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RESEARCH

Effect of a Surface Sealant Agent on the Color Stability and Surface Roughness of Polymethyl Methacrylate and Nylon Denture Base Materials

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Purpose: To evaluate the effect of a surface sealant agent on the color stability and surface roughness (Ra) of two denture base materials: polymethyl methacrylate (PMMA) and nylon. Materials and Methods: A total of 96 disk-shaped specimens (10 × 2 mm) were fabricated from heat-cured PMMA and nylon denture base materials (n = 48/material). Each of the color stability and Ra tests were performed on half of the samples in each material group (n = 24), and these subgroups were then subdivided according to the surface treatment applied: 12 specimens were conventionally polished, serving as the control group, and 12 specimens received a sealant on the surface in addition to the surface polishing. Color stability was assessed through measuring the CIEL*a*b* color parameters before and after immersion in coffee solution. Ra was measured and scanning electron microscopy (SEM) photomicrographs were taken before and after thermocycling. Statistical analysis was done using 2-way analysis of variance (α = .05). Results: The surface sealant agent significantly increased the color stability of both materials (P = .047). However, it had no significant effect on the Ra of materials before (P = .600) or after (P = .583) thermocycling. Nylon had a significantly rougher surface than PMMA both before and after thermocycling (P < .001). Similarly, SEM observations show a more irregular texture for nylon than for PMMA. Conclusion: Although the sealant agent had no significant effect on the Ra before or after thermocycling, it significantly decreased the color change of nylon and PMMA disks. Based on both statistical analyses and SEM observations, the Ra of PMMA was lower than nylon denture base material. Int J Prosthodont 2021;34:70–78. doi: 10.11607/ijp.6715

Polymethyl methacrylate (PMMA) resin is the most common material for fabricating denture bases. In addition to its excellent esthetic properties and low water sorption and solubility, this material is simple to process and repair.1,2 However, some restricting factors, such as hypersensitivity to PMMA and allergic reactions to residual monomer, have been reported.3 Polyamide thermoplastic polymers were first used as a denture base material in the 1950s and were recommended for patients with frequent denture fracture or allergy to acrylic resins.3 While PMMA is an amorphous polymer, nylon has a crystalline nature, which makes it insoluble, highly heat-resistant, and strong but flexible. The higher flexibility of polyamide dentures compared to PMMA allows it to engage undercuts and thus improves the denture retention. However, its low melting point makes it difficult to achieve a satisfactory polished surface. Despite wet polishing, the surface gloss of polyamide is less than that of PMMA.4,5

The surface properties of denture base materials are particularly important, since surface roughness (Ra) is reported to be directly associated with plaque accumulation and adherence of Candida albicans.6,7 Increased presence of Candida spp has been reported in denture-related stomatitis.8–10 An Ra of 0.20 μm has been reported as the clinically acceptable threshold. While a decrease in plaque accumulation is expected
Color change of prosthodontic materials studies have shown that Ra and staining do not always correlate. Color change of denture base materials before or after thermocycling.

The second null hypothesis was that there would be no differences between the color stability and Ra of either denture base material before or after thermocycling. The aim of this study was to evaluate the effect of a surface sealant agent (Biscover) on color stability and Ra of nylon and PMMA denture base materials before or after thermocycling.

Conventionally, denture base materials are finished and polished mechanically in a dental laboratory using fine pumice and polishing pastes, respectively. Recently, surface sealant agents have been developed to eliminate Ra and increase stain and wear resistance. Previous research has reported that applying sealant agents improve smoother and more color-stable denture tooth surfaces than conventional polishing techniques. Surface sealants of methacrylate or dimethacrylate resins improve stain resistance and reduce the roughness of a composite resin provisional material.

Ra and color stability of denture base materials have been widely investigated; however, no study has evaluated if these properties are affected by surface sealant agent before or after thermocycling. The aim of this study was to evaluate the effect of a surface sealant agent (BisCover, Bisco) on color stability and Ra of PMMA and nylon denture base materials before and after thermocycling. The first null hypothesis was that the surface sealant agent would not affect the color stability or Ra of either denture base material before or after thermocycling. The second null hypothesis was that there would be no differences between the color stability and Ra of nylon and PMMA denture base materials before or after thermocycling.

### MATERIALS AND METHODS

In this experimental study, 48 disk-shaped specimens (10 × 2 mm) were fabricated from heat-cured PMMA (Ivoclar Vivadent), and 48 were fabricated from a nylon denture base material (nylon grains, Valplast) (Table 1). Half of the specimens of each material were used for the color stability test, and the other half for the Ra test.

To fabricate the PMMA specimens, silicone disks (10.0-mm diameter, 2.0 ± 0.1 mm thick) were invested in dental flasks, and heat polymerization was performed. For fabricating the nylon specimens, gypsum molds in the flasks were obtained by investing silicone disks of the same diameter as the specimens (10.0-mm diameter, 2.0 ± 0.1 mm thickness). The silicone disks were attached to each other and to the outside of the flask by waxed sprues. A cartridge designed to be inserted into the injection device was heated up to 240°C and maintained at this temperature for 12 minutes before being injected into a stainless steel flask (#61B Two Flask Compress, Handler Manufacturing). Nitrogen pressure (5 Kgf) was maintained for 25 seconds before deflasking to direct the melted polymer to fill the areas of the mold.

After deflasking, all specimens were first finished using a tungsten carbide bur and smoothed with 400-grit silicon carbide paper (Met II, Buehler). Then, all specimens were polished using a slurry of coarse pumice (Pumice Fine, Benco Dental) and water on a polishing lathe (P1000, Zuber) for 1 minute at 1,500 rpm. Fine polishing was done with a polishing paste (Fabulustre, Grobet) for 90 seconds. All specimens were measured and set to 10-mm diameter and 2-mm thickness using a digital caliper of 0.1-mm accuracy (Mini Electronic Caliper, Zhejiang).

The 24 specimens of each material for each test were subdivided into two subgroups (n = 12) to receive different surface treatments as follows. The specimens in the control group underwent only conventional laboratory polishing as previously described and did not receive further surface treatment. For the specimens in the case group, conventional laboratory polishing was followed by applying surface sealant agent (Biscover). The sealant agent was applied with a soft brush on both sides of the specimens in an even, thin layer in one direction, avoiding air bubble formation. Twenty seconds later, the
specimens were polymerized for 30 seconds with an LED curing unit (Radii Plus, SDI) (Fig 1).

**Color Stability Test**

A digital spectrophotometer (VITA Easyshade, VITA Zahnfabrik) was used to measure the Commission Internationale de l’Eclairage (CIE) color parameters L*, a*, and b* of the specimens. The instrument was calibrated before each measurement according to the manufacturer’s instructions. The spectrophotometer CIEL*a*b* output was based on D65 illuminant and a 2-degree standard observer. For each single specimen, initial color measurements were repeated three times, and the mean values were recorded as $L_0$, $a_0$, and $b_0$. Staining solution was prepared by dissolving 7.5 g of coffee (Nescafé Classic, Nestlé) in 500 mL of boiled distilled water. Specimens were immersed in this solution and stored at 37°C in a dark environment for 7 days to simulate intraoral conditions. Then, final color measurements were done three times for each specimen using a spectrophotometer, and the mean values were recorded as $L_1$, $a_1$, and $b_1$. All color measurements were done at the same time of

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**Fig 1** Case and control specimens of PMMA and nylon denture base materials. (a) Control PMMA. (b) Sealant-coated PMMA. (c) Control nylon. (d) Sealant-coated nylon.
day by the same clinician (R.G.) on a white background. The color change value (∆E) was determined with the CIE color difference formula:

The acceptability threshold of color difference (∆E) for pink restorations is 3.7 to 4; the clinically acceptable threshold was set to 4 in this study.26–29

Ra Test
For all specimens in the experimental subgroups, Ra (µm) was measured using a contact profilometer (Rugosurf 20, TESA) with 0.25-mm cutoff length, 4-mm transverse length, and 0.001-µm resolution. The measuring speed was set at 0.5 mm/second. Measurements were repeated three times for each specimen, and the collective mean was obtained. The profilometer was calibrated before measurements in each group. All measurements were done by the same clinician (R.G.). Higher Ra values indicate a rougher surface. For qualitative characterization of specimens, two specimens in each group were ultrasonically cleaned in distilled water for 5 minutes, rinsed, and dried. These specimens were gold coated with a sputter coater (S150B, Edwards) and examined at 15 kV using a scanning electron microscope (JSM-6335F, JEOL). For visual inspection and assessment of surface morphology, SEM photomicrographs were taken at ×500 and ×1,000 magnifications.

The specimens were then subjected to thermal cycling between 5°C and 55°C for 3,000 cycles for 30 seconds in distilled water according to a previous study.22 Ra was remeasured after thermal cycling, and the eight above-mentioned specimens were reevaluated with SEM photomicrographs at ×500 and ×1,000 magnifications.

Statistical Analysis
Statistical analyses were done with SPSS version 20 statistical software (IBM). Kolmogorov-Smirnov test was used to assess whether the data were normally distributed. The assumption of homogeneity of variance among groups was tested using Levene F test. The mean and SD values for ∆E and Ra before and after thermocycling were analyzed using 2-way analysis of variance (ANOVA; α = .05).

RESULTS
Color Change
The results of 2-way ANOVA revealed that the surface treatment method significantly (P = .047) affected the ∆E values of specimens; however, the effects of denture base material (P = .218) and the interaction between denture base material and surface treatment method (P = .478) were not statistically significant. Application of surface sealant agent significantly decreased the ∆E values for both denture base materials (P = .047). ∆E values were not significantly different between the two denture base materials with any surface treatment method (P = .218) (Table 2, Fig 2).

Surface Roughness
The results of 2-way ANOVA also showed that the effect of denture base material was significant (P < .001) on the prethermocycling Ra of specimens. However, the effects of surface treatment method (P = .600) and the interaction of denture base material and surface treatment method (P = .515) were not significant on
The present study evaluated the effect of a surface sealant agent on the color stability and Ra of PMMA and nylon denture base materials before and after thermocycling. The first null hypothesis was rejected for color stability but accepted for Ra because the surface sealant agent significantly increased the color stability but did not change the Ra of denture base materials either before or after thermocycling. The second null hypothesis was accepted for color stability, but rejected for Ra, since no significant difference existed between the color stability of the two denture base materials; however, the Ra of nylon was significantly higher than PMMA before and after thermocycling.

**DISCUSSION**

**Color Stability**

This study found no significant difference between the color change of nylon and PMMA denture base materials. However, application of a sealant agent significantly decreased the color change of both materials to a level below the clinically acceptable threshold ($\Delta E = 4$) compared to conventional polishing alone.

Coffee was used as a staining solution in the present study. Stainability of polymers by coffee is related to the yellow colorants with different polarities. Tannic acid in particular is responsible for the staining potential of this beverage. Moreover, as an aqueous solution, it might be

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**Table 3**  Mean ± SD Surface Roughness (Ra [µm]) and Effect Size (Partial $\eta^2$)

<table>
<thead>
<tr>
<th>Denture base material</th>
<th>Surface treatment technique</th>
<th>Prethermocycling</th>
<th>Postthermocycling</th>
<th>Difference in Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMMA</td>
<td>Control</td>
<td>0.6 ± 0.2a</td>
<td>0.9 ± 0.4a</td>
<td>0.3 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>Sealant</td>
<td>0.6 ± 0.4a</td>
<td>0.6 ± 0.4a</td>
<td>0.0 ± 0.2</td>
</tr>
<tr>
<td>Nylon</td>
<td>Control</td>
<td>2.1 ± 0.9b</td>
<td>2.0 ± 0.6b</td>
<td>–0.1 ± 0.8</td>
</tr>
<tr>
<td></td>
<td>Sealant</td>
<td>1.96 ± 0.6b</td>
<td>2.1 ± 1b</td>
<td>0.2 ± 0.9</td>
</tr>
</tbody>
</table>

Effect size

- Denture base material: .605 .435
- Surface treatment technique: .009 .006
- Interaction: .009 .016

Different superscript lowercase letters represent significant difference among the subgroups in each column.

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**Fig 3**  Surface roughness (a) before and (b) after thermocycling.
expected that polymers absorb the water molecules of this beverage. Chan et al investigated the staining potential of some beverages on composite restorative materials and stated that the greatest amount of discoloration occurred during the first week. Therefore, an immersion time of 1 week was chosen in this study to determine the potential for long-term stain retention.

Staining of resin base materials is related to their water sorption and hydrophobicity/hydrophilicity. If the denture base acrylic resin absorbs water, it can also absorb other fluids and undergo discoloration. Nylon denture base material is hygroscopic in nature, and the frequency of amide groups along the chain affects the water sorption of each type of nylon.

Likewise, Kurtulmus et al detected no significant difference in the mean values of liquid sorption of some heat-polymerized and nylon resins. However, they noted less sorption in the denture base material containing

![Fig 4 Scanning electron micrographs (x500 and x1,000 magnification, respectively) of the denture base materials before thermocycling. (a, b) Control PMMA. (c, d) Sealant-coated PMMA. (e, f) Control nylon. (g, h) Sealant-coated nylon.](image-url)
cross-linking agents than in those without cross-linking agents. Sepúlveda-Navarro et al.\textsuperscript{25} reported that the color change of thermoplastic nylon resin (Transflex) was greater than PMMA in different beverages. However, there was no significant difference in the color change between the two denture base materials in the present study. This difference in results can be attributed to the differences in composition and processing between PMMA and nylon denture base materials, as well as the different polishing techniques employed in the two studies.

The sealant agent improved the stain resistance in the present study most likely because it reduced the liquid sorption of specimens. Discoloration of sealant agent–coupled specimens highly depends on the intrinsic and extrinsic staining factors of the sealant agent, whereas

![Fig 5 Scanning electron micrographs (×500 and ×1,000 magnification, respectively) of the denture base materials after thermocycling. (a, b) Control PMMA. (c, d) Sealant-coated PMMA. (e, f) Control nylon. (g, h) Sealant-coated nylon.](image_url)
conventionally polished specimens may be affected by the surface characteristics and chemical behavior of the material itself. The sealant agent can fill out the microdefects and microfissures on the restorative materials via capillary action. In confirmation of the present study, Sarac et al.\textsuperscript{24} observed significantly lower color change values in nanohybrid composite resin materials with sealant agent (Biscover) than in those that were only conventionally polished. Likewise, Dedè et al.\textsuperscript{34} reported that application of different sealant agents (Palaseal, Optiglaze, and Biscover) decreased the color change of composite specimens into the range of visually perceptible but clinically acceptable levels. In the study by Şahin et al.,\textsuperscript{22} Palaseal and Optiglaze sealant agents provided more color-stable denture tooth surfaces than the conventional polishing technique. In contrast to the present study, Valentini et al.\textsuperscript{35} reported that application of surface sealant decreased the color stability of microhybrid composite resins. Such a different result compared to the present study may be explained by the variations in composition and roughness of the tested resins. Additionally, the duration of polymerization and composition of surface sealant agents are known as important factors in the stain resistance of these materials. The methacrylate- or dimethacrylate-containing sealant materials resulted in better stain resistance than those containing ethoxylated bisphenol-A dimethacrylate.\textsuperscript{21}

**Surface Roughness**

In the present study, the Ra values of all study groups were higher than the plaque accumulation threshold (0.20 μm)\textsuperscript{11,12} and the surface sealant agent did not significantly affect the Ra of either denture base material before or after thermocycling. In agreement with this study, Şahin et al.\textsuperscript{36} reported that all the sealant-coated and noncoated specimens of PMMA and polyamide denture base materials investigated in their study had Ra higher than the plaque accumulation threshold, and application of surface sealant had no significant effect on the Ra of the tested denture base materials. However, in a different study, Şahin et al.\textsuperscript{22} observed that the surface sealant agents decreased the Ra values of the tested denture tooth materials. The different results of this study could be related to the different composition and surface characteristics of the denture tooth materials and denture base materials.

The present study also found that PMMA had significantly lower Ra than nylon denture base material both before and after thermocycling. SEM images also revealed a more irregular texture for the nylon groups compared to the PMMA groups. This may be explained by the different physical properties of the materials. Polyamides are difficult to finish and polish and have a low melting temperature; therefore, careful wax-up and minimal adjustment to the polyamide dentures after processing is recommended.\textsuperscript{37} In line with the present findings, Abuzar et al.\textsuperscript{37} showed that polyamide specimens had a rougher surface than PMMA both before and after polishing. Furthermore, Kawara et al.\textsuperscript{38} used a scratch test to evaluate the Ra of thermoplastic denture base resins and suggested that the surface of thermoplastic denture base resins was easily scratched compared to PMMA.

Among the limitations of this in vitro study was evaluating only one brand of denture base material for PMMA and nylon materials and using only one type of staining solution to simulate the intraoral condition. Further studies are recommended to evaluate the effects of other types of surface sealant agents on the color stability and Ra of other types of denture base and tooth materials.

**CONCLUSIONS**

While application of surface sealant agent did not significantly affect the Ra of PMMA and nylon denture base materials, it significantly decreased the color change values of both denture base materials. Although the color change did not significantly differ between PMMA and nylon denture base materials, the Ra of PMMA specimens was significantly lower than that of their nylon counterparts both before and after thermocycling.

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**REFERENCES**

The purpose of this study was to compare the clinical and radiographic outcomes of < 7-mm–length short (SH) implants inserted in native bone vs longer (ST) implants placed in vertically augmented partially edentulous posterior jaws. A further aim was to evaluate whether the residual bone dimension plays a role in the outcomes of SH and extra-SH implants. This review was registered with PROSPERO. An electronic literature search was performed in PubMed, Scopus, and Web of Science. Randomized controlled trials with at least 1-year follow-up comparing fixed prostheses supported by SH vs ST implants in augmented sites were included. Marginal bone level (MBL) changes, implant survival rate, and complications were evaluated through a meta-analysis. Subgroup analysis was performed dividing the SH implants according to length at each follow-up (1, 3, and 5 years of function). Twenty-five articles fulfilled the inclusion criteria, with at least a 5-year follow-up are needed to confirm the promising outcomes observed with < 5-mm–length implants.


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