Influence different polishing systems on roughness and colour stability of chairside CAD/CAM blocks with laminate veneer thickness

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Abstract
Objective: The aim of this study was to evaluate the effect of different polishing systems on the colour stability of different laminate veneer blocks for chair-side CAD-CAM after ultraviolet (UV) ageing.

Methods: About 240 sample (13 × 13 × 0.7) were prepared from four different CAD-CAM blocks IPS e.max CAD (IP), IPS Empress CAD (IE), Mark II (M) and Lava Ultimate (LU)) with A1 shade. Each group was divided into five subgroups (n = 12) according to the control (C) and four different polishing system: Sof-Lex (S), Edenta (E), Identoflex (I) and Zircon Brite (Z). Surface roughnesses (Ra) were measured by a profilometer before and after polishing. The baseline colour values were recorded according to the CIELab system. The colour coordinates (L*, a* and b*) of the samples were measured before and after UV ageing, and colour differences (ΔE00) were calculated by using the CIEDE2000 colour difference formula. A two-way ANOVA and Tukey test methods were used to analyse the data (α = 0.05).

Results: A significant interaction was observed between CAD-CAM blocks and polishing system (p < 0.001). The higher Ra and colour difference was calculated in LU in the Z group after polished and the lower Ra and colour difference was calculated in the IP in the S group after polished. For the IP group, the glazing procedure showed higher Ra and ΔE values with Z group than polished S system, whereas there is no statistical differences.

Conclusion: It is concluded that polishing with the Sof-Lex system improves significantly smoothness and colour stability. However, there is no success in using the Zircon Brite polishing system.

Keywords
Polishing system, laminate veneers, colour stability, surface roughness, CAD-CAM

Introduction
The demands for dental aesthetic treatments such as laminate veneers have increased in the last three decades. As a result of the development of dental materials, different CAD-CAM blocks have been used for laminate veneers because of their varying flexural strength and cosmetic qualities. Therefore, in dentistry, blocks for use in CAD-CAM technology are made from materials such as feldspar ceramic glass reinforced with leucite and lithium disilicate.

Laminate veneers are difficult to repair if the glazed layer is damaged for any reason after cementation. So it is useful to polish them carefully to preserve their colour. Therefore, mechanical polishing has become more critical,
and as the quality of CAD-CAM chairside restorations improves, polishing treatment takes less time. Moreover, recent studies have shown that a smooth and bright surface can also be obtained by using manual polishing as well as glazing. An advantage of polishing includes the glossy surface of a polished restoration, which creates a plaque-resistant environment for the patient, making it easier for them to clean and thus contributing to the excellent health of the patients’ gingival tissues. Furthermore, these factors lead to increased longevity of the restoration.

Different polishing systems are used in dental restorations, such as tungsten or diamond carbide burs, aluminium oxide– or silicon carbide–coated abrasive rubber discs, silicone rubber discs, rubberised cups and silicon carbide brushes. The colour of the CAD-CAM blocks may vary after different polishing processes due to the respective mechanical behaviours and ageing. Therefore, choosing the optimal polishing technique for different ceramic block ingredients is critical.

Artificial ageing is an in vitro experimental technique that simulates oral environmental conditions. A few studies have reported using ultraviolet light to artificially corrode prosthetic materials. Some researchers have claimed that the UV-ageing method simulates intraoral conditions.

The current research aimed to assess the surface smoothness of different CAD-CAM blocks for laminate thickness treated by different polishing methods and investigate their impact on colour stability. The null hypothesis of the present research was that the different polishing systems would not affect the roughness and stability of the colour of varying CAD-CAM blocks with laminate thickness after UV ageing.

**Material and methods**

Four commercially available computer-aided design and manufacturing (CAD-CAM) materials were tested: lithium disilicate (IPS e. max CAD; Ivoclav Vivadent AG, Germany (IP)), leucite-reinforced (IPS Empress CAD; Ivoclar Vivadent, Germany (IE)), feldspathic aluminosilicate (Mark II; VITA Zahnfabrik, Germany (M)), and nanoceramic resin (Lava Ultimate; 3M/ESPE, USA (LU)) (Table 1).

A total of 240 samples (13 × 13 × 0.7 mm) of CAD-CAM material were cut with a low-speed diamond saw (Isomed 1000, Buehler Ltd) under running water. A horizontal grinding machine (HRG-150; AM Technology) was used to fix the thickness of the samples. Each sample was pre-polished using silicon carbide papers (Grids 600, 800 and 1200; English Abrasives Ltd) under cooling water. The thickness of each samples was measured with a digital calliper (Model Absolute Digimatic Caliper; Mitutoyo Corp) to be 0.7 mm.

The Glaze subgroup samples (N=36) of IP, M, IE groups (n=12) were glazed (IPS e. max Ceram Glaze Power; Ivoclar Vivadent AG) in a ceramic furnace (Programat P310; Ivoclar Vivadent AG) according to the manufacturer’s instructions. For LU group (n=12), Light-cure Optiglaze (GC) (as light-polymerised glazing agent for LU was not available, Optiglaze; GC) was applied. Each group was divided into five subgroups (n=12) according to the control (C) and polishing systems – polishing discs; Sof-Lex (S), polishing kit; Edenta (E), polishing kit; Identoflex (I) and polishing paste, Zircon Brite (Z).

**Table 1. Materials used in the test.**

| Filler | Polymer | Shade |
|-------|---------|-------|
| IPS Emax CAD (IP), Lithium disilicate glass ceramic | 57%–80% SiO<sub>2</sub>, 11%–19% Li<sub>2</sub>O, other oxides | A1 |
| IPS Empress CAD (IE), leucite-reinforced glass ceramic | Leucite glass ceramic, SiO<sub>2</sub> (60%–65%), Al<sub>2</sub>O<sub>3</sub> 16%–20%, Na<sub>2</sub>O (3.5%–6.5%), K<sub>2</sub>O (10%–14%), other oxides | A1 |
| Mark II (M) feldspathic aluminosilicate | Fine particle feldspar ceramic, SiO<sub>2</sub> (56–64), Al<sub>2</sub>O<sub>3</sub> (20–23), Na<sub>2</sub>O (6–9), K<sub>2</sub>O (6–8), other oxides | A1 |
| Lava Ultimate (LU), Resin nanoceramic | 80% SiO<sub>2</sub> and ZrO<sub>2</sub> nanoparticle | 20% BisGMA, UDMA, BisEMA, A1 |

BisEMA: ethoxylated bisphenol A dimethacrylate; BisGMA: bisphenol A glycidyl methacrylate; BisMEPP: 2,2-bis(4-methacryloxypropoxyphenoxyphenyl) propane; TEGDMA: triethylene glycol dimethacrylate; UDMA: urethane dimethacrylate.

Group C: Control group with glaze layer.

Group S: The sample surfaces were polished with 12.7 mm–diameter polishing discs (Sof-Lex; 3M/ESPE, USA) (medium, fine, super fine. Grit size 29, 14, 5 µm) with an electric low-speed handpiece set (Taurus G2, Shinhung, Seoul, Korea). The polishing procedure was performed at 5000 rpm for 60 s.

Group E: The Edenta ceramic polishing rubber (AG Dentalprodukte, Switzerland), which is grey and pink, and super Exa-Cerapol polishing rubber were used to polish each of the samples for 20 s at 5000 rpm with an electric handpiece.
Group I: The Identoflex diamond ceramic polisher (KerrHawe, SA, Switzerland) with green, grey, pink colour discs were applied sequentially for 60 s to the samples with an electric handpiece at 5000 rpm.

Group Z: By using an electric handpiece at 5000 rpm for 60 s, Zirconia Brite polishing paste (Dental Ventures, USA) was performed. In all groups, steps were executed by a single calibrated operator.

Samples were cleaned in an ultrasonic cleaner (Branson Ultrasonics) for 10 min with deionised water and air-dried for 20 s. A profilometer (Perthometer M2, Mahr GmbH, Gottingen, Germany) initially and after polishing was used to determine the three roughness measurements. After calibrating the device, the cutting value of the diamond tip was set to 0.25 mm. A diamond stylus (HNT-6), having a radius of 2 μm and an angle of 90°, was placed transversely with a force of 0.7 N at a constant speed opposite each sample. Three parallel measurements were done at the centre of each sample, and mean surface roughness (Ra) was calculated.

The colour of the samples was measured using a clinical spectrophotometer (CM-3600A; Konica Minolta) according to the CIEDE2000 colour coordinates in ‘tooth single’ mode before the ageing process. The aperture size of the spectrophotometer was 8 mm. The samples’ colour was measured under a D65 (MASTER TL-D Super 80 18 W/865 1SL; Philips)20,21 standard illumination light source at 0° and 45° angles.22 Measurements were made on a neutral grey background simultaneously and were repeated three times. The CIELab values were recorded on both black (B) \((L^* = 2.3, a^* = 0.5, b^* = 2.1)\) and white (W) \((L^* = 94.6, a^* = 0.2, b^* = -0.8)\) backgrounds.22,23

Before the second measurement, aluminium plates were prepared based on the sample size, and the samples were fitted in the mould. A procedure was done to submit the samples to artificial ageing. In the test machine (Atlas UV 2000, Weather-O-meter, Atlas Material Testing Technology LLC), the samples were exposed to ultraviolet light and water spray for 300 h and run for total radiant energy of 450 kJ/m². Each sample’s surface was exposed to a light source. A black panel temperature of 70°C (light cycle) and 38°C (dark cycle), a dry bulb temperature of 47°C (light cycle) and 38°C (dark cycle), and wetness of 50% (light cycle) and 95% (dark cycle) were established upon testing. The experiment has consisted of only 40 min of light, 20 min of light with front water spray, 60 min of light and 60 min of dark with backwater spray.16 After ageing, the colour coordinates \(L^*, a^*\) and \(b^*\) were re-recorded. The measurements of each sample were recorded after ageing.

The colour difference after thermal ageing was calculated using the CIEDE2000 \((ΔE_{00})\) colour difference formula:

\[
ΔE_{00} = \left[ \frac{ΔL'}{K_L S'_L} \right]^2 + \left[ \frac{ΔC'}{K_{C'} S'_C} \right]^2 + \left[ \frac{ΔH'}{K_{H'} S'_H} \right]^2 + R_t \left( \frac{ΔC'}{K_{C'} S'_C} \right) \left( \frac{ΔH'}{K_{H'} S'_H} \right)
\]

Where \(ΔL\), \(ΔC\) and \(Δh\) are differences between the corresponding colour coordinates computed based on the uniform colour space used in CIEDE2000, \(K_L, S'_L\), \(K_{C'}, S'_C\) and \(K_{H'}, S'_H\) are empirical terms for converting the differences for each coordinate into the CIEDE2000 difference formula.

The parametric factors of the CIEDE2000 colour difference formula were set to one.\(^ {25}\) \(ΔE_{00} > 1.30\) was considered the perceptibility threshold, and \(ΔE_{00} > 2.25\) was used as the acceptability threshold.\(^ {25}\)

The statistical analyses were done using statistical software (IBM SPSS Statistics, v24.0; IBM Corp). The Kolmogorov–Smirnov test was used to analyse distribution \((p < 0.05)\). In addition, a two-way ANOVA was used to analyse the surface roughness and colour changes in different CAD-CAM blocks with veneer laminate \((α = 0.05)\).

**Results**

According to the two-way ANOVA results in Table 2, a significant interaction was observed between the CAD-CAM blocks and the polishing system \((p < 0.001)\).

The means and standard deviation of Ra and \(ΔE_{00}\) values for polishing systems and CAD-CAM blocks are provided in Table 3. A significant difference was found in Ra and \(ΔE_{00}\) values among four CAD-CAM materials when four polishing methods were applied after UV ageing \((p < 0.001)\). According to the \(t\)-test \((p < 0.05)\), the highest Ra value was observed in the LU group polished with Z, and the lowest Ra value was observed in the IP group polished with S. The samples from E and I groups in polishing group and M and IE group in CAD-CAM block which presented statistically similar superficial smoothness. Overall, Ra values respectively were in polishing groups \(Z < E < I < S\) and CAD-CAM block groups \(LU > M > IE > IP\).

According to the \(t\)-test \((p < 0.05)\), the greater \(ΔE_{00}\) values were observed in the LU group polished with Z, which was above the acceptability threshold \((2.26)\). The lowest Ra value was observed in the IP group polished with S \((0.62)\), which was imperceptible \((ΔE_{00} < 1.30)\). The samples from E and I groups in the polishing group and M and IE group in CAD-CAM block presented statistically similar colour changes. Overall \(ΔE_{00}\) values respectively were in polishing groups \(Z < E < I < S\) and CAD-CAM block groups \(LU > M > IE > IP\).

**Discussion**

The current study design was a two-factor (CAD-CAM blocks and polishing systems). The null hypothesis was
Table 2. Result of Ra and ΔE<sub>00</sub> values for CAD-CAM blocks with laminate veneer thickness and different polishing systems by two-way ANOVA.

| Parameter | Resource | SS   | Df | MS  | F    | p    |
|-----------|----------|------|----|-----|------|------|
| Ra        | Polishing technique (A) | 5.889 | 3  | 1.927 | 3.533 | <0.001 |
|           | Porcelain Interaction (B) | 47.64 | 3  | 15.551 | 15.401 | <0.001 |
|           | PolishingXporcelain (AXB) | 15.842 | 9  | 6.365 | 0.949 | <0.001 |
| ΔE<sub>00</sub> | Polishing technique (A) | 0.466 | 3  | 0.155 | 5.633 | <0.001 |
|           | Porcelain Interaction (B) | 8.647 | 3  | 0.549 | 12.552 | <0.001 |
|           | PolishingXporcelain (AXB) | 0.385 | 9  | 0.042 | 0.965 | <0.001 |

Table 3. Mean and standard deviation of Ra and ΔE<sub>00</sub> values for test groups.

| Material     | Glaze       | Sof-Lex     | Edenta      | Identoflex  | Zircon Brite |
|--------------|-------------|-------------|-------------|-------------|--------------|
| Ra           | IPS e.max CAD | 0.1801 ± 0.50<sup>AA</sup> | 0.1760 ± 0.56<sup>AA</sup> | 0.3806 ± 0.43<sup>Bb</sup> | 0.3805 ± 0.58<sup>Bb</sup> | 0.4202 ± 0.43<sup>Bb</sup> |
|              | Mark II     | 0.3018 ± 0.96<sup>Bb</sup> | 0.2820 ± 0.65<sup>Bb</sup> | 0.4412 ± 0.34<sup>Bb</sup> | 0.4402 ± 0.41<sup>Bb</sup> | 0.6219 ± 0.31<sup>Bb</sup> |
|              | IPS EmpressCAD | 0.3790 ± 0.89<sup>Bb</sup> | 0.3601 ± 0.60<sup>Bb</sup> | 0.4399 ± 0.33<sup>Bb</sup> | 0.4402 ± 0.67<sup>Bb</sup> | 0.6080 ± 0.30<sup>Bb</sup> |
|              | Lava Ultimate | 0.4800 ± 0.58<sup>Bb</sup> | 0.4790 ± 0.54<sup>Bb</sup> | 0.6008 ± 0.56<sup>Bb</sup> | 0.6001 ± 0.25<sup>Bb</sup> | 0.8350 ± 0.43<sup>Cc</sup> |
| ΔE<sub>00</sub> | IPS e.max CAD | 0.64 ± 0.88<sup>AA</sup> | 0.62 ± 0.36<sup>AA</sup> | 1.22 ± 0.47<sup>Aa</sup> | 1.21 ± 0.63<sup>Aa</sup> | 1.30 ± 0.40<sup>Aa</sup> |
|              | Mark II     | 1.26 ± 1.22<sup>AA</sup> | 1.22 ± 0.38<sup>Aa</sup> | 1.82 ± 0.33<sup>Bb</sup> | 1.80 ± 0.48<sup>Bb</sup> | 2.11 ± 0.44<sup>Bb</sup> |
|              | IPS EmpressCAD | 1.27 ± 0.93<sup>AA</sup> | 1.25 ± 0.30<sup>Aa</sup> | 1.80 ± 0.63<sup>Bb</sup> | 1.79 ± 0.24<sup>Bb</sup> | 2.03 ± 0.58<sup>Bb</sup> |
|              | Lava Ultimate | 1.80 ± 1.56<sup>Bb</sup> | 1.70 ± 0.36<sup>Bb</sup> | 2.20 ± 0.48<sup>Bb</sup> | 2.16 ± 0.46<sup>Bb</sup> | 2.26 ± 0.36<sup>Cc</sup> |

The same uppercase letter indicates statistical similarity between the columns. Different lowercase letters indicate statistical differences in the same line.

 rejected since the polishing system affected the surface roughness and colour stability of laminate thickness after UV ageing. Several previous studies reported surface finishing and polishing treatment affected surface roughness and colour stability.<sup>5,11,12</sup> According to Bollen et al.,<sup>6</sup> a surface roughness for both natural teeth and restorations should be (Ra=0.2 µm) to prevent plaque buildup because when the surface roughness is above the threshold (Ra=0.2 µm), bacterial retention increases. The previous studies demonstrated the ability of Sof-Lex discs to create the smoothest surface compared to other polishing systems.<sup>26</sup> Another study reported good results with the Sof-Lex system compared with other polishing techniques used with Mark II and IPS Empress.<sup>3</sup> In this study Ra mean values of all groups were significantly higher than the plaque accumulation threshold (0.2 µm) except for the IP and C groups. Sof-Lex polishing system produced surface favourable roughness below the critical threshold (<0.2 µm). This was consistent with the literature.<sup>26</sup> In addition, using the Sof-Lex polishing system, the surface roughness of all samples (0.17) was favourable compared to that of the glazed samples (0.18). The tongue is sensitive to roughness changes with a maximum threshold of 0.5 µm.<sup>13</sup> Therefore, patients’ comfort can be adversely influenced by rough surfaces restorations. However, natural enamel roughness was reported to be about 0.64 µm.<sup>4,13</sup> In this study, all groups were close to the Ra value threshold except the LU group when polished with Z. Polishing pastes were found to improve surface smoothness in research.<sup>27</sup> High sintering and glazing temperatures can cause damage to resin-containing materials.<sup>19,26</sup> The IPS e.max CAD was composed of 70 vol% crystalline lithium disilicate filler in ceramic glass matrix. During polishing, this dense composition becomes a regular surface topography.<sup>3</sup> The results of this study may show that IPS e.max CAD can be polished more effectively after applying four different polishing systems. Ra values ranged showed between 0.17 and 0.50. The microstructure has great influence on the performance of the ceramics. Some ceramics are more easily polish. This is likely related to the composition of its glass matrix. The leucite content may play an essential role in the easiest polishing of these materials.<sup>28</sup> IPS EmpressCAD (contains lithium disilicate and ceramic fluorapatite crystals) is fine smaller than Mark II group (feldspathic crystalline particles embedded in a glassy matrix).<sup>28</sup> In this study IE group had smoother surface than M group. A few studies have evaluated the effect of surface treatment on the discoloration of nano-fluorapatite ceramics and have reported a strong correlation between discoloration and the roughness of ceramics.<sup>10,11</sup> Many authors have suggested that Lava Ultimate has the highest colour change significance in research. Several previous studies reported surface finishing and polishing treatment affected surface roughness and colour stability.<sup>5,11,12</sup>
artificial ageing. The mean $\Delta E_{00}$ value was found between the range of 0.62 and 2.26. The greater $\Delta E_{00}$ values were observed in the LU group when polished with Z (2.26), which was above the acceptability threshold ($\Delta E_{00} > 2.25$).

Lava Ultimate resin ceramic can be affected by UV ageing, which causes colour change.\textsuperscript{14} LU is a nanoceramic material and the resin content of nanoceramic is susceptible to chemical degradation.\textsuperscript{14} Polymers uptake water and therefore may be more prone to absorbing the pigments of staining solutions.\textsuperscript{30} IP, IE and M are bis-GMAe-free materials; however, LU contains 20% bis-GMA despite having low viscosity and hydrophilicity monomers. Because of its hydroxyl side groups, Bis-GMA is very hydrophilic, contributing to greater water sorption and, as a result, colour stainability.\textsuperscript{30} Note, Lava Ultimate is not the material of the first choice for laminate veneers and comes with some considerable drawbacks compared to the more stable ceramics studied.

The limitation of this study was that the evaluation of the colour change was conducted on samples that were not cemented to teeth. The inability of the study to mimic the intraoral conditions using saliva as in an in vitro experiment process used can also be considered deficiencies.

**Conclusion**

Within the limitations of this study:

IP showed a smoother surface and higher colour stability after glazing or polishing with four different systems compared to the other chairside CAD-CAM materials. The smoothest surfaces were obtained for all selected materials after polishing with the Sof-Lex system.

The smoothness and colour stability are material and surface treatment dependent.

Chairside ceramic materials and polishing systems should be carefully matched to obtain natural-looking restorations with optimum colour stability.

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