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ORIGINAL RESEARCH

Evaluation and Comparison of the Surface Roughness and Porosity of Different Provisional Restorative Materials: An *in vitro* Study

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ABSTRACT

Aim: The purpose of this study was to evaluate and compare the surface roughness and porosity of different provisional restorative materials.

Materials and methods: Provisional restorative materials were divided into following three groups: Dental products of india (DPI), Protemp, Tempofit. For each group, wax block with 20 × 10 × 3 mm was made for making vinyl polysiloxane impression material to give 12 samples in each group of three different provisional restorative materials. The acrylic resin was inserted into the silicon impression mold. A total of 12 specimens of one material were obtained. The specimens were finished with the help of lathe using a sequence of grit sand paper. The surface roughness was verified with the help of a micron dial indicator. To facilitate the porosity readings, the specimens were immersed in dye for 2 hours. The number of pores in each area was determined with a stereomicroscope with magnification 1× 50× to check the porosity of three different provisional restorative materials. Values were subjected to statistical analysis.

Results: Analysis of variance (ANOVA) test was used to compare between Tempofit, Protemp, and DPI. The results obtained indicated that surface roughness of Protemp was least compared with Tempofit and DPI. The ANOVA test was used to check surface area of porosities in each provisional material, followed by Kruskal–Wallis test and Mann–Whitney test (highly significant) ($p < 0.001$). The results obtained indicate that Protemp material showed the least number of porosities and minimal surface roughness followed by Tempofit and DPI. Henceforth, it can be concluded that among the three tested materials, Protemp was the best material which can be used for provisional restorations.

Conclusion: Surface roughness and porosity were compared among Protemp, Tempofit, and DPI material; the best results were obtained with the use of Protemp material which had shown the least number of porosities and minimal surface roughness.

Keywords: Dental products of india, Porosity, Protemp, Surface roughness, Tempofit.

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INTRODUCTION

Provisional restorations are used during the interval between tooth preparation and the placement of the definitive restoration. Temporary restorations should have good marginal integrity, esthetics, and sufficient durability to withstand the forces of mastication.[1,2]

Materials commonly used to fabricate provisional restorations are polymethylmethacrylate (PMMA), polyethyl methacrylate, Bis-acryl composite (BAC) resin, and Epimine resins. Provisional fixed partial denture (FPD) materials must be strong enough to withstand the masticatory forces, particularly for long-span FPDs or for patients with parafunctional habits.[3] The latest class of materials is formed by BAC resins, which are comparable to composite resins used for direct restoration therapy. These consist of an organic matrix and inorganic fillers. Less heat and shrinkage produced by BACs during polymerization than other resins result in a better marginal fit. Esthetically, they are reasonable and are more color stable than PMMA or polyethyl methacrylates.[4] Composite provisionals (e.g., Protemp) became available first. These are stronger, are radiopaque, have good color stability, and have the advantage of being repairable with other composites. This generation of provisional materials was succeeded by Protemp IV, which was more translucent and much easier to handle.

Currently available provisional materials are functional, esthetic, and easy to repair (by the addition of flowable composite). The major concerns facing the practitioner are ease of use and polishing.[5] Lack of attachment of dental bacterial plaque is essential for the success of provisional fixed prostheses, which in turn is an important factor in the success of definitive fixed prostheses. Dental materials with rough surfaces have been found to favor bacterial attachment and hinder oral hygiene methods.[6] Provisionals can be made either chair side (direct technique) or with the help of a dental laboratory (indirect technique). According to the technique used, the processing of acrylic resins to make the provisional crowns can result in a surface that presents roughness and porosity.[7]

Porosity has been attributed to a variety of factors that include the following: Air entrapment during mixing, monomer contraction during the polymerization, monomer vaporization associated with exothermic reaction, the presence of residual monomer, and insufficient mixing of monomer and polymer.[8] Porosity is an undesirable consequence of the processing and polymerization of acrylic resins. This is a complex phenomenon of multifactorial origin related to the vaporization of monomer, lack of uniformity of the acrylic resin mixture, or lack of adequate pressure during the polymerization process. Rough and/or porous surfaces on provisional crowns create favorable conditions for the proliferation of microorganisms.

The purpose of this study was to evaluate and compare the surface roughness and porosity of different provisional restorative materials.

AIMS

- To evaluate roughness and porosity of autopolymerized PMMA resin [Dental Products of India (DPI) tooth molding powder]
- To evaluate roughness and porosity of autopolymerized BAC (Protemp)
- To evaluate roughness and porosity of autopolymerized BAC (Tempofit)
- To compare roughness and porosity between above-mentioned three different provisional restorative materials

MATERIALS AND METHODS

Materials used in the Study

- Autopolymerized PMMA – (DPI self-cure tooth molding powder)
- Autopolymerized BACs (Protemp)
- Autopolymerized BACs (Tempofit)
- Vinyl polysiloxane impression material (3M ESPE)
- Modeling wax
- Grit wet sand paper
- Dye
- Tissue paper (Fig. 1)

Armamentarium used in the Study

- Finishing machine lathe
- Micron dial indicator
- Stereomicroscope (Olympus SZX 12 Optical Co. Ltd., Japan) with Trinocular 3 Chip charge-coupled device (CCD) camera
- Software (Proimage analysis)
- Silicon mixing jar (mixing DPI Tooth molding powder)
- Glass slab
- Dappen dish

Method of Collection of Data (including Sampling Procedure, if any) Specimens

Provisional restorative materials were divided into three groups:

1. Autopolymerized PMMA resin (DPI)
2. Autopolymerized BAC (Protemp)
3. Autopolymerized BAC (Tempofit)

METHODOLOGY

For each group, wax block with 20 × 10 × 3 mm (Fig. 2) was made for making vinyl polysiloxane impression material to give 12 samples in each group of three different provisional restorative materials. Wax blocks were embedded in putty impression mold (Fig. 3). Autopolymerizing resin (DPI tooth molding powder) was poured in a vinyl polysiloxane matrix. The liquid (monomer) was saturated with the powder (polymer). Then the resin was allowed to reach its plastic stage (1.5–2 minutes after mixing). Then,

Fig. 1: Materials used

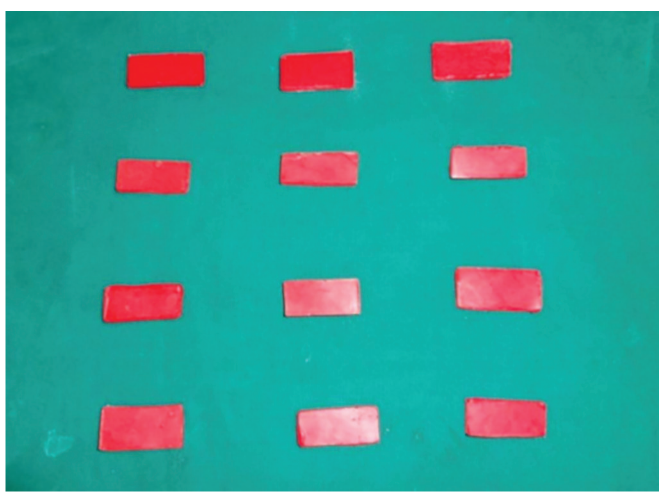

Fig. 2: Wax blocks

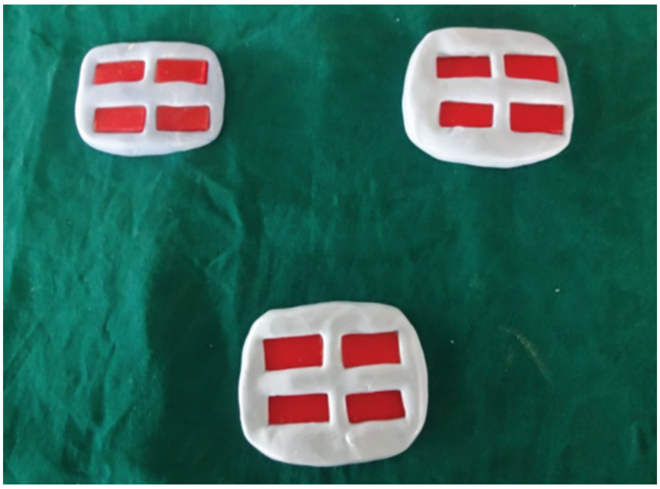

Fig. 3: Wax blocks embedded in putty impression mold

Fig. 4: Acrylic resin (DPI) inserted into the polysiloxane impression mold

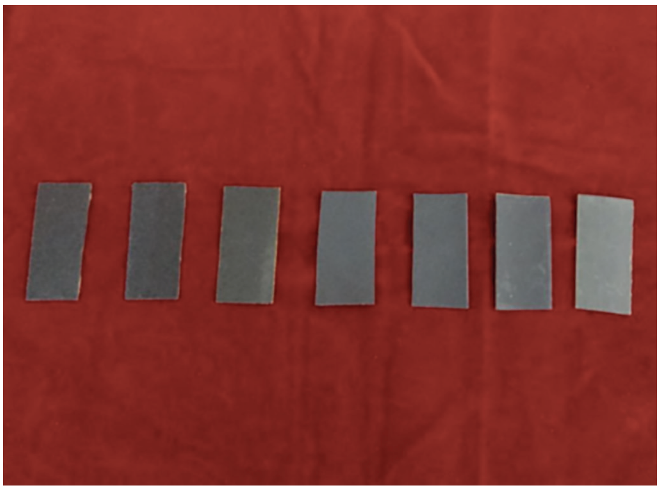

Fig. 5: Finished with a sequence of 80, 100, 120, 150, 200, 400, 600 grit sand paper

Fig. 6: Surface roughness measured with the help of micron dial indicator

the acrylic resin was inserted into the silicon impression mold with a spatula; 12 specimens of one material were obtained (Fig. 4). The other two different autopolymerized BAC (Protemp, Tempofit) methods were followed according to manufacturer instructions. These materials were dispensed into the impression matrix directly from the automixing gun and tip. The specimens were finished using a sequence of 80, 100, 120, 150, 200, 400, 600 grit sand paper (Fig. 5). This stage was to standardize the surfaces of the specimens before the roughness and porosity readings. The surface roughness (µm) was measured with micron dial indicator (Fig. 6). To facilitate the porosity readings, the specimens were immersed in dye for 2 hours. Then the specimens were rinsed in running water for 10 seconds and dried with tissue paper. The number of pores in each area was determined with a stereomicroscope (Olympus SZX 12 Optical Co. Ltd, Japan) (Fig. 7). With magnification 1× 50× along with Trinocular 3 Chip CCD camera along with software (Proimage analysis) the porosity of provisional restorative materials was checked (Fig. 8).

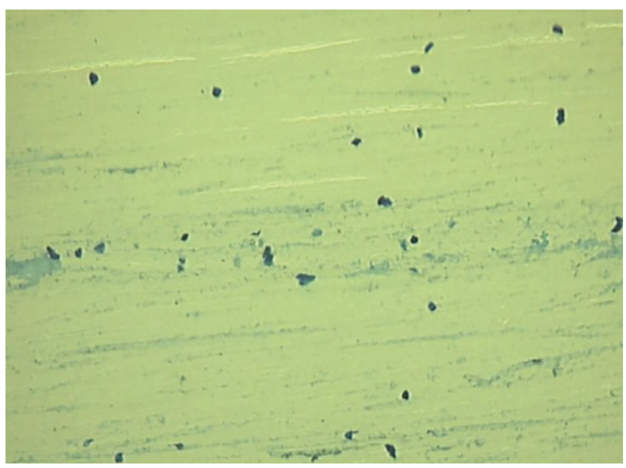

Fig. 7: Surface porosities of DPI provisional material observed in stereomicroscope under 1× 50× magnification

RESULTS

The results were subjected to statistical analysis. The analysis of variance (ANOVA) test was used to compare between Tempofit, Protemp, and DPI. The results

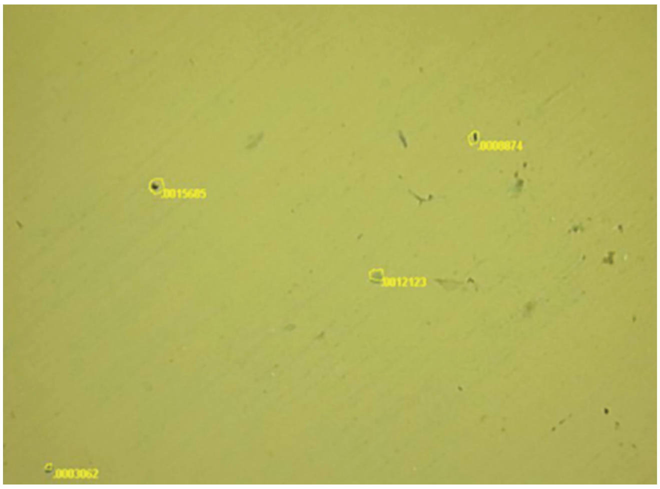

Fig. 8: Surface porosities measured with the help of software (Proimage analysis)

obtained indicated that, surface roughness of Protemp was least compared with Tempofit and DPI.

The ANOVA test was used to check surface area of porosities in provisional materials, followed by Kruskal–Wallis test and Mann–Whitney test (highly significant) ($p < 0.001$). The results obtained indicated that use of Protemp material showed the least number of porosities and minimal surface roughness followed by Tempofit and DPI.

DISCUSSION

Fixed prosthetic treatment commonly relies on indirect fabrication of a definitive prosthesis in the dental laboratory. Fabrication of this definitive prosthesis on an average takes about 7 to 10 days during which the prepared tooth needs to be protected from the oral environment and also its relationship with the adjacent and opposing tooth needs to be maintained. Thus, in order to protect these prepared abutment teeth, provisional restorations are fabricated and the process is called as temporization.[9]

Fabrication of provisional crowns uses a wide variety of materials and techniques. The requirements can be biological, mechanical, and esthetic. The provisional crown protects the pulp from thermal, chemical insults after crown preparation and enamel removal. It serves to maintain gingival health and contour while providing for an esthetic and/or functional interim restoration. Provisional crowns should be easy to clean and not impinge on the tissues. Most importantly, it should maintain interocclusal and intra-arch tooth relationships. Finally, they should exhibit a good shade match and have a highly polished surface so that they are esthetically pleasing to the patient. All these factors are extremely important to the success or failure of treatment outcomes.[10]

Materials used for provisional restorations can be classified as acrylics or resin composites. Acrylic materials have been used for provisional restorations since the 1930s and are usually available as powder and liquid. Their popularity is due to their low cost, acceptable esthetics, and versatility. They produce acceptable short-term provisionals but tend to discolor over time. Other disadvantages include an objectionable odor, significant shrinkage, and heat generation during setting. The types of acrylics are PMMAs, poly-R′ methacrylates and epimines. Advantages of PMMAs include low cost, good wear resistance, good esthetics, and high polishability.[11]

Composite provisionals encompass a fairly variable category by virtue of the fact that they are chemically comprised of a combination of two or more types of materials. Most of these materials use bis-acryl resin, a hydrophobic material, i.e., the same as bis-glycidyl methacrylate. Composites are available as autopolymerized, dual-polymerized, and visible light-polymerized materials. Bis-acryl provisional materials are resin composites and represent an improvement over the acrylics because shrinkage is less, gives off less heat during setting, excellent esthetics, minimal odor, and can be easily polished at chair-side. The latter reduce polymerization shrinkage. Bis-acrylic exhibits high strength because its monomers have a high molecular weight. Compared with methacrylate resins, BAC has more flexural strength and surface hardness, higher wear resistance, better marginal adaptation, and lower shrinkage. However, the rigid core of the aromatic group makes the backbone very stiff. It also prevents rotation, hindering complete polymerization of resin. Moreover, provisional bis-acrylic resin restorations for long span bridges and teeth with minimal preparation are too susceptible to fracture.[12]

Therefore, the material used should be able to resist fracture, offer a smooth, good looking surface profile, be color-stable to resist staining from food, beverages, and have an accurate marginal adaptation over the tooth. In addition, while the properties of provisional restoration depend on the type of material used, they appear to be product specific (Protemp IV). The addition of fine particle sizes can also enhance polish ability and smoothness of the cured provisional restorative material.[13]

Several studies have demonstrated that rough acrylic resin surfaces are significantly more prone to bacterial accumulation and plaque formation than smooth surfaces. The results of several studies indicated that supragingivally the impact of surface roughness on microbial adhesion is much more important than the influence of surface free energy. Some *in vivo* studies have suggested a threshold level of surface roughness (Ra = 0.2 μm) below which no further reduction in plaque accumulation could be expected. An increase in roughness of surface beyond this borderline level, however, resulted in simultaneous increase in plaque accumulation.[14]

Few *in vitro* studies reported to have influence of surface roughness on plaque formation. When teeth were suspended in bacterial cultures, a 10-fold increase in colony fusing units was seen after surface roughening (Swartz and Phillips).[15] However, when the adhesion of *Streptococcus sanguinis* to composite materials was examined with comparable roughness (ranging from 0.8 to 1.4 µm), only negligible differences were registered. Thus, these studies indicate a positive correlation between surface roughness and initial bacterial adhesion.[16]

Numerous *in vivo* studies examined the effect of surface roughness on supragingival plaque formation and on periodontal health. Rough surfaces (crowns, implant abutments) accumulate and retain more plaque (thickness area, and colony forming units). These observations were less obvious in patients with optimal oral hygiene or when plaque was scored with crude indices. After several days of plaque formation, rough surfaces harbor mature plaque characterized by an increased proportion of motile organisms and spirochetes. As a consequence, crowns with rough surfaces were more frequently surrounded by an inflamed periodontium, characterized by higher bleeding index, an increased crevicular fluid production, and histologically inflamed tissue. Shiny and smooth surfaces without porosities, strength, retention, cleansibility, esthetics, comfort, desirable contours, adequate embrasures, harmonious occlusion, and color stability are factors that have contributed to a well-integrated provisional restoration.[17]

The current study conducted was based on surface roughness and porosity of three provisional restorative materials. In this study were methylmethacrylate-based autopolymerized provisional restorative material (DPI) and BAC-based autopolymerized provisional restorative materials (Tempofit, Protemp IV). To check surface roughness of each material, the specimens were finished with the help of lathe using a sequence of 80, 100, 120, 150, 200, 400, 600 grit sand paper. Bis-acrylic composite-based provisional restorative materials are gaining in popularity, because of their cartridge delivery system. This dispensary method is convenient, allows for a more accurate and consistent mix, and thereby improves its physical and mechanical properties. Bis-acrylic composite is different from methacrylate resins. It is similar to composite restorative materials because it is made of bis-acryl resin and inorganic fillers.[18]

According to manufacturer instructions, the resin system is the organic matrix in which other components are dispersed or dissolved. It consists of monomers and can be polymerized. The filler system consists of discrete particles that are dispersed in the resin system. Size range of the fillers varies from fine particles (0.5–3 µm) to microfine particles (0.04–0.2 µm). Particles of different sizes and shapes are sometimes blended to obtain desired properties. Filler particles are surface treated (Protemp IV). Tempofit is composed of a mixture of methacrylic resins and silane-treated glass with auxillary matters and pigments. It is a two-part base/catalyst, automix, self-curing and BAC-based provisional restoration material.[19]

Surface roughness is an important feature associated with biofilm formation. Ra represents surface roughness. Ra values were near 0.2 µm, which can be considered as susceptible to microorganism colonization. The specimens were subjected to an initial surface roughness test (Ra – µm). These were then finished with 150 to 600 grit waterproof sandpaper under flowing water (Aropol E. Arotec, SP, Brazil) at a standard speed of 300 rpm until they reached a thickness of 3.0 ± 1.0 mm. One of the surfaces was machine polished with pumice and water, followed by whiting slurry with polishing cloths (conventional or standard polishing) and the other side was polished with special tips (Tec®, São Paulo, Brazil). The specimens were then measured with a profile meter (Mitutoyo® – Surf Test 301) calibrated for a 0.25 mm sample surface. The roughness of each specimen was measured twice and the mean value recorded.[6]

The current study evaluated and compared the surface roughness between three provisional materials (Protemp, Tempofit, and DPI). Surface roughness of Protemp mean value was 0.1 µm, Tempofit mean value was 0.3 µm, and DPI mean value was 0.8 µm. The ANOVA test was used to check surface roughness; p-value was obtained ($p < 0.001$). Results were highly significant. Protemp had less surface roughness followed by Tempofit and DPI.

Surface roughness affects the initial adhesion of cells but seems independent of bacterial accumulation once initial adhesion has taken place. With respect to plaque prevention, 0.2 µm Ra should be targeted for surfaces of dental restorations. Wietnam and Eames reported that plaque accumulation occurs on composite specimens with a surface roughness of 0.7 to 1.44 µm.[20] Because the Ra values obtained by single-phase finishing in this study ranged above 0.2 µm, this simple procedure can only be justified for short-term, interim restorations.[21]

Young et al[17] compared bis-acryl and PMMA materials in terms of occlusion, contour, marginal fidelity, and finish. For both anterior and posterior teeth, they found the bis-acryl materials significantly superior to PMMA in all categories and among the various materials, studies have conducted that Protemp IV is most color stable and with superior mechanical and physical properties.[22]

The current study conducted was also based on porosity depending upon pores of surface area and number of pores in each provisional material compared with the porosity of surface area and number of pores between provisional materials (Protemp, Tempofit, DPI). To facilitate the porosity readings, the specimens were immersed in dye for 2 hours. Then specimens were rinsed in running water for 10 seconds, dried with the help of a tissue paper.

The number of pores in each area was determined with the help of stereomicroscope (Olympus SZX 12 Optical Co. Ltd, Japan) with magnification 1× 50× along with Trinocular 3 Chip CCD camera along with software (Proimage analysis) to check the porosity of three different provisional restorative materials (DPI, Protemp, and Tempofit). The ANOVA test was used to check surface area of porosity in each provisional material. Results were recorded. Mean surface area of DPI value was 0.0020, mean surface area of Tempofit value was 0.0011, mean surface area of Protemp value was 0.0012; p-value was obtained; $p = 0.428$ (not significant). Hence, results were not significant (Tempofit > Protemp > DPI).

Porosity has been attributed to a variety of factors that include the following: Air entrapment during mixing, monomer contraction during the polymerization, monomer vaporization associated with exothermic reaction, the presence of residual monomer, and insufficient mixing of monomer and polymer.Jerolimov et al reported that occurrence of porosity is dependent on the concentration of the initiator, generally benzoyl peroxide in the polymer.[23] Depending on the conditions of polymerization, 11% porosities have been associated with decreased mechanical properties, poor esthetics, harboring of organisms, and fluid retention. Optical microscope was used to investigate surface porosities in all the samples. As per the literature available, this instrument is being used for the first time to measure the porosity. It is a reliable method of measuring area of surface pores. Portion of the sample being scanned is displayed on the computer with the help of software and surface area of pores could be calculated.[8] When surface roughness and porosity were compared among Protemp, Tempofit, and DPI material, the best results were obtained with the use of Protemp material, which had shown the least number of porosities and minimal surface roughness followed by Tempofit and DPI.

CONCLUSION

Surface roughness and porosity were compared among Protemp, Tempofit, and DPI material; the best results were obtained with the use of Protemp material, which had shown the least number of porosities and minimal surface roughness followed by Tempofit and DPI. Henceforth, it can be concluded that among the three tested materials, Protemp was the best material which can be used for provisional restorations.

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