A comparative evaluation of the marginal accuracy of crowns fabricated from four commercially available provisional materials: An *in vitro* study

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Abstract

Purpose: The purpose of this *in vitro* study was to evaluate and compare the primary marginal accuracy of four commercially available provisional materials (Protemp 4, Luxatemp Star, Visalys Temp and DPI tooth moulding powder and liquid) at 2 time intervals (10 and 30 min). **Materials and Methods:** A customized stainless steel master model containing two interchangeable dies was used for fabrication of provisional crowns. Forty crowns ($n = 10$) were fabricated, and each crown was evaluated under a stereomicroscope. Vertical marginal discrepancies were noted and compared at 10 min since the start of mixing and then at 30 min. **Observations and Results:** Protemp 4 showed the least vertical marginal discrepancy (71.59 μ), followed by Luxatemp Star (91.93 μ) at 10 min. DPI showed a marginal discrepancy of 95.94 μ while Visalys Temp crowns had vertical marginal discrepancy of 106.81 μ. There was a significant difference in the marginal discrepancy values of Protemp 4 and Visalys Temp. At 30 min, there was a significant difference between the marginal discrepancy of Protemp 4 crowns (83.11 μ) and Visalys Temp crowns (128.97 μ) and between Protemp 4 and DPI (118.88 μ). No significant differences were observed between Protemp 4 and Luxatemp Star. **Conclusion:** The vertical marginal discrepancy of temporary crowns fabricated from the four commercially available provisional materials ranged from 71 to 106 μ immediately after fabrication (at 10 min from the start of mix) to 83–128 μ (30 min from the start of mix). The time elapsed after mixing had a significant influence on the marginal accuracy of the crowns.

Keywords: Crowns, marginal accuracy, provisional

Introduction

Interim coverage of a prepared tooth during various stages of treatment is an important step in the construction of fixed dental prostheses. The provisional restoration is currently recognized to have a fundamental role in the determination of success or failure of permanent restorations. Marginal accuracy is of paramount importance because an acceptable fit at the margins is essential in maintaining gingival health and protecting the tooth from physical, chemical, bacterial and thermal injuries.[1,2]

The marginal fit or accuracy of a restoration can be defined best in terms of the "misfit" or the gap measured at various points between the restoration and the tooth. The term used for measuring marginal misfit in this study is vertical marginal discrepancy, which has been defined by Holmes *et al*.[3] as the vertical marginal misfit measured parallel to the path of draw of the casting at various points along the margins between the casting and the respective abutment.

A limited number of *in vitro* studies have been conducted to assess the degree of marginal gap formation of monomethacrylates and bis-acryl composite materials. Results of these studies show contradicting results. Some studies indicate that monomethacrylates have lower marginal discrepancies compared to dimethacrylates,[1,4] some of them show comparable fit between both the types,[5,6] while one study shows bis-acryl composite resin to be superior to methacrylate resin. One of the inherent properties of polymer based interim materials is polymerization shrinkage which causes dimensional changes that can adversely affect precise fit (marginal discrepancies and occlusal interferences) and lead to internal stresses within the restoration.[7,8]

Even though marginal discrepancies are usually accredited to polymerization shrinkage phenomenon,[1,9] no study could identify the correlation between the amount of shrinkage and marginal discrepancy in a single set up.[4] However, the time elapsed after mixing was shown to have a significant influence on the marginal discrepancy with greatest changes observed within first 30 min of mixing. Removal of these interim crowns at the appropriate time to limit distortion and allow complete polymerization prior to adjustment is crucial.[8]

The fabrication procedure of the interim restoration also influences its marginal adaptation. The techniques commonly

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used include direct, indirect and indirect-direct/reline technique. Several studies have evaluated the techniques used for making these restorations. Some researchers have demonstrated the superiority of the indirect technique of making provisional restorations extraorally with relining and venting[10,11] while others have advocated the intraoral direct technique.[12-14]

The purpose of this *in vitro* study was to compare the primary marginal accuracy of four autopolymerizing provisional materials one polymethyl methacrylate and three dimethacrylates fabricated using the direct method by measuring the vertical marginal discrepancy.

The aim of this *in vitro* study was to accomplish the following objectives:

- To evaluate and compare the vertical marginal discrepancy of crowns fabricated from four provisional materials
- To evaluate and compare the change in vertical marginal discrepancy with time elapsed after mixing.

Materials and Methods

Materials used

- Autopolymerizing bis-acrylic temporary crown and bridge material (Protemp-10:1 cartridge, 3M ESPE, Minnesota, USA)
- Autopolymerizing bis-acrylic temporary crown and bridge material-(Luxatemp Star-10:1 cartridge, DMG Dental, Hamburg, Germany)
- Autopolymerizing bisphenol A free multifunctional acrylic composite resin (Visalys Temp-10:1 cartridge, Kettenbach, Germany)
- Polymethyl methacrylate autopolymerizing resin (DPI self-cure tooth moulding powder and monomer liquid, Mumbai, Maharashtra).

Stainless steel model

The study model comprised of a circular stainless steel base and a custom impression tray. The base was 15 mm in height, 20 mm in diameter with a circumferential ledge on the superior surface (1 mm) to act as a stop for proper orientation and positioning of the tray. In the center of the base, a cylindrical space was created to hold two interchangeable stainless steel dies. The tray (height-15 mm, diameter-20 mm) was fabricated to provide a uniform space of 4 mm on either side of the centrally positioned die and had 2 mm perforations. The edges of the tray (1 mm in thickness) were seated on the circumferential ledge created on the base model. An orientation groove was marked on the tray extending onto the base, so that the tray could be repeatedly and consistently seated in the same way each time an impression was made. A ring handle was attached at the center of outer surface of the tray, parallel to the long axis of the die so as to ensure a vertical path of removal of the tray after impression making. A window was created on one aspect of the tray (2 mm × 5 mm) to aid in lifting the tray off the base and to allow escape of the excess provisional material [Figure 1]. Die 1 simulated an unprepared tooth (base diameter-10 mm, height-8 mm, taper-5°) and Die 2 simulated a prepared tooth (base diameter-10 mm, height-6.5 mm, shoulder margin-1.5 mm, taper-5°) [Figure 2]. Die 1 was used for impression making and then replaced by Die 2 in the same base for fabrication of the provisional crown. Die 2 had a flat surface machined at an angle to the superior surface to help in reseating of the provisional crown in the same position. For the purpose of measurement, reference lines were inscribed on the base of Die 2 at four different sites below the margin.

Making of the putty index and fabrication of the provisional crown

Before making of the index, Die 1 was placed in the base. The elastomeric impression material used in this study was an addition silicone impression material (Aquasil soft putty/regular set, Aquasil LV-Dentsply, France). The set putty in the area of the window was cut off to provide a channel for excess provisional material to flow. A direct method of fabricating the provisional crown was used to simulate intraoral fabrication. Die 1 was replaced with Die 2 which simulated a prepared tooth.

For the dimethacrylates, the material was dispensed directly into the impression from the cartridge by means of an automixing tip using a dispensing gun. The impression was seated onto the model and checked for correct positioning with the help of the orientation groove. Firm finger pressure was applied to the tray until the initial setting time mentioned by the manufacturer had elapsed. After this, the crown was removed as per the manufacturer's instructions and allowed to attain its final set. For the polymethyl methacrylate group, powder and liquid were dispensed in a ratio of 3:1 by volume, powder was saturated with the liquid monomer and hand mixed. The material was allowed to turn into matte finish before being placed on the die. After initial set, it was elevated and reseated on the die to simulate the direct technique [Figure 3].

After complete polymerization of the material, the crown was removed and checked for irregularities and voids. The excess was removed with a scalpel (No. 11 blade) using a magnifying glass. The crown was reseated with finger pressure onto the die. This procedure was repeated for all crowns ($n = 10 \times 4$; 40 crowns from 4 materials).

Measurement of the vertical marginal discrepancy of the provisional crowns

The die along with the seated provisional crown was placed perpendicular to the field of view of the microscope in order to observe the vertical marginal discrepancy. The instrument used for measuring the specimens was SZ16 Stereozoom binocular microscope with DP2 camera (Olympus, Japan) and DP2-BSW (Binocular microscope (SZ16 Stereozoom with DP2 camera and DP2-BSW software, Olympus, Japan) software.

Figure 1: Customized stainless steel circular base and custom impression tray

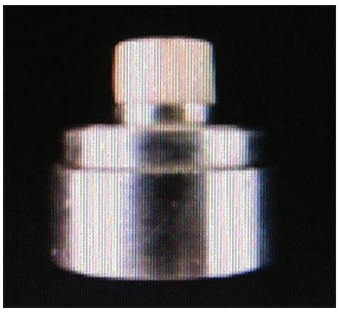

Figure 3: Provisional crown seated on Die 2

Each specimen was placed under a ×6.3 magnification. The vertical distance from the external crown margin to a perpendicular corresponding point on the margin of the die was measured with the help of a micrometer ruler placed in the field of view to calibrate the computer software program [Figure 4]. Three measurements were taken at each reference line, and this was repeated for the four marked reference lines. A total of 12 measurements at each time interval were made.

The vertical marginal discrepancy was measured at 2 time intervals after fabrication:

- Immediately after fabrication (corresponding to 10 min after mixing)
- 20 min after fabrication (corresponding to 30 min after mixing).

This allowed evaluation of shrinkage properties of the materials as correlated with increase in the marginal discrepancy and determination of the time interval after mixing, within which maximum amount of dimensional change occurs.

Observations and Result

The crowns were numbered as follows:

- Group A (Protemp 4): A1–A10
- Group B (Luxatemp Star): B1–B10
- Group C (Visalys Temp): C1–C10
- Group D (DPI self-cure tooth molding powder with monomer liquid): D1–D10.

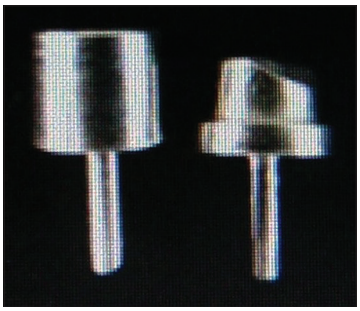

Figure 2: Die 1 and Die 2

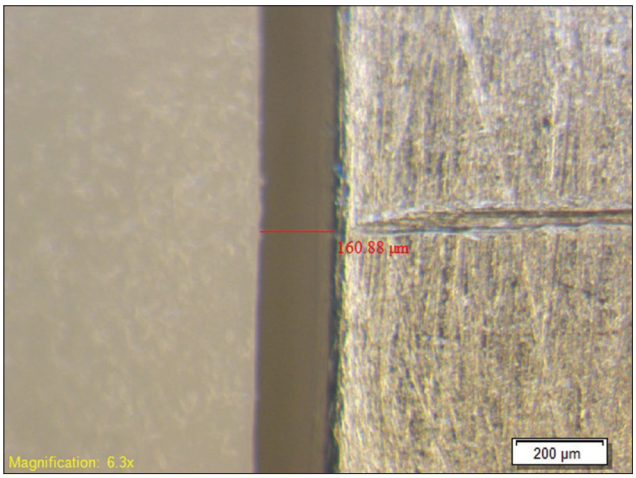

Figure 4: Vertical marginal discrepancy as seen through the stereomicroscope at both time intervals

The mean values of vertical marginal discrepancy were calculated for each group of materials at 10 and 30 minutes post mixing as shown in Table1 and Figure 5.

One-way ANOVA test was carried out to determine whether there was a difference between the four groups of materials and within each of them. Multiple comparisons between the materials at 10 min and at 30 min were carried out using the Scheffe *post-hoc* tests.

At 10 min

It was observed that there was a significant difference in the vertical marginal discrepancy of Group A crowns and Group C crowns ($P = 0.003$), with Group C showing greater discrepancy. No significant difference was observed between Group A and Group B ($P = 0.144$). Group D showed greater marginal discrepancy compared to Group A, but the difference was not statistically significant ($P = 0.057$). No significant differences were observed between Groups B, C and D. Group C had marginal discrepancy values greater than the other three materials.

At 30 min

A significant difference was observed between Group A and Group C ($P = 0.000$) and between Group A and Group D ($P = 0.005$). Group C showed greater discrepancy values compared to Group B and Group D, but the difference

Table 1: Mean vertical marginal discrepancy values of the provisional crowns at 10 and 30 minutes

Material	Mean vertical marginal discrepancy at 10 minutes	Mean vertical marginal discrepancy at 30 minutes
Group A (Protemp 4)	71.59 µm	83.11 µm
Group B (Luxatemp star)	91.93 µm	102.05 µm
Group C (Visalys temp)	106.81 µm	128.97 µm
Group D (DPI)	95.94 µm	118.88 µm

was not statistically significant ($P = 0.053$ and 0.361 respectively).

The difference in each provisional material at 10 min and 30 min was determined using the paired sample *t*-test. The paired samples *t*-test revealed that there were statistically significant differences observed in the vertical marginal discrepancy of crowns made from the four materials.

- Group A provisional crowns-increase of 11.52 µ ($P = 0.000$)
- Group B provisional crowns-increase of 10.11 µ ($P = 0.000$)
- Group C provisional crowns-increase of 22.16 µ ($P = 0.001$)
- Group D provisional crowns-increase of 22.93 µ ($P = 0.000$)

Discussion

The aim of this study was to determine the primary marginal fit of a provisional crown, that is, directly after fabrication without finishing and relining procedures. The reason to evaluate primary marginal fit was to avoid the influence of the temporary cement and inaccuracies that may be caused by the thickness of temporary cement or which may occur during the functional period of a temporary restoration (e.g., occlusal loading, thermocycling, aging, water uptake). In this way, the inherent property of each material could be tested. The time interval selected was closely related to the clinical situation, as the seating of the temporary restoration is usually delayed due to trimming and polishing procedures, intermediate steps such as impression making and in case of fabrication of multiple temporary restorations.

Two dies were milled to simulate an unprepared and a prepared tooth with dimensions that provided provisional crowns with a uniform thickness of 1.5 mm. A single die (Die 1) was used to make the putty indices and all crowns were fabricated on a single die (Die 2) to ensure standardization. Putty indices were fabricated using addition silicone impression material which is proven to be more dimensionally stable than other materials and is also used clinically for fabrication of provisional crowns.

The debate over the maximum acceptable gap size includes a wide range of values; from about 50 to 120 µm.[15] According

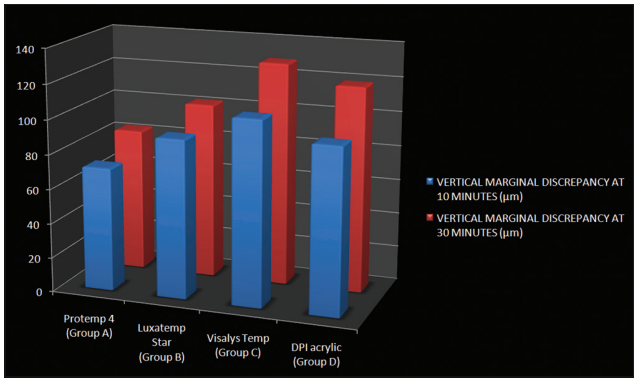

Figure 5: Bar diagram comparing the vertical marginal discrepancy values (in microns) of provisional crowns fabricated using the four materials at 10 min and at 30 min postmixing

to American Dental Association specification 8, marginal gaps >25–35 µm are unacceptable. The materials used in this study showed mean marginal discrepancy values of 71–106 µ immediately after fabrication. Of the four materials used, three were autopolymerizing dimethacrylates resins (Protemp 4, Luxatemp Star and Visalys Temp) while one was an autopolymerizing monomethacrylate (DPI). The least marginal discrepancy was observed with Protemp 4 (71.59 µ) while the highest discrepancy was observed with Visalys Temp (106.81 µ). Luxatemp Star (91.93 µ) and DPI (95.94 µ) showed intermediate values.

In the present study, a marginal discrepancy of the provisional crowns was evaluated at 10 min and 30 min after mixing since maximum polymerization shrinkage is reported to occur within this period. A time interval post 30 min was not chosen for the study since provisional crowns are usually cemented within this time in a clinical setup.

A reduction in bisphenol A glycol dimethacrylate in favour of triethylene glycol dimethacrylate leads to a higher rate of conversion and consequently to increased shrinkage.[16] Visalys Temp used in this study is a bisphenol A free multifunctional acrylic composite. Therefore, the different results obtained for this material could be assumed to be predominantly related to a different monomer composition and/or initiator system in comparison to the other dimethacrylates tested.

The crowns were not removed off the die during the 30 min period since the associated shrinkage would make it difficult to reseat the crown precisely and give variable discrepancy values. By keeping the crowns on the die, the inherent properties of the materials could be tested without the influence of factors such as reseating pressure. Balkenhol *et al*.[4] used 0.5 N of force exerted by a Digimatic dial indicator, but this force was far less than average finger pressure used clinically which is found to be approximately 38–42 N.[17] Spring loaded devices would also not maintain constant force for multiple crowns due to gradual deformation of the spring.

A direct comparison of the results of this study with previous studies cannot be done since the methods employed for sample preparation and measurement (materials, fabrication procedure, storage times, pressure exerted during seating), which influence marginal fit, vary in all the different studies.

Limitations

The effect of oral fluids on the polymerization of the provisional materials was not considered in this *in vitro* study. In addition, the specimens were not thermocycled or experimentally aged which could result in greater marginal discrepancy. The results obtained are applicable to single crowns and the data reported may differ from multiple units.

Clinical Implications

One of the most important requirements of provisional restorations is accurate marginal adaptation. Polymerization shrinkage of these materials can jeopardize the marginal integrity of interim restorations. Primary marginal discrepancies must be expected with both monomethacrylates and dimethacrylates. This requires approaches to compensate for the effects of polymerization shrinkage. One solution could be coating the tooth with a spacer prior to repositioning the index loaded with the provisional material to provide a slightly oversized crown, which compensates for the shrinkage. Relining of the temporary crown could offer another solution.

With temporary fixed partial dentures, the provisional material also shrinks in the area of the pontic, thus increasing the final misfit of the restoration in comparison to a single crown. Each brand of resin materials used for interim restorations should be evaluated individually for stability in the oral environment. In this study, bis phenol A free multifunctional acrylic was seen to have the maximum marginal discrepancy followed by polymethyl methacrylate.

Conclusion

Within the limitations of this study, it can be concluded that:

- The vertical marginal discrepancy of temporary crowns fabricated from the four commercially available provisional materials ranged from 71 to 106 μ immediately after fabrication (at 10 min from the start of mix) to 83–128 μ after 30 min from the start of mix
- Among the four materials, crowns fabricated from Protemp 4 showed the least vertical marginal discrepancy (71.59 μ), followed by Luxatemp Star (91.93 μ) at 10 min. There was a significant difference noted in the marginal discrepancy values of Protemp 4 and Visalys Temp. The bis phenol A free multifunctional methacrylate (Visalys Temp) showed comparable marginal fit to the conventional acrylic resin
- At 30 min, there was a significant difference observed between the marginal discrepancy of crowns fabricated from Protemp 4 (83.11 μ) and Visalys Temp (128.97 μ) and between Protemp 4 and DPI tooth molding powder and monomer (118.88 μ). No significant differences were observed between the bisacrylates that is, Protemp 4 and Luxatemp Star (102.05 μ).

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