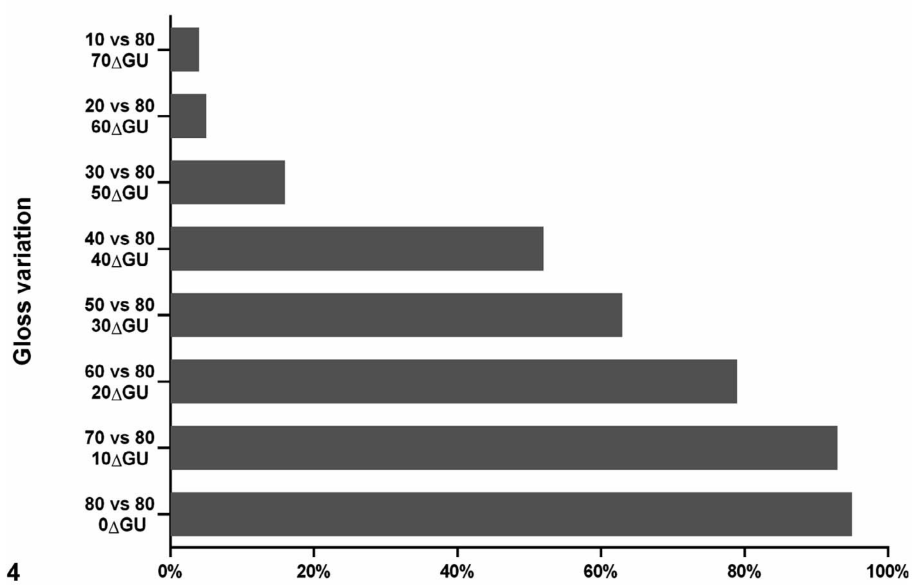
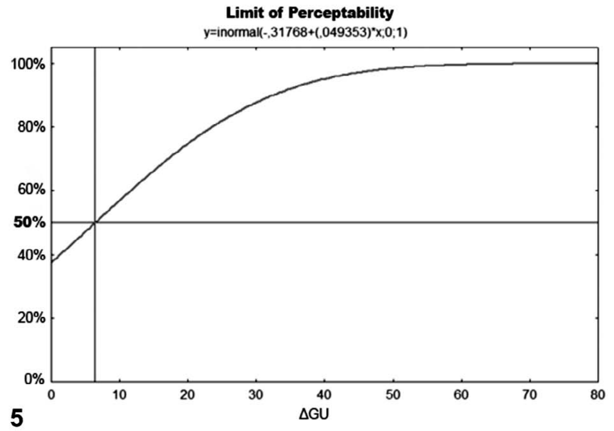


Figure 3. *Percentage of perceptibility by observers according to differences in gloss of specimens. The x-axis is arranged according to the percentage (%) of detected differences. The y-axis represents the difference of gloss (ΔGU) and the combination of specimens assessed.*

Figure 4. *Percentage of acceptability by observers according to differences in gloss of specimens. The x-axis is arranged according to the percentage (%) of accepted differences. The y-axis represents the difference of gloss (ΔGU) and the combination of specimens assessed.*



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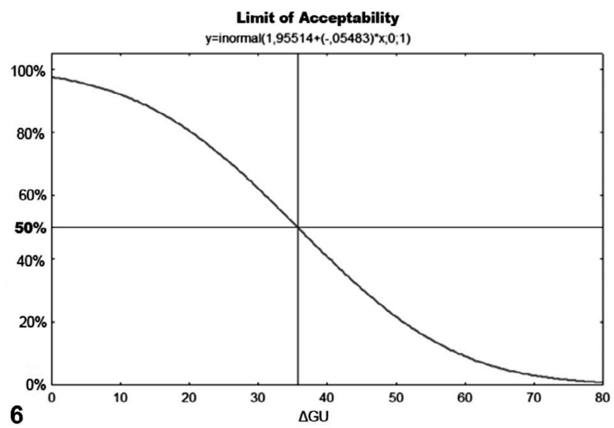

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Figure 5. *Limit of perceptibility at 6.4 ΔGU defined by probit nonlinear regression. The x-axis presents the ΔGU values. The y-axis shows the estimated percentage of observers perceiving the difference. The limit of perceptibility is defined by the ΔGU, in which 50% of observers perceive the gloss difference. ΔGU indicates the difference of gloss.*

Figure 6. *Limit of acceptability at 35.7 ΔGU defined by probit nonlinear regression. The x-axis presents the ΔGU values. The y-axis shows the estimated percentage of observers accepting the difference. The limit of acceptability is defined by the ΔGU, in which 50% of observers still accept the gloss difference. ΔGU indicates the difference of gloss.*

creased gloss variations resulted in decreased acceptability levels, with no acceptance differences between 0 and 10GUs, and between 60 and 70GUs (ΔGU 0=10>20>30>40>50>60=70).

The limit of perceptibility for surface gloss, determined by nonlinear estimation probit, taking into account the value in which more than 50% of observers detected differences, was 6.4 GU.

In relation to the limit of acceptability, defined as the value in which half of the observers would still accept gloss differences in a restoration, the value was 35.7 GU.

Figures 5 and 6 correspond to the curves of perceptibility and acceptability, obtained by nonlinear regression, according to gloss variations. The figures also present the detected limits of perceptibility and acceptability of gloss variations.

DISCUSSION

There is no reported protocol for the methodology proposed in the present study. Thus, considering two main aspects (complexity in gloss observation and possible variables in the observation process), the methodology was designed to include the greatest number of variations in order to obtain an overall scenario for surface gloss perception and acceptability in dentistry. The questions, sample size of observers, and sample arrangements were based on studies determining the limit of perceptibility and acceptability of differences in the color of restorative materials.[26]

In relation to the gloss evaluation, it is known that the subjective assessment of surface gloss seems to be a complex task.[30] It is reported that observers, in general, consider two aspects to classify gloss: (1) the amount of light reflected on a surface and (2) the sharpness of images seen from a reflective surface.[31] No previous information was provided to the volunteers regarding gloss properties and gloss observation; thus, the study considered the previous education of volunteers. In order to obtain a general overview of possible variations in the observers, various volunteers were included in the study (laypeople, dental students, and dentists). The authors do not know if educated observers would perform better, suggesting an area for new studies to assess that concern.

The possible variables affecting the visualization process were exposure to different illuminants (D65 and fluorescent light)[32,33] and the angle of visualization of specimens (nonfixed or at 60°). Two illuminant types, D65 and fluorescent, were used in this study, as D65 (daylight representative) and fluorescent (light representative of houses and business facilities) illuminants are considered the most frequent in the daily routine.[32,33] A material's characteristics are differentiated by light reflection.[34] If a large portion of light is diffusely reflected, one perceives the material as having a rough and spongy surface, like a plaster surface. On the other hand, if spectral reflection is more prevalent, one perceives the material as having a glossy and polished surface, like metals.[34] Besides the specular reflection areas, gloss might be regulated by the object's sharpness, contrast, and surface curvature.[30]

The angle of visualization can also affect the surface gloss qualification in terms of time, as observed in the present study (data not shown). This assumption is related to the fact that while observing the same object under different angles of light incidence, observers presented a visual compensation toward the incidence of light, leading to no significant differences in gloss assessment.[35] This is named *gloss constancy*, and this compensation might also be influenced by the angle of observation. The two visualization possibilities in the present study were used to reduce the influences of routine exposure esthetic restorations undergo.

The null hypothesis was rejected. As expected, the perceptibility of gloss increased with increasing gloss differences (ΔGU 10<20<30<40<50=60=70) (Figure 3). No differences were detected after ΔGU of 50, mainly due to the high rates of detected differences in those combinations. Acceptability, on the other hand, increased with decreasing gloss variations (ΔGU 0=10>20>30>40>50>60=70). No differences were detected in the two extremes in gloss differences (ΔGU of 0 and 10 or ΔGU of 60 and 70) (Figure 4). The patterns of perceptibility and acceptability are similar to the findings in studies on color assessment of restorative materials[26] and a preliminary study on gloss assessment.[19] Although the observed pattern was expected (Figures 3 and 4), the importance of the present results is related to the fact they might be used to compare or support studies or to indicate that new studies associating gloss with roughness and biofilm accumulation in clinical scenarios are needed.

The gloss variation used in this study took into account data obtained in a systematic review,[6] which gathered GU values for different finishing and polishing devices in different types of resin composites. In such a revision, the gloss minimum value was 12.5 GU, and the gloss maximum value was 94.7GU. Based on those values, the variation adopted in the present study was 10 to 80 GU, with an interval of 10 GU.

It is reported that gloss perception presents breakpoints in the observation pattern in areas close to 20 GU and 80 GU.[25] That condition was noticed in the present study, once the perception of gloss variation was hindered, in combinations of 10 vs 20 GU and 70 vs 80 GU (Figure 3).

The results of the present study might not be completely related to clinical conditions, especially due to the characteristics of specimens, polishing protocols, and assessment conditions. The specimens used during the study were flat and regular and had no mesostructures (bumps on the surface), which might have facilitated the qualification of surface gloss.[32] In clinical practice, other elements should be considered. The human anterior tooth presents depression areas near the mesial and distal line angles, which results in greater light reflection.[7,9] However, this feature cannot be evaluated in laboratory conditions, as a flat surface is required for assessing a specimen's objective gloss. Any surface irregularity would change the direction of light reflection, leading to an incompatible amount of luminosity received by the sensor, therefore compromising the gloss results. Thus, the polishing might not be related to clinical protocols and may be a possible limitation of the study while considering clinical extrapolation.

Still, specimens were placed inside the light box under a black matte background. In a study by Doerschner and others,[36] the authors concluded that spheres were perceived as glossier when analyzed on a black background instead of a white one. According to the authors, dark backgrounds lead to a glossier appearance of objects. Thus, the present data might have been different if a white background had been used. Considering that the background of teeth in clinical conditions is usually dark, the use of a black background may be more realistic for the clinical scenario. Overall, a 6.4 GU was achieved as the limit of perceptibility and 35.7 GU as the limit of acceptability, meaning that 50% of the observers detected differences of 6.4 GU and accepted differences up to 35.7 GU (Figures 5 and 6). These data may strongly support the discussion of future studies assessing different polishing protocols or analyzing resin characteristics in relation to surface gloss toward aging.

Rodrigues-Junior and others[17] assessed the effects of different finishing and polishing protocols, together with different types of resin composites, in relation to the objective gloss. According to that study's data, Z350XT resin surface polished with the Superflix device presented average surface gloss values of 41.32 GU, while the same resin polished with DFL presented values of 52.4 GU. The variation was even larger when the authors compared Enhance and Sof-Lex devices, with surface gloss results at 14 and 59 GU, respectively. In light of the present perceptibility results, different polishing systems might lead to different gloss results that are visible to the human eye. Moreover, knowing the average values between Enhance and Sof-Lex, if two restorations in the maxillary anterior teeth were polished with each device, it is likely that the esthetic issues would be perceived and that the treatment would not meet patient expectations once the previously defined gloss difference is greater than the acceptability limit, as presently detected.

However, there is an obstacle when exploring this study in clinical practice. In a real situation, several other elements might influence surface gloss qualification. The oral cavity is an area full of shadows, impairing light incidence and reflection. Teeth may present mesostructures that would possibly cause different reflection patterns. In addition, the presence of saliva on the dental surface is likely to completely modify the perception and/or evaluation of this optical property. New studies should be carried out to complement the present results, taking into consideration other aspects that may influence surface gloss in dentistry.

CONCLUSIONS

Based on the study methodology, it can be concluded that increasing gloss variations resulted in greater perceptibility and reduced acceptability. A variation of 6.4 GU is required so that 50% of observers notice the differences between two composite specimens regarding surface gloss. In relation to acceptability, a variation of 35.7 GU is necessary for observers to reject the gloss differences in the restoration treatment.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the ICT - UNESP. The approval code for this study is: #1.824.169.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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