Effect of Storage Solution on Surface Roughness of Provisional Crown and Fixed Partial Denture Materials

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Purpose: This study evaluated the surface roughness of polished provisional materials at baseline and after storage in artificial saliva and artificial saliva–coffee solutions.

Materials and Methods: Ten specimens (25 mm × 25 mm × 2 mm) of 12 commercially available provisional crown materials (5 methacrylate and 7 bis-acryl resins) were fabricated and polished. Baseline surface roughness measurements (Ra) were made using a surface roughness tester. Specimens were divided into 2 groups and stored in artificial saliva or artificial saliva–coffee solution at 37°C for 2 weeks. Baseline surface roughness data were analyzed using the analysis of variance; multiple comparisons adjustment was made using the Tukey method. Multiple linear regression methods were used to analyze change in roughness relative to baseline and to assess the impact of storage medium, material, and baseline roughness on this change, including potential interactions among these 3 factors; descriptors of poststorage surface roughness were obtained.

Results: Alike demonstrated the greatest surface roughness, both at baseline and after storage ($p < 0.05$ after adjustment for all Pairwise comparison by Tukey method). Temphase, Temporary Bridge Resin, Instatemp, Unifast, Jet, and Zeta had the lowest baseline surface roughness measurements. The lowest poststorage roughness scores were associated with Protemp Garant, Jet, and Integrity. Five materials (Protemp Garant, Instatemp, Unifast, Jet, and Zeta), formed the group having the lowest rough poststorage outcomes. The data provided strong evidence of a material effect ($p < 0.0001$) at baseline. Evaluation of change in Ra following storage indicated that surface roughness increased for the majority of materials after storage in a moist environment, and that provisional crown materials that exhibit less initial surface roughness tend to undergo greater surface roughness change in a moist environment. Strong indications were found that the effect of the type of storage solution used differed among the materials.

Conclusions: There were significant differences in surface roughness of provisional crown materials when polished under the same conditions. Methacrylate resins in general exhibited smoother surfaces after initial polishing. Surface roughness increased for nearly all materials after storage in either moist environment.

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INDEX WORDS: provisional crown, surface roughness, polish

PROVISIONAL CROWNS and fixed partial dentures (FPDs) are an integral part of prosthodontic treatment. These materials must meet esthetic, mechanical, and biologic requirements; a key requirement is the maintenance of periodontal health.[1,2] Since provisional restorations have been described as contributors to gingival inflammation and recession,[3-5] suggestions have been made to ensure soft tissue health. To promote optimal periodontal health, the provisional crown should demonstrate good marginal fit, proper contour, and smooth surface topography.[1] The provisional crowns are polished before temporary cementation to create a surface that is more comfortable to the patient, and may inhibit the adherence of plaque and stain. Various methods involving a series of steps have been

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described for finishing and polishing of provisional resins. One recommended method is to use a muslin wheel to apply a slurry of fine pumice to the surface followed by a second muslin wheel coated with polishing compound to induce a higher lustre.[1] Other techniques include the use of various rubber wheels, points, discs, and polishing pastes to smooth and polish the surface.[6]

A number of provisional crown materials are available. Most are composed of methacrylate resin or bisacrylate composite material. Each material has a unique chemical composition that imparts various physical properties. Characteristics such as marginal fit, color stability, fracture toughness, and exothermic release have been studied.[7-16] Clinicians often select a specific material based on ease of manipulation, cost, setting time, and esthetics. Ease of polishability and the resultant surface roughness should also be considered when choosing a provisional material. Furthermore, the surface may be smooth after initial polishing, but over time in the oral environment it may exhibit increased surface roughness. This is of concern when patients must wear a provisional crown or FPD in an esthetic zone and for optimal health of the gingival tissues. Although the polishability and resultant surface roughness of provisional crown materials immediately postfabrication have been studied,[16] the effect of storage in a moist environment on the surface roughness of these materials has not been examined. The purpose of this study was to measure the surface roughness of 12 provisional crown and FPD materials, at time of fabrication and after 2 week storage in 2 artificial saliva solutions.

Materials and Methods

Five methacrylate resins and 7 bis-acryl resins were selected (Table 1). Ten specimens (25 × 25 × 2 mm) of each material were fabricated. A polyvinylsiloxane mold was used (Aquasil, Dentsply Caulk, Milford, DE) onto which a glass slab was approximated under a 2.5 kg weight. Polyvinylsiloxane was chosen as the mold material, as polyvinyl impression materials are often used as matrices to form provisional crowns via direct or indirect methods. All bis-acryl resins were cartridge dispensed and auto-polymerizing, except Provipont DC, which required visible light application. The methacrylate resins were measured, hand-mixed, and allowed to autopolymerize. Unifast LC also required visible light application.

Each specimen was polished with coarse pumice, flour of pumice (Whip Mix, Louisville, KY) and high shine compound (Green Polishing Compound, Dixon Mfg., Carlstadt, NJ). The measured amounts of pumice and distilled water were individually dispensed to obtain consistent slurries. A dental lathe (KaVo Polishing

Table 1. Materials and Manufacturers

Product Name	*Manufacturer*	*Lot Numbers*	*Resin Type*
Alike	GC America, Alsip, IL	100799A-powder 031600A-liquid	Methacrylate
Instatemp	Sterngold Restorative Systems, Attleboro, MA	98320147	Bis-acryl
Integrity	Dentsply Caulk, Milford, DE	00425	Bis-acryl
Jet	Lang Dental Mfg. Co., Wheeling, IL	40870-powder 14420019-liquid	Methacrylate
Luxatemp	Zenith-DMG/ Foremost Dental, Englewood, NJ	0030056	Bis-acryl
Protemp Garant	ESPE, Norristown, PA	B076C099	Bis-acryl
Provipont	Vivadent, Liechtenstein	C16177	Bis-acryl
Provitec	GC America, Alsip, IL	100891	Bis-acryl
Temporary Bridge Resin	Dentsply Caulk, Milford, DE	990615-powder 99109-liquid	Methacrylate
Temphase	Kerr USA, Orange, CA	003742	Bis-acryl
Unifast LC	GC America Inc., Alsip, IL	061500A	Methacrylate
Zeta C & B Acrylic	Vita Zahnfabrik H Rauter GmbH & Co., Bad Sackingen, Germany	KX47–001-powder and liquid	Methacrylate

Unit EWL 80, KaVo America Corp., Lake Zurich, IL) operating at 1500 r.p.m. was used for all polishing steps. The same operator (DRH) polished all specimens. The specimens were polished on the testing side using a 15 second application of coarse pumice applied with a moist muslin wheel, followed by a 90° rotation of the specimen and another 15 second coarse pumice application. The same sequence was repeated using flour of pumice and high shine compound. Visual gross inspection of polished surfaces of all specimens was made. Surface flaws and any apparent subsurface air inclusions were noted. Baseline surface roughness measurements were made using a Surftest SJ-201 Surface Roughness Tester (Mitutoyo, Mitutoyo America Corporation, Aurora, IL). The position of specimens was standardized in the tester so that poststorage measurements could be made at the same site on the specimen. Three measurements were taken at 2 mm intervals spaced around the center of the specimens. Mean Ra's were calculated and recorded for each specimen.

Five specimens were placed in artificial saliva (1 L double distilled H_2O, 1.6802 g $NaHCO_3$, 0.41397 g $NaH_2PO_4 \cdot H_2O$, 0.11099 g $CaCl_2$)[17] or artificial saliva–coffee solutions. The pH was measured and recorded for each solution (pH Meter, Model 420A, Orion Research, Inc., Boston, MA). The coffee was made in a drip coffee maker using 32 g of ground coffee and 8 cups of water (Folgers Classic Roast Coffee, Procter & Gamble, Cincinnati, OH). To simulate oral conditions, the coffee was diluted with artificial saliva (pH = 7.2 ± 0.1) at a ratio of 400 cc coffee to 800 cc saliva (pH = 7.3 ± 0.1).[15] Specimens were stored at 37°C for 2 weeks, and solutions were changed every other day. The samples were reoriented in the roughness tester, and 3 measurements were taken. Mean surface roughness (Ra) was calculated for each material.

Following natural logarithmic transformation of surface roughness measurements at baseline, the standard one-way analysis of variance procedures were used to evaluate differences in the distribution of surface roughness at baseline among the 12 materials. Transformation was used in order to ensure conformity with distributional requirements of the statistical model, including normality and variance homogeneity. Pairwise comparisons were performed with adjustment for multiple comparisons using the Tukey method; an overall 5% level of Type I error was associated with the multiple comparisons adjustment. Standard multiple linear regression methods were used to further examine change scores (change in roughness relative to baseline after log transformation), including consideration of the effects of material, storage medium, and baseline roughness value on this change, and possible interactions among the 3 factors.

Table 2. Baseline Surface Roughness (Ra) in μm for Provisional Materials After Polishing

*Material (Type)**	*Baseline All (n = 10;Ra, μm; Mean and SD)*	*Tukey Grouping***
Alike (m)	1.95 (0.65)	A
Provitec (b)	0.68 (0.29)	B
Provipont (b)	0.54 (0.16)	B
Integrity (b)	0.50 (0.15)	BC
Luxatemp (b)	0.49 (0.15)	BC
Protemp Garant (b)	0.45 (0.12)	BCD
Temphase (b)	0.40 (0.20)	BCDE
Temp. Bridge Resin (m)	0.38 (0.16)	BCDE
Instatemp (b)	0.31 (0.13)	CDE
Unifast (m)	0.30 (0.08)	CDE
Jet (m)	0.27 (0.11)	DE
Zeta C & B Acrylic (m)	0.21 (0.03)	E

*m = methacrylate; b = bis-acryl.
**Pairwise differences of means were evaluated using the Tukey adjustment for multiple comparisons in conjunction with an overall 5% level of Type I error. Means of materials marked with the same letter do not differ significantly.

Results

Baseline Measurements of Surface Roughness

Analysis of variance based upon natural logarithms of the baseline roughness measures provided strong evidence that mean surface roughness differed among the 12 materials ($p < 0.0001$). Table 2 summarizes the results of pairwise baseline comparisons among the 12 materials, adjusting for multiple comparisons using the Tukey method in conjunction with an overall 5% level of Type I error. Five groups based upon the similarity of surface roughness measures were identified, greatest surface roughness measurements being found in the Alike group, which differed significantly from all the other materials. Six materials (Temphase, Temp. Bridge Resin, Instatemp, Unifast, Jet, and Zeta) formed the group having the lowest rough baseline outcomes.

Evaluations of Change from Baseline After Storage in Solution

For specimens stored in artificial saliva–coffee solution, the overall mean change in surface roughness from baseline levels, averaging over all materials, was 0.075 μm, while the mean change for artificial saliva solution was 0.073 μm. Both represent highly significant increases in roughness relative to baseline ($p < 0.0001$).

More detailed assessment of change in surface roughness scores was carried out using standard regression methods to assess the potential influences of baseline status, material, and storage in either artificial saliva or artificial saliva–coffee solutions, and to determine whether there were significant interactions among the 3 factors in terms of their effect on change in Ra. Differences in log-transformed values were utilized to achieve conformity with assumptions of the statistical model. There was no evidence of three-way interaction among the 3 factors, nor of interaction between baseline level and either material or solution ($p > 0.3$ in all instances).

The data provided strong evidence of an interaction between material and solution factors ($p = 0.007$), indicating that the effect of material differed with the storage solution used. These differences in pattern are clearly seen in the nonparallel profiles for the 2 storage solutions given in Figure 1. Table 3 gives the descriptive statistics for change in Ra by material and solution, and Table 4 gives the analogous descriptors for post-storage levels of surface roughness. Both, clearly, illustrate the interaction between material and solution, in that the impact of adding coffee to the storage solution does not have a uniform effect across all provisional materials.

The data also provided strong evidence of a decreasing relationship between the change in log Ra and the baseline Ra level ($p < 0.0001$), indicating that the change in surface roughness scores tended to be proportionately larger for those specimens that were smoother at baseline, although exceptions were noted. This trend is illustrated in Figure 2. However, while the effect of baseline Ra values is statistically significant, it explains only a modest amount of the variability (about 17.8%, compared to 38.6% for effects related to material and storage solution) in the change scores, showing a highly significant, but

Table 3. Mean Change in Surface Roughness (ΔRa) in μm of Provisional Materials, Calculated as (Ra After Storage—Ra at Baseline), for Samples Stored in Artificial Saliva and in Saliva–Coffee Solution

*Material (Type)**	*Saliva Storage; ΔRa (μm) mean (SD) (n = 5)*	*Saliva–Coffee Storage; ΔRa (μm) mean (SD) (n = 5)*
Alike (m)	0.08 (0.25)	0.16 (0.10)
Provipont (b)	0.26 (0.12)	0.15 (0.17)
Provitec (b)	−0.04 (0.22)	0.06 (0.13)
Temp. Bridge Resin (m)	0.20 (0.11)	0.13 (0.13)
Luxatemp (b)	0.0257 (0.09)	0.05 (0.02)
Integrity (b)	0.02 (0.05)	0.01 (0.04)
Temphase (b)	0.08 (0.06)	0.15 (0.18)
Protemp Garant (b)	−0.08 (0.13)	0.06 (0.05)
Instatemp (b)	0.09 (0.05)	0.07 (0.11)
Unifast (m)	0.15 (0.07)	−0.01 (0.10)
Jet (m)	0.003 (0.10)	0.04 (0.05)
Zeta C & B Acrylic (m)	0.10 (0.02)	0.05 (0.04)

*m = methacrylate; b = bis-acryl.
Negative values indicate negligible changes, and do not reflect an increase in smoothness.

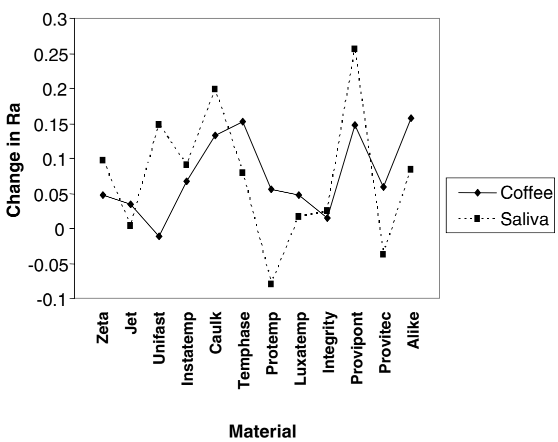

Figure 1. Change in surface roughness (Ra) after 2 weeks of storage in either artificial saliva solution or artificial saliva + coffee solution, for 12 provisional crown materials. The materials are listed in increasing order based upon surface roughness at baseline.

Table 4. Mean Poststorage Surface Roughness (Ra) in μm of Provisional Materials, for Samples Stored in Artificial Saliva and in Saliva–Coffee Solution

*Material (Type)**	*Saliva Storage (Ra, μm; mean (SD); n = 5)*	*Saliva–Coffee Storage (Ra, μm; mean (SD); n = 5)*
Alike (m)	1.98 (0.74)	2.15 (0.68)
Provipont (b)	0.74 (0.22)	0.74 (0.09)
Provitec (b)	0.68 (0.34)	0.71 (0.26)
Temp.Bridge Resin (m)	0.56 (0.31)	0.53 (0.15)
Luxatemp (b)	0.57 (0.21)	0.48 (0.15)
Integrity (b)	0.48 (0.13)	0.57 (0.17)
Temphase (b)	0.38 (0.10)	0.66 (0.19)
Protemp Garant (b)	0.38 (0.13)	0.49 (0.11)
Instatemp (b)	0.36 (0.19)	0.42 (0.11)
Unifast (m)	0.45 (0.15)	0.27 (0.06)
Jet (m)	0.31 (0.14)	0.27 (0.09)
Zeta (m)	0.31 (0.04)	0.26 (0.04)

*m = methacrylate; b = bis-acryl.

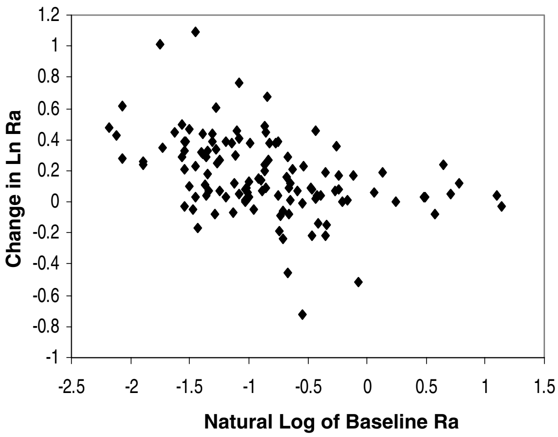

Figure 2. Plot of change in natural log-transformed Ra after 2 weeks of storage by baseline levels (combined data from all materials and storage solutions).

moderate, level of correlation ($r = -0.419$, $p < 0.0001$). The effect of baseline level is not as clearly seen in the mean values given in Tables 3 and 4, which list materials in decreasing order of baseline surface roughness. In these tables of mean values, the more subtle effect associated with baseline Ra illustrated in Figure 2 is overwhelmed by the effects of material and storage solution. There remains a great deal of variation in change in Ra among the materials, as seen in Figure 1, particularly for those samples stored in artificial saliva.

Further examination of the data showed that, after adjusting for the effect of baseline roughness, there were no significant differences ($p = 0.13$) among materials in terms of change in surface roughness for those specimens stored in the saliva–coffee solution. In contrast, when the same comparison was made for specimens stored in artificial saliva, there were significant differences in change scores among the materials ($p < 0.0001$), even after the effect of baseline Ra was taken into consideration. Figure 1 illustrates these patterns of change, including the greater variation in mean change among the materials when storage was in artificial saliva, as compared to the artificial saliva–coffee storage solution. Mean change among the materials in the saliva-storage group ranged from -0.080 μm for Protemp Garant to 0.256 for Provipont. Before and after adjustment for the effect of baseline roughness, the greatest increases in poststorage Ra were seen for the Provipont, Temp. Bridge Resin, and Alike products (Table 3), all of which showed high levels of poststorage roughness, as quantified in Table 4.

It may be noted that the analogous modeling of the poststorage measurements of surface roughness would yield identical interpretations, as discussed by Blomqvist,[18] if adjustments were made for material, storage solution, and baseline Ra, so these results are not presented. Means and standard deviations for the level of roughness observed for each material following 2 weeks of storage in each of the 2 solutions are given in Table 4 for descriptive purposes.

Discussion

This study examined the differences in surface roughness when 12 provisional crown and FPD materials were polished using a controlled, standardized technique. It also investigated the changes in surface roughness after a 2 week storage period in artificial saliva and artificial saliva–coffee solutions. While there are other techniques and products for polishing provisional restorations,[6] a traditional pumice and muslin wheel method was chosen. The polishing media used are part of the standard armamentarium of most dental offices. This polishing technique is recommended by authors of several prosthodontic texts.[1,2] The 2 week storage period in the artificial saliva and artificial saliva–coffee solutions was selected to represent the average amount of time a patient is required to use a provisional restoration while the laboratory fabricates a single crown. Both solutions exhibited pH values very near neutral. Exposure to increasingly acidic to basic solutions or changes in temperature may provide different results. Future testing of this hypothesis is planned.

The methacrylate products, with the exception of Alike, produced the smoothest baseline surfaces. This agrees with the findings of Wang et al, who reported that the surfaces of bis-acryls appeared rougher than methacrylates.[16] The polishability of resin composites is directly related to particle size of the filler. Methacrylate resins are not filled, and therefore should be more responsive to traditional polishing techniques, provided a homogenous, void-free surface is obtained. The methacrylate materials used in the study demonstrated consistent, void-free mixes, with the exception of Alike. Small, but visible, surface voids and porosity of the Alike material may explain the higher surface roughness values of this material.

Many of the products exhibited an increase in surface roughness after exposure to a moist environment. Products that initially demonstrated lowest surface roughness tended to experience more change (greater increase in surface roughness poststorage); however, small changes to products with greatest baseline surface roughness may render them clinically unacceptable. As daily exposure to numerous food products, dentifrices, and mouth rinses occurs, the adherence of plaque and the tendency to stain may be magnified with products having greater surface roughness. When provisional restorations are required for longer periods of time, gingival inflammation and deterioration of esthetic appearance may result.

No provisional crown material is superior in every respect.[16] One must consider all the characteristics of a provisional restorative material to decide which is appropriate for the patient.

Conclusions

Under the conditions of this research, the following conclusions were made:

1. There were significant differences in the baseline surface roughness of the materials analyzed in this study.
2. Methacrylate resins, in general, exhibited smoother surfaces after initial polishing.
3. Surface roughness increased for the majority of materials after storage in a moist environment.
4. The effect of the type of storage solution (i.e., the impact of the addition of coffee to the artificial saliva storage solution) on change in surface roughness differed with the particular material.
5. Provisional crown materials exhibiting less initial surface roughness may undergo greater surface roughness change in a moist environment.

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