

A COMPARATIVE EVALUATION OF TEMPERATURE CHANGES, SURFACE ROUGHNESS AND COLOUR STABILITY OF THREE CHEMICALLY CURED COMPOSITE RESIN CROWN AND BRIDGE MATERIALS FOR DIRECT PROVISIONAL RESTORATIONS - AN IN VITRO STUDY

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Abstract:

Fixed prosthodontic treatment, whether involving complete or partial coverage and natural tooth or dental implant abutments, commonly relies on indirect fabrication of definitive prostheses in the dental laboratory.

The aim of this study was to comparatively evaluate the temperature changes, surface roughness and colour stability of three chemically activated composite resin crown and bridge materials for direct provisional restorations, to arrive at a conclusion which commercially available material would have less temperature rise, least surface roughness and increased colour stability. This would help to have better provisionalization for good esthetics, pulp protection and plaque accumulation.

Keywords: Temperature changes, surface roughness, colour stability, composite resin crown & bridge, provisional restorations

Introduction

A provisional restoration is a fixed prosthesis, which enables to enhance esthetics, stabilize occlusion, protects pulp and helps in function of mastication for a limited period of time which is replaced by a definitive prosthesis in a planned manner.

This is especially useful with treatment involving highly esthetic areas. A provisional fixed restoration will provide a template for defining tooth contour, esthetics, proximal contacts, occlusion, and for evaluating the potential consequences from an alteration in the vertical dimension of occlusion.¹ Provisional treatment can also provide an important tool for the psychological management of patients.²

Provisional restorations should be the same as definitive restorations in all aspects, except for the material from which they are fabricated. The materials and techniques used for interim restoration must reflect the variable treatment demands and requirements.³⁻⁵ Mechanical, physical, and handling properties, as well as biocompatibility influences, material selection for fabricating provisional restorations.

The purpose of this study was to comparatively evaluate the temperature changes, surface roughness and colour stability of three chemically activated composite resin crown and bridge materials for direct provisional restorations, to arrive at a conclusion which commercially

available material would have less temperature rise, least surface roughness and increased colour stability. This would help to have better provisionalization for good esthetics, pulp protection and plaque accumulation.

Materials

Materials used in this study included the following

I. Material for making index:

1. Elastomeric impression material- Express™ STD Putty Soft, 3M ESPE
2. Small metal cylinders to make discs of provisional restorative materials

II. Materials for provisional restoration

1. Protemp 4 3M ESPE Available in automix cartridge with a dispensing gun and mixing tips of ratio 1:4.
2. Luxatemp Fluorescence DMG (Available in automix cartridges with 1:1 mixing tip)
3. Cooltemp ColteneWhaledent Automix cartridge with a dispensing gun and mixing tips of ratio 1:2.

III. Equipment used to number the teeth

Micromotor-
Contra angled Micromotor handpiece

IV. Equipment used for measurement of temperature changes

Thermocouple Fluke 179 s

Thermocouple is a thermoelectric device for measuring temperature, consisting of two wires of different metals connected at two points, a voltage being developed between the two junctions in proportion to the temperature difference.

V. Material used for preparation of thermocouple wire for heat conduction

Silver foil- Superwrap Aditya Birla Hindalco.

VI. Equipment used for measurement of surface roughness

Scanning electron microscope (SEM) JFC-110 E

High resolution Field Emission Gun -SEM (FEG-SEM) with magnification in the range of nanometers.

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons.

VII. Equipment used for measurement of colour changes

Spectrophotometer Data color CS 60011

VIII. Materials for staining

1. Coffee powder- Nescafe
2. Distilled water
3. Petridish
4. Beaker

IX. Miscellaneous

1. Hand gloves
2. Mouth mask
3. Head cap
4. Protective eye wear

Materials



Fig 1. Putty index and metal cylinder for fabrication of discs

Method

The following method was carried out for comparative evaluation of temperature changes, surface roughness and colour changes in the three chemically cured composite resin crown and bridge materials for direct provisional restorations.

Ninety disc shaped specimens were prepared from three chemically cured composite resin materials (elastomeric impression material Express™, STD Putty Soft & 3M ESPE) with the dimensions of 10 mm diameter and 2 mm thickness. Digital calliper was used to check the specimen dimensions.

Specimens were divided into three groups of thermal changes, surface roughness and colour Stability and then subdivided into three sub groups (ten specimens in each sub group) of elastomeric impression material Express™, STD Putty Soft & 3M ESPE.

Evaluation of temperature changes

The free end of the wire of the thermocouple is covered with a silver foil for increasing thermal conductivity and protecting the metal tip from being engaged inside the composite material. This free end of the thermocouple was then introduced in the base of the putty index so that it will directly come in contact of the material while setting. Temperature changes take place in the composite resin provisional materials during the polymerisation reaction. The temperature changes of all the discs would be recorded with a thermocouple while the discs were being fabricated, at a 5 sec time interval to a time period of 6 minutes.

Evaluation of surface roughness

The evaluation was done using Scanning Electron Microscope.

Evaluation of colour changes

Each disc was placed on the stand of spectrophotometer and held against the aperture.

The specimens were immersed in a staining solution. The staining solution was prepared by adding 3 grams of coffee powder in 150 ml of distilled boiling water and filtered. Fresh solution was prepared everyday for the study. All the samples of Group I, Group II, and Group III were immersed in the solution for 10 days at room temperature (37 degree C) in covered petri dishes. The solution was changed every day for 10 days. Then the samples were evaluated in similar manner washed with distilled water

after removing from staining solution, dried with gauze and stored in distilled water. The stained samples were evaluated for colour changes using spectrophotometer in similar manner as done before staining.

The total colour difference before staining and after staining, and delta E was calculated using the Hunters formula.

Results

Temperature changes during polymerization of temporization restoration material

Thirty discs of chemically cured provisional restoration material evaluated for temperature changes using a thermo coupling agent, starting with baseline of 30 degree Celsius till 6 minutes. Peak Mean Temperature for the Group I was 38.2 degrees Celsius, Group II was 37.22 degrees Celsius, and Group III was 38.37 degrees Celsius.

The one-sample Kolmogorov-Smirnov test was applied to the temperature changes. The test revealed that the overall distributions of both the parameters was normal ($p > .05$).

The results for the temperature changes were not statistically significant. Homogeneity of variances held satisfying requirement to interpret ANOVA. Statistical analysis was carried out using parametric test or by One-way ANOVA. This comparison among three groups could be made using One-way ANOVA, provided the assumption of normality holds.

Evaluation of Surface Roughness (Photomicrograph I), (Photomicrograph II), (Photomicrograph III)

Qualitative and visual analysis was done at 10 Kv x 1900, at a resolution of 10 micrometers. The surface roughness observed in Group I, Group II, and Group III in photomicrographs showed difference in roughness when analyzed individually. At microscopic level, the surface roughness of group III was more as the topography of Group III showed more unevenness. Similarly, Group II and Group I were analyzed visually and they showed progressively less surface roughness. Hence it can be concluded that, the surface roughness observed in group III was greater than Group II and Group I showed the minimum surface roughness.

Evaluation of colour changes

The descriptive statistics reveal that the mean ΔE for Luxatemp (19.23) is lowest and that of the Cooltemp (21.70) is highest. Mean ΔE of the Prottemp (20.18) stands between the means of the other two groups.

The results of one-way ANOVA associated with the mean ΔE of three chemical groups indicate that the F value is not statistically significant ($F = .80$, $p = .46$). This signifies that differences observed in the mean ΔE of three groups and could be treated equal with respect to mean ΔE .

Discussion

Provisional restorations are vital components of fixed prosthodontic treatments.^{6,7} They must fulfill several functions for the duration of their use in the mouth. Ideally, they should protect pulpal tissue against physical, chemical and thermal injuries, maintain positional stability and occlusal function; should provide strength, retention and esthetics for the prepared teeth, which are all essential factors for clinical success.^{2,3} The terms *provisional*, *interim*, or *transitional* have also been routinely used interchangeably in the literature which generates a misconception that eventual placement of the permanent restoration will immediately and miraculously remedy the detrimental effects of the poorly conceived and fabricated provisional restoration.^{1,3,9,10}

Acrylic resins have a rise in temperature more than 10 degrees Celsius.¹¹⁻¹⁷ These materials were therefore not taken up for this study and the newer composite materials which claim to have better properties were selected for the study. Properties of Prottemp improved from Prottemp I to Prottemp IV, hence Prottemp IV was taken up for the study. The second group was the Luxatemp also a composite resin self cure material. The third group was the Cooltemp. As the light cure materials may have higher temperature due to the curing light which is used for the curing, they were not included in the study.¹³

According to several studies conducted the bis-acryl composite materials excel in all the above mentioned criteria over the traditional provisional restoration materials, hence they were chosen for the current study.^{12,13,17-22}

Three self cure provisional materials Prottemp IV, Luxatemp

and Cool temp were used to comparatively evaluate the temperature changes in the provisional restoration materials due to polymerization reaction. Ten discs each for the three materials were prepared using the putty index and stainless steel metal cylinder which was in accordance to the study done by Sen D, Goller G, and Issever H in 2000¹⁹ where a total of one hundred eighty specimens were fabricated using circular stainless steel molds.

The dimension of the provisional restoration material discs were in accordance to the study done by Rutkunas V, and Sabaliauskas V in 2009²³ and Buergers R, Rosentritt M, Handel G in 2007²⁴ where a provisional discs of dimension 10 x 2 mm were used. In a study conducted by Ko MJ, Pae A and Kim HS in 2006¹⁴ while examining the temperature changes during polymerization of the provisional materials it was seen that the lowest temperature rise was recorded in Luxatemp Plus, Prottemp 3, Luxatemp Fluorescence followed by other acrylic resin materials. As composite resins showed a controlled temperature rise they were taken up for the study.

Even in these above studies, temperature rise for acrylic resins was higher, however in our study the highest temperature in composite resin did not go above 8 degrees Celsius which would be better tolerated by pulp as compared to acrylic resins. According to the studies conducted by Grajower R, Kaufman E and Stern N in 1979²⁵, Tjan AH, , Castelnuovo J, Tjan HLA, and Dent in 1997¹¹, Chiodera G, Gastaldi G, and Millar BJ²⁷ in 2009 and Manak E, and Arora A in 2011¹⁶ it could be concluded that polyvinylsiloxane impression materials have high heat capacity and sufficient thermal conductivity resulting in least temperature rise during the exothermic setting reaction of provisional materials. Therefore in the current study the polyvinyl siloxane impression material was chosen as the matrix for the formation of provisional material discs.

In this study the temperature rise was measured starting from dispensing of the materials till the material sets which was approximately 6 minutes. The temperature rise was measured using thermocouples. The temperature changes of all the 30 discs were recorded with thermocouple while the discs were being fabricated, at a 5 sec time interval to a time period of 4-5 minutes. Castelnuovo J, Tjan HLA, and Dent in 1997¹¹ for a similar study analyzed the thermal changes during polymerization of three autopolymerizing resins and two photopolymerizing resins using a thermocoupling agent. With the use of a thermocoupling

agent the temperature changes were recorded and compared. Thermocouples were also used in a study done by Kima HS and Watts CD in 2003²⁶ to evaluate exothermic reaction in three dimethacrylate based materials and one monomethacrylate based material during polymerization.

Chiodera G, Gastaldi G, and Millar BJ in 2009²⁷ also evaluated the temperature change in the pulp cavity using a thermocouple placed in the pulp chamber recorded the temperature change every fifteen seconds for ten minute duration during polymerization of the resins using different matrices Therefore in this study thermocouple was used for the measurement of temperature changes.

Starting with baseline room temperature of 30 degrees Celsius approximately, the temperature rise was evaluated till 6 minutes at an interval of 5 seconds for all the three provisional materials

In our study the peak mean temperature for Protemp 4, Luxatemp and Cooltemp and were 38.2, 37.22 and 38.37 degrees Celsius respectively. Cooltemp showed the highest peak mean temperature.

Protemp 4 and Luxatemp reached the peak temperature at the same time at 70 seconds whereas Cooltemp reached the peak temperature at 50 seconds.

Protemp 4 showed gradual rise in temperature from initiation of polymerization till it reached the peak temperature of 38.2 degrees Celsius. Erratic Temperature changes were seen in between 70-95 seconds.

Luxatemp showed step like formation in graphical representation before it attained peak temperature of 37.22 degrees Celsius at 70 seconds.

Cooltemp showed gradual rise in temperature initially till 35 seconds, later showing steep temperature rise till 60 seconds. After reaching the peak temperature the decline in temperature was seen until it reached the baseline temperature. It was observed that there is no significant difference between the rise in temperature of Protemp IV, Cooltemp or Luxatemp.

In the present study the temperature rise of approximately 8 degrees Celsius observed in all the provisional materials examined therefore they could be considered to cause no pulpal damage and could be advocated for provisional

restoration materials.

The surface roughness affects the esthetics, colour stability, bacterial attachment and biofilm Smooth surface of the restoration should be achieved to reduce plaque adhesion, minimize gingival inflammation as well as to limit potential discoloration process.^{20,28}

Bollen CM, Lambrechts P, and Quirynen M in 1997²⁸ evaluated the initial surface roughness of several intraoral hard materials, as well as changes in their surface roughness as a consequence of different treatment modalities. The study was stated that very smooth surface of composites could be achieved by methods such as compressing the material against matrix. This is in accordance to our study where a polyvinylsiloxane matrix is used to achieve a smooth surface of the material in contact with the matrix. It was also concluded that an increase in surface roughness above threshold roughness resulted in a simultaneous increase in plaque accumulation, thereby increasing the risk for both caries and periodontal inflammation.

Based on the study by Maalagh Fard A, Wagner WC, Pink FE, and Neme AM in 2003²⁹ it was concluded that with composite provisional materials, the unfinished surfaces were smoother than with bur or abrasive-disk finished surfaces. Therefore in the present study, surface in contact with polyvinyl siloxane was taken into consideration and no polishing was done

Scanning electron microscope was used in studies conducted by Sen D, Goller G, and Issever H in 2000¹⁹ and Buegers R, Rosentritt M, Handel G in 2007²⁴ to examine the surface roughness of the provisional restoration materials.

Similarly in the current study photomicrographs obtained using scanning electron microscope were taken to evaluate surface roughness and it was observed that Protemp IV had minimum surface roughness followed by Luxatemp and Cooltemp.

Colour stability of a provisional restoration is essential for obvious esthetics reasons and psychological satisfaction of the patient. In esthetically critical areas it is desirable for provisional restorations to provide an initial accurate color shade match and then to remain color-stable over the course of provisional treatment.

Ten discs each for the three self cure provisional materials

Protemp IV, Luxatemp and Cooltemp were prepared using the putty index and they were stained using coffee solution for evaluation of colour stability.

Use of coffee as a staining solution was in accordance to the previous studies conducted by Dietschi D, Campanile G, Holz J, Meyer JM in 1994³⁰, Sham.S, Chu.C.S.F in 2004¹⁸, Haselton RD, Arnold DAM, and Dawson VD in 2005 in 2005³¹, Gupta G and Gupta T in 2011²², Gujjari AK, Bhatnagar VM, Basavaraju RM in 2013³² and Mahdisiar F, Nasoohi N, Nematianaraki S, Seresht AG, Sedighi M in 2014³³. Coffee brought about the maximum change in colour of provisional restoration materials. Hence coffee solution was used in the current study for the provisional discs.

The samples were evaluated for colour before and after staining using spectrophotometer. The parameter used to measure colour was CIE L*a*b* units.

Seghi RR, Hewlett ER, and Kim J in 1989³⁴ used CIELAB colorimetric system for the study of the relationship between measured colour difference values and human observation. This study verified that a specific, visually meaningful and precise relationship exists between the magnitude and direction of the measurements and the average dental-observer responses.

The use of spectrophotometer was in accordance to the previously conducted studies by Seghi RR, Hewlett ER, and Kim J in 1989³⁴, Awliya WY, Alwani JD, Gashmer SE, and Mandil BH in 2010³⁵, Gupta G and Gupta T in 2011²² and Mahdisiar F, Nasoohi N, Nematianaraki S, Seresht AG, Sedighi M in 2014³³. Sham.S, Chu.C.S.F in 2004¹⁸ evaluated the color stability of 5 provisional prosthodontics materials. The color change of bis-acryl methacrylate based provisional materials Luxatemp was significantly less than that of 3 methyl/ethyl methacrylate-based provisional materials.

Results indicated the presence of strong interaction between material and storage solution regardless of the aspect of colour considered. Coffee solution relative to saliva solution had the most significant impact on color change for Luxatemp, Protemp, and Temphase materials at 4 weeks, but the greatest overall colour change for both coffee and saliva solutions was found for Provipont and the least overall colour change for both solutions was found for Zeta CC.

Givens JE, Neiva G, Yaman G, and Dennison BJ in 2006³⁵ evaluated the colour change in auto-cure materials, Protemp Garant and dual-cure material, Luxatemp Solar. The results exhibited a clinically noticeable change in shade of Protemp Garant after 1 week in staining solution. Luxatemp Solar, did not demonstrate a clinically detectable change in shade after staining.

Gujjari AK, Bhatnagar VM, Basavaraju RM³² in 2013 did a similar experiment and evaluated the colour stability and flexural strength of polymethylmethacrylate and bis-acrylic composite based provisional crown and bridge auto-polymerizing resins exposed to tea, coffee, cola, and food dye. The findings of the study showed that for materials used in the study, polymethyl methacrylate was more colour stable than bis-acrylic composite based resin. Also, material based on polymethyl methacrylate was more resistant to damage from dietary beverages as compared to bis-acrylic composite based provisional crown and bridge resin.

It was observed that the group III absorbed more stains as compared to group I and group II. Group I showed more staining than group II. Group II showed the least staining, however the stain absorption in all three groups was not statistically significant.

Clinical Significance

A provisional restoration is a fixed prosthesis, which enables to enhance esthetics, stabilize occlusion, protects pulp and helps in function of mastication¹. Hence, the materials, their properties and the techniques of provisional restorations are important. This study addresses the temperature changes, surface roughness and colour stability of three chemically activated composite resin crown and bridge materials for direct provisional restorations which allows us to conclude which provisional material should be used for temporization in fixed partial dentures without affecting the health of the pulp due to temperature rise, smooth surfaces to prevent attachment of material alba and absorption of stains.

Limitations of the study

The limitation of the study is that only the chemically cured provisional restoration materials were considered for the study. Staining with only coffee solution was carried out

other staining solutions such as tea and turmeric were not taken into account for staining. Further research of the provisional materials intraorally also needs to be conducted to visualize the effect of temperature rise on the pulp, surface roughness and absorption of stains.

Conclusion

Within the limitation of the study, the following conclusions were drawn:

1. The temperature changes of three chemically cured provisional restoration materials was evaluated and it was observed that Cooltemp was having the highest temperature rise as compared to Protemp IV and Luxatemp. However, the changes in temperatures were not statistically significant.
2. The evaluated surface roughness of Cooltemp was highest followed by Luxatemp and Protemp IV. Protemp IV had the least surface roughness as compared to the other materials.
3. The colour stability of Luxatemp was highest followed by Protemp IV and Cooltemp. The difference in colour changes of all the three materials however was not statistically significant.
4. Cooltemp showed the highest temperature change, had the highest surface roughness and had the highest colour change. Whereas, Protemp IV had second highest temperature rise, but moderate colour changes. Luxatemp had the least temperature rise, least colour absorption and moderate surface roughness.

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