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ORIGINAL ARTICLE

An In Vitro Evaluation of the Microleakage under Complete Metal Crowns Using Three Adhesive Luting Cements

Sudhir Bhandari · Meena Aras · Vidya Chitre

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Abstract Despite the material advancements and precise laboratory techniques, cement lines are inevitable in fixed prosthodontics which leads to increased dependence on the integrity of the cement to maintain the marginal seal. The material class of luting agent is known to influence microleakage. Studies of cement dissolution and disintegration have produced varying results. Hence, this study was done to evaluate marginal leakage under complete metal crowns using three adhesive cements, two resin cements (one self cure, one dual cure) and a glass ionomer cement. Metal crowns were prepared on sixty intact extracted premolars and were randomly divided into three groups of twenty each, with each group using a different cement for luting. All the samples were then subjected to thermocycling and were sectioned using a diamond saw. Reflected Binocular Stereomicroscope at 100× magnification was used to study the extent of microleakage at both metal cement (MC) and tooth cement (TC) interface, at two opposite margins of each sectioned specimen. Data was analyzed with a one way analysis of variance. For comparison among the groups multiple comparison Bonferroni test was done. Within group data was analysed with independent student *t* test. Between three groups, metal crowns cemented with multilink cement showed significantly less microleakage at both the interfaces. Glass ionomer cement recorded maximum combined microleakage amongst three cements irrespective of the interfaces. Within group, glass ionomer and multilink cement showed more microleakage at MC interfaces than at TC interface. A complex interaction between variables related to dental restoration, luting agent and tooth structure probably influence microleakage. In vitro studies must always be followed by in vivo studies before definite conclusion can be drawn.

Keywords Adhesive luting cements · Microleakage · Thermocycling

S. Bhandari (✉)
Unit of Prosthodontics, Oral health Sciences Centre,
PGIMER, Chandigarh, India
e-mail: drsudhirbhandari@yahoo.co.in

M. Aras · V. Chitre
Department of Prosthodontics, Goa Dental College and Hospital,
Bambolim, Goa

Introduction

The ultimate goal of any prosthetic treatment is providing the patient with a precisely fabricated restoration which preserves the long term integrity of natural abutments of fixed partial dentures and their pulpal vitality [1]. An extracoronal restoration that has been completed precisely with attention to detail on a sound foundation has the best and most predictable prognosis [2].

Despite the material advancements and precise laboratory techniques, cement lines are inevitable in fixed prosthodontics and some degree of marginal discrepancy is always expected. Fusayama et al [3] discovered that marginal adaptation of cemented crowns is never perfect and the cast restorations usually display a marginal discrepancy [4]. This leads to increased dependence on the integrity of the cement to maintain the marginal seal [5].

At present, there is no luting cement with zero or complete insolubility in the oral environment and due to this solubility, luting cements in general have been described as the "weak link" in restoring teeth with cast restoration [4–7]. The cement therefore must have good mechanical properties, be as stable and insoluble as possible in the oral environment, should have a good adhesion to the tooth structure as well as to the restoration to resist bacterial penetration [8, 9]. Luting materials offering a high degree of bonding strength and relative insolubility in the oral environment have shown to have a negative impact on microleakeage around the restoration [10–13].

There is no universally accepted technique to determine marginal permeability at the interface between the tooth and the restoration. Use of dyes [1, 2, 6], radioactive isotopes [14], air pressure [15], bacteria [16], neutron activation analysis [17, 18], and artificial caries [19] has been documented. Modification of axial walls and alteration in configuration of the finish lines have been done to see the effect of tooth preparation variables on microleakage [20, 21]. Microleakage assessment has been done under complete coverage restoration*s* by completing the wax pattern on spaced dies, using vents during cementation [22, 23], with different crown foundation materials [2, 10, 24] and luting with different cements [1, 2, 4–6, 8, 10, 11, 13, 14, 25, 26].

Studies of cement dissolution and disintegration have produced varying results. Hence, this study was done to evaluate marginal leakage under complete metal crowns using three adhesive cements, which included two resin cements (Self cure and Dual cure) and a glass ionomer cement.

Statement of Problem

The need to obtain an adequate thickness of the restoration that maintains dental anatomy causes exposure of millions of dentinal tubules. These tubules are potential channels for the diffusion and colonization of the bacteria to the pulp [27].

Normally, there is a balance between the rate of diffusion of bacterial products permeating dentin due to microleakage and the rate at which they are removed by the pulpal circulation. The exposure of more dentin surface during tooth preparation combined with decreased pulpal blood flow, increases the potential for greater microleakage and can permit the concentration of these products to increase, resulting in inflammation [28, 29].

In addition, marginal opening causing cement dissolution and microleakage allows saliva with its bacterial components to penetrate the gap and gain access to circumpulpal dentin from where bacteria and their products easily diffuse to the pulp [12]. This is a major cause of postoperative sensitivity, secondary caries and pulpal necrosis, ultimately leading to clinical failure of the treatment provided [29, 30].

Materials and Method

Preparation of the Samples

Sixty intact extracted human premolars of comparable coronal dimension were stored in water at room temperature till the time of their preparation for complete metal crowns. Teeth were mounted individually in the Typodont jaw (kavo, Charlotte, Germany) and were supported with putty (Flexi Time, Heraeus Kulzer, Germany). The coronal portion of each tooth was prepared with chamfer finish line and a flat occlusal surface. Parallel prep (Parallel-a-Prep, Dentatus, USA) was used for maintaining the uniform taper of the axial wall preparation.

Wax pattern was made (Crown wax: hard blue, Bego, Germany) after applying 2 layers of die spacer on all the surfaces, except around 1 mm of the prepared margin for the crown. Sprue (Bego, Germany) was attached while the pattern was still on the die and then was invested in phosphate bonded investment (Star glow, Starvest, Germany). Casting was completed using base metal alloy (Bellabond Plus, Bego, Germany) in an induction casting machine and were adjusted on their respective dies, polished and fitted on the prepared teeth. All sixty samples were randomly divided into three groups of twenty teeth each, with each group using a different cement for luting.

Group 1 self cure resin luting cement (Multilink cement, Ivoclar Vivadent, Leichenstein, Germany).
Group 2 dual cure resin luting cement (Adhesive bridge cement, Ivoclar Vivadent, Leichenstein, Germany).
Group 3 glass ionomer luting cement (GC Fuji, GC Corporation, Japan). Manufacturer's instructions were followed to mix the cements.

Thermocycling Procedure

One hour after cementation of the crowns, all the samples in each group were mounted in the plaster base and were stored for 24 h in water at room temperature (31°C, 74% relative humidity) before thermocycling. Each thermal cycle consisted of immersing the samples alternatively in water bath (Metzer Biomedical and Electronics Ltd, Mumbai, India) maintained at 5 and 55°C. 1,000 cycles were done in each water bath with 30 s dwell time and 5 s of transition time.

Microleakage Assessment

After thermocycling was completed, the samples with only their exposed portion were immersed in 5% solution of Indigo carmine dye for 72 h. Samples were then washed in the running water to remove the superficial stains.

Each group was then randomly divided into two subgroups of ten samples each, which were sectioned using diamond wheel (Model 650, South Bay Technology, CA). Reflected Binocular Stereomicroscope (SZX-12, Olympus, Tokyo, Japan) at 100× magnifications was used to study the extent of microleakage, which was indicated by the dye

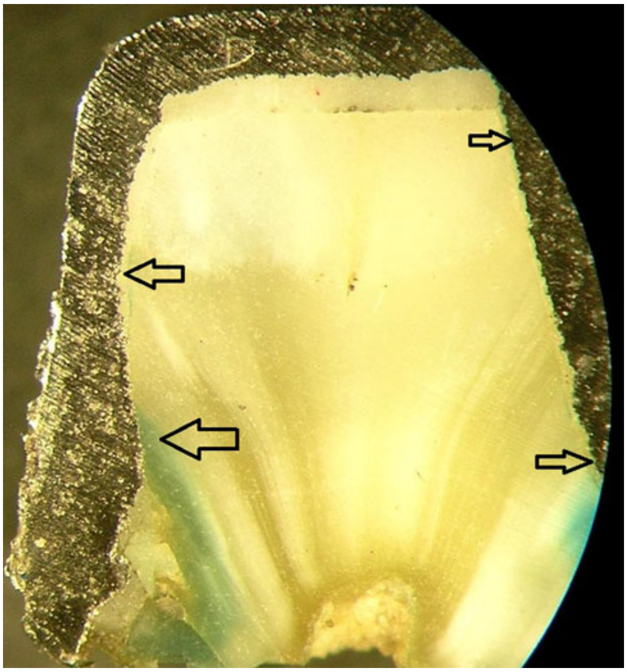

Fig. 1 *Arrows* showing microleakage (dye penetration) more than 2/3rd the axial wall length on left side and on the occlusal surface on the right side

penetration recorded at both metal cement (MC) and tooth cement (TC) interface, at two opposite margins of each sectioned specimen (Fig. 1).

Qualitative assessment of microleakage was done according to the criteria proposed by Tjan et al. [31];

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 marginal leakage of each sample was the average of the scores of dye penetration recorded at the opposite margins of each sectioned specimen, both at MC and TC interface. The data of all the three groups was analyzed with a one way analysis of variance. For comparison among the groups multiple comparison Bonferroni test was done and student *t* test was used to compare the microleakage scores within the group at both the interfaces. The statistical analysis was done with a software package (SPSS/PC+, SPSS, version 7.50, Chicago).

Results

Raw data of marginal leakage for the three cements at both the interfaces (Table 1) and mean, standard deviation, standard error and minimum and maximum of the microleakage scores at TC and MC interface (Table 2) is shown.

One way analysis of variance revealed highly significant association between the cement type and microleakage at TC interface and MC interface (Table 3). Therefore, the multiple comparison Bonferroni test was conducted to find out difference between various pair of cements (Table 4).

The Bonferroni test at both the interfaces revealed that there was a highly significant difference in mean microleakage values between multilink cement and both the other cements. Difference in mean microleakage between glass ionomer and adhesive bridge cement was not statistically significant (Fig. 2).

The combined microleakage (TC + MC) was maximum for glass ionomer cement however the difference was

Table 1 Raw data of marginal leakage at both metal cement and tooth cement interface

Cement	Multilink				Adhesive bridge				Glass ionomer			
Number	TC		MC		TC		MC		TC		MC	
	BL	MD	BL	MD	BL	MD	BL	MD	BL	MD	BL	MD
1	0.5	0	0	0	1.5	1	0.5	0	1	1	4	2
2	0	0	0	0	2	0	0	0.5	1	0	1	4
3	0.5	0	0	0	1	0.5	2.5	0.5	0.5	1.5	1.5	3
4	0.5	0	0.5	1.5	0.5	1	2	0	0.5	3.5	0	3
5	0	0	0	0	0.5	1.5	2	2	0.5	0	1	0
6	0	0.5	0	0	1	1	2	0	1	0.5	1.5	1
7	0	0	0	0	1	1	0	2.5	0	1	3	0
8	0.5	0	0.5	0	0.5	0.5	3.5	0.5	3	1	0	2.5
9	0	0	0	0	1	1.5	0	0.5	2.5	0	4	1
10	0	0	0	1.5	0.5	0	2.5	0	0.5	1	1	2
Mean	0.125		0.2		1.1		1.075		1		1.775	

Table 2 Mean standard deviation, standard error and minimum and maximum of the microleakage scores at tooth cement and metal cement interface

Interface	Cement	*N*	Mean	Std. deviation	Std. error	Min.	Max
TC	Multilink	20	0.125	0.2221	0.0497	0	0.5
	Glass ionomer	20	1	0.9733	0.2176	0	3.5
	Adhesive bridge	20	1.1	1.0463	0.2340	0	2.0
	Total	60	0.74166	0.9320	0.1203	0	3.5
MC	Multilink	20	0.2	0.4702	0.1051	0	1.5
	Glass ionomer	20	1.775	1.3715	0.3067	0	4
	Adhesive bridge	20	1.075	1.1502	0.2572	0	3.5
	Total	60	1.01666	1.2350	0.1594	0	4

Table 3 One-way analysis of variance at tooth cement and metal cement interface

		DF	Sum of squares	Mean square	*F* ratio	Significance
TC	Between groups	2.0000	11.5083	5.7542	8.2539	0.00
	Within groups	57.0000	39.7375	0.6971		
	Total	59.0000	51.2458			
MC	Between groups	2.0000	24.9083	12.4542	10.9088	0.00
	Within groups	57.0000	65.0750	1.1417		
	Total	59.0000	89.9833			

Table 4 Multiple comparison Bonferroni test

Dependent variable	(I) Cement	(J) Cement	Mean diff (I−J)	Std. error	Sig. *P* value
TC	Multilink	Glass ionomer	−0.875	0.264035816	0.004808
		Adhesive bridge	−0.975	0.264035816	0.001496
	Glass ionomer	Multilink	0.875	0.264035816	0.004808
		Adhesive bridge	−0.1	0.264035816	1
	Adhesive bridge	Multilink	0.975	0.264035816	0.001496
		Glass ionomer	0.1	0.264035816	1
MC	Multilink cement	Glass ionomer	−1.575	0.337885582	0.00
		Adhesive bridge	−0.875	0.337885582	0.04
	Glass ionomer	Multilink	1.575	0.337885582	0.00
		Adhesive bridge	0.7	0.337885582	0.13
	Adhesive bridge	Multilink	0.875	0.337885582	0.04
		Glass ionomer	−0.7	0.337885582	0.13

statistically significant only between multilink cement and the other two cements (Fig. 3).

Table 5 shows the group statistics for multilink cement for the comparison of microleakage within each group at both the interface. This was done by independent samples student *t* test (Table 6).

Discussion

Multiple factors ranging from non retentive tooth preparation, poor casting fit, poor cementing technique, weak cement, to malocclusion, excessive forces of mastication and improper prosthesis usage influence microleakage [1–14, 22].

In addition to the inevitable errors at the margin of restorations, the type of luting agent and its mechanical properties has significant effect on microleakage [32, 33]. Compressive strength may be critical to retention [34], tensile strength to retention and marginal seal [35–37]. Cement with high modulus of elasticity is important to prevent microleakage [38–44]. Water soluble cements (zinc phosphate, glass ionomer, polycarboxylate) are susceptible to tensile failure while resin cements (with higher

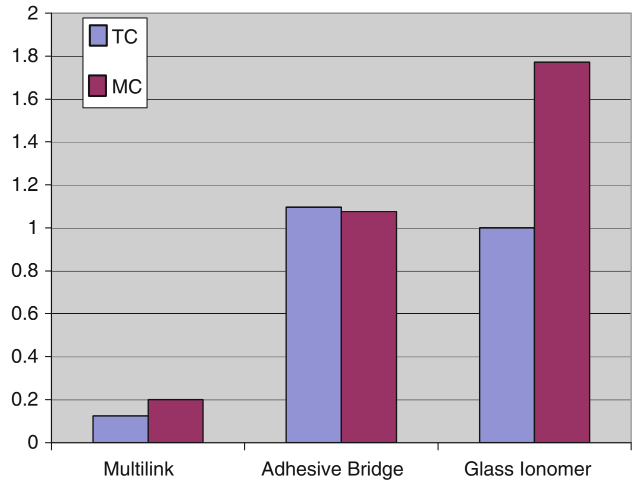

Fig. 2 *Multiple bar diagram* showing mean microleakage of the three cements at metal cement (MC) and at tooth cement (TC) interface

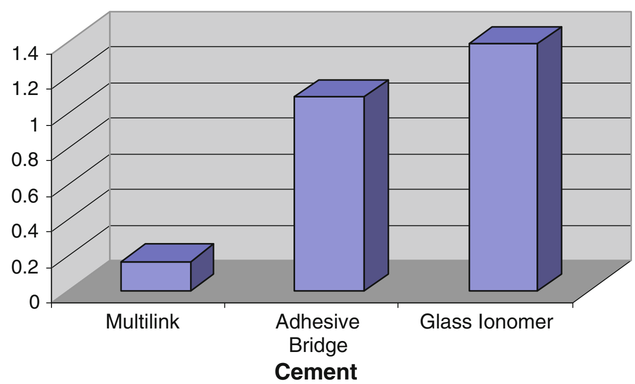

Fig. 3 Simple *bar diagram* showing combined mean microleakage of the three cements. Maximum for glass ionomer cement and minimum for self cure resin cement

Table 5 Group statistics for Multilink cement

Group	*N*	Mean	Std. deviation	Std. error mean
TC	20	0.125	0.222130829	0.04967
MC	20	0.2	0.470162346	0.105131

Table 6 Independent samples student *t* test

T	DF	Sig. (2-tailed)
−0.64502589	38	0.52278592

tensile strength) are prone to fail through cyclic fatigue stresses [39–44].

Glass ionomer cement has shown maximum combined microleakage amongst the three cements evaluated. This may be attributed to its susceptibility to disintegration due to early water contact before maturation and relative weak bond with both dentin and metal superstructure. Powers and Sakaguchi [40] suggested protection for 24 h at the margin and use of acid conditioner followed by aqueous solution of ferric chloride on dentin, while sandblasting and tin plating the castings have been advocated by Graver, Vallittu, Hotz and Hondrum [25, 45–47] to improve glass ionomers bond strength with both the tooth and restoration.

Glass ionomer cement is most susceptible to dissolution during and immediately after initial set due to its prolonged setting reaction in progressive, multiple and overlapping stages. Its modulus of elasticity increases over time and the cement might mature over a period of 24 h to 1 year [40, 42, 44].

In the present study, the glass ionomer cement samples were stored in water after 1 h of the cementation. The effect is dramatically shown in the results by the relatively high leakage with glass ionomer cement due to the presence of excess water during the growth of the hydrated silica phase [48, 49].

Improved bonding to both teeth and the restoration is an advantage with resin cements. However, inherent polymerization shrinkage and high coefficient of thermal expansion are potential concerns with resin based luting agents [41]. These stresses may exceed the adhesive and cohesive strength of the material itself resulting in the formation of the marginal gap at the point of weakest bond leading to marginal leakage at the interface. Davidson et al. [50] highlighted the importance of establishing early bond formation between the resin cements and the two interfaces and hygroscopic expansion to counteract stresses of polymerization shrinkage and decreasing the marginal gap. However, polymerization shrinkage occurs immediately while adequate compensatory hygroscopic expansion would require hours or days. Therefore, the immediate bond strength to dentin is crucial to resist the combined forces of polymerization shrinkage, pattern of contraction and coefficient of thermal expansion mismatch. If adhesion to dentin is lost at the time of resin polymerization, any compensatory hygroscopic expansion cannot completely seal this interface [50–53].

In this study, the samples were stored in water for 24 h. This is a brief period compared to the life expectancy of the cast restorations, but this early storage may have allowed some relaxation of internal stresses caused by polymerization shrinkage of the resin materials. Hygroscopic expansion coupled with their high flexural strength, high modulus of elasticity and adhesive potential might have led to their low microleakage values in comparison to glass ionomer cement [54, 55].

Both resin based cements recorded less microleakage as compared to glass ionomer cement which can be related to their better adhesion to conditioned metal and

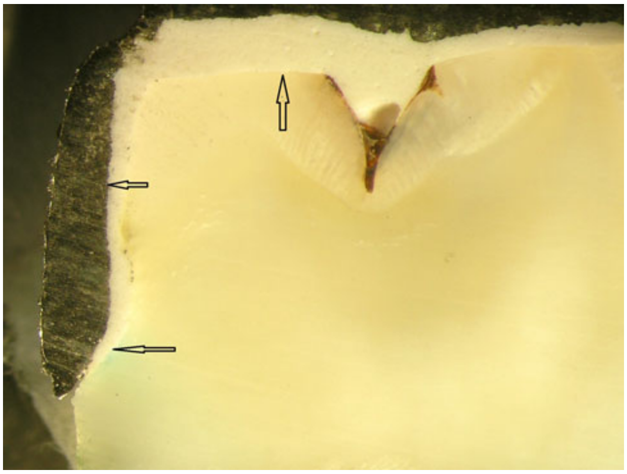

Fig. 4 *Arrows* showing microleakage (dye penetration) more than 2/3rd the axial wall length with adhesive bridge cement. Also showing is the excessive cement layer thickness

tooth, their high mechanical strength and inherent relative insolubility.

Between the two resin cements multilink has recorded less microleakage. This better result may be related to its self-curing nature with low curing rate, rapid and superior adhesion to both dentin and restoration and better mechanical properties [56].

A poor interfacial seal and more leakage for adhesive bridge cement as compared to multilink cement may be attributed to the mechanical insufficiency of the bond (between the cement and both the interfaces), combined with its high viscosity, decreased flow, high cement film thickness (Fig. 4), greater polymerization shrinkage due to the bulk of the cement, and inadequate degree of cure through metal restoration (DC%) [39, 57, 58].

In addition to its inherent advantages of the resin cements in inhibiting microleakage, use of metal primers has been advocated to improve the bond strength between the cement and the metal surface which further reduces the micro-leakage and hence improve clinical durability [58–61].

In vitro microleakage tests carried out with dyes are considered stricter than those carried out in the oral cavity. Therefore, it may be suggested that if a material responds positively to the dye test, it is likely to respond even better on a clinical level.

Conclusion

1) Between three groups, metal crowns cemented with Multilink cement showed least microleakage. The result was statistically significant both at tooth cement and metal cement interface in comparison to the other two cements.
2) Glass ionomer cement recorded maximum combined microleakage amongst three cements irrespective of the interfaces.
3) Within group, glass ionomer and multilink cement showed more microleakage at MC interfaces than at tooth cement interface. Result was statistically significant only for glass ionomer cement. Adhesive bridge cement showed almost equal amount of leakage at both the interface.

A complex interaction between variables related to dental restoration, luting agent and tooth structure influence microleakage. Therefore, precaution has to be taken to standardize these variables and in vitro studies must always be followed by in vivo studies before definite conclusion can be drawn.

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