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Original Article

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Effect of different placement techniques on color stability and surface roughness of resin composites

Efeito das técnicas de inserção e alisamento na estabilidade de cor e rugosidade superficial de resinas compostas

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Resumo

Introdução: A longevidade e o sucesso clínico das restaurações dentárias podem ser influenciados por muitos fatores durante os procedimentos restauradores. **Objetivo:** Avaliar a influência da técnica de alisamento na estabilidade de cor e rugosidade superficial de duas resinas compostas. **Material e método:** Os grupos de amostras (n=10) foram divididos conforme a resina composta (Filtek™ Z250 XT e Filtek™ Z350 XT) e as técnicas empregadas: tira de poliéster, espátula, pincel seco, selante de superfície. A cor e a rugosidade da superfície foram avaliadas por espectrofotômetro (espaço de cor CIELab) e rugosímetro (corte padrão de 0,8 mm), respectivamente, após o armazenamento em água. Posteriormente, as amostras foram imersas em café por 48h e a cor final foi aferida. Os dados foram analisados usando teste ANOVA e Tukey *post hoc* (α = 5%) e a correlação entre rugosidade da superfície (R_a) e variação de cor (ΔE_{ab}) através do coeficiente de correlação de Pearson. **Resultado:** As técnicas de alisamento influenciaram a R_a e a ΔE_{ab} em ambas as resinas compostas. Os grupos tratados com selante de superfície apresentaram maior diferença na ΔE_{ab}. A resina Filtek™ Z250 XT apresentou maior estabilidade de cor comparada à Filtek™ Z350 XT, independentemente da técnica utilizada. A R_a das técnicas de alisamento foi semelhante entre os compósitos, exceto para o grupo do líquido modelador da Filtek™ Z350 XT, que apresentou os menores valores. Uma correlação entre R_a e manchamento (p = 0,268) foi identificada. **Conclusão:** A estabilidade da cor e a R_a são influenciadas pelas técnicas de alisamento utilizadas.

Descritores: Materiais dentários; estética dental; coloração.

Abstract

Introduction: Longevity and clinical success of dental restorations can be influenced by many factors during the restorative procedures. **Objective:** This study aimed to evaluate the influence of different placement techniques on color stability and surface roughness of two resin composites. **Material and method:** The groups of specimens (n=10) were divided according to resin composite (Filtek™ Z250 XT and Filtek™ Z350 XT) and placement technique: Mylar strip, spatula, dry brush, modeling liquid, and surface sealant. Color stability and surface roughness were accessed using a spectrophotometer (CIELab color space) and a rugosimeter (standard cutoff of 0.8 mm), respectively, after water storage. Subsequently, the specimens were immersed in coffee for 48 h and final color was measured. The data were analyzed using ANOVA and the Tukey's *post hoc* test (α=5%) and the correlation between surface roughness (R_a) and color change (ΔE_{ab}) was assessed using the Pearson's correlation coefficient. **Result:** The different placement techniques influenced R_a and ΔE_{ab} on both resin composites. The groups treated with surface sealant showed greater difference in ΔE_{ab} for both resin composites. The Filtek™ Z250 XT resin showed greater color stability compared with the Filtek™ Z350 XT resin regardless of the placement technique used. R_a of each placement technique was similar among the resin composites except for the Filtek™ Z350 XT modeling liquid group, which presented lower R_a values compared with those of Filtek™ Z250 XT. A correlation between R_a and staining was identified (p=0.268). **Conclusion:** Color stability and R_a are influenced by different placement techniques.

Descriptors: Dental materials; dental esthetic; staining.

INTRODUCTION

Resin composites are frequently applied in esthetic dental restorations[1]. The use of these composites through well-executed techniques provides restorations with excellent clinical performance over time and, due to their positive mechanical and optical properties, they are presented as a conservative solution for many cases[2].

Resin composite composition and properties play an important role in the longevity and esthetics of restorations[3]. In general, these materials are basically composed of an organic matrix, inorganic filler particles, a silane coupling agent, and curing initiators[4,5]. The size and arrangement of filler particles are directly related to the surface roughness (R_a) of resin composites. Rough surfaces may increase the susceptibility of staining by deposition of pigments, favor plaque accumulation and, consequently, the development of gingival inflammation and secondary caries[6,7].

The introduction of nanoparticles represents an evolution of these materials. Increased filler content provides smoother surfaces as a result of the smaller size and better distribution of the fillers in the resin matrix[8]. The characteristics of the monomers present in the organic matrix are also important to the clinical performance of resin composites. Hydrophobic monomers are associated with greater color stability compared with hydrophilic monomers, which tend to stain in higher proportions due to water affinity[8,9].

Longevity and clinical success of restorations may be influenced by factors related to operator experience as well as to the manipulation, insertion and smoothing techniques used during the restorative procedures[10,11]. The placement protocol used in clinical practice is partially applied empirically, and knowledge of its effects regarding the quality and longevity of restorations is still unclear[12].

There are many placement and smoothing techniques for direct resin composite restorations. The most commonly used are spatulas, Mylar strips, brushes, modeling liquids, and application of surface sealants to protect the restoration[12-14]. Although these techniques are widely applied, few studies have evaluated their effects on resin composite restorations. Most studies only compare different polishing procedures and evaluate the influence of surface sealants application on the R_a and color stability of materials[15-17]. Therefore, the influence of placement, manipulation and smoothing techniques on the quality and longevity of restorative procedures is still unclear, remaining an empirical issue.

In this context, this study aimed to evaluate the influence of placement techniques on the color stability and R_a of two resin composites. The null hypothesis tested was that the different placement techniques would not influence the R_a and color stability of the resin composites used.

MATERIAL AND METHOD

Study Design

This *in vitro* study evaluated the color stability and surface roughness (R_a) of the Filtek™ Z250 XT and Filtek™ Z350 XT (3M ESPE St. Paul, MN, USA) resin composites using different placement techniques: Mylar strip, spatula, dry brush, modeling liquid, and surface sealant application. Figure 1 presents the flowchart of study design and group division. The shade, composition, manufacturer, and batch number of the materials are described in Table 1.

Group Division and Specimen Preparation

The groups were divided according to resin composite and placement technique. A stainless steel matrix measuring 8.0 mm in diameter and 2.0 mm in thickness was used to prepare the disc-shaped specimens (n=10) by a trained and calibrated operator. The placement techniques used for each group preparation are described below:

Group 1 - Mylar strip

The resin composite was applied by placing an increment into the matrix using a spatula and covering it with a Mylar strip. In order to obtain a flat and uniform surface, a 2 mm-thick glass plate was placed over the Mylar strip. After that, the resin composite was light cured for 20 s on each side using a light-emitting diode (LED) (Bluephase, Ivoclar Vivadent, Schaan, Liechtenstein) with 1000 mW/cm^2 irradiance. After removal of the glass plate, the specimens were light cured for another 20 s and stored in distilled water at 37 ºC for 24 h.

Group 2 – Spatula

An increment of the resin composite was applied into the matrix and a flat and uniform surface was obtained using of a spatula (Suprafilln 1, SSWhite). Then the resin composite was light activated on both sides for 20 s as previously described. In order to ensure the complete polymerization of the surface layer, a glycerin gel was applied and additionally light cured for another 20 s. After that, the specimens were stored as previously described.

Group 3 - Dry Brush

The resin composite was placed as described for Group 2 and then a dry brush was used to obtain a smooth surface. The brush was gently applied on the surface twice in each direction according to the following sequence: from left to right; from right to left; from top to bottom; from bottom to top. After that, each specimen was light cured and stored as previously described.

Group 4 - Modeling liquid

This group followed the same sequence of the previous groups; however, instead of using only the dry brush, the resin composite was smoothed using a brush with a drop of adhesive (Adper Single Bond 2 - 3M ESPE, St. Paul, MN, USA), which was used as modeling liquid, and then light cured and stored as previously described.

Group 5 - Surface sealant

This group was prepared as in Group 2 and immersed in water for 24 h. Then the specimens were polished and the surface sealant was applied as follows: all specimens were gently dried with absorbent paper and etched with a 37% phosphoric acid for 30 s, rinsed for 60 s, and dried with a stream of compressed air. A drop of surface sealant (Natural Glaze, DFL, Jacarepaguá, RJ, Brazil) was gently applied using a brush according to manufacturer's instructions on the top surface of the specimen and light cured for 20 s. A glycerin gel layer was applied on the surface sealant and light cured for additional 20 s to prevent inhibition of the oxygen layer.

Storage and Polishing

After light activation, the specimens were stored in distilled water at 37 ºC for 24 h prior to polishing. All groups of specimens, expect the Mylar strip group, were polished under dry conditions using medium, fine and extra-fine abrasive discs (Soft – Lex Pop On, 3M ESPE, St. Paul, MN, USA). Each disc was used for 20 s with a hand piece (10,000 rpm) and discarded after use on six specimens. To remove debris after each stage, the specimens were rinsed with running water for 10 s and air dried for 5 s. After completion of the polishing stage and for the baseline condition prior to testing, the specimens were immersed again in water for 24 h as previously described and then had their color stability and R_a measured.

Staining

For color stability evaluation, all groups of specimens were immersed in coffee solution (3.6 g of coffee powder dissolved in 300 ml of boiling water according to manufacturer's instructions) at 37 ºC for 48 h[18].

Color Stability

Color stability was accessed before (baseline) and after coffee staining using a reflection spectrophotometer (SP60 - EX-Rite/Grand Rapid, MI, USA) in triplicate according to the CIE L*a*b* color space[19] (*Commission Internationale de I'Eclairage*). This color system is a tridimensional color measurement: L* refers to the lightness coordinate and its value ranges from 0 for perfect black to 100 for perfect white, a* and b* are chromaticity coordinates on the green-red (-a*=green; +a*=red) and blue-yellow (-b*=blue; +b*=yellow) axes.

Each specimen was positioned on a white background and evaluated under the same environmental conditions. Before color measurements, the spectrophotometer was calibrated according to the manufacturer's instructions. After staining, all specimens were rinsed with running water and dried with absorbent paper for final color measurement.

Color change was calculated according to CIELAB formula: $\Delta E_{ab} = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$.

Surface Roughness

Surface roughness (R_a) was assessed using a rugosimeter (Suftest SJ – 201P, Mitutoyo, Tokyo, Japan) with a diamond tip of 5 µm in diameter, angled 90^0 at 0.5 mm/s. A total of six measurements (R_a, µm) per specimen were performed: three in the *x*-axis and three in the *y*-axis. The cut-off used was 0.8 mm of 4 mm length. The R_a parameter was calculated by the average of the measures performed in the center of each specimen.

Statistical Analyses

Normal distribuition of the data was verified by the Shapiro-Wilk test. The mean ΔE and Ra values were analyzed by Two-way ANOVA and the Tukey's test (α=5%). The Student's *t*-test was applied to compare R_a and color stability between the resin composites (nanohybrid and nanofilled) (p<0.05) Correlation between R_a and ΔE_{ab} was verified using the Pearson's correlation coefficient. All data analyses were performed using the Statistical Package for Social Sciences Software (SPSS 20.0; SPSS, Chicago, IL, USA).

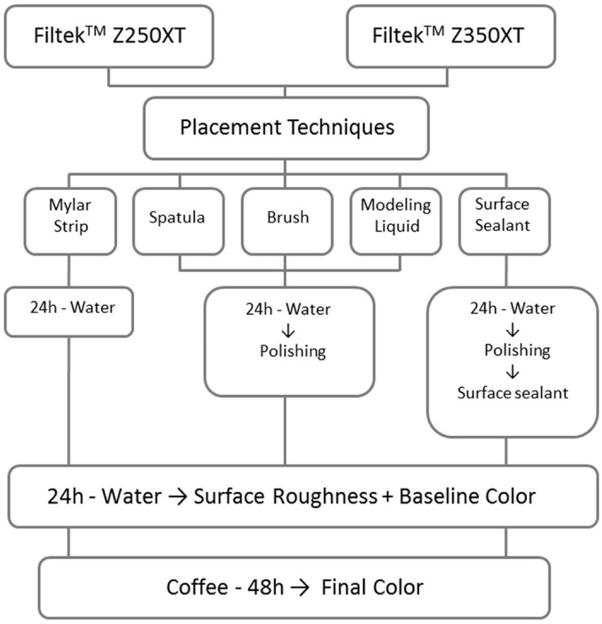

Figure 1. Flowchart of study design and group division.

Table 1. Shade, composition, manufacturer, and batch number of the materials used in this study

Material	Shade	Composition	Manufacturer	Batch Number
Filtek™ Z250XT (Nanohybrid)	A2	0.01 μm to 3.50μm Bis-GMA, UDMA BisEMA	3M ESPE (St. Paul, Minnesota, USA)	37277
Filtek™ Z350XT (Nanofilled)	A2E	0.004 μm to 0.02 μm Bis-GMA, UDMA BisEMA	3M ESPE (St. Paul, Minnesota, USA)	17664
Natural Glaze (Surface Sealant)	-	Bis-GMA, TEGDMA, 2,6-tert-butylphenol, ethylurethane, B200P, BenzylDimethylKetal, Camphorquinone, Quantacure EHA	DFL (Jacarépagua, RJ, Brazil)	12112053
Adper Single Bond 2 (Single Bottle Adhesive)	-	Bis-GMA, HEMA, dimethacrylates, polyalkenoic acid copolymer, camphorquinone, ethanol, water, dimethacrylate, glycerol 1.3, 10 wt% silica filler	3M ESPE (St. Paul, Minnesota, USA)	N504822

Captions: Bis-GMA: bisphenyl glycidyl dimethacrylate, UDMA: urethane dimethacrylate, BisEMA: ethoxylated bisphenol-A dimethacrylate, TEGDMA: triethylene glycol dimethacrylate.

RESULT

The color change (ΔE_{ab}) means and standard deviations obtained are presented in Table 2. Interaction between factors (resin composite and placement technique) was statistically significant (p<0.05). Intergroup analysis revealed a statistical difference between the resin composites for each placement technique, with lower ΔE_{ab} values for Filtek™ Z250 XT. Statistical difference was also observed in the intragroup analysis between the placement techniques for each resin composite. The highest ΔE_{ab} value was observed when surface sealant was applied to both resin composites.

Surface roughness (R_a) means and standard deviations are presented in Table 3. Intergroup analysis revealed the same R_a pattern between resin composites for each placement technique, except for the Filtek™ Z350 XT - modeling liquid group, which presented lower R_a values compared with the Filtek™ Z250 XT - modeling liquid group. Statistical difference was also observed in the intragroup analysis between the placement techniques for each resin composite. The lowest R_a value was observed in the Mylar Strip group for both composites. Similar R_a results were observed between the other placement techniques for Filtek™ Z250 XT. In contrast, the Filtek™ Z350 XT resin presented greater variation in the R_a pattern between the different placement techniques, with the highest R_a value obtained in the Spatula group.

The Pearson' correlation coefficient (0.268) revealed a weak and positive correlation between color stability and R_a.

Table 2. Color change (ΔE^*_{ab}, mean ±standard deviation) of resin composites and placement techniques

Resin Composites	Techniques				
	Mylar Strip	**Spatula**	**Dry Brush**	**Modeling Liquid**	**Surface Sealant**
Filtek™ Z250XT	5.65 (1.04)^{Aa}	6.22 (1.08)^{Aa}	5.89 (0.66)^{Aa}	5.60 (0.81)^{Aa}	9.73 (0.62)^{Ab}
Filtek ™ Z350XT	7.8 2 (0.89)^{Bb}	8.82 (0.82)^{Bc}	7.19 (0.69)^{Bab}	6.66 (0.59)^{Ba}	10.66 (0.77)^{Bd}

Different uppercase letters in columns indicate significant difference intergroup (p<0.05). Different lowercase letters in lines indicate significant difference intragroup (p<0.05).

Table 3. Surface roughness (R_a, mean ±standard deviation) of resin composites and placement techniques

Resin Composites	Techniques				
	Mylar Strip	**Spatula**	**Dry Brush**	**Modeling Liquid**	**Surface Sealant**
Filtek™ Z250XT	0.11 (0.02)^{Aa}	0.45 (0.13)^{Ab}	0.43 (0.12)^{Ab}	0.45 (0.09)^{Ab}	0.48 (0.11)^{Ab}
Filtek™ Z350XT	0.13 (0.05)^{Aa}	0.53 (0.10)^{Ac}	0.35 (0.14)^{Ab}	0.34 (0.12)^{Bb}	0.46 (0.12)^{Abc}

Different uppercase letters in columns indicate significant difference intergroup (p<0.05). Different lowercase letters in lines indicate significant difference intragroup (p<0.05).

DISCUSSION

Several placement techniques are applied during the insertion, accommodation, shaping, and contouring of resin composite restorations. Sculpting instruments, brushes, Mylar strips, modeling liquids, and application of surface sealants are widely used in clinical practice. Although these techniques are frequently used, few studies have evaluated their influence on the properties and final outcome of restorations[13,14,20].

Color stability of resin composites is an expected feature and, ideally, the restoration color should be stable overtime[13]. Due to esthetic demands, color change in resin composite restorations is considered as one of the major causes of restoration replacement in the anterior area[1,10]. Restorations with smooth surfaces and color stability depend on many factors, such as eating and parafunctional habits of the patient, ability and experience of the operator, and effectiveness of the polishing systems, as well as on properties and characteristics inherent in the resin composites and placement techniques[8,10,12,13,21].

Extrinsic discoloration of resin composites is considered a relevant issue for restoration longevity[12]. Absorption and adsorption of food and beverage pigments may lead to restoration degradation[14,22]. The present study used immersion in coffee for staining not only because this is a widely consumed beverage, but also because the coffee pigments have small molecular weight and can easily penetrate in the resin composite[22]. According to the National Coffee Association (NCA), the average daily consumption of coffee is 3.2 cups[23]. Assuming that the consumption time among coffee drinkers is of about 5-15 min, 48 h of immersion in coffee should simulate approximately two months of coffee consumption[18].

For accurate color measurement, objective methods are preferable over visual ones, because results are not affected by subjective interpretations[24]. In this study, color change (ΔE_{ab}) was evaluated using a spectrophotometer, which is an instrument that produces reliable values with excellent repeatability. Based on the results of the present study, the null hypothesis was rejected, since the placement techniques affected the color and surface roughness (R_a) of both resin composites.

Significant color change was observed among the resin composites regardless of the placement techniques used, with higher ΔE_{ab} for the Filtek™ Z350 XT resin. When visual perceptibility and acceptability thresholds were considered, although Filtek™ Z250 XT presented better color stability[25], both resin composites reached ΔE_{ab} values above the acceptable range, and would probably lead to replacement of the restoration for esthetic reasons. The increased staining susceptibility may be attributed to the composition of the resin composite organic matrix[1,8,14]. Filtek™ Z350 XT contains hydrophilic monomers, such as TEGDMA, which tends to present higher stain susceptibility by water sorption and transport of pigments through the resin matrix. In contrast, the monomers Bis-GMA, UDMA, and Bis-EMA present in Filtek™ Z250 XT provide it with higher hydrophobicity and, consequently, lower water uptake and greater color stability[8].

As the organic matrix, filler content plays an important role in color stability and R_a of resin composites. The presence of large inorganic particles and interstitial spaces increases roughness and stain susceptibility by facilitating the deposition of food pigments on the restoration surface. The combination of nanofillers in nanoclusters - as founded in Filtek™ Z350 XT - reduces the interstitial space between filler particles by increasing the percentage of fillers in the material and improving physical properties such as surface smoothness[8]. However, the present study revealed that Filtek™ Z350 XT presented similar R_a and lower color stability for most placement techniques compared with Filtek™ Z250 XT.

The present study revealed that surface sealant application resulted in higher ΔE_{ab} in both resin composites, even though the surface sealant was applied after polishing and was polymerized with glycerin gel to prevent the formation of oxygen-inhibition layer[21]. The higher ΔE_{ab} may be explained by the absence of inorganic fillers in the composition of the surface sealant used in this study, which may have favored the staining of the surface layer of the resin composite.

The critical value for mean R_a is 0.2 μm, i.e., R_a with higher threshold values tend to lead to bacterial accumulation and, consequently, to gingival inflammation or secondary caries[7]. This study found that Mylar strip was the only placement technique that provided R_a within the acceptable threshold (<0.2 μm) in both resin composites. The greater smoothness provided by the Mylar strip may be related to the presence of a larger amount of organic matrix on the restoration surface. These results are in agreement with those reported by Tuncer et al.[20], who obtained smoother surfaces with Mylar strips compared with those finished using aluminum discs.

Possible adverse effects caused by the placement techniques can be minimized by appropriate polishing techniques[13]. In the present study, the specimens were polished after different placement techniques - except for the Mylar strip - with a multi-step polishing system that provides excellent smoothness[20]. Higher R_a values were achieved with the Spatula and Surface Sealant techniques for the Filtek™ Z350 XT resin composite. Despite the fact that the same polishing system with standardized steps was applied in all test groups, it was not able to compensate the different types of voids left by the placement techniques.

Modeling liquids are used to facilitate the handling, accommodation and contouring of resin composites[12-14,20]. Color change of resin composites may be influenced by the composition of the modeling liquid. Hydrophobic adhesives, when used as modeling liquids, tend to present greater color stability, whereas adhesives with hydrophilic properties tend to present increased color change[12,14]. In the present study, Adper Single Bond was applied on the surface layer of the resin composites and, despite its hydrophilic nature, color and R_a were not negatively affected. These findings are in agreement with studies that evaluated the use of adhesives as modeling liquids[12,14].

Professionals should be aware of the effects of placement techniques and resin composite type on color and R_a of resin composites, because esthetic factors are one of the main reasons for resin composite restoration replacement on anterior teeth[10]. Current knowledge on placement techniques is limited and more studies are needed to elucidate the effects of the insertion protocols and placement techniques on the physical properties, esthetic outcome, and longevity of dental restorations.

CONCLUSION

Color stability and surface roughness (R_a) were influenced by the placement techniques. The nanohybrid resin composite (Filtek™ Z250 XT) presented greater color stability compared with that of the nanofilled resin composite (Filtek™ Z350 XT). Application of surface sealant resulted on greater color change (ΔE_{ab}) in both resin composites. The Mylar strip technique provided lower R_a in both resin composites.

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CONFLICTS OF INTERESTS

The authors declare no conflicts of interest.

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