

## Wear of depth perception and shade matching outcome in the pre-clinical setting

Percepção da profundidade de desgaste e compatibilidade de cor no ambiente pré-clínico

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### ABSTRACT

**Objective:** The present study investigated whether the perception of dental wear depth by undergraduate students has influence on the final color of direct anterior restorations performed on artificial teeth. **Material and Methods:** Eighty-one participants were assigned to one of three groups (n = 27): G1, beginning dental students; G2, intermediate dental students; and G3, advanced dental students. To investigate dental wear depth perception, each undergraduate student received one manikin containing an intact upper central incisor and a flyer instructing the technique of tooth preparation for veneer. All groups were required to prepare 1mm in depth. Dental wear depth was analyzed using a thickness gauge. Subsequently, teeth were restored with opaque or translucent composite resin using a pre-shaped matrix. Color was measured by means of a spectrophotometer (L\*a\*b\* system). Data were statistically analyzed by the Kruskal-Wallis and Dunn's post hoc tests ( $\alpha = 5\%$ ). **Results:** Dental wear depth was different among all groups ( $p < 0.05$ ). G1, G2 and G3 obtained a median of 1 mm, 0.5 mm and 0.8 mm, respectively. G3 presented more accuracy in the dental wear depth. Color values did not vary according to the dental wear depth or to the type of resin composite used in the restoration ( $p > 0.05$ ). **Conclusion:** Technical training and clinical experience contribute to the better dental wear depth perception of undergraduate dental students. In the pre-clinical setting, dental wear depth has little or no influence on the final color of direct anterior restorations. Moreover, regardless to the type of resin composite used, all restorations performed on artificial teeth had similar aesthetic outcome.

### RESUMO

**Objetivo:** O presente estudo investigou se a percepção de profundidade de desgaste dental por alunos de graduação tem influência sobre a cor final de restaurações anteriores diretas, realizadas em dentes artificiais. **Material e Métodos:** Oitenta e um participantes foram divididos em três grupos (n = 27): G1, estudantes do início do curso de odontologia; G2, estudantes de odontologia de nível intermediário; e G3, estudantes de odontologia de nível avançado. Para investigar a percepção de profundidade de desgaste dental, cada aluno de graduação recebeu um manequim que continha um incisivo central superior intacto e instruções sobre a técnica de preparação do dente para faceta direta. Todos os grupos foram instruídos a realizar os preparos com 1 mm de profundidade. A profundidade de desgaste dentário foi analisada utilizando um espessímetro. Posteriormente, os dentes foram restaurados com resina composta opaca ou translúcida utilizando-se uma matriz de pré-moldada. A cor foi medida por meio de um espectrofotômetro (L \* a \* b \*). Os dados foram analisados estatisticamente pelo teste Kruskal-Wallis e post hoc de Dunn ( $\alpha = 5\%$ ). **Resultados:** A profundidade do desgaste dental foi diferente entre todos os grupos ( $p < 0,05$ ). G1, G2 e G3 obtiveram uma média de 1, 0,5 e 0,8 mm, respectivamente. G3 apresentou maior precisão na profundidade de desgaste dental. Os valores de cor não variaram de acordo com a profundidade de desgaste dental ou para o tipo de resina utilizada na restauração ( $p > 0,05$ ). **Conclusão:** A formação técnica e experiência clínica contribuiu para uma melhor percepção de desgaste dental em profundidade por estudantes de graduação em Odontologia. Na configuração pré-clínica, a profundidade de desgaste dental teve pouca ou nenhuma influência sobre a cor final de restaurações anteriores diretas. Além disso, independentemente do tipo de resina composta usada, todas as restaurações realizadas em dentes artificiais tiveram resultado estético similar.

## KEYWORDS

Dental education; Motor skills; Color; Dental esthetics.

## PALAVRAS-CHAVE

Educação em Odontologia ;Destreza Motora; Estética Dental; Cor.

## INTRODUCTION

The acquisition of psychomotor skills by undergraduate students is an important step in the dental education. In fact, the technical ability to properly execute tooth preparation is essential to attend patient needs – either functional or aesthetic – and might be developed with practice [1-5]. Despite of that, the acquisition of such competence is desirable in an early context during the undergraduate program, prior to performing procedures that may be invasive and/or irreversible in patients [6]. In the pre-clinical disciplines, operative procedures are taught on bench-top typodonts-mounted manikins adapted to phantom heads. Accordingly, manikins are well controlled and uniform as simulating training devices [7]. On the other hand, manikins lack details that may impair the learning of mechanical and aesthetic concepts in operative dentistry.

Depth perception, in particular, is an important parameter in the dental practice [8]. The aesthetic result of direct restorations performed with resin composite is highly affected by the color, opacity, and light transmission of the remaining tooth [9]. In this sense, in the majority of cases, the tooth background governs the depth of tooth preparation and, consequently, the thickness and type of dental material to be inserted [10]. Accordingly, shallow or very deep tooth preparations may directly interfere in the aesthetic quality of the final dental restoration [10]. Nonetheless, such correlation may not be true in the pre-clinical setting once artificial teeth used worldwide contain limitations, such as a standardized background, an incongruous color with natural teeth and an undefined limit between enamel and dentin “tissues”.

Many studies so far have investigated how undergraduate dental students evolve throughout the dental course or how their psychomotor skills vary in comparison to experienced professionals [2,4,5,8,11]. Nevertheless, few studies have assessed whether educational tools used in the pre-clinical settings are reproducing or not important aspects of the clinical practice. In accordance, the improvement of educational tools could help speed up the acquisition of psychomotor skills. In order to evaluate dental manikins as suitable models of the clinical settings, this study aimed to investigate whether dental wear depth perception of students in different levels of the dental course has influence on the final color of aesthetic direct restorations performed on artificial teeth.

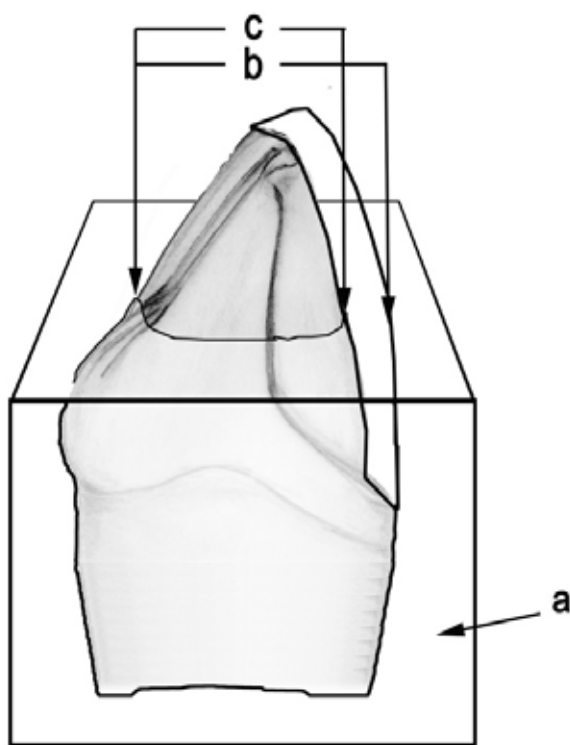
## MATERIAL AND METHODS

This study was previously approved by the Research Ethics Committee of the School of Dentistry, University of São Paulo (CAE: 03325012.0.0000.0075). All participants were asked to sign an informed consent form to participate in the study.

Eighty-one participants were assigned to one of three groups according to the progressive levels of the dental course (n = 27 per group): group 1 (G1), consisting of students from the 6th semester who were finishing the pre-clinical discipline of indirect operative dentistry (ODP); group 2 (G2), consisting of students from the 7th semester who were finishing the clinical discipline of indirect operative dentistry (ODC); and group 3 (G3), consisting of students from the eighth semester who had passed both ODP and ODC.

To investigate their dental wear skill, each undergraduate student received a drill

kit (#1013; #4138; #4142; #4141; #2135F; #2135FF (KG Sorensen, Cotia, SP, Brazil), one typodont-mounted manikin model (P-oclusal Produtos Odontológicos Ltda, São Paulo, SP, Brazil) containing an intact upper left central incisor (21 element), and a flyer instructing the technique of tooth preparation for veneer. The ideal dental wear depth was considered to be 1 mm. Thus, the students were asked to perform the preparation of tooth 21 with a highspeed handpiece using the maximum period of 20 min. Dental wear depth was measured using a thickness gauge (GOLGRAN Indústria e Comércio de Instrumentos Odontológicos Ltda, São Caetano do Sul, SP, Brazil) positioned at the geometric center of the labial surface of the upper central incisor. The final wear was calculated by subtracting the thickness of the intact tooth by the thickness of the worn tooth (Figure 1).



**Figure 1** - Measuring procedures of the dental wear depth. A silicon mold device was used to standardize the procedures (a). The initial measurements using a thickness gauge are represented in (b) and the final measurements in (c). Dental wear depth was calculated by subtracting distance (c) from (b).

Subsequently, the teeth were randomly restored using a transparent silicon matrix (FGM Produtos Odontológicos, Joinville, SC, Brazil) to standardize the dental shape. The silicon matrix was molded over an intact tooth, which was used as a model. Next, the missing volume of each worn tooth was filled with opaque (AO3) or translucent (A3) composite resin (Charisma Opal, Heraeus Kulzer GmbH, Gruner Weg, BE, Germany). As the silicone matrix provided a smooth and uniform tooth surface, no finishing nor polishing was performed on the surface of the restorations. All procedure described above was performed by one trained operator.

The color of the restorations was recorded using a digital spectrophotometer model CM-3700A (Konica Minolta Inc., Chiyoda-ku, TKY, Japan). The digital spectrophotometer measures color variables as defined by Commission Internationale de L'Eclairage [12]. Accordingly,  $L^*$  represents the value (lightness or darkness),  $a^*$  is the measurement along the red-green axis (redness), and  $b^*$  is the measurement along the yellow-blue axis (yellowness), thus allowing one to determine the colors in a three-dimensional space. The overall color change  $\Delta E$  was determined using the following formula:  $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ . The  $\Delta E$  values are calculated to verify whether the changes in the overall shade are perceivable by a human observer. The difference was obtained based in the mean values of the color of the teeth with 1 mm of dental wear restored with opaque or translucent resin composites (Gold Standard).

A plane silicon (Clonage, Nova DFL, Rio de Janeiro, RJ, Brazil) matrix was manufactured to ensure the repeated positioning of the instrument's measuring-head aperture on the same surface area of each restored tooth. The matrix consisted of a central niche produced by an intact upper left central incisor – 21. In this manner, each restored tooth could be fitted in a parallel position with the instrument's measuring-head aperture to standardize all

measurements. The center of the readable area was coincident with the geometric center of the labial surface of the teeth.

### Statistical Analysis

All data were recorded in GraphPad Prism 5.0 statistics program (GraphPad Software Inc., La Jolla, CA, USA). Comparison between groups related to differences in dental wear depth and in  $L^*$ ,  $a^*$ , and  $b^*$  values of restored teeth were analyzed using the Kruskal-Wallis and Dunn's post hoc tests according to a significance level of 5%.

## RESULTS

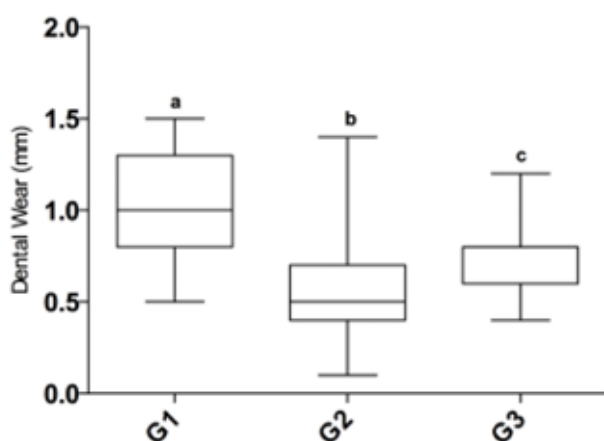
Data from the dental wear analysis are presented in Figure 2. The comparison of the three undergraduate student groups showed significant difference among them ( $p < 0.0001$ ). The results can be better analyzed by the median parameter. The median of G1 was of 1 mm, as required by the technique. The median of G2 was of 0.5 mm, while the median of G3 was of 0.8 mm (coinciding with the 75% percentile).

It could be observed that G2 executed shallower tooth preparations than did G1 and G3 ( $p < 0.0001$ ). G3 presented more homogeneous results, with the majority of tooth preparations

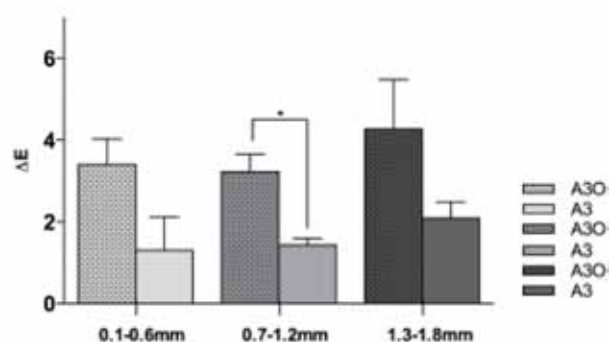
ranging from 0.6 to 0.8 mm. In addition, outliers of G3 were closer to the recommended dental wear depth than were those of G1 and G2.

Table 1 depicts the spectrophotometer measurements in relation to the wear thickness and type of resin composite. The values  $L^*$ ,  $a^*$ , and  $b^*$  did not vary among the arbitrary ranges of dental wear thickness within the same resin composite group ( $p > 0.05$ ). This could be observed for both opaque and translucent resin composites. Color value comparisons between A3O and A3 groups were significantly different in the mild and deeper ranges of dental wear (0.7-1.2 mm and 1.3-1.8 mm, respectively). Higher scores for  $a^*$  (more redish in color) and  $b^*$  (more yellowish in color) could be observed for the A3 group, while the  $L^*$  value (lightness) was higher for the A3O group ( $p < 0.0001$ ).

$\Delta E^*$  values are presented in Figure 3. No statistically significant differences could be found regarding  $\Delta E^*$  values among the different ranges of dental wear within the same resin composite group. On the contrary, in the dental wear range of 0.7-1.2 mm a significant difference between the A3O and A3 shades could be observed ( $p < 0.0001$ ). Intact teeth presented  $L^* = 67.1 \pm 0.02$ ,  $a^* = 0.221 \pm 0.1$  and  $b^* = 18.3 \pm 0.9$ .  $\Delta E^*$  values between intact teeth and teeth with 1 mm of wear depth restored with either opaque or translucent resin were  $\Delta E^*$  12.29 and 5.98, respectively.



**Figure 2** - Comparison of dental wear thickness produced by undergraduate students allocated in three different levels of the dental course groups. Different letters indicate significant differences among groups.



**Figure 3** -  $\Delta E$  values of the different arbitrary ranges of dental wear between A3 and A3O resin composite groups and within the same resin composite group. Asterisk indicates significant difference between the A3 and A3O resin composite groups.

**Table 1** - Means and standard deviations of the spectrophotometer measurements of color values according to the arbitrary ranges of dental wear and resin composite group

Dental Wear	A30			A3		
	L*	a*	b*	L*	a*	b*
0.1-0.6mm§	69.55(1.63) <sup>abA</sup>	-1.22(0.57) <sup>abA</sup>	6.39(3.93) <sup>abA</sup>	66.99(1.26) <sup>abA</sup>	0.34(0.53) <sup>abA</sup>	11.61(1.25) <sup>abA</sup>
0.7-1.2mm§	69.93(1.55) <sup>abA</sup>	-1.32(0.61) <sup>abA</sup>	5.17(3.15) <sup>abA</sup>	66.2(1.19) <sup>abB</sup>	0.46(0.28) <sup>abB</sup>	11.98(0.97) <sup>abB</sup>
1.3-1.8mm§	70.86(1.11) <sup>abA</sup>	-1.77(0.97) <sup>abA</sup>	3.17(4.23) <sup>abA</sup>	64.98(1.20) <sup>abB</sup>	0.65(0.16) <sup>abB</sup>	11.25(0.95) <sup>abB</sup>

§ Means (standard deviation), \*Color values are lightness (L\*), redness (a\*) and yellowness (b\*)

Means with identical lowercase letters in the same columns for each group are not statistically different

Means with identical capital letters for each group and each color value within the same rows are not statistically different

## DISCUSSION

Development of operative skills in a pre-clinical environment is of relevance for the training of undergraduate students in restorative dental courses [10]. Depth perception is particularly difficult to be estimated, especially in the early years of the dental course [5]. Nonetheless, slight changes in the instructional process could make a significant difference in the improvement of dental students' performance, including the prevention of procedural errors related to manual skills. The paucity of research in this field has drawn attention to issues derived from the dental education process and how to solve them, focusing on a translational proposal. With this in mind, this study was conducted to investigate the dental wear depth perception of undergraduate students at different levels of the dental course and whether or not this factor influences the final color of dental restorations.

It was observed that undergraduate students presented different dental wear abilities as they progress throughout the dental course. Most undergraduate students at the beginner level have shown obedience to the technical recommendations for tooth preparation for veneers. As previously reported in the literature, [13] the greater contact with teaching materials, laboratory training, and demonstration procedures may have contributed to the positive outcome of this group. Nevertheless, G1 presented a greater range of depth wear measurements than did the other groups. In fact, accuracy appears to improve with clinical experience [5].

Intermediate level undergraduate students (G2) presented, on the whole, the shallowest tooth preparations. These students were evaluated after they had completed the indirect clinical discipline (ODC). In the ODC, the majority of possible clinical interventions include onlays and total crowns in posterior teeth. Veneer cases are very infrequent, especially when considering the socioeconomic factors of the underserved population assisted by the oral health services of the School of Dentistry, Universidade de São Paulo. In this light, most of the students from the G2 group did not practice tooth preparation for veneers. Their slight contact with the theoretical and practical aspects of this technique and little time of clinical practice may have compromised their depth perception during tooth preparation.

In the group of more advanced undergraduate students, although all tooth preparations were lagging behind the requested dental wear depth, the majority achieved results close to the desirable levels. Moreover, tooth preparations from the G3 group proved to be more homogeneous than the others, which reflect the better motor coordination of these undergraduate students during dental wear. These findings were also observed in previous studies, although performed under different experimental conditions [1,5]. The increased security and greater clinical experience of these students may have influenced these favorable results.



Regardless of the beginner level of undergraduate students, most participants tended to underestimate the dental wear depth to be executed. This result can be closely related to the findings of Dimitrijevic and others, [5] who have investigated distance, depth perception, and writing tasks among dental students and dentists. The participants estimated depth perception and distance by observation or executing a mark of a specific distance on paper. The authors found that the participants tended to overestimate depth and distance when they were merely observing. On the contrary, they tended to underestimate values when they were required to execute marks. Interestingly, the authors concluded that even experienced dental practitioners were unable to gauge small measurements appropriately. Likewise, when undergraduate students from the present study were requested to perform tooth preparation, they showed the same trend of participants from the previous study, underestimating the dental wear depth. Findings from Dunne [14] also corroborate with the present study's results, since they observed that visual perception of a "dental" millimeter is consistently smaller than a "real" millimeter.

Spectrophotometers have been used to measure the color of a wide range of materials and substrates [15]. These instruments include a stable light source and have been used to measure the reflectance of light within the entire visible spectrum [15,16]. Data from the spectrophotometric analysis have shown that, regardless of the dental wear depth executed within the same resin composite group, all restorations had no significant differences among their color values. This was observed for both opaque and translucent resins. Differences between A3O and A3 could be observed for all color values ( $L^*$ ,  $a^*$ , and  $b^*$ ) in mild and deeper dental wear depth. The A3 group showed positive scores for  $a^*$  (more redish in color), higher  $b^*$  (more yellowish in color) and lower  $L^*$  values than the A3O group ( $p < 0.0001$ ). The  $a^*$  and  $b^*$  increase in magnitude for more saturated or intense colors [17]. The  $L^*$  is a measure of lightness, where perfect black has an

$L^*$  value of zero and a perfect reflecting diffuser has a  $L^*$  value of 100 [17]. Accordingly, artificial teeth restored with opaque resin composite have shown improved aesthetics, closer to the natural teeth, than teeth restored with A3 resin composite. Nonetheless, this outcome may have been skewed by the high contrast ratio ability of opaque resin composite, which covered the yellowish background of artificial teeth.

The human ability to perceive a threshold can vary from  $\Delta E^* = 1.0$  to  $\Delta E^* = 3.7$  units in the literature [18-20]. Under controlled conditions, color differences of less than  $\Delta E^* = 1.0$  are visually detectable by 50% of human observers [18]. However, under less controlled clinical conditions, only color differences above  $\Delta E^* = 3.7$  can be noticed by human observers [19,20]. In this study, despite the significant difference between A3 and A3O resin composites in the dental wear range of 0.7-1.2 mm, only the  $\Delta E^*$  value for the opaque resin at the dental wear range of 1.3-1.8 mm was slightly above the perceivable threshold (3.7 units). This result indicates that restoring artificial teeth with any range of dental wear depth, irrespective to the resin type, produced similar aesthetic outcomes.

Typodonts are important tools used to teach operative procedures in a pre-clinical environment and has contributed to operative skills acquisition on the part of dental students [7]. Although the use of typodonts is employed worldwide, the model does have some limitations. In addition to artificial tooth rigidity being incongruous with natural tooth tissues, perfect shade matching of resin composites is impossible or hard to achieve on artificial teeth. A recent study has shown that typodonts are poor predictors of undergraduate students' clinical performance on patients [7]. In fact, the overall color change between intact artificial teeth and teeth restored with opaque and translucent resin composites were way above the perception threshold. Bearing this in mind, one can affirm that appropriate shade matching between commercially available resin composites and artificial plastic teeth is very unlikely, maybe even considering a stratification technique.

In this study, no correlation between dental wear depth and the final color of restored artificial teeth was observed. This means that, in the pre-clinical environment, it does not matter if the dental wear depth produced is deep, middle-term, or shallow. Whenever the tooth preparation is restored, the final color of the dental restorations will always be quite similar. This finding does not corroborate with the clinical settings, given that translucency and depth are completely intertwined in a dentist's routine [10]. Considering this, the characterization of artificial teeth with color, hue, and chroma closer to the natural tooth or produce artificial teeth compatible-resin composites may improve the teaching of restorative dentistry in the pre-clinical environment. Moreover, producing artificial teeth in different grades of severity of tooth staining and presenting clear limits between enamel and dentin may also contribute to improve operative dentistry teaching.

## CONCLUSION

In this study, although dental wear depth perception increased according to the progress of undergraduate students throughout the dental course, it had little or no influence on the final color of direct anterior restorations performed in the pre-clinical setting. Indeed, regardless to the type of resin composite used, all restorations performed on artificial teeth had similar aesthetic outcome.

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