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Superficial Effects of Different Finishing and Polishing Systems on the Surface Roughness and Color Change of Resin-Based CAD/CAM Blocks

Efectos superficiales de diferentes sistemas de acabado y pulido en la rugosidad superficial y el cambio de color de los bloques de Resina CAD/CAM

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ABSTRACT: CAD/CAM blocks are widely used in dental restorations around the world. This study aimed to investigate the effects of different polishing and finishing systems on surface roughness and color change of resin-based CAD/CAM blocks. In this study, material samples of 2×7×12mm were prepared. In three different experimental groups, surface polishing was carried out with one-step, two-step and multi-step polishing systems. The samples in one subgroup of each experimental group were polished with the diamond paste. Once the initial roughness and color values of the samples were measured using a profilometer and a spectrophotometer, the samples were immersed in coffee. Surface roughness and color change (ΔE_{00}) results were statistically analyzed using two-way variance analysis (ANOVA). Finishing and polishing systems created significantly different levels of surface roughness on the hybrid ceramic block (Vita Enamic) but not on the composites block (Brilliant Crios, Grandio Blocs). While the two-step and multi-step finishing and polishing systems produced the lowest color change on hybrid ceramic blocks, one-step and two-step systems achieved this on composite blocks ($p<0.05$). In all test groups, the supplementary polishing performed after regular polishing procedures helped us reduce the surface roughness and color change on CAD/CAM blocks. The findings obtained in this study suggest that one and two-step polishing systems are more suitable for resin-based composite CAD/CAM blocks; for hybrid ceramic CAD/CAM blocks, on the other hand, two and multi-step finishing and polishing systems seem to be more efficient concerning lower surface roughness and resistance to color changes.

KEYWORDS: CAD/CAM; Color stability; Surface roughness.

RESUMEN: Los bloques CAD/CAM son ampliamente utilizados en las restauraciones dentales, alrededor del mundo. El objetivo de este estudio es investigar los efectos de diferentes sistemas de pulido y acabado sobre la rugosidad de la superficie y el cambio de color de los bloques CAD/CAM de resina. En este estudio se prepararon muestras de material de 2×7×12mm. El pulido de la superficie se llevó a cabo en tres grupos experimentales con sistemas de pulido de un paso, de dos pasos y de varios pasos. Las muestras de un subgrupo de cada grupo experimental se pulieron con la pasta de diamante. Una vez medidos los valores iniciales de rugosidad y color de las muestras mediante un perfilómetro y un espectrofotómetro, las muestras se sumergieron en café. Los resultados de la rugosidad superficial y el cambio de color (ΔE_{00}) se analizaron estadísticamente mediante un análisis de varianza de dos vías (ANOVA). Los sistemas de acabado y pulido crearon niveles de rugosidad superficial significativamente diferentes en el bloque cerámica híbrida (Vita Enamic) pero no en el bloque de composites (Brilliant Crios, Grandio Blocs). Mientras que los sistemas de acabado y pulido de dos y varios pasos produjeron el menor cambio de color en los bloques de cerámica híbrida, los sistemas de un paso y dos pasos lo consiguieron en los bloques de composite ($p<0,05$). En todos los grupos de prueba, el pulido suplementario realizado después de los procedimientos de pulido regulares nos ayudó a reducir la rugosidad de la superficie y el cambio de color en los bloques CAD/CAM. Los hallazgos obtenidos en este estudio sugieren que los sistemas de pulido de uno y dos pasos son más adecuados para los bloques CAD/CAM de resina; en cambio, para los bloques CAD/CAM de cerámica híbrida, los sistemas de acabado y pulido de dos y varios pasos parecen ser más eficientes en lo que respecta a la menor rugosidad de la superficie y la resistencia a los cambios de color.

PALABRAS CLAVE: CAD/CAM; Estabilidad de color; Rugosidad superficial.

INTRODUCTION

Today, different esthetic restorative materials are utilized by dentists to meet the demands of individuals who desire esthetically perfect and whiter teeth (1,2). Developed as an alternative to ceramic blocks, resin-based and hybrid ceramic CAD/CAM blocks are ceramics integrated into a polymer network that polymerizes at higher degrees of temperature and pressure (3). These blocks have been reported to have better or comparable fracture toughness and less wear potential than composite resin materials (4). However, those new generation blocks are supposed to offer clinically acceptable optical and mechanical properties in long-term use (5).

The esthetic appearance of the restored teeth is affected by the characteristic features of the restorative material, such as the surface roughness, gloss and color stability (6). Bollen *et al.* (7) stated in an in vitro study that the surface roughness above 0.2µm formed a retention area for the bacterial plaque. Park *et al*. (8) reported that the surface roughness below 0.15µm decreased the adhesion of the streptococcus.

Finishing and polishing the restorative materials, as a major procedure that affects the properties above, could be performed with various systems. The systems may require one-step, two-step or multi-step applications, and they may vary according to their composition, presentation, type, and hardness of abrasive particles. Although it is stated that simplified systems are more time-saving, the findings related to the surface quality obtained with those finishing and polishing systems are insufficient (9).

To evaluate the surface roughness of restorative materials, devices, such as optical and mechanical profilometers, AFM (atomic force microscope) and SEM (scanning electron microscope), are commonly used (10). Since mechanical profilometers do not require preparation time to measure the surface roughness of the samples, and they let the measurement be repeated at different times, so they have been preferred for many years (11).

Besides the mechanical properties of the materials used in the restoration of the teeth, color stability determines the success and longevity of the restorations. Dental restorations are influenced by oral hygiene and dietary habits, and discolorations have been associated with water absorption, chemical reaction, diet, smoking, poor oral hygiene, also surface roughness (12,13). Also, different compositions of the materials, particle properties and polishing procedures have been reported to increase or decrease vulnerability to discolorations (14). Beverages, such as coffee, tea, cola and red wine, may cause different degrees of coloration on the surfaces of resinous CAD/CAM materials (15,16).

To evaluate the color stability of restorative materials, instrumental techniques, such as spectrophotometers, colorimeters, or digital cameras are employed (ΔE*) by referring to the Commission Internationale De L'éclairage (CIE) system (17). CIE L*a*b* values are the representative parameters indicating the color. Several studies aimed to determine the perceptibility threshold (PT) and acceptability threshold (AT) for CIE L*a*b* values. The PT refers to the magnitude of color difference (ΔE) that is visually detectable by the human eye, while the AT corresponds to the magnitude of color difference that constitutes the acceptability between tooth-colored restorative materials (18,19). In their comprehensive study, Paravina *et al*. (20) found that 50:50% PT value was ΔE_{00}:0.8 and 50:50% AT value was ΔE_{00}:1.8.

As widely used CAD/CAM blocks are expected to show high resistance to discoloration due to their industrial polymerization process, there has been growing literature on alternative materials. However, studies examining the effects of different finishing and polishing systems surface roughness and color change of resin-based and hybrid ceramic CAD/CAM blocks are limited. The present study aims to investigate surface roughness and color change of resin-based and hybrid ceramic CAD/CAM blocks after finishing and polishing them with comparable systems. In this study, the first null hypothesis is that different finishing and polishing systems will not create a significant difference in the surface roughness values of CAD/CAM blocks. The second null hypothesis is that the color changes in CAD/CAM blocks will not differ as to which finishing and polishing procedure is applied.

MATERIALS AND METHODS

In our study, Vita Enamic (VITA Zahnfabrik, Germany) hybrid ceramic, Brilliant Crios (Coltene/Whaledent AG, Switzerland) and Grandio Blocs (VOCO GmbH, Germany) resin-based CAD/CAM blocks were examined (Table 1). Samples of 2×7×12mm were obtained with the planned CAD/CAM blocks using a precision cutting machine (MICRACUT 201, Bursa, Turkey) at low speed (150rpm) with a water-cooled diamond disk. In our study, the sample size was calculated with 0.05 significance at 80% power level using the analysis package program (G* Power 3.1; Universität Düsseldorf). Accordingly, 56 samples of each restorative material (a total of 168 samples) were prepared. One-step (Dimanto, Voco GmbH, Germany), two-step (Clearfil Twist Dia, Kuraray Noritake, Tokyo, Japan) and multiple-step (OptiDisc, Kerr Corporation, Orange, USA) finishing and polishing systems were utilized to finish and polish the prepared samples. In addition, each group was divided into two subgroups according to whether the diamond polishing paste (Diapolisher, GC, Tokyo, Japan) was applied or not (Table 2).

Table 1. Resin-based CAD/CAM blocks used in the study.

Materials	Material type	Composition by weight		Lot No
		Filler	Polymer	
Vita Enamic (VITA Zahnfabrik, Germany)	Hybrid ceramic block	86% feldspat ceramic	Methacrylate Polymer, UDMA, TEGDMA	81060
Brilliant Crios (Coltene/Whaledent AG, Switzerland)	Composite resin block	70% of glass and amorphous silica	Cross-linked methacrylates (Bis-GMA, Bis-EMA, TEGDMA)	I89523
Grandio Blocs (VOCO GmbH, Germany)	Composite resin block	86% nanohybrid fillers	14% UDMA+ DMA	1904625

Table 2. Properties of finishing and polishing discs and spirals.

Material	Manufacturer	Type	Abrasive Type	Lot No
Dimanto	VOCO GmbH, Germany	One-step rubber polishing cup	Diamond particle	6581205
Clearfil Twist Dia	Kuraray Noritake, Tokyo, Japan	Two-step rubber wheels polishing system	Diamond particle	409294
OptiDisc	Kerr Corporation, Orange, CA, USA	Four-step rubber polishing discs	Aluminum oxide particle	6581205
Diapolisher Paste	GC, Tokyo, Japan	Diamond paste	Diamond particle	1711061

The finishing and polishing procedures were performed underwater cooling for 20 seconds at 10000 rpm. No polishing process procedure was applied to the control group. All samples were then cleaned with deionized water for 10 seconds in an ultrasonic cleaning device (Pro-Sonic 600; Sultan Healthcare, NJ, USA).

After finishing and polishing procedure, material samples were incubated in distilled water at 37oC in an incubator (FN 500, Nüve, Turkey) for 24 hours. Then, the initial colors of the samples (L*, a* and b* values) were measured with the spectrophotometer device (Vita Easyshade V; VITA Zahnfabrik, Germany) under D65 lighting conditions and surface roughness value (Ra) was measured with the profilometer device (Perthometer M2; Mahr GmbH, Germany). The surface roughness and color measurements were performed at the center points of the same samples. While measuring the surface roughness values of the samples, the measurement length was taken as 1.75mm and the cut-off value as 0.25. The average of these values was calculated by performing three measurements on the surface of each sample.

After determining the initial color and surface roughness of the samples, they were immersed in coffee (Nescafe Classic, Nestlé, Turkey) in the incubator (FN 500, Nüve, Turkey) for seven days at 37°C. L*, a* and b* values of the samples were recorded on the 1st and 7th days. The coffee solution was prepared by dissolving 2grams of coffee powder and 200ml of boiled distilled water in line with the manufacturer's recommendation. The samples were immersed in the coffee solution at 37°C. The coffee solution was replaced with a new one every 24 hours. Following the treatment, the samples were washed with water for 10 seconds before color measurement. CIEDE2000 formula (ΔE_{00}) was employed to measure the color change of the samples.

Statistical analysis was conducted using SPSS 22.0 (SPSS Inc., Chicago, IL, USA). The Kolmogorov Smirnov test was performed to assess the normality of the Ra and ΔE_{00} values. Surface roughness and color change results at the end of the 1st and 7th days were evaluated using two-way analysis of variance (ANOVA) and Tukey post hoc test ($p < 0.05$).

RESULTS

In this study, one, two, and multi-step finishing and polishing systems provided significantly different results ($p<0.05$). While the finishing and polishing systems created a significant difference in the surface roughness of hybrid ceramic blocks (Vita Enamic), they did not cause such a difference in the composite blocks (Brilliant Crios, Grandio Blocs) (Table 3). Finishing and polishing systems provided the lowest roughness (one-step: 0.079μm, two-step: 0.161μm and multi-step: 0.116μm) in the composite reinforced block (Brilliant Crios), (Figure 1). Apart from that, additional polishing with diamond paste applied following the standard finishing and polishing provided us with reduced surface roughness in all groups. However, the difference was not statistically significant ($p>0.05$). The surface roughness value of CAD/CAM block samples without finishing and polishing was the highest (Table 3).

There was a significant difference between the 1st-day and 7th-day color change values of resin-based and hybrid ceramic CAD/CAM blocks according to finishing and polishing systems ($p<0.05$). One-step, two-step, and multiple-step finishing and polishing systems showed a significant color change in the hybrid ceramic (Vita Enamic) and composite resin block (Brilliant Crios) on 1st-day measurement, while the other composite resin block (Grandio Blocs) did not exhibit a significant color change (Table 4). Although one-step and two-step systems led to the lowest color change (ΔE_{00}:0.8) in composite blocks (Brilliant Crios and Grandio Blocs), the lowest discoloration value (ΔE_{00}:0.8) was obtained with the two-step and multi-step systems in the hybrid ceramic block (Vita Enamic).

At the end of the 7th day, two-step and multi-step finishing and polishing systems produced the lowest color change (ΔE_{00}:0.9) in the hybrid ceramic block (Vita Enamic), while the one-step finishing and polishing system caused the highest color change (ΔE_{00}: 1.4). In composite blocks, the one-step and two-step finishing and polishing system created the lowest color change although the multi-step finishing and polishing system produced the highest color change (Table 4).

In all groups of CAD/CAM blocks tested within our study, although additional polishing performed with the diamond paste diminished the amount of color change occurring after the 1st and 7th-day of coffee immersion. Finally, the control in which no finishing and polishing procedure was applied exhibited the highest amount of discoloration ($p<0.05$).

Table 3. Surface roughness (Ra) values of CAD/CAM blocks after finishing and polishing systems.

Finishing and polishing system/Materials	Vita Enamic Ra (µm)±SD	Brilliant Crios Ra (µm)±SD	Grandio Blocs Ra (µm)±SD
One step	0.398 ± 0.08^{aA}	0.079 ± 0.03^{abB}	0.127 ± 0.01^{abB}
One step +Paste	0.246 ± 0.07^{bA}	0.043 ± 0.01^{aB}	0.097 ± 0.02^{aB}
Two step	0.162 ± 0.02^{cA}	0.161 ± 0.03^{bA}	0.172 ± 0.01^{bA}
Two step +Paste	0.121 ± 0.01^{cA}	0.092 ± 0.03^{abA}	0.112 ± 0.03^{abA}
Multi-step	0.201 ± 0.02^{bcA}	0.116 ± 0.02^{abB}	0.148 ± 0.01^{abB}
Multi-step + Paste	0.143 ± 0.04^{bA}	0.068 ± 0.01^{abB}	0.104 ± 0.03^{aB}
Control (No polishing)	0.448 ± 0.06^{aA}	0.351 ± 0.08^{cB}	0.506 ± 0.07^{cC}

*The limit of significance among columns (A-C) and between lines (a-c). $p<0.05$.

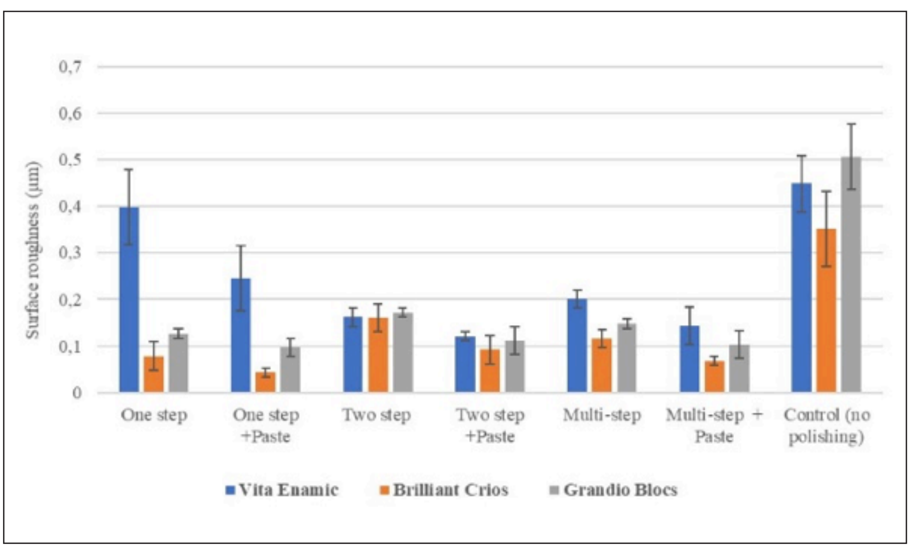

Figure 1. Surface roughness values (Ra) of CAD/CAM blocks after different finishing and polishing systems.

Table 4. Examination of color change values (ΔE00) of CAD/CAM blocks after finishing and polishing systems.

Finishing and polishing system/materials	Vita Enamic		Brilliant Crios		Grandio Blocs	
	1st day ΔE_{00}	7th day ΔE_{00}	1st day ΔE_{00}	7th day ΔE_{00}	1st day ΔE_{00}	7th day ΔE_{00}
One step	1.2±0.1[a]	1.5±0.1[a]	0.8±0.1[a]	1.0 ±0.2[ab]	0.8±0.1[a]	1.3±0.2[a]
One step +Paste	1.0±0.2[b]	1.3±0.2[b]	0.6±0.1[b]	0.9±0.1[a]	0.7±0.1[a]	1.2±0.2[a]
Two step	0.8±0.1[c]	1.0±0.1[c]	0.8±0.1[a]	1.0±0.1[b]	0.8±0.1[a]	1.3±0.2[a]
Two step +Paste	0.7±0.1[c]	0.9±0.1[cd]	0.6±0.1[b]	0.9±0.1[ab]	0.7±0.1[a]	1.2±0.2[a]
Multi-step	0.8±0.1[c]	1.1±0.1[c]	1.5±0.1[c]	1.7±0.1[c]	1.0±0.1[b]	1.6±0.1[b]
Multi-step + Paste	0.7±0.1[c]	0.9±0.1[cd]	1.1±0.1[d]	1.4±0.1[d]	0.8±0.1[a]	1.3±0.2[a]
Control (no polishing)	1.3±0.1[a]	1.5±0.2[a]	2.3±0.1[c]	3.1±0.2[c]	2.6±0.2[c]	3.2±0.3[c]

*The limit of significance among between lines (a-c). $p < 0.05$.

DISCUSSION

New generation resin-based and hybrid ceramic CAD/CAM blocks are widely preferred by clinicians as they offer several advantages, such as easy preparation, polishing and reparability. Although the mechanical and physical properties of these materials have been improved, the surface roughness obtained after finishing and polishing affects the clinical success of the material. Low surface roughness increases the total esthetic quality and success of the restoration, while rough surfaces cause plaque accumulation, recurrent caries and discoloration of the restoration (21).

The surface roughness of composite resins may vary depending on the polishing process applied and the structure, flexibility, hardness, and grain sizes of the materials used in these processes (9). It has also been reported that the multi-step finishing and polishing systems perform better than one-step systems (22,23). Flury *et al*. (24) stated that the multiple-step (Sof-Lex XT) finishing and polishing system with aluminum oxide created less surface roughness on tooth-colored CAD-CAM materials than diamond particles containing two-step (Vita Polishing Set Clinical) system.

In our study, the one-step system with diamond particles performed better on composite CAD/CAM blocks, while the two-step system with diamond particles created the least surface roughness on the hybrid ceramic block. In addition, although hybrid ceramic block (Vita Enamic) and composite block (Grandio Blocs) had the same proportion of filler (86%), hybrid ceramic block showed higher surface roughness with one-step and multi-step systems. In the literature, it is stated that the hybrid ceramic block has a polymer infiltrated network structure and shows higher microhardness than composite blocks (25). Therefore, we evaluate that one and multi-step finishing and polishing systems create more roughness on the hybrid ceramic block.

It has also been stated in the literature that the application of additional polishing after the finishing and polishing process reduces the surface roughness of composite resins (26). In our study, additional polishing applications, consistent with the previous studies in literature, reduced the surface roughness of all resin-based CAD/CAM blocks.

Although there is no reference threshold to evaluate the surface roughness, it has been reported that higher surface roughness is associated with bacterial adhesion and that the surface roughness below 0.15μm has decreased adhesion of the streptococcus (8). In our study, the highest surface roughness was observed in the control group, in which no polishing procedure was applied. While one-step, two-step and multiple-step finishing and polishing systems and paste application reduced the surface roughness of composite blocks below 0.15μm, only two-step and multi-step systems and paste application decreased the roughness of the hybrid ceramic block to that level. It was observed that the supplementary polishing paste applied after the finishing and polishing procedure had a positive effect on surface roughness.

Despite effective finishing and polishing procedures performed on restorative materials, discolorations that are regarded as the esthetic inadequacy of the materials may occur over time and cause patient dissatisfaction. It has been reported that the color changes in the materials are associated with many factors, both internal and external, and that surface roughness is one of the main culprits for external discolorations (27).

In recent years, colorimeters and spectrophotometers are widely used for measuring tooth color (28). In this study, a clinical spectrophotometer (Vita Easyshade Advance) and the L*a*b* CIE coordinate system were utilized, as they were reported to offer more objective results with a higher level of accuracy and repeatability (29). CIELAB is calculated with a formula using L*, a*, b* values to evaluate color changes in materials. In 2001, a new formula as CIEDE2000 ΔE00, updated by CIE, was introduced (30). The CIEDE2000 formula was preferred in our study as Gómez-Polo *et al*. (31) stated in their study that CIEDE2000 (ΔE_{00}) formula was more sensitive in measuring color changes than the CIELAB (ΔEab) formula.

Although it is stated that the degree of discolorations may differ depending on how long dental materials are immersed in beverages, red wine, coffee, and tea are described as the top colorants (16,32). Kurt *et al*. (33), evaluating the physical and optical properties of hybrid CAD/CAM materials in their study, stated that the hybrid ceramic material (Cerasmart) with the highest resin content showed a higher color change than the resin infiltrated material (Enamic), and the lowest color change was observed in the ceramic CAD/CAM material (Suprinity) without resin. Seyidaliyeva *et al*. (34) examined the color changes of hybrid ceramic (Enamic), composite (Grandio Blocs), and lithium disilicate (e.max CAD) CAD/CAM materials following a thermocycling process in a staining solution and reported that the highest color change was observed on wine-immersed composite CAD/CAM material (Grandio Blocs).

In our study, two-step and multi-step finishing and polishing systems produced the lowest color change (ΔE_{00}:0.9) on the hybrid ceramic block (Vita Enamic), while the one-step system producing the highest change (ΔE_{00}:1.4). On composite blocks, one and two-step finishing and polishing systems created the lowest color change, while the multi-step system led to the highest change. The fact the one-step system created the lowest color change on the composite block has been considered to be associated with the low surface roughness of these blocks.

In dental materials, increased amounts of resin often result in higher levels of water absorption, which creates hydrolytic degradation on the material. Consequently, the erosion of the material that is triggered by hydrolytic degradation can cause its physical and optical properties to change (35). In our study, composite block

(Brilliant Crios; 70%) and hybrid ceramic block (Vita Enamic; 86%) with different filler proportions showed similar degrees of color change with the two-step finishing and polishing system. The similarity of the discoloration levels is considered to be associated with that the composite block (Brilliant Crios) showed a lower surface roughness even if it was not statistically significant.

While measuring the amount of color loss on restorative materials and assessing their color stability, the acceptability and the perceptibility thresholds (AT and PT) are taken as essential reference values. The 50:50% PT was determined at ΔE_{00}:0.8 and 50:50% AT at ΔE_{00}:1.8 in the literature (20). In our study, all CAD/CAM materials immersed in coffee for seven days showed discoloration over 50:50% PT despite the additional polishing. The control groups kept out of the finishing and polishing procedure, however, showed a color loss even above 50:50% AT.

This study involved an *in vitro* experimental procedure that induced discoloration on both sides of the restorative material, which provided us with limited results. In clinical procedures, on the other hand, the restoration is fixed on the tooth itself, and the restoration surface is simply exposed to solutions. Also, it remains true that discolorations on restorations are often occurring externally. That is, with good oral hygiene and after polishing procedures applied clinically, external discolorations could be eliminated or reduced to lower degrees.

CONCLUSION

Our *in vitro* experiment examining the surface roughness and color changes after finishing and polishing of resin-based and hybrid ceramic CAD/CAM blocks found that in composite CAD/CAM blocks, the lowest surface roughness was obtained with the one-step finishing and polishing system with diamond particles, while the two-step system performed better in the hybrid ceramic block. Besides, the additional diamond paste application made after regular finishing and polishing reduced the surface roughness of all CAD/CAM samples even more. Additional diamond paste application after finishing and polishing systems reduces the resin-based CAD/CAM block surface roughness below 15µm (one step; hybrid ceramic block excluded). The lowest color change was obtained with one and two-step finishing and polishing systems in composite blocks, while the two and multi-step systems brought about better results in hybrid ceramic blocks. The additional diamond paste application performed after regular finishing and polishing further reduces the color change of CAD/CAM blocks.

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