Microleakage of cements for stainless steel crowns

Kanoknuch Shiflett, DDS   Shane N. White, B Dent Sc, MS, MA

Abstract

Microleakage is related to recurrent decay, inflammation of vital pulps, and reinfection of previously treated root canals. The purpose of this investigation was to compare the abilities of new adhesive cements and conventional nonadhesive controls to prevent microleakage under stainless steel crowns on primary anterior teeth. Standardized preparations were made, and stainless steel crowns were adapted. Specimens were assigned randomly to cement groups: zinc phosphate (ZP), polycarboxylate (PC), glass-ionomer (GI), resin-modified glass-ionomer (RMGI), RMGI with a dentin bonding agent (RMGI + DBA), adhesive composite resin (ACR) and zinc oxide eugenol (ZOE). Specimens were stored in water, aged artificially, stained, embedded, and sectioned, and the microleakage was measured. Group means and standard errors were calculated. ANOVA discerned differences among groups (P < 0.0001), and Tukey's multiple comparisons testing (P < 0.05) ranked the groups from least to most microleakage as follows: [RMGI + DBA, RMGI, ACR, GI], [ZP], and [PC, ZOE]. The adhesive cements significantly reduced microleakage. (Pediatr Dent 19:262–66, 1997)

Stainless steel crowns (SSCs) often are used to restore primary teeth with extensive carious lesions when there is inadequate retention or resistance form for direct amalgam or composite restorations.[1-3] Although SSCs have high success rates, a significant number of clinical failures occur due to loss of the crown, periapical pathology, or defective margins.[4-7] SSC success depends on the quality of the tooth preparation, selection and adjustment of an appropriate crown, and the luting cement.[8-12] Despite careful crimping and contouring, gingival margins of SSCs are often less than perfectly adapted, and SSC margins are known to collect considerable amounts of plaque.[13-15] Therefore, the ability of cements to seal crown margins is important.

A wide range of luting cement classes are now available, including: zinc phosphate, polycarboxylate, reinforced zinc oxide eugenol, glass-ionomer, resin-modified glass-ionomer, and composite resin cements.[16-21] Many of the newer materials adhere to tooth structure and have superior physical properties.[19-22] Glass-ionomer and resin-modified glass-ionomer cements also release fluoride.[19, 21, 23] Resinous materials can be used in conjunction with dentin bonding agents if additional adhesion is required.[24] Thus, new adhesive cements have the potential to provide greater clinical success than conventional nonadhesive cements.

Poor marginal seals may allow microleakage of bacteria and their toxic metabolic waste products into tooth structure.[25-31] Such microleakage can lead to recurrent decay, inflammation of vital pulps, or reinfection of previously treated root canals by coronal microleakage.[25-35] Coronal microleakage (reinfection of treated root canals by oral bacteria through leaky coronal restorations) is now known to be a major cause of root canal treatment failure.[32-35] Many studies have investigated luting cement microleakage, but these studies have generally been performed on well-fitting cast crowns on permanent molars or premolars.[36-43] Very few studies have examined microleakage of SSCs luted to primary teeth.[44] Studies on primary teeth have not included a wide variety of cement classes, used quantitative measurements, or examined anterior teeth.[44]

The purpose of this investigation was to compare the ability of new adhesive cements and conventional nonadhesive cements to prevent microleakage of cements under SSCs on primary anterior teeth.

Methods and materials

Thirty-five largely intact primary maxillary and mandibular anterior teeth were selected for this study and stored in tap water at 37°C. These teeth had been extracted for orthodontic reasons or due to untreatable trauma and had no caries, long roots, and sufficient intact coronal tooth structure. The teeth were hand scaled and cleaned to remove debris. Anterior teeth were chosen instead of molars, because intact primary molars usually have little remaining root structure due to physiologic resorption. Root resorption in molars could more easily lead to confounding die penetration through the tooth structure and pulp chamber, not through the crown margin. The apical part of the roots was mounted in acrylic resin blocks. Standardized tooth preparations for SSCs were performed by a single operator. The teeth were anchored in a water bath, and water spray was used throughout tooth preparation. A
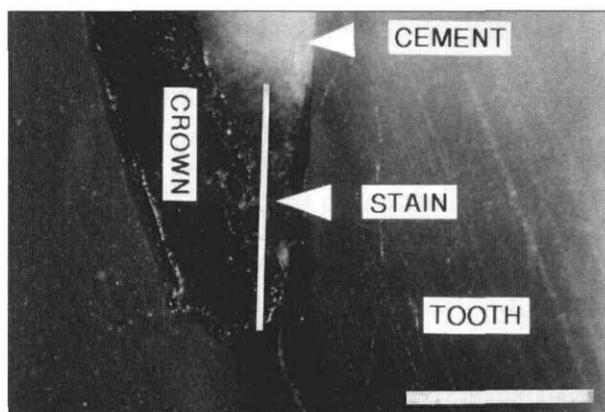
Fig 1. Micrograph of zinc phosphate cement specimen with some stain ingress. Wide horizontal scale line represents 500 μm. Narrow vertical line represents linear stain ingress measurement.

number 169 bur (Brassler USA Inc., Savannah, GA) was used to reduce 1.0–1.5 mm of the incisal edges and proximal surfaces. A prefabricated SSC (Unitek, Monrovia, CA) was selected, trimmed, and crimped until a satisfactory fit was achieved. As this was a laboratory study, the marginal adaptation could be visualized easily and adjusted until the optimal contact between tooth structure and crown margin was achieved (Fig 1). The roots of the teeth, from one millimeter below the crown margins to the acrylic blocks, were sealed with five coats of a dentin bonding agent (Tenure, Den-Mat, Santa Maria, CA) to prevent later penetration of the unprepared exposed roots by silver nitrate stain. Reference marks were scratched at the midlingual and midfacial surfaces of each tooth on root structure to provide orientation for subsequent sectioning.

Five specimens were assigned randomly to each of the seven cement groups listed in Table 1. Glass-ionomer, resin-modified glass-ionomer, and adhesive composite resin are considered to have adhesive properties.[19-21] The resin-modified glass-ionomer was used both with and without a dentin bonding agent.[24] Three non-adhesive control materials— zinc phosphate, polycarboxylate, and zinc oxide eugenol— which are usually not considered to have long-term adhesive properties, were also included.[16-18] The cements were used according to their manufacturers' instructions.

The SSCs were filled with cement and placed on their teeth using finger pressure. Then the incisal edges of the SSCs were loaded axially with 5 kg in a custom-made loading jig until 10 min after the cement mix was initiated to hold the crowns in place in a standardized manner until the cement had set. Excess cement was removed 10 min after mix began using hand instruments. Then the specimens were transferred to an atmosphere of 100% humidity at 37°C for an additional 50 minutes.

One hour after the cement mix was initiated, the restored teeth were transferred to distilled water at 37°C for 14 days. Then they were artificially aged by thermalcycling from 5 to 50°C for 2000 cycles with a travel time of 20 sec and a dwell time of 30 sec. Differential thermal expansion of the restoration and tooth mechanically stressed the tooth-restoration interface during thermalcycling. After thermalcycling, the restored teeth were immersed in a 50% (by weight) aqueous silver nitrate solution and stored in the absence of light for 60 min. The surface-adhered silver nitrate then was removed by rinsing for 1 min in distilled water before exposing the samples to fluorescent light in a photodeveloping solution (D76, Eastman Kodak, Rochester, NY) for 8 hr to fix the silver nitrate stain, prevent further diffusion, and turn the stain black. After rinsing in water and air drying, the samples were embedded in a slow setting clear epoxy resin that was allowed to set for 24 hr. The samples were sectioned longitudinally in the buccolingual plane through the reference marks with a slow-speed diamond saw (Isomet, Buehler Ltd, Evanston, IL). This created two interfaces on each tooth for measuring microleakage. Adjacent interfaces were separated by 1.0 mm, the thickness of the diamond saw cut. Each interface contained two measurement points, buccal and lingual. Thus, each tooth specimen provided four measurement points.

Marginal microleakage was defined as the linear penetration of silver nitrate stain from the margin of SSC, where the cement interfaced with the tooth, inward along the tooth-cement interface (Figure). Microleakage was recorded as micrometers of distance of stain penetration, measured at 100x magnification using a toolmakers microscope (Unitron, Newton Highlands, MA) with digital positioners with an accuracy of 0.1 μm (Boeckeler Instruments, Tuscon, AZ). Specimens were identified only by a numerical code. The order of specimen measurement and remeasurement was randomized. The operator did not have access to the numerical code during specimen

TABLE 1. MATERIALS USED			
Material Class	*Code*	*Brand Name*	*Manufacturer*
Dentin bonding agent	DBA	Tenure	Dent-Mat, Santa Maria, CA
Resin-modified glass-ionomer	RMGI	Infinity	Dent-Mat, Santa Maria, CA
Adhesive composite resin cement	ACR	Panavia 21	Kuraray, Osaka, Japan
Glass-ionomer cement	GI	Ketac Cem	ESPE, Seefeld/Oberbay, Germany
Zinc phosphate cement	ZP	Flecks	Keystone, Cherry Hill, NJ
Polycarboxylate cement	PC	Durelon	ESPE, Seefeld/Oberbay, Germany
Zinc oxide eugenol cement	ZOE	Fynal	Caulk/Dentsply, Milford, DE

TABLE 2. MICROLEAKAGE OF DIFFERENT CEMENTS UNDER STAINLESS STEEL CROWNS

Material Class	Mean Microleakage, µm	Standard Error, µm	Homogenous Groups*		
RMGI + DBA	217.2	17.8	X		
			X		
RMGI	276.3	35.0	X		
			X		
ACR	335.8	39.9	X		
			X		
GI	416.6	45.9	X		
ZP	853.7	92.8		X	
PC	1113.6	156.0			X
					X
ZOE	1221.1	143.1			X

* Homogenous groups linked by vertical lines of Xs are not significantly different at $P < 0.05$.

TABLE 3. ONE-WAY ANALYSIS OF VARIANCE FOR MICROLEAKAGE BY CEMENT CLASS

Source of Variation	Sum of Squares	Degrees of Freedom	F-ratio	P value
Between groups	21217360	6	21.1	< 0.0001
Within groups	22283163	133		
Corrected total	43500523	139		

measurement. Each specimen was measured twice, separated in time, by the same operator. The mean of the two separate independent measurements was used to describe each point. Four points were measured for each sample. Five samples per group gave 20 points per group.

The mean stain penetration and its associated standard error were calculated for each cement group. ANOVA was performed to determine whether significant differences existed among cement groups ($P < 0.05$). In the event of significant differences, Tukey's multiple comparisons testing was performed to determine which groups differed from one another ($P < 0.05$).

Results

Microleakage means and their associated standard errors in µm are listed in Table 2. ANOVA discerned significant differences among the cement groups ($P < 0.0001$) (Table 3). Multiple comparisons testing ranked the cement groups from least to most microleakage as follows: [RMGI + DBA, RMGI, ACR, GI], [ZP], and [PC, ZOE] (Table 2).

Discussion

This study compared four different classes of new adhesive cement with three conventional nonadhesive

cements. The study used primary anterior teeth, not permanent teeth or resin dies, to more closely model clinical practice. A fixable stain was used to quantify microleakage, so that the time for stain diffusion could be controlled and limited. Microleakage was quantified with direct parametric measurements, not by a more subjective nonparametric scoring technique. The sample size was small, but was sufficient to discern significant differences among the test groups. As this was a laboratory study using a small sample size in a carefully controlled and standardized environment, its results should not be extrapolated to more complex clinical situations.

The results of this study show that a variety of adhesive cements can reduce leakage significantly under SSCs in comparison to nonadhesive cements such as zinc phosphate, polycarboxylate, and zinc oxide eugenol. Decreased microleakage has the potential to reduce clinical failures caused by recurrent caries, pulpal pathology, and failure of root canal treatments caused by coronal microleakage.[25-35] Since many SSCs are placed on teeth following pulpotomy or pulpectomy,[5-7] this may be an important clinical benefit.[45, 46] Less reinfection of these teeth would reduce patient suffering and decrease premature tooth loss.[32-35, 45, 46]

All the adhesive groups significantly reduced microleakage compared with the nonadhesive groups (Table 2). Differences among the adhesive groups were too small to have statistical significance given the sample size (Table 2). Since this study ranked the four adhesive groups equally, the clinical choice among these cements should be made on factors other than microleakage. Addition of a dentin bonding agent to the resin-modified glass-ionomer cement did not have a statistically significant effect, but it did tend to reduce leakage (Table 2). This tendency might become larger after extended aging or storage. Polycarboxylate and zinc oxide eugenol leaked significantly more than zinc phosphate cement (Table 2). Although none of these three cements are considered to have long-term adhesive properties, zinc phosphate's superior physical properties, lower solubility, and dimensional stability may account for its slightly better performance.[16-18, 22] Contrary to earlier research,[18] many recent studies have demonstrated that the adhesion of polycarboxylate to tooth structure is poor and of short duration.[36, 42, 43]

Adhesive cements do not have as long a clinical track record as zinc phosphate.[16] However, glass-ionomers have been widely used for 25 years and have been validated in clinical trials of SSCs.[19, 47, 48] Modern adhesive composite resin cements have been available for 10 years and are being used more widely in fixed prosthodontics.[20] Dentin bonding agents have been used widely for the cementation of other types of indirect restorations such as veneers, inlays, and onlays, as well as for crowns and fixed partial dentures.[24] Cur-

rently, several resin-modified glass-ionomer materials are being marketed exclusively for cementation. Thus, these adhesive cements have already achieved reasonable clinical track records in other areas.

Adhesive cements do have some disadvantages. They may be more difficult to manipulate and more technique sensitive than conventional cements. Also, dentin bonding agents require additional clinical steps. Glass-ionomers are considered to be more moisture sensitive than other materials. Isolation and protection of unset cement may be more critical than for conventional cements. The removal of excess cement may be more difficult, particularly for the stronger composite resin cements. Most new adhesive materials also tend to cost more than conventional cements.

Like our study on microleakage of SSCs on primary teeth, many previous studies have shown that adhesive cements decrease microleakage of cast crowns on permanent teeth.[36-43] However, few studies have investigated microleakage of SSCs luted to primary teeth. Berg et al.[44] used a radioactive tracer to evaluate microleakage of SSCs luted to primary molars with polycarboxylate, zinc phosphate, and glass-ionomer cements. Unlike most microleakage studies, which simulate the ingress of microbial products by measuring tracer ingress, these investigated tracer egress. After 1, 3, 7 and 56 days of storage, no difference was found among their cement groups. Their result contrasts with the results of our study. Escape of the radioactive tracer through exposed and unsealed root surfaces, or their different experimental techniques, might account for this difference.

Little comparative data on the performance of cements for SSCs has been reported. Various authorities have recommended zinc phosphate, polycarboxylate, zinc oxide eugenol, and glass ionomer cements for SSCs.[1-3] Laboratory studies on SSC retention have produced limited results because most classes of new adhesive cement have not been included and because epoxy dies were sometimes used instead of natural teeth.[9, 10] Adhesive cements have been shown to improve the retention of cast crowns on extracted permanent teeth.[49] Garcia-Godoy[50] compared zinc phosphate to polycarboxylate cements in an 18-month clinical trial and found no significant difference between those materials, but a low recementation rate was noted. Other comparable clinical studies on glass-ionomer cement performance reported zero recementation rates over 1-to 12-month periods.[47,48] Long-term comparative results have not yet been published. Further laboratory and clinical research is needed to indicate the best possible SSC cement for specific clinical situations. However, our in vitro study indicates adhesive cements may offer important benefits.

Conclusion

This in vitro study demonstrated that four adhesive cement groups significantly reduced microleakage compared with three classes of conventional nonadhesive cements under SSCs on primary anterior teeth.

Dr. Shiflett is a graduate student in advanced pediatric dentistry at the University of Southern California School of Dentistry and Dr. White, is assistant professor and director of clinical research, Department of Restorative Dentistry/Biomaterials, University of Southern California School of Dentistry in Los Angeles.

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