Original Article

Comparative evaluation of marginal leakage of provisional crowns cemented with different temporary luting cements: *In vitro* study

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Abstract

Background or Statement of Problem: As, the longevity of provisional restorations is related to, a perfect adaptation and a strong, long-term union between restoration and teeth structures, therefore, evaluation of marginal leakage of provisional restorative materials luted with cements using the standardized procedures is essential.

Aims and Objectives: To compare the marginal leakage of the provisional crowns fabricated from Autopolymerizing acrylic resin crowns and bisphenol A-glycidyl dimethacrylate (BIS-GMA) resin crowns. To compare the marginal leakage of the provisional crowns fabricated from autopolymerizing acrylic resin crowns and BIS-GMA resin crowns cemented with different temporary luting cements. To compare the marginal leakage of the provisional crowns fabricated from autopolymerizing acrylic resin (SC-10) crowns cemented with different temporary luting cements. To compare the marginal leakage of the provisional crowns fabricated from BIS-GMA resin crowns (Protemp 4) cemented with different temporary luting cements.

Methodology: Freshly extracted 60 maxillary premolars of approximately similar dimensions were mounted in dental plaster. Tooth reduction with shoulder margin was planned to use a customized handpiece-holding jig. Provisional crowns were prepared using the wax pattern fabricated from computer aided designing/computer aided manufacturing milling machine following the tooth preparation. Sixty provisional crowns were made, thirty each of SC-10 and Protemp 4 and were then cemented with three different luting cements. Specimens were thermocycled, submerged in a 2% methylene blue solution, then sectioned and observed under a stereomicroscope for the evaluation of marginal microleakage. A five-level scale was used to score dye penetration in the tooth/cement interface and the results of this study was analyzed using the Chi-square test, Mann–Whitney U-test, Kruskal–Wallis H-test and the results were statistically significant $P < 0.05$ the power of study - 80%.

Results: Marginal leakage was significant in both provisional crowns cemented with three different luting cements along the axial walls of teeth ($P < 0.05$) confidence interval - 95%.

Conclusion: The temporary cements with eugenol showed more microleakage than those without eugenol. SC-10 crowns showed more microleakage compared to Protemp 4 crowns. SC-10 crowns cemented with Kalzinol showed maximum microleakage and Protemp 4 crowns cemented with HY bond showed least microleakage.

Key Words: Luting cements, microleakage, provisional crowns

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INTRODUCTION

Provisional restorations have been demonstrated to function as an important component in the majority of the various dental disciplines. Provisional means established for the time being, pending a permanent arrangement. Provisional restorations are the protype on which functional, occlusal and esthetic adjustments are made to optimize the definitive prosthesis.[1,2] Even though a definitive restoration may be placed as quickly as 2 weeks after tooth preparation, the provisional restorations must satisfy important needs of the patient and dentist. Materials used to fabricate provisional restorations can be classified as acrylics or resin composites.[3,4]

Multiple factors affect the success of fixed prosthodontic restorations with preparation design, oral hygiene/microflora, mechanical forces and restorative materials being some of them. However, the key to success is the choice of proper luting cement and cementation procedure.

The word "LUTING" is derived from a Latin word lutum-which means mud. Dental luting agents provide a link between the restoration and the prepared tooth, bonding them together through some form of attachment, which may be mechanical, micro-mechanical, chemical or combination.[5] This is necessary to prevent microleakage and pulpal irritation and mechanically lock the restoration in place to prevent its dislodgment during mastication. Provisional crowns cemented with temporary cements are, however, susceptible to cement washout, marginal leakage, bacterial infiltration and caries, especially when placed for prolonged periods. The earliest provisional cements were made from zinc-oxide powder and eugenol liquid. Eugenol has an obtundent effect on the pulp but inhibits the setting reaction of acrylic resins and softens acrylic resins. Therefore, a number of manufacturers introduced provisional cements that are eugenol-free. Furthermore, polyorganic acid and polycarboxylate formulation was used to make them eugenol-free and to improve their strength and provides an excellent seal while allowing the material to be easily removed from the tooth preparations when desired.

Cement dissolution can cause microleakage, but other possible causes include lack of adhesion between luting cement and tooth structure, shrinkage of luting agent on setting and mechanical failure of the luting agent. The location of margins whether sub-gingival or supra-gingival may also influence the leakage by exposure to different quantities of oral fluids and microflora.

GPT8 defined microleakage as leakage of minute amounts of fluids, debris, and microorganisms through the microscopic space between a dental restoration or its cement and the adjacent surface of the cavity preparation.

Microleakage is determined today by many *in vitro* techniques[6] and according to Van Meerbeek *et al*., (2003), methods of assessing microleakage can be divided into qualitative, semiquantitaive or true quantitative measurements of sealing effectiveness. *In vitro* studies evaluating the microleakage of provisional restorations cemented with various temporary luting cements have been reported. Luting cements were chosen because there are very few studies related to evaluation of microleakage of provisional crowns cemented with luting cements which is important as leakage occurring at the tooth-cement interface has greater biological significance since it causes dentinal sensitivity, secondary caries formation, corrosion or dissolution of dental materials, discoloration of dental materials and surrounding tooth structure, and percolation of fluid and if leakage is severe it may lead to the irritation of pulp and inflammatory pulpal lesions. So, to prevent the consequences of microleakage for long-term provisionalization and that too with cements available in Indian market.

Microleakage is related to dimensional changes of provisional crown materials due to polymerization shrinkage, thermal contraction, absorption of water and mechanical stress[7] and any marginal gap combined with an inherently weak provisional cement will provide an ideal site for microleakage to occur.[2] Therefore, an *in vitro* study was designed and carried following standardized procedures out to compare the marginal microleakage of provisional crowns cemented with three temporary luting cements. Verma *et al*., marginal accuracy of provisional restoration material used in fixed partial dentures an *in-vitro* study. Indian Journal of Dental Sciences 2012; 4 (3):25. Sadan A clinical considerations in cement selection for provisional restorations – Part 1: Pract Period Aest Dent 2000; 12:638.

The marginal accuracy of provisional crowns is due to a combination of factors that include: Material properties, fabrication techniques and dynamic loading factors. Any marginal gap combined with inherently weak provisional cement will provide an ideal site for microleakage to occur. In the past, mostly studies were related to marginal discrepancy of interim restorations and microleakage of permanent luting cements but in this study instead of the permanent luting cements, microleakage of provisional crowns cemented with different temporary luting cements had been assessed. Thus, interim crown material with least microleakge could be assessed and along with this, the technique of fabrication of the provisional crowns was also more standardized as a single silicone mold was used.

METHODOLOGY

This study was designed to compare the marginal leakage of the provisional crowns fabricated from polymethyl methacrylate (PMMA) resin crowns and bisphenol A-glycidyl

dimethacrylate (BIS-GMA) resin crowns cemented with different temporary luting cements.

In this study, provisional crowns were fabricated and divided into two groups as following:

- Group 1: Provisional crowns fabricated by SC-10 (PMMA resin) ($n = 30$)
- Group 2: Provisional crowns fabricated by Protemp 4 (BIS-GMA composite resin) ($n = 30$).

The provisional crown samples were further subgrouped according to different luting cements used viz. Kalzinol (Samit) (zinc oxide and eugenol [ZOC], rely temp NE [zinc oxide and poly organic acid] and HY bond [zinc oxide and polycarboxylate]).

Each subgroup has 10 cemented provisional crowns, therefore, making of 60 cemented provisional crowns.

Methodology has been discussed under the following headings:

- Teeth selection and storage
- Mounting of the tooth
- Tooth preparation
- Fabrication of wax pattern
- Fabrication of provisional crowns
- Cementation of provisional crowns
- Thermocycling and immersion of specimens in dye
- Mounting of specimens
- Sectioning of specimens
- Assessment of marginal leakage.

Extracted natural Maxillary first premolars of approximately same dimensions were selected and mounted in dental plaster using custom made metal jig consisting of the stabilizing metal base and two concentric cylindrical metal rings in which the inner ring was sectioned into two equal halves to allow for the easy retrieval of the mounted tooth, which was in turn supported by the outer ring. The upper surfaces of both the rings had grooves which were made to coincide with each other during mounting. After, dental plaster was poured in the inner ring, a metal scale was passed across the grooves on the surface of the rings and cross markings were obtained over the surface of dental plaster for the centralized mounting of tooth. Following this, the tooth was vertically positioned in dental plaster using Ney's surveyor up to cemento-enamel junction [Figure 1a]. As microleakage was found to be influenced by the preparation design, the standardized tooth preparation protocol was followed using custom made paralleling device attached to a surveyor [Figure 1b]. Each tooth was prepared for a complete crown with a 1 mm shoulder. The axial walls were prepared with a convergence angle of 6°, the occluso-cervical height was kept 6 mm approximately and the occlusal surface was made flat using small wheel diamond bur as the occlusal anatomy varied for each premolar. Following this, the provisional crowns

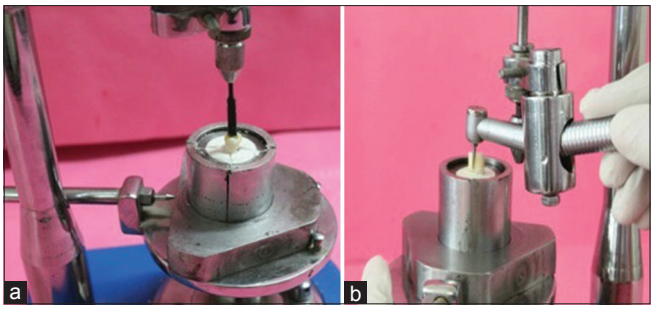

Figure 1: (a) Mounting of tooth and (b) preparation of tooth

were fabricated using the direct technique. For this, the wax pattern of standardized dimension was fabricated over the prepared tooth using computer aided designing/computer aided manufacturing milling machine. This was followed by the fabrication of the silicone mold to achieve the provisional crowns of approximately same dimensions [Figure 2a and b]. The reference grooves were made on the silicone mold circumference corresponding to the grooves on the plaster base of mounted tooth which were reproduced from the customized stabilizing metal base used during mounting. The provisional crowns both from SC-10 and Protemp 4 were fabricated using the mold in which the prepared tooth was seated using digital pressure [Figure 2c and d]. To standardize the placement into the mold, the markings on the plaster base of mounted tooth should coincide with that of the mold. Once set, the prepared tooth with the provisional crown was retrieved, and an excess flash of resin was trimmed and then provisional crown finished and polished.

The provisional crowns were then cemented over prepared teeth using three different luting cements and were kept in the distilled water.[8] They were then thermocycled to mimic the oral environment using water baths maintained at 5°C and 55°C for subjecting the restoration to thermal stresses.[9,10]

Following this, the cemented provisional crowns were then immersed in 2% methylene blue solution. The specimens were then embedded in the clear auto polymerizing acrylic resin following standardized technique using custom made metal jig. The standardized method for sectioning was followed and the sectioning of the specimens was done buccolingually through the middle of the prepared specimen using diamond blade attached to die cutting machine following the grooves on the surface of the resin [Figure 3a and b]. The sectioned specimens were then seen under stereomicroscope to evaluate the level of dye penetration. Microleakage values were recorded according to the scale given by Tjan *et al*.[11] as [Figure 4]:

- 0: No microleakage
- 1: Microleakage to one-third of the axial wall
- 2: Microleakage to twothirds of the axial wall
- 3: Microleakage along the full length of the axial wall
- 4: Microleakage over the occlusal surface.

OBSERVATIONS AND RESULTS

After the specimens were immersed in 2% methylene blue solution, they were sectioned and visualized under the stereomicroscope for the level of dye penetration. After compilation of data, appropriate statistics were applied.

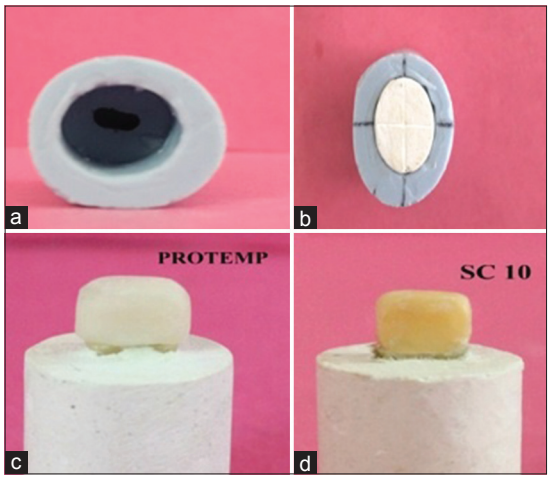

Figure 2: (a and b) Silicone mold (c) Protemp 4 provisional crown (d) SC-10 provisional crown

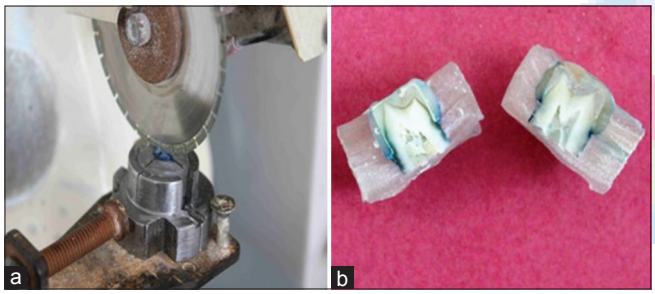

Figure 3: (a) Sectioning of specimens using diamond disc attached to die cutting machine and (b) cut sections

DISCUSSION

Among numerous determinants responsible for the quality of retention and marginal seal, cement characteristics used for cementing of the restorations enabling intimate contact between the surfaces of prepared teeth and restorations are to be particularly emphasized.[12,13] Cement disintegration through its decomposition or dissolution in oral fluids, shrinkage on setting, strength and weakening of the bond between the cement and dentine or cement and restoration are reported as possible causes of microleakage and loss of bonding effect.[14] Microleakage is also related to dimensional changes of provisional crown materials due to polymerization shrinkage, thermal contraction, absorption of water and mechanical stress.[15,16] The polymerization shrinkage of a resin can create contraction forces that may disrupt the bond to the cavity walls, leading to marginal failure and subsequent microleakage. The integrity and durability of the marginal seal have always been of prime concern in the investigation of the performance of a dental restorative material.[17]

There are many material choices available to temporize a single crown as well as multi-unit fixed partial dentures, and the selection of provisional materials should be made based on a case-by-case evaluation.[18] Materials used to fabricate provisional restorations can be classified as acrylics and composites.

From the literature review, it appears that despite the use of different restorative materials, polymerization techniques, luting cements, microleakage is still a problem.

In this study, comparison of microleakage had been done using PMMA resin (SC-10) and BIS-GMA resin (Protemp) cemented with Kalzinol (ZOC), rely temp NE (zinc oxide

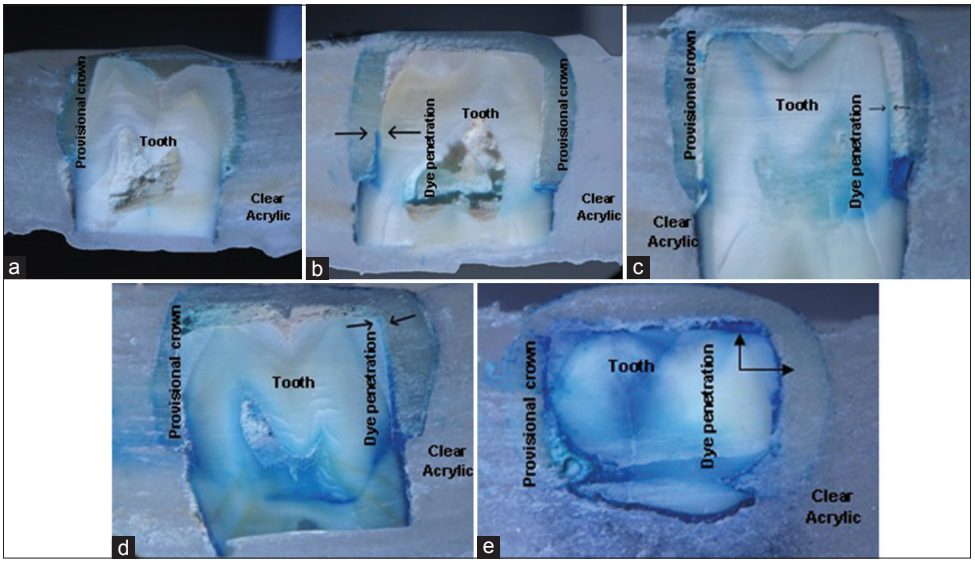

Figure 4: Assessment of microleakage. (a) Grade 0: No microleakage. (b) Grade 1: Microleakage to one-third of axial wall. (c) Grade 2: Microleakage to two-thirds of axial wall. (d) Grade 3: Microleakage along full length of axial wall. (e) Grade 4: Microleakage over occlusal surface

and polyorganic acid) and HY bond (zinc oxide and polycarboxylate) luting cements. These materials were selected as they are commonly used clinically and are cost effective. Also, they are less technique sensitive and are easily available in Indian markets.

After compilation of data, appropriate statistics were applied.

Table 1, Figure 5 and Graph 1 shows the comparison of microleakage between the provisional crowns fabricated from SC-10 and Protemp 4. It was evaluated that the provisional crowns fabricated from Protemp 4 (Group 2) had less microleakage compared to that fabricated from SC-10 (Group 1). The comparison between Group 1 and Group 2 was found to be statistically significant ($P = 0.001$).

The observation and results of the present study were in confirmation with the studies done by Tjan *et al*.[19] who evaluated that Protemp materials had the best marginal adaptation and Young *et al*.[20] who concluded that BIS-acryl composite resin, because of increased filler content, was significantly superior to PMMA with respect to contour, occlusion, fit and finish when used in both anterior and posterior regions.

In this study, variation was found in the microleakage for each group which might be due to the different compositions of the evaluated provisional crown materials, that is, PMMA and BIS-GMA resin cemented with three different temporary cements (ZOC, noneugenol containing zinc oxide poly organic acid, and polycarboxylate).

From the above findings, it was concluded that Protemp 4 (BIS-GMA) provisional material shows less microleakage compared to SC-10 (autopolymerizing acrylic resin). The possible explanation for this is that BIS-GMA are multi-functional methacrylate esters containing inorganic fillers like glass and/or silica particles producing minimal heat and shrinkage during the polymerization process compared to PMMA.[21,22] Moreover, they exhibit higher polymerization shrinkage compared to composites due to the lower molecular weight of the monomers involved, resulting in marginal gaps. Also, high microleakage in SC-10 crowns might result from considerable variations in material manipulation (as the ratio of powder: Liquid might alter the shrinkage rate), as opposed to the auto mix cartridges in Protemp 4 crown material.

Table 1: Comparison of microleakage between group 1 and group 2 by Chi-square test

Grade	SC-10 provisional crowns (group 1)	Protemp 4 provisional crowns (group 2)	Total	χ^2	*P*
Grade 0	1	9	10	18.319	0.001*
	3.3%	30.0%	16.7%		
Grade 1	9	15	24		
	30.0%	50.0%	40.0%		
Grade 2	5	4	9		
	16.7%	13.3%	15.0%		
Grade 3	12	1	13		
	40.0%	3.3%	21.7%		
Grade 4	3	1	4		
	10.0%	3.3%	6.7%		
Total	30	30	60		
	100.0%	100.0%	100.0%		

*Statistically significant

The findings in this study agree with the work conducted by:

Lepe and Bales[23] who evaluated volumetric polymerization shrinkage is 6% for PMMA and 1.0–1.7% for BIS-acryl composite materials. They also stated that composites allow better marginal fit than unfilled PMMA because of less contraction during polymerization.

Verma *et al*.[24] who compared the marginal accuracy of provisional restorations and evaluated that provisional restorations made from the BIS-GMA tested produced better marginal fit. They also stated that PMMA demonstrated significant increase in marginal gap size.

Also, according to the findings it was observed that, SC-10 crowns and Protemp 4 crowns cemented with Kalzinol (ZOC) showed the highest microleakage, followed by rely temp NE (zinc oxide and polyorganic acid) and least for HY bond (zinc oxide and polycarboxylate) [Figure 5 and Graph 2]. The possible explanation for this is that eugenol-containing provisional cement (Kalzinol) has high film thickness, which results in improper seating of the provisional crowns and therefore increasing the chances of microleakage. Also, an increase in cement thickness can lead to higher amounts of water absorption those results in hydrolytic degradation of cements, thus reducing the elastic modulus and the mechanical properties ultimately resulting in microleakage. Further, an increased solubility of eugenol-containing provisional cement in oral fluids leads to dimensional changes, loss of retention, staining, and breaking in margin contours resulting in microleakage. Moreover, eugenol in these cements have negative effects on dental resins as the residual eugenol remaining after setting, acts as a plasticizer, resulting in softening of resin.[25]

Therefore, a number of improved eugenol-free cements have been introduced that contain polyorganic acid, polycarboxylate, etc. Advantages of these cements are they do not interfere with definitive cementation and also have low film thickness. They have the characteristics of being compatible with resin provisional materials, with permanent resin cements and show greater retention compared to ZOE cements.[26] Between the two eugenol free cements (rely temp

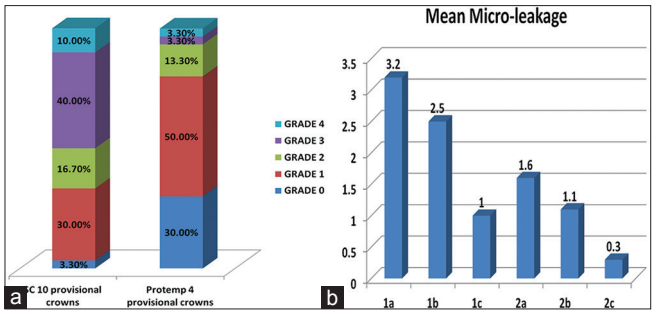

Figure 5: (a) Graph 1: Comparison of microleakage between Group 1 and Group 2. (b) Graph 2: Comparison of mean microleakage of different subgroups within Group 1 and Group 2

NE and HY bond), microleakage was found to be least with HY bond that contains polycarboxylate, which helps in preventing microleakage and improves the marginal seal, has excellent bonding strength for provisional restorations and fluoride additive for protection of tooth structure and reduction of postoperative sensitivity.

The findings in this study agree with the work conducted by:

Richter and Ueno[27] who evaluated that EBA ZOC cement had the highest rate of deterioration resulting in gap formation causing percolation of oral fluids and microleakage.

Bandgar *et al*.[28] evaluated the marginal microleakage of three zinc-oxide-based noneugenol temporary luting agents (rely X temp NE [3M ESPE], Freegenol [GC]). Marginal microleakage was highly significant in all the three cements. They evaluated that rely temp NE had the highest marginal microleakage and Freegenol showed intermediate values.

Rekow *et al*.[29] who demonstrated that an excessively thick cement layer may cause residual stresses as a result of the viscoelastic deformation of the cement material under cyclic loading.

Yu *et al*.[30] also recommended limited use of eugenol containing cements in clinical practice due to high film thickness resulting in higher amounts of water absorption that results in reducing mechanical properties ultimately resulting in microleakage.

CONCLUSION

- SC-10 crowns cemented with Kalzinol showed the maximum microleakage with mean grade of 3.2 and Protemp 4 crowns cemented with HY bond showed the least microleakage with mean grade of 0.3
- From the results, it can be concluded that SC-10 crowns showed more microleakage compared to Protemp 4 crowns
- Also, it can be concluded that Kalzinol exhibited more microleakage than rely temp NE followed by HY bond which exhibited least microleakage
- So, according to the results, Protemp 4 provisional crown material and HY bond luting cement should be recommended for clinical use and for long-term treatment periods.

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Conflicts of interest

There are no conflicts of interest.

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