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RESEARCH ARTICLE

An in vitro comparison of marginal microleakage of four groups of temporary cements in provisional crowns

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Abstract

Purpose: The aim of this in vitro study was to compare the marginal microleakage in provisional crowns cemented on extracted human premolars using four temporary cements formulated using different chemical bases (zinc oxide eugenol, zinc polycarboxylate, resin, and additional-silicone).
Materials and Methods: Twenty-four non-carious human premolars were prepared in a standardized manner for full-coverage crown restorations. Provisional crowns were made from a methacrylate resin using a direct technique and the specimens were randomized into four groups of temporary cementing agents (n=6): zinc oxide eugenol cement (TempBond®), zinc polycarboxylate cement (UltraTemp®), additional silicone cement (TempoSil® 2), and resin-based cement (UltraTemp® REZ). After 24 hours of storage in distilled water at 37ºC, the specimens were thermocycled and then stored again for 24 hours in distilled water at room temperature. Next, they were placed in freshly prepared 2% aqueous methylene blue dye for 24 hours, then embedded in autopolymerizing acrylic resin blocks and sectioned in buccolingual and mesiodistal direction to assess the dye penetration using a stereomicroscope. The results were statistically analyzed using a non-parametric Kruskal-Wallis test. Dunn's post hoc with a Bonferroni correction test was used to compute multiple pairwise comparisons that identified differences among groups; the level of significance was set at $P<0.05$.
Results: All groups showed marginal microleakage; the resin-based temporary cement and the additional silicone temporary cement showed the lowest microleakage scores, which were statistically different from those of polycarboxylate temporary cement and zinc oxide eugenol cement.
Conclusions: The results of this study demonstrated that the temporary cementing agents exhibited different sealing abilities. Resin based temporary cement (UltraTemp® REZ) and additional-silicone based cement (TempoSil® 2) exhibited the most favorable sealing properties against dye penetration compared with polycarboxylate based cement (UltraTemp®) and conventional zinc oxide eugenol cement (TempBond®).

INTRODUCTION

Microleakage has been defined as the passage of bacteria, fluids, molecules or ions along the tooth-restoration interface (Hersek et al., 2002). This leakage may be clinically undetectable, but it causes many significant biological effects on the restored tooth including the recurrence of caries, pulpal pathology, hypersensitivity, discoloration and marginal breakdown (Hilton, 2002).

Preparing teeth to receive full-coverage indirect restorations implies that 15,000–50,000 dentinal tubules per square millimeter are transected (Fosse et al., 1992). While the combined surfaces of dentinal tubules represent only 1% of the dentine wall on the outside of the tooth, the percentage increases to 22% in the vicinity of the pulp (Marshall et al., 1997). Therefore, preventing micro leakage after tooth preparation, especially during the provisional restoration phase when the dentinal tubules are freshly cut and the pulp is already inflamed due to insult from the clinical procedure, is extremely important to preserve the biological health of the dentin-pulp complex and prevent complications of micro leakage, which account for approximately 50% of clinical restoration failures (Dahl, 1977; Mjör, 2005).

Preventing microleakage can be accomplished by two means: fabricating a well-fitting provisional restoration or through the selection of proper temporary cements (Rosensteil et al, 2006; Baldissara et al., 1998).The longest-available provisional cements on the market are zinc oxide eugenol (ZOE) temporary cements. For many years, ZOE cements have continued to be the cements of choice for provisional restorations because of their sedative and excellent antibacterial effects (Sadan, 2000). Unfortunately, ZOE cements inhibit free radical polymerization in the resins; therefore, they have negative effects on the polymerization of methylmethacrylate resins used in provisional restorations (Rosensteil and Gegauff, 1988). In addition, if the final restoration will be bonded to the prepared tooth, the polymerization of both the adhesive system and the permanent resin cement may be inhibited, increasing the risk of debonding or even fracture in the case of low-strength ceramic or indirect composite restorations (Abo-Hamar et al., 2005). Furthermore, some patients are hypersensitive to eugenol (Howard, 2008).

A number of manufacturers have addressed the problems of ZOE cements by introducing provisional cements that are eugenol-free and formulated using different chemical bases, including zinc oxide non-eugenol temporary cements, which are designed to replace eugenol with various types' poly-organic acid systems, typically polycarboxylic and polyacrylic acids (Anusavice et al., 2013). These ZOE-like materials have the characteristics of being compatible with resin provisional materials and permanent resin cements (Abo-Hamar et al., 2005).

Many studies have investigated the sealing ability of both zinc oxide eugenol and zinc oxide non-eugenol temporary cements and concluded that these cements have poor sealing abilities (Baldissara et al., 1998; Lewinstein et al, 2003a, b; Duymu et al., 2005; Lewinstein et al, 2007). In addition, Felton et al. (1991) reported that if the provisionalization period extends to more than 4 weeks, the incidence of pulpal necrosis will significantly increase, which indicates a high microleakage and bacterial penetration in provisional restorations. These processes are likely to worsen in time, leading to pulp inflammation and then pulp necrosis. As a result, some authors have suggested adding antibacterial agent to temporary cements to compensate for their poor sealing abilities; these agents include tetracycline (Cohen et al., 1989), and chlorhexidine (Lewinstein et al, 2007).Other authors suggest adding sodium fluoride (Lewinstein et al, 2003), tannin fluoride and potassium nitrate (Hodosh, et al., 1993) for tooth desensitization.

Recently, new temporary cements formulated using different chemical bases have exhibited improved sealing abilities.For instance, zinc polycarboxylate-based cement is one new arrival on the market, which has the potential for chemical adhesion via chelation to the tooth structure. Resin-based temporary cements also exhibit high strength, excellent retention, better aesthetics, low solubility and easy cleanup. Addition-cured silicone-based zinc oxide temporary cement with a silane agent for improved adhesion and marginal integrity also exists (Miller, 2012). Despite their different chemical compositions, strengths and weaknesses, the marginal seal of these cements is the major parameter by which these cements are assessed. These cements have been recently introduced to the market and their sealing ability has not been widely investigated.

The primary function of temporary cements is to provide a seal and prevent marginal leakage and hence pulp irritation (Rosensteil et al, 2006).Therefore, the purpose of this study was to compare in vitro the marginal microleakage of four groups of provisional cements formulated using different chemical bases (zinc oxide eugenol, zinc polycarboxylate, resin, and additional-silicone) in order to determine the most suitable material for cementing provisional restorations. The major null hypothesis is that there is no difference between these temporary cements in terms of marginal microleakage.

Materials and Methods

I. Sample Preparation

Twenty-four human premolar teeth without caries were extracted for periodontal or orthodontic reasons and kept in distilled water at 37ºC.Debris were cleaned away until the time of the experiment. The teeth were dried and the roots were painted with nail polish to within 1mm beyond the cemento-enamel junction and then embedded in transparent cold-cure acrylic resin (Eco CrylCold, Protechno, Spain, lot#14-34951) utilizing a mold obtained from 19 mm-diameter cylindrical polyethylene pipe. An impression of each tooth crown was then made using a Vinyl Polysiloxane Impression Materials (Express STD®, 3M ESPE, St. Paul, MN, USA) to obtain an external surface form matrix for direct fabrication of the provisional crown later.

Each tooth was prepared using a rotary diamond cutting instrument in a high-speed hand piece with water spray coolant. The preparations for the full crowns were performed with flat occlusal reduction, a 1 mm radial shoulder finish line and 1.5 axial reductions. The preparations were completed using a diamond bur (REF 5862 104 018 Komet,Brasseler GmbH, Lemgo, Germany) attached to a Dental Milling machine (Minicruise 420 JM, Silfradents.r.l.Sofia (FC), Italy) to ensure that all the preparations had a 10 degree total occlusal convergence angle.

A provisional crown using the provisional resin Radica® Dentin (DeguDent GmbH, Hanau, Germany, lot #101221) was fabricated for each tooth by one operator as follows: warmed Radica® dentin was extruded into the external surface form matrix previously obtained from the unprepared tooth crown. The matrix was now adapted to the prepared tooth. After the Radica® resin cooled, the matrix was removed and the provisional crown was adapted and excess was removed by metal tip #8 attached to WaxpencilPro® (Dentsply/Caulk, Milford, Del, USA) before the crowns were light and heat-cured with a glaze-like sealer in the Eclipse® unit (DeguDent GmbH,Hanau, Germany).

The teeth with their provisional crowns were randomly allocated to four groups, and each group (n=6) received a different temporary cement (Table 1). The cements were mixed according to the manufactures' instructions at room temperature (23± 1ºC). All of the tested cements were available in a dual-cartridge with a static auto-mix system, except for zinc oxide eugenol, which was available as a two-tube paste-paste system for hand mixing. The zinc oxide eugenol was mixed as follows: the two pastes are dispensed in equal lengths onto the mixing pad provided by the manufacturer. Then, the pastes were mixed with a metal cement spatula until a homogeneous color was obtained. A small quantity of cement necessary to obtain an even distribution was applied just occlusally to the cavo-surface margin of the provisional crowns. Then, the crowns were seated with finger pressure and placed under a controlled axial load of 5 kg for 10 minutes at room temperature to ensure complete seating. After 10 minutes, the excess cement was removed with a curette. Then, the teeth were stored in distilled water for 24 h in an incubator at 37± 1°C.

II. Thermocycling Process

The specimens were subjected to thermal cycles 100 times. Each thermal cycle consisted of immersing the specimens alternatively in water baths maintained at 5 and 55°C with 20 s of dwell time and 15 s of transition time. Subsequently, the specimens were again placed in distilled water at 23± 1°C for 24 hours. Then, the specimens were dried and painted with nail polish three times over the entire provisional crown, except for 1 mm from the restoration cavo-surface margin. Next, the specimens were kept in freshly prepared 2% aqueous methylene blue solution at 23± 1°C for 24 hours and then removed and gently washed with tap water for 10 minutes. The nail polish was scratch removed and then the specimens were dried.The coronal portion was then embedded in transparent acrylic resin (Eco Cryl Cold, Protechno.Spain, lot#14-34951) and left on the benchtop to set.

III. Microleakage Assessment

After setting for3 hours, each tooth was sectioned longitudinally in the buccolingual and mesiodistal directions with a diamond disc (Super Diamond Disc no. 800.104.355.524.190; NTI-Kahla GmbH, Germany) under dry conditions. This sectioning provided four separate measurement points per specimen, which were examined under a stereomicroscope (Hamilton, Hamilton international s.r.l. Lazio, Italy) at an original magnification of 20×. The extent of the dye penetration was scored by a single operator according to the 5-point scale adopted by Tjan et al. (1992):

0- No microleakage
1- Microleakage less than 1/3rd the axial wall length
2- Microleakage more than 1/3rd but less than 2/3rd the axial wall length
3- Microleakage all along the axial wall length
4- Microleakage on the occlusal surface

The value of the marginal microleakage assigned to each specimen was the average of the scores of dye penetration recorded from the four measurement points.

IV. Statistical Analysis

A non-parametric Kruskal-Wallis test was applied to determine if there were differences in microleakage scores among different temporary cements groups. Dunn's (1964) procedure with a Bonferroni correction was used for pair-wise comparisons when the Kruskal-Wallis tests were significant. The level of significance was set at $P< 0.05$. Statistical analysis was performed using statistical Package for Scientific Studies v. 20.0 software (Statistical Package for Scientific Studies Inc., Chicago, USA).

Results

The means and standard deviations of microleakage score for cements are given in Table 2. Statistical analysis (Kruskal-Wallis) revealed that the distributions of microleakage scores were not similar for all cement groups, as assessed by a visual inspection of a boxplot. The distributions of microleakage score were statistically significantly different among groups, H (3) =2.435, $P< .001$.

Pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. This post hoc analysis revealed that there were statistically significant differences ($P<.05$) in microleakage scores between UltraTemp® REZ and TempBond® ($P<.001$), UltraTemp® REZ and UltraTemp® ($P=0.037$), and between TempoSil® 2 and TempBond® ($P=0.009$). No statistically significant differences were found among the other cement combinations.

The lowest mean microleakage score was seen in UltraTemp® REZ (1.17 ± 0.2) and the TempBond®Group showed the highest mean microleakage score (3.41 ±0.3) (Figure 1).

Tables

Table1. Description of temporary cementing agents used in this study.

Brand	Type	Main composition*	Manufacturer	Lot No.
Temp-Bond®	Zinc Oxide Eugenol Cement	Base: Zinc oxide Catalyst : 4-Allyl-2- Methoxyphenol (Eugenol, Oil of Cloves)	Kerr Corp, Orange, Calif. USA	5004236
UltraTemp® (Regular)	Zinc Polycarboxylate cement	Base: Zinc oxide Catalyst: Benzoic Acid, Phenol, 4-methoxy-	Ultradent Products, Inc. South Jordan, USA	BB7V3
UltraTemp®REZ (Regular)	Resin cement	Base: Mono-2-(Methacryloyloxy) Ethyl Succinate, hydroxy propyl methacrylate, GDMA-Phosphate Catalyst: Bis-GMA, TEGDMA	Ultradent Products, Inc. South Jordan, USA	BBBL6
TempoSil ® 2 (White)	Additional silicone zinc oxide cement	Zinc Oxide, polydimethylsiloxane	Coltene/Whaledent, Inc, Ohio, USA	F80559

GDMA, 1, 3-glycerol dimethacrylate; .Bis-GMA, Bisphenol-A-glycidyldimethacrylate; TEGDMA, Triethylene glycol dimethacrylate.
*According to the information provided by the manufacturer.

Table2. Microleakage mean scores (SD), and median of the 4 temporary cements

Cement	Mean (SD)	Median
Zinc oxide eugenol (TempBond®)	3.4167 (0.30277)	3.375
Zinc Polycarboxylate (UltraTemp®)	2.7500 (0.22361)	2.75
Resin (UltraTemp® REZ)	1.1667 (0.20412)	1.125
Additional Silicone Zinc oxide (TempoSil® 2)	1.4583 (0.24580)	1.5

SD, standard deviation.

Figures

Figure 1 Microleakage mean scores, and standard deviations of the 4 temporary cements

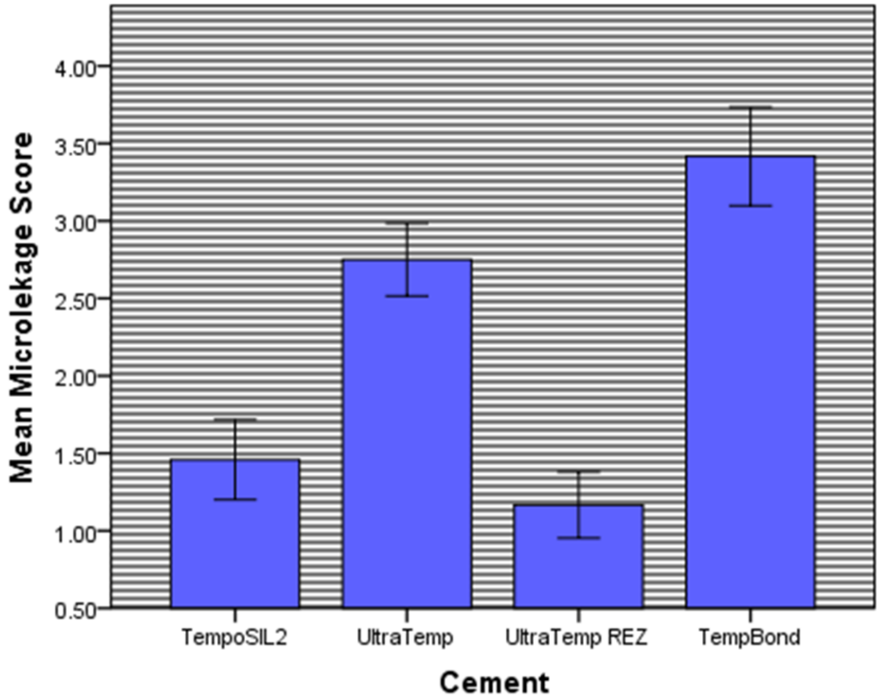


Figure 2 Stereomicroscopic figure: group 4 (A-silicone based cement-TempoSil® 2)

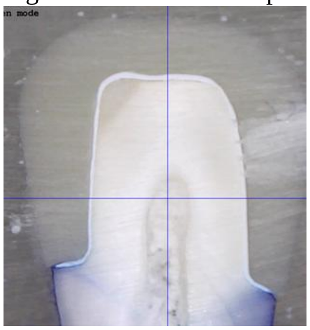


Figure 3 Stereomicroscopic figure: group 1 (Zinc-oxide Eugenol-TempBond®) Dye leakage (Red arrows) at cement-tooth interface.

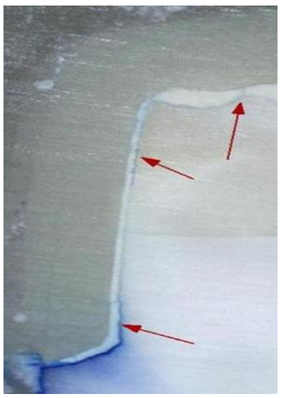
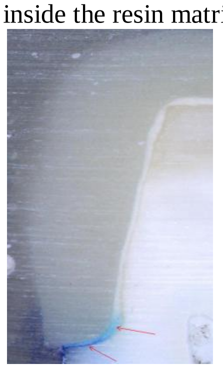


Figure 4 Stereomicroscopic figure: group 4 (A-silicone based cement-TempoSil® 2) Dye leakage (Red arrows) at both the cement-tooth and cement- provisional crown interfaces.

Figure 5 Stereomicroscopic figure: group 3 (Resin based cement-UltraTemp® REZ) Dye leakage (Red arrows) inside the resin matrix in addition to cement-tooth interface.



Discussion

The microleakage scores of four temporary cements in provisional crowns were investigated using the dye penetration method, which has been the most popular method for microleakage assessment (Tyler and Lynch, 1992). The selection of materials for this investigation was based on a wide variety of chemical compositions representing the spectrum of temporary cements that are commercially available.

In this experimental setup, every effort was made to address all of the factors that may affect microleakage, starting from standardized tooth preparation and provisional restoration fabrication technique using light curable Urethane Methacrylate material that lead to improvements in the average quality of prostheses adaptation and a reduction in both the marginal gap and cement film thickness, which have a dramatic effect on reducing microleakage (Kerby et al., 2013). The thermocycling process is used to simulate the temperature fluctuations in the oral cavity. The low number of thermocycles employed in this study corresponded to the short period of service of provisional restoration in the oral cavity. Moreover, the temperature range of the cycles is more important than the number of cycles, as stated by (Crim and Garcia, 1987; Tanaka et al., 1995).

The sealing ability of any cement is affected by mechanical, physical and chemical properties of that cement, which depend mainly on its chemical composition. In general, cements with desirable mechanical properties, dimensional stability, good adhesion to tooth structure, low film thickness, low solubility in oral fluids and a similar coefficient of thermal expansion to the coronal tooth structure typically possess good sealing abilities (Bullard et al., 1988; Piwowarczyk et al., 2005). Unfortunately, temporary cements do not possess these properties. Furthermore, the need for the easy removal of the provisional restoration and temporary cement from the teeth (without damaging the restoration or the tooth) makes it difficult to use cements with these characteristics.

In this study, the tested null hypothesis was rejected because the temporary cements had a significant effect on microleakage.The lowest microleakage scores were obtained in specimens cemented with UltraTemp® REZ, followed by teeth cemented with TempoSil® 2.On the other hand, the highest microleakage scores were obtained in samples cemented with Tempbond®, followed by samples cemented with UltraTemp®.

The resin-based cement (UltraTemp® REZ) was the most effective at preventing microleakage under provisional crowns in spite of its high volumetric shrinkage, which varied between 2% and 5%(Feilzer,1988), and its higher linear coefficient of thermal expansion (76–85× 10^{-6}/°C), compared with the tooth structure (Sidhu et al., 2004). The good sealing properties of this cement may be attributed to main three factors: first, hygroscopic expansion due to water uptake, which compensates for volumetric shrinkage. The water uptake of this temporary cement was enhanced via the addition of the co-monomer TEGDMA (tri [ethlene glycol] methacrylate) to the cement formula, which consists mainly of high-molecular weight Bis-GMA monomers (bisphenol-A glycidyldimethacrylate). The increased TEGDMA fraction from 0 to 1% will increase the water uptake of Bis-GMA-based resins from 3 to 6%. In addition to the use of different proportions of TEGDMA, which are employed to modify the handling properties of the materials, one can lower the viscosity and thereby improve the adaptation of the cement to the tooth structure via a thinner film (Toledano et al, 2003; Ellakwa et al, 2007). Second low solubility of resin cements, and third the high mechanical properties of resin temporary cements which are considered to be the highest compared with other temporary cements. The flexural strength of resin-based temporary cements has been reported to be approximately 40 MPa; other temporary cements exhibit values less than 7 MPa (Lawson et al., 2007).

TempoSil® 2, which is addition-cured, silicone-based zinc-oxide temporary cement, showed good sealing ability that was comparable to resin-based cements. The addition of a silane agent to the cement formula and elastic properties of silicone contribute significantly to the improved adhesion and marginal sealing ability of this cement (Howard, 2008). Its firm-but-elastic property makes separating the cement from the tooth and the surfaces of restorations very easy. In addition, dispensing the cement is easy due to the auto mix system and the very small mixing tip that fits easily into provisional crowns, ensuring an even distribution of bubble-free cement mix, as demonstrated in the stereomicroscope photographs (Figure 2).

Polycarboxylate-based cements were the first cements to show chemical adhesion to teeth via polyacrylic acid bonds to calcium ions on the surface of enamel or dentin (Chun and White, 1999).In addition, polycarboxylate-based cements exhibit low initial cytotoxicity on dental pulp.The larger size of the polyacrylic acid molecules reduces penetration into the dentinal tubules, contributing to the excellent biocompatibility and lack of postoperative sensitivity of the polycarboxylate cement (Malkoç et al., 2015).Unfortunately, this temporary cement exhibited a high microleakage score, which was not significantly different from that of zinc oxide eugenol cement.This result may be due to the high solubility and weak mechanical properties of these cements combined with their high viscosity compared with other temporary cements. This finding is consistent with the results of Zmener et al. (2004) who investigated the sealing properties of three temporary restorative materials using the dye penetration method and showed a high microleakage of a polycarboxylate-based cement (UltraTemp® Firm, Ultradent Products, Inc.South Jordan, USA).

Zinc oxide eugenol cement exhibited the highest microleakage score of all cements examined in this study, which is consistent with previous reports (Baldissara et al., 1998; Lewinstein et al., 2003). Its high solubility, hydrolytic breakdown, and low mechanical properties are major drawbacks that lead to the poor sealing ability of this cement (Craig et al, 2012). Fortunately, this cement possesses antibacterial properties due to the presence of eugenol, which translates into an inhibitory effect against plaque accumulation in microleakage areas.

Regarding the mode of dye penetration, in both Zinc oxide eugenol cementand polycarboxylate cement the dye penetration occurred at the cement-dentine interface, which was obvious based on stereomicroscope photographs (Figure 3). This finding is in accordance with previous reports (Baldissara et al., 1998; Duymu et al., 2005), but in TempoSil® 2 the leakage was in both the cement-dentine and cement-provisional crown interfaces (Figure 4), which may be due to the high coefficient of thermal expansion of additional silicone compared with both the resin of the provisional crown and the coronal tooth structure.This fact may allow for the easy removal of the cement from both the tooth structure and the provisional crown. The penetration mode in resin-based cements occurred at the cement-dentine interface in addition to the diffusion of the dye inside the cement itself (Figure 5). This result may be due toboth absorption and adsorption of the dye, which can penetrate deeper into the polymer matrices of the resin cement (Khalachandra and Turner, 1987; Um and Ruyter, 1991). Furthermore, water uptake of the cement may play a role and may explain the clinical observation of discoloration of crown margins when cemented with temporary resin-based cements.

All temporary cements that were tested demonstrated different degrees of microleakage. This study suggests that no temporay cement can completely prevent microleakage. Fortunately, in vitro tests of microleakage using dyes penetration tests are considered to be stricter than microleakage occurring in the oral cavity due to the smaller particle size of the in vitro dye compared with oral bacteria. The dimensions of methylene blue are extremely small (1.634 × 0.793 ×0.4nm) compared with those of a typical bacterium (500–100 nm). Furthermore, the intra-pulpal pressure and calcification of proteins and debris at the crown marginal gap may also contribute to reducing marginal microleakage in real clinical situations (Pasley, 1990; Jacobs and Windeler 1991).Therefore, the tested cements may respond better in real clinical situations. Further investigations and clinical studies with a larger sample size are necessary in order to gain more insights into the clinical performance and sealing abilities of these temporary cements.

Conclusions

Within the limitations associated with this in vitro study, resin-based temporary cements exhibited significantly less microleakage after the dye penetration test compared with both polycarboxylate-based temporary cements and conventional zinc oxide-based temporary cements.

The microleakage of zinc oxide eugenol temporary cement and polycarboxylate-based cement occurred at the cement-tooth interface. For additional-silicone temporary cement, the leakage occured both the cement-tooth and cement- provisional crown interfaces. For the resin-based temporary cement, the dye was able to discolor and diffuse inside the resin matrix in addition to leakage at the cement-tooth interface.

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Conflict of Interests

The authors declare no conflict of interest regarding the publication of this paper.

References

Abo-Hamar SE, Federlin M, Hiller KA, Friedl KH, Schmalz G. (2005) Effect of temporary cements on the bond strength of ceramic luted to dentin.Dent Mater. 21(9):794-803.

Anusavice KJ, Shen C, Rawls HR (2013) Phillips' science of dental materials. 12th ed. St. Louis: W.B. Saunders: 331-332.

Baldissara P, Comin G, Martone F, Scotti R. (1998) Comparative study of the marginal microleakage of six cements in fixed provisional crowns. J Prosthet Dent 80(4):417-22.

Bullard RH, Leinfelder KF, Russell CM. (1988) Effect of coefficient of thermal expansion on microleakage. J Am Dent Assoc 116:871-874.

Chun LZ, White SN. (1999) Mechanical properties of dental luting cements. J Prosthet Dent81:597–609

Cohen RB, Hallmon WW, Culliton CR, Herbold ET.(1989)Bacteriostatic effect of tetracycline in a temporary cement.J Prosthet Dent.62(5):607-9.

Craig RG, Powers JM, Sakaguchi RL. (2012) Craig's restorative dental materials. 13th ed. St. Louis: Mosby Elsevier: 338-339.

Crim GA, Garcia GF. (1987) Microleakage: the effect of storage and cycling duration. J Prosthet Dent 57:574–6.

Dahl BL. (1977) Dentine/pulp reactions to full crown preparation procedures. J Oral Rehabil. 4(3):247-54.

Duymu ZY, Yanikoglu ND, Bayindir F. (2005) The investigation of the marginal microleakage of four temporary cements in metal castings. Atatürk Üniv. Di Hek.Fak.Derg. 15(1):22-28

Ellakwa A, Cho N, Lee IB. (2007) The effect of resin matrix composition on the polymerization shrinkage and rheological properties of experimental dental composites.Dent Mater. 23(10):1229-35.

Feilzer AJ, De Gee AJ, Davidson CL (1988) Curing contraction of composites and glass–ionomer-cements. J Prosthet Dent59:297–300.

Felton DA, Boyne MS, Konoy BE, Zopatero B. (1991) A crown for clinically investigatingmicroleakage. J Prosthet Dent; 66:34-38

Fosse G, Saele PK, Eide R. (1992) Numerical density and distributional pattern of dentin tubules. ActaOdontol Scand. 50(4):201-10.

Hersek N, Canay S, Akça K, Ciftçi Y. (2002) Comparison of microleakage properties of three different filling materials: An autoradiographic study. J Oral Rehabil. 29:1212-7.

Hilton TJ. (2002) Can modern restorative procedures and materials reliably seal cavities? In vitro investigations. Part 1. Am J Dent. 15(3):198-210.

Hodosh AJ, Hodosh S, Hodosh M.(1993) Potassium nitrate-zinc oxide eugenol temporary cement for provisional crowns to diminish postpreparation tooth pain.J Prosthet Dent.70(6):493-5.

Howard E (2008) Provisional Cements, Inside Dentistry January, Volume 4, Issue 1.

Jacobs MS, Windeler, A.S (1991) An investigation of dental luting cement solubility as a function of the marginal gap. J Prosthet Dent65:436-442.

Kerby RE, Knobloch LA, Sharples S, Peregrina A.(2013) Mechanical properties of urethane and bis-acryl interim resin materials.J Prosthet Dent.110(1):21-8.

Khalachandra, S., Turner, D.T. (1987) Water sorption of polymethacrylate networks: Bis-GMA/TEGDM copolymers. Journal of Biomedical Materials Research. 21: 329–338.

Lawson NC, Burgess JO, Mercante D (2007) Crown retention and flexural strength of eight provisional cements. J Prosthet Dent 98:455-460,

Lewinstein I, Chweidan H, Matalon S, Pilo R. (2007) Retention and marginal leakage of provisional crowns cemented with provisional cements enriched with chlorhexidine diacetate. J Prosthet Dent. 98(5):373-8.

Lewinstein I, Fuhrer N, Ganor Y. (2003) Effect of a fluoride varnish on the margin leakage and retention of luted provisional crowns. J Prosthet Dent. 89(1):70-5.

Lewinstein I, Fuhrer N, Gelfand K, Cardash H, Pilo R. (2003) Retention, marginal leakage, and cement solubility of provisional crowns cemented with temporary cement containing stannous fluoride. Int J Prosthodont. 16(2):189-93.

Malkoç MA, Demİr N, Şengün A, Bozkurt ŞB, HakkiSS (2015) Cytotoxicity of temporary cements on bovine dental pulp-derived cells (bDPCs) using realtime cell analysis. J Adv Prosthodont. 7(1):21-6.

Marshall GW Jr, Marshall SJ, Kinney JH, Balooch M. (1997) The dentin substrate: structure and properties related to bonding. J Dent. 25(6):441-58.

Miller MB. (2012) Provisional cements--are they getting better? Gen Dent. 60(2):98-9.

Mjör IA. (2005) Clinical diagnosis of recurrent caries. J Am Dent Assoc. 136(10):1426-33.

Pasley DH. (1990) Clinical considerations of microleakage. J Endod; 16: 70-77.

Piwowarczyk A, Lauer HC, Sorensen JA (2005) Microleakage of various cementing agents for full cast crowns. Dent Mater. 21:445-453

Rosenstiel SF, Land MF, Fujimoto J. (2006) Contemporary fixed prosthodontics. 4th ed. St. Louis: Elsevier Mosby: 909-927.

Rosentiel SF, Gegauff AG. (1988) Effect of provisional cementing agents on provisional resins. J Prosthet Dent; 59: 29-33.

Sadan A (2000) Clinical considerations in cement selection for provisional restorations—Part I. Pract Periodontics Aesthet Dent.; 12(7): 638.

Sidhu SK, Carrick TE, McCabe JF. (2004) Temperature mediated coefficient of dimensional change of dental tooth-colored restorative materials. Dent Mater. 20:435-40.

Tanaka T, Kamada K, Matsumura H, Atsuto MA. (1995) Comparison of water temperatures for thermocycling of metal bonded resin specimens. J Prosthet Dent; 74:345-449.

Taylor MJ, Lynch E. (1992) Microleakage.J Dent. 20(1):3-10.

Tjan AH, Dunn JR, Grant BE. (1992) Marginal leakage of cast gold crowns luted with an adhesive resin cement. J Prosthet Dent; 67: 11-4.

Toledano M, Osorio R, Osorio E, Fuentes V, Prati C, Garcia-Godoy F.(2003) Sorption and solubility of resin-based restorative dental materials.J Dent. 31(1):43-50.

Um CM, Ruyter IE. (1991) Staining of resin-based veneering materials with coffee and tea. Quintessence International. 22(5):377-386.

Zmener O, Banegas G, Pameijer CH. (2004) Coronal microleakage of three temporary restorative materials: an in vitro study. J Endod. 30(8):582-4.