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Microhardness, Color Stability and Microstructural Analysis of Prefabricated Composite Resin Veneers

Estudo da Microdureza, Estabilidade de cor e Microestrutura de Facetas Pré-Fabricadas de Resina Composta

Pedro Paulo Albuquerque Cavalcanti de Albuquerque*[ab]; Marina Barreto Pereira Moreno[c]; Alexander Cassandri Nishida[d]; Ezequias Costa Rodrigues Júnior[d]; Carlos Eduardo Francci[d]

[a]University of São Paulo, Stricto Sensu Graduate Program in Dentistry. SP, Brazil.
[b]Mauricio de Nassau University Center. PE, Brazil.
[c]University of Campinas, Stricto Sensu Graduate Program in Dental Materials. SP, Brazil.
[d]University of São Paulo, School of Dentistry. SP, Brazil
*E-mail: pedroalbuquerque2@gmail.com
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Abstract

The aim of the work was to determine Knoop microhardness (KH), color stability (ΔE00) and microstructure of prefabricated composite resin veneers (PCRVs). Two PCRVs systems (Componeer Brilliant New Generation, Coltene, Altstätten, Switzerland; and Direct Veneer, Edelweiss, Wolfurt, Austria) were tested. KH was measured at the buccal surface of the PCRVs. Color analyze was evaluated by a spectrophotometer and ΔE00 calculated using CIEDE2000 formula. Microstructure of the PCRVs was characterized using scanning electron microscopy (SEM). Data of KH and ΔE00 were subjected to One-way ANOVA followed by Tukey *post hoc* test (α=0.05). Componeer (KH = 46) and Edelweiss (KH = 43) presented statistical similar hardness results (p>0.05). Componeer ($\Delta E00_{water}$= 0.1 and $\Delta E00_{coffee}$= 13.4) showed lower ΔE00 than Edelweiss ($\Delta E00_{water}$= 0.5 and $\Delta E00_{coffee}$= 18.7). SEM-images indicated similar microstructures of the PCRVs tested. Although PCRVs present similar microhardness and microstructure, Componeer showed higher color stability and lower extrinsic pigmentation to coffee in comparison to Edelweiss. Direct composite resin veneer treatment might be simplified with PCRVs. However, the high pigmentation observed in the PCRVs could generate aesthetic failures over the time.

Keywords: Microscopy, Electron, Scanning. Color. Dental Veneers.

Resumo

O objetivo do trabalho foi determinar a microdureza Knoop (KH), estabilidade de cor (ΔE00) e a microestrutura de facetas de resina composta pré-fabricadas. Os sistemas de facetas Componeer e Edelweiss foram testados. Para cada sistema, a microdureza foi avaliada na superfície vestibular das facetas. A análise da estabilidade de cor foi feita mediante o emprego de um espectrofotômetro e a alteração de cor foi calculada seguindo a fórmula determinada pelo CIEDE2000. A microestrutura dos sistemas foi observada e caracterizada a partir de um microscópio eletrônico de varredura. Os resultados de microdureza e alteração de cor foram submetidos a análise de variância de um fator complementados pelo teste de Tukey (α=0,05). Os sistemas de facetas pré-fabricadas de resina composta apresentaram valores estatisticamente similares de microdureza (p>0,05). O grupo Componeer apresentou uma alteração de cor inferior em relação ao grupo Edelweiss. Os dois sistemas apresentaram uma elevada pigmentação após imersão em solução com café. A microestrutura dos sistemas se mostrou similar em função da avaliação das imagens em microscopia. Apesar dos sistemas apresentarem microdureza e microestrutura similares, o sistema Componeer gerou menor alteração de cor com menor pigmentação a bebida corante empregada em comparação ao sistema Edelweiss. A técnica de facetas dentárias pode ser simplificada utilizando um sistema de facetas pré-fabricadas de resina composta. Todavia, a elevada pigmentação observada no presente estudo deve ser levada em consideração já que o tratamento com esse tipo faceta tende a ser um procedimento estético com durabilidade elevada.

Palavras-chaves: *Microscopia Eletrônica de Varredura. Cor. Facetas Dentárias.*

1 Introduction

Composite resins are an aesthetic solution for restorative treatments on anterior and posterior teeth. To achieve this possibility, optical characteristics and mechanical properties of the composites were improved with the development of new monomers associated with nanometric fillers and silane coupling agent.[1,2] Nowadays, direct restoration with composite resin is the most executed restorative procedure in the clinical practice. Unfortunately, despite the large popularity of this material, composite restorations are not associated with primary caries lesions. The main reason is associated with the replacement of composite restorations with clinical evidence of secondary caries or material fracture/debonding.[3]

Regarding the technique, the insertion of the resin into the dental cavity can be done in a bulk or incremental step. It is important to highlight that special attention should be given to the handling of the material in order to achieve high degree of conversion and limited polymerization stress.[1,4] In addition, an appropriate light curing unit should be used to ensure a proper polymerization. The correct execution of the adhesive steps is also important to prevent failures of the treatment and the necessity of restoration replacement.

For the anterior teeth, direct composite veneer is commonly used in cases of replacement of large deficient restorations,

tooth fractures and to correct smile asymmetry.[3] Despite the several clinical indications, the time required to execute the veneer technique associated with the color instability of the composite can inhibit some dentists to perform the protocol.[5] In an attempt to simplify the clinical steps, an old concept of prefabricated composite resin veneers (PCRVs) was revitalized with release of Componeer (Coltene) and Direct Veneer (Edelweiss). PCRVs are manufactured under ideal polymerization conditions with controlled light, pressure and temperature.[6,7] The difference between these PCRVs systems is associated with a laser treatment applied on the buccal surface of Edelweiss.[6] It is suggested that this laser treatment aims to produce a smooth surface vitrification with increased hardness, wear resistance and color stability. Previous studies[8,9] reported that composites that received post cure heat treatment have higher mechanical properties in comparison to materials subjected solely to light activation. Nevertheless, the effect of the laser melting is still unknown.

At the present moment, there are no reports testing the PCRVs properties. Therefore, the aim of the present investigation was to determine Knoop microhardness (KH), the color stability (ΔE00) and microstructure of Componeer and Edelweiss. The first research hypothesis was that PCRVs will present similar KH and ΔE00 regardless storage condition. The second research hypothesis was that PCRVs will present similar microstructure.

2 Material and Methods

The composition of PCRVs are shown in Table 1. Upper large size veneers (#12 and #22) were selected to standardize the assessed area during the tests. PCRVs were evaluated in a stereomicroscopic (Olympus SZ61, New York, EUA) and veneers containing pores/bubbles/defects were eliminated.

Table 1 – Composition of the prefabricated composite veneers

Material	Composition	#Lot
Componeer Brilliant New Generation*	Organic Matrix: BISGMA, TEGDMA. Photoinitiator and co-initiators. Inorganic filler size 0.02 to 2.5µm (80 wt%)	1400004
Edelweiss Direct Veneers**	Highly filled nano-hybrid composite filling material (83 wt%)	14/03-127

*Coltene Whaledent; **Edelweiss Dentistry
Source: Componeer and Edelweiss brochure.

2.1 Knoop microhardness

PCRVs (n=3) of each system were selected and fixed in a metal plate with a conventional resin composite. The composite was photoactivated using a light curing unit (Valo Cordless, Ultradent, South Jordan, UT, EUA) with irradiance of 1.200 mW/cm^2, for 40 s. KH measurements were performed in a microhardness machine (Shimadzu, HMV-2, Tokyo, Japan) with a constant load of 100g for 15s. The load was applied at the buccal surface of the PCRVs as demonstrated in Figure 1. Six indentations per specimen were performed with a distance of 200 µm.

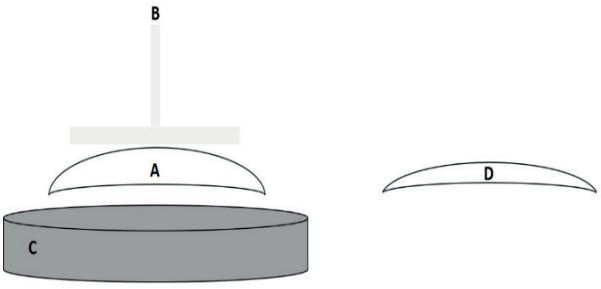
Figure 1 - Knoop hardness indentation positions.

Source: the authors

2.2 Color stability

Optical analysis was obtained using a spectrophotometer (CM-3700d, Konica Minolta, Tokyo, Japan) with a D65 illuminant and SCI condition. The measures were performed in reflectance mode using a standard white background (CIE L* = 91.3, CIE a* = -1.4, and CIE b* = 3.25). CIE L*, a*, and b*-values were automatically calculated by color data software. CIE L* is the lightness, with 100 for white and 0 for black. The CIE a* and CIE b*-axis are the red-green and yellow-blue chromatic coordinates respectively. A positive CIE a* or CIE b* value represents a red or yellow shade, and negative CIE a* or CIE b*, represents green or blue respectively. PCRVs (n=6) were selected and the inner edge of each veneer was polished with 600 grit SiC abrasive papers. A paralellometer was used during the polish procedure to ensure a similar wear with the maintenance of the original thickness at the center of the veneer (Figure 2). This procedure aimed to reduce the concavity of the veneers. This specific wear is similar to the clinical protocol of PCRVs and allows that veneer become flatter, not interfering in the spectrophotometer analysis. A water-based glycerin gel was interposed between the veneer and the background to maintain the optical continuity with no air influence. The optical measurements were peformed[10]: 1) dry condition at the buccal surface (baseline); 2) after 30 days in distilled water storage at 37 ºC; and 3) after 30 days in coffee storage (PCRVs were maintained in coffee for 10 minutes per day) at 37 ºC. Before each analysis, the veneers were washed with water and dried with absorbent paper. The coffee solution was made with 3.6g powder coffee (Melitta Extra Forte, Melitta do Brazil, São Paulo, Brazil) dissolved in 300 mL of distilled water. After 10 min of stirring, the solution was filtered with the aid of a filter paper (Melitta do Brazil, São Paulo, Brazil).[8] ΔE00 was calculated following the formula:[11,12]

Figure 2 - Illustration of the polishing procedure executed to reduce the concavity of the PCRVs. A – initial aspect of the PCRV; B – paralellometer used during polishing; C – abrasive paper fixed in an automatic polish machine; and D – final aspect of the PCRV.



Source: the authors

2.3 Scanning electron microscope (SEM)

PCRVs (n=3) were cleaned in ultrasonic bath with distilled water for 5 min. The veneers were dried in an oven with controlled humidity at 37 ˚C and gold-coated prior to the analysis. SEM-images were performed in a microscope Quanta 650 FEG (Bruker-FEI, Germany) with magnification of 130X, 8.000X, 30.000X and 100.000X at the transversal area of the veneer.

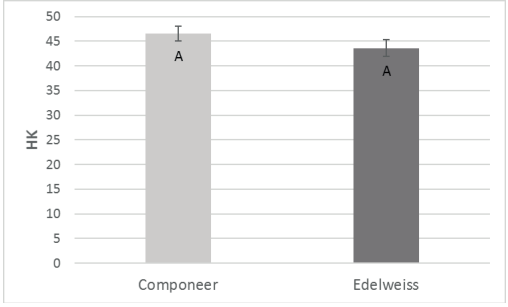
2.4 Statistical analysis

Data were subjected to normality and homoscedasticity tests. After that, the results of KH and ΔE00 were subjected to One-way ANOVA. All pairwise multiple comparison procedures were carried out by Tukey's *post hoc* method (α=0.05).

3 Results and Discussion

The results of KH are shown in Figure 3. Componeer and Edelweiss showed statistically similar KH values. The results of ΔE00 are expressed in Table 2. Componeer presented lower color difference in comparison to Edelweiss after storage in water and coffee. SEM-analysis of Componeer and Edelweiss are represented in Figure 4 (A, B and C) and Figure 5 (A, B, C and D) respectively. It is possible to observe similar microstructures for the veneer systems and no surface vitrification/melting was identified at the buccal surface of Edelweiss (Figure 5 – III and IV).

Figure 3 – Means* (standard deviations) of Knoop hardness (KH) results



*Different letters indicate significant statistical difference (p<0.05).

Source: the authors

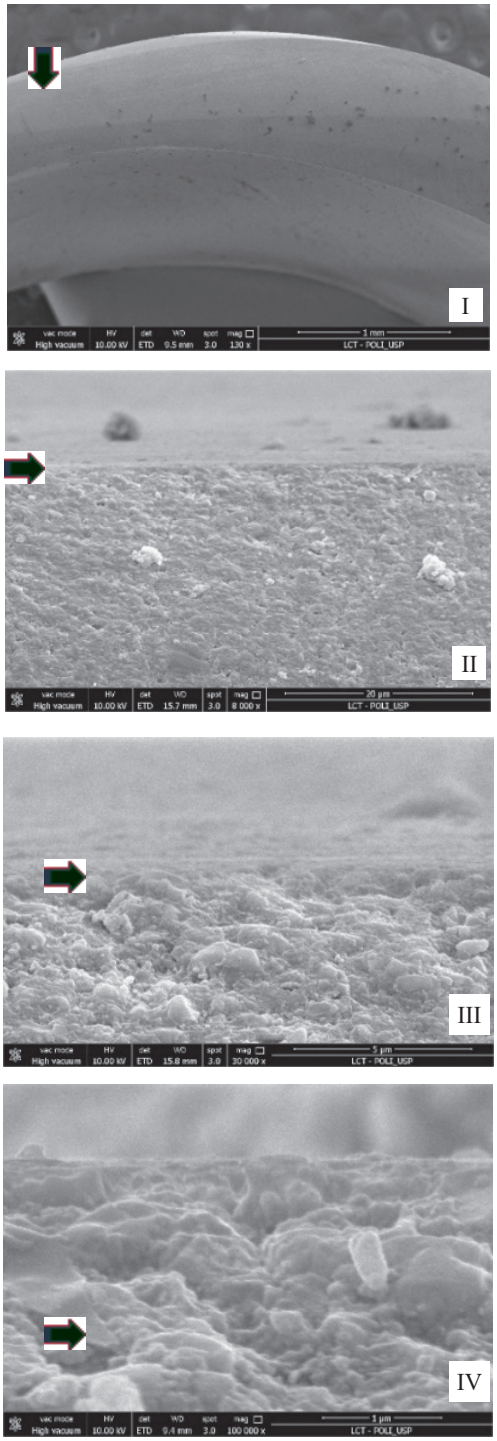
Table 2 – Means* (standard deviations) of color stability (ΔE00) results

Material	ΔE00	
	Water	Coffee
Componeer	0.1 (0.1) B	13.4 (0.5) B
Edelweiss	0.5 (0.2) A	18.7 (0.3) A

*Different letters in the same column indicate significant statistical difference (p<0.05).

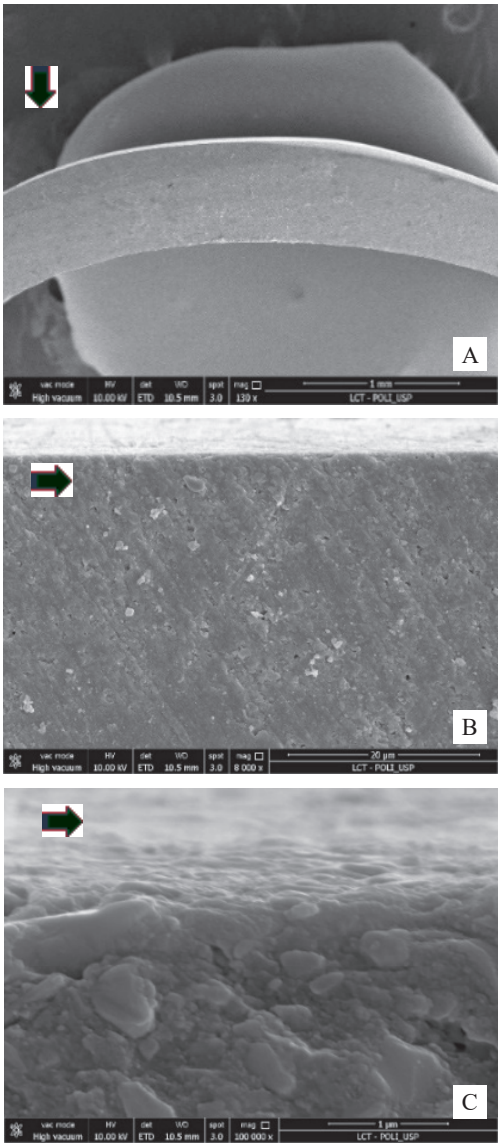
Source: the authors

Figure 4 – SEM analysis of the transversal section of a PCRV Edelweiss specimen under different magnifications. I – 130X; II – 8.00X; III – 30.000X and IV – 100.000x. The red arrow indicates the buccal surface of the PCRV.



Source: The authors

Figure 5 - SEM-analysis of the transversal section of a PCRV Componeer specimen under different magnifications. A – 130X; B – 8.00X; C – 100.000X. The red arrow indicates the buccal surface of the PCRV.



Source: The authors

In the present investigation, the PCRVs Componeer and Edelweiss showed similar KH even with different composition and manufacturing mechanisms. In addition, the veneers showed different ΔE00 values after the storage in water and coffee. So, the first research hypothesis was rejected. SEM-images exhibited similar microstructures for the PCRVs. Therefore, the second research hypothesis was accepted.

Hardness is defined as the resistance to surface indentation and can be used as an indirect method for measuring the degree of polymerization. The material hardness is extremely influenced by their composition.[1,13] The PCRVs used in the present study are formulated with hybrid and nano-hybrid inorganic content but their full composition is unknown. The most common scientific classification used for resin composite is related to the inorganic size. These materials can be classified as microfilled, microhybrid and nanocomposites (i.e., nanofill or nanohybrid) according to the filler size.[13] Microhybrid composite usually showed higher hardness in comparison to nanofilled and microfilled resin[14,15], since materials with high inorganic filler size tend to exhibit higher mechanical properties.[1,2] In the present investigation, the PCRVs present similar inorganic content (Table 1) which could explain the KH observed (Figure 3).

The degree of conversion can be correlated with the hardness of the composite and both parameters are extremely affected by the light curing unit used, time/irradiance and material composition.[4,16] In the present study, the PCRVs tested were polymerized under laboratory conditions. Therefore, the authors understand that the treatment used in the PCRV is sufficient to ensure high degree of conversion. Since both systems had statistically similar KH, it is possible to theorize that the PCRVs may present similar degree of conversion.

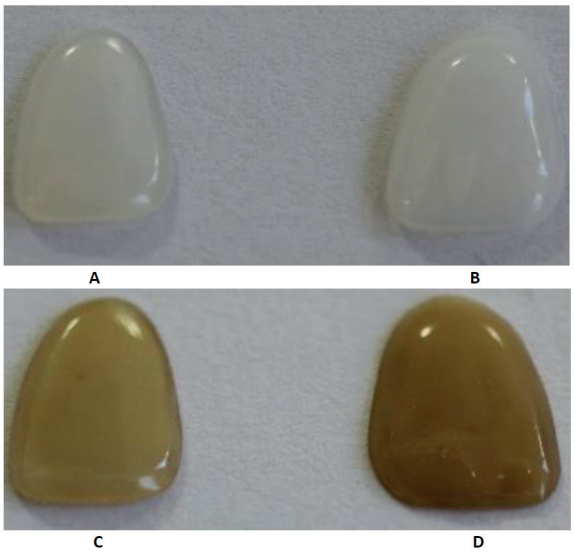
Resin composites subjected to heat treatment present higher degree of conversion and improved mechanical properties in comparison to solely light-cure materials.[8,9] In addition to the light activation, pressure and temperature used during the manufacturing of the PCRVs, Edelweiss is subjected to a specific surface treatment with a laser.[6] It can be speculated that such treatment increases the surface properties as hardness and wear resistance. Although claimed as a commercial strategy, the melting/vitrification mechanism produced by the laser was not observed in the present study. The SEM-analysis did not show any specific inorganic layer at the buccal surface of the Edelweiss (Figure 4 – III and IV). It is possible to observe a similar microstructure for the Componeer (Figure 5 – A, B and C) and Edelweiss (Figure 4 – I, II, III and IV). This result corroborates with the understanding of the similar KH observed (Figure 3).

PCRVs are indicated for esthetic treatments. Thus, a high color stability of the veneers is desirable. Optical values are measured by the amount of light reflected by selected colors (e.g., red, green, and blue). The Commission Internationale de L'Eclairage (CIE 1978) determined color parameters recorded in the L*a*b* color space. This system is related to human color perception in all three dimensions. L*-axis is associated with the lightness variable, proportional to Munsell's value; a* and b* are considerate chromaticity coordinates. Color stability is often calculated using CIELab or CIEDE2000 parameters. Although the CIELab is commonly used in dental analysis, the CIEDE2000 resulted in color difference that better correlated to visual observations.[11]

Several factors can affect the color stability of the composites. Low degree of conversion can generate residual non-reactive components at the crosslink network. These components can be leached by water, which would increase the solubility and consequently decrease the color stability.[17] Since the polymerization of the PCRV is performed under ideal laboratory conditions, it is theorized that few non-reactive components will be formed and the material should present higher color stability. However, going against this theory, the

PCRVs showed high color instability manly after the coffee storage (Table 2). This result could be associated with the organic matrix degradation and extrinsic pigmentation due to contact with coffee.[18] PCRVs showed ΔE00 lower than 1 after water storage, which is lower than the values of perceptibility (ΔE00 = 0.8) and acceptability threshold (ΔE00 = 1.8) determined by CIEDE2000.[19] On the other hand, the storage in coffee caused high pigmentation in the PCRVs tested (Figure 6) which may lead to failures of long-term aesthetic treatment.

Figure 6 - Initial and coffee stained condition of the PCRVs. A and C – Componeer; B and D - Edelweiss



Source: the authors

In vitro test using staining solution aims to simulate the extrinsic pigmentation generated by dye components from food intake and drink ingestion. Coffee is one of the most used staining solutions due to the large consumption by the population. The literature reports periods in coffee immersion ranging from 7 to 30 days.[10] During these days the material remains in contact with the dye solution for 5, 10 and 15 minutes. As the PCRVs are claimed to be an aesthetic material used for dental veneer, the authors decided to use the protocol of 10 minutes of immersion in coffee per day for 30 days. As a result, the PCRVs tested presented extremely high pigmentation which goes against with previous studies.[20,21] Corroborating with the present results, Poggio et al.[22] also reported high pigmentation for different resins subjected to coffee immersion. The authors of the present investigation speculated that the veneers lingual roughness may have influenced the color stability after coffee storage. I*n vitro* tests situations, the specimen receives a polish procedure in both sides to reduce the matrix roughness used to produce the specimen. However, in the PCRVs tested, the roughness at the lingual surface of the PCRVs is created by the company to increase the bond strength between the luting material and the veneer. So, new studies with different specimen shapes should be performed to clarify and confirm the optical behavior observed.

4 Conclusion

Considering the limitations of the present study regarding the design of the veneers, it is possible to concluded that although PCRVs present similar microhardness and microstructure, the Componeer group showed higher color stability and lower extrinsic pigmentation to coffee in comparison to Edelweiss.

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