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In Vitro Comparison of Microleakage and Tensile Bond Strength of Self Adhesive Cement and Conventional Adhesive Luting Cements for Cementation of Stainless Steel Crowns in the Primary Molars

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Research Article

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ABSTRACT

Background: The stainless steel crowns (SSC) offers the advantage of full coronal coverage following pulpotomy or pulpectomy treatments. Despite careful crimping and contouring, gingival margins of SSCs are often less than perfectly adapted and lead to gingival inflammation. Luting cements play an important role in retention of crowns, obtaining a suitable marginal seal and reducing microleakage. So this study was conducted to evaluate and compare the microleakage and tensile bond strength of stainless steel crowns cemented with GC Fuji I cement, Rely XTM luting 2 cement and new self-adhesive cement that is Smart cemTM 2 cement.

Material and methods: Tooth preparation was performed on 90 extracted primary molar teeth for SSC restoration. Two groups of 45 samples each for microleakage and tensile bond strength tests were performed and further subdivided into 15 for each of the three cement groups, cemented glass ionomer (GIC), resin-modified glass ionomer cement (RMGIC) or Smart cemTM 2 cement. The samples for evaluation of microleakage were then processed for dye penetration which was scored under a stereomicroscope and tensile bond strength was evaluated by Instron testing machine.

Results: The data were analysed using version 20 of the SPSS. Mean microleakage value of Smart CemTM2 cement was less when compared to Rely XTM luting 2 cement ($p<0.002$**) and GC Fuji I cement ($p<0.0001$**) and it was statistically highly significant. Mean tensile bond strength of Smart CemTM2 cement was high when compared with GC Fuji I cement and Rely XTM luting 2 cement and it was statistically highly significant ($p<0.0001$**).

Conclusion: Self-adhesive cements were more effective in reducing microleakage and they yielded higher tensile bond strength in cementing stainless steel crowns than adhesive cements.

INTRODUCTION

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].

The stainless steel crowns (SSC), first introduced in 1950 by Engel and developed by Humphrey, is an extremely durable, relatively inexpensive treatment [2]. The advantages offered by SSC are the low cost, less chair time, prevention of recurrent caries, lack of mercury and preservation of normal vertical dimensions [3].

Success of SSC depends on the quality of the tooth preparation, selection and adjustment of an appropriate crown and the luting cements [4]. Despite careful crimping and contouring, gingival margins of SSCs are often less than perfectly adapted. This leads to considerable amount of plaque accumulation at the margins of SSCs [5].

Poor marginal seals may allow microleakage of bacteria and their toxic metabolic waste products into tooth structure [6]. Such microleakage can lead to recurrent decay, inflammation of vital pulps or reinfection of previously treated root canals [7]. During function in the oral environment SSC are subjected to repetitive dynamic loading of tensile stresses during mastication and parafunction [8]. Thus, luting cements play an important role in obtaining a suitable marginal seal and reducing microleakage through the crown margins 1 and maintains their integrity during the stress transfer and helps in the retention of Stainless steel crowns [9].

Different kinds of luting cements have been used to cement SSCs. The earliest “conventional” luting cements also described as non-adhesive luting cements namely zinc phosphate and zinc oxide eugenol provided only a mechanical bond to the tooth [10].

To overcome the shortcoming of non-adhesive luting cements, these adhesive luting cements like glass ionomer cement, resin modified glass ionomer cement were developed. But these cements have initial slow setting, elastic deformation in areas of high masticatory stress, microleakage in GIC based cements and HEMA in RMGIC being responsible for increased water sorption posed problems [11].

With the advent of development in this field, a new generation of luting cements namely new self-adhesive cement (Smart CemTM2 cement) could prove to be offering improved mechanical and chemical bonding to the tooth with relatively less technique sensitivity.

Therefore the present study is unique in its design and aimed at evaluating and comparing the microleakage and tensile bond strength of stainless steel crowns cemented with glass ionomer cement (GC Fuji I cement), resin modified glass ionomer cement (Rely XTM luting 2 cement) and new self-adhesive cement that is Smart cemTM2 cement.

MATERIAL AND METHODS

Inclusion Criteria

Teeth which are caries free.

Exclusion Criteria

Teeth which have hypoplastic enamel, cracks, caries or restorations.

Study Design

Experimental, *in vitro* and inter group randomized control trial study.

Ninety intact primary maxillary and mandibular 2nd molar teeth extracted for therapeutic reasons were selected for this study and stored in tap water at 37 °C till its use. The apical part of the roots was mounted in acrylic resin blocks. Standardized tooth preparation for SSCs was performed by a single operator. A pear shaped bur (#330 NO. DENTSPLY) was used to reduce 1.0-1.5 mm of the occlusal surface and tapering fissure bur (#169L NO. DENTSPLY) was used to reduce proximal surface. A prefabricated SSC (3M ESPE) was selected by trial and error method, 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 [1].

Samples were randomly divided into two groups of 45 samples each for microleakage and tensile strength tests.

Within each group, the procedure of adapting SSCs for cementation on the primary molars is described as follows.

1. Group I: SSCs were cemented using a GIC (GC Fuji I glass ionomer cement).
2. Group II: SSCs were cemented using a Rely XTM luting 2 cement (3M ESPE).
3. Group III: SSCs were cemented using a Smart CemTM2 (DENTSPLY IND).

All the cements were mixed according to manufacturer's instructions. After cementation, excess cement was removed using a dental explorer [12]. All cemented SSCs were kept in distilled water for aging over 4 weeks at 37 °C. After this period, all teeth were subjected to 500 thermal cycles in 5 °C and 55 °C water baths with a dwell time of 30 s and a 20 s transit time between baths.

Evaluation of Microleakage

The root surfaces, except for a 1 mm wide zone around the margins of each SSC, were sealed with 2 coats of nail polish and stored in distilled water. All teeth were then immersed in 1% methylene blue dye solution for 24 h. Upon removal from the dye, the teeth were rinsed and sectioned faciolingually across the center of the restorations using a diamond disc with continuous water irrigation and examined the sectioned teeth under a stereomicroscope (LEICA WILD M 3 Z) at 40x magnification and scored linear dye penetration [13] **(Figure 1)**.

Criteria for evaluation were as follows:

0=No leakage **(Figure 2)**

1=Leakage up to one third of axial wall

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2=Leakage up to two third of axial wall

3=Leakage along entire length of axial wall

4=Leakage extending on to occlusal aspect [14] **(Figure 3)**

Evaluation of Tensile Bond Strength

Before the crowns were cemented on the prepared teeth, SSCs were altered by making a hole through the central fossa with carbide bur (#557 NO. DENTSPLY). A 1 inch nail was inserted through the hole from the under surface of the crown for subsequent gripping by the test machine. They were then tested with an Instron testing machine (HOUNSFIELD) at a cross-head speed of 0.5 mm/min. Testing preceded for each specimen until the SSC was separated from the tooth. The values obtained were recorded in Newtons (N) [12] **(Figure 4)**.

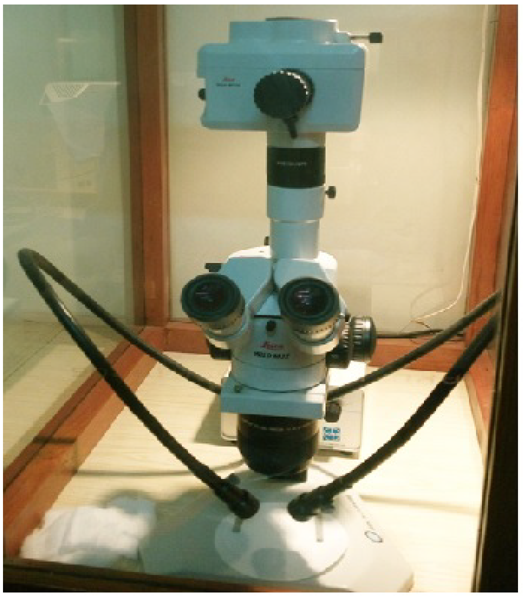

Figure 1. LEICA WILD M 3 Z stereomicroscope.

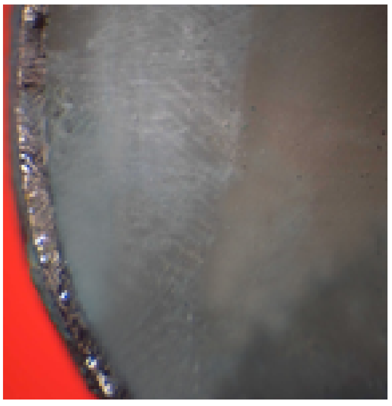

Figure 2. No microleakage.

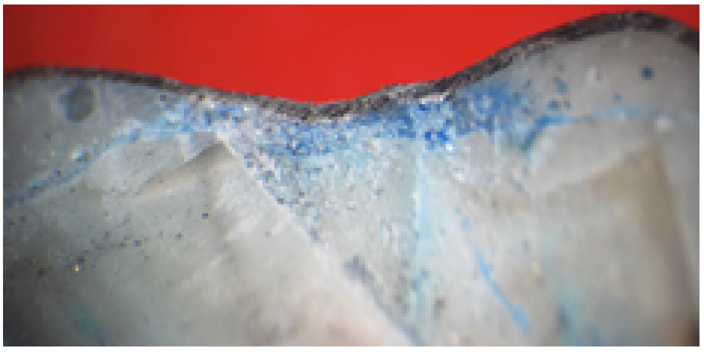

Figure 3. Leakage extending on to occlusal aspect.

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Figure 4. Teeth tested using Instron testing machine to measure tensile bond strength.

RESULTS

The results were tabulated and statistically analyzed using Statistical Package for Social Sciences (SPSS version-20) by using Kruskal–wallis test to know the differences in the microleakage of different cements and one way Analysis of Variance (ANOVA) test for inter group comparison and Tukey's Post hoc test was performed to know the differences in the tensile bond strength of different cements.

Observations from **Table 1**: Shows the descriptive statistics of mean rank of microleakage of cements. The mean rank of microleakage of GC Fuji I cement, Rely XTM luting 2 cement and Smart CemTM2 cement was 31.77, 25.67, 11.57, respectively.

Observations from **Table 2**: The mean micro leakage value of Smart CemTM2 cement was less when compared to micro leakage of Rely XTM luting 2 cement (p<0.002**) and GC Fuji I cement (p<0.0001**) and it was found to be statistically highly significant. When microleakage of Rely XTM luting 2 cement was compared to microleakage of GC Fuji I cement it was found to be not statistically significant (p<0.134).

Observations from **Table 3** and **Graph 1**: Shows the descriptive statistics of mean tensile bond strength of cements. The mean tensile bond strength of GC Fuji I cement, Rely XTM luting 2 cement, Smart CemTM2 cement was (mean ± SD) 108.58 ± 7.81, 163.06 ± 6.48, 367.63 ± 14.30, respectively.

Observations from **Table 4**: The mean tensile bond strength value of GC Fuji I cement was less when compared to tensile bond strength of Rely XTM luting 2 cement and Smart CemTM 2 cement and it was found to be statistically highly significant (P<0.0001**).

When tensile bond strength of Rely XTM luting 2 cement was compared to tensile bond strength of Smart CemTM2 cement in which Smart CemTM 2 cement bond strength value was higher than Rely XTM luting 2 cement and it was found to be statistically highly significant (P<0.0001**).

Table 1. Comparision of mean ranks of microleakage of cements.

	Groups	Mean Rank
Microleakage	GC Fuji I cement (G_M)	31.77
	Rely X^{TM} luting 2 cement (R_M)	25.67
	Smart Cem^{TM}2 cement (S_M)	11.57
Chi-Square	19.537	
p value	<0.0001	

Table 2. Pair wise comparison of microleakage of cements.

Variable	Interventional group	Interventional group	Probability Value
Microleakage	GC Fuji I cement (G_M)	Rely X^{TM}luting 2 cement (R_M)	0.134
		Smart Cem^{TM}2 cement (S_M)	<0.0001**
	Rely X^{TM} luting 2 cement (R_M)	Smart Cem^{TM}2 cement (S_M)	<0.002**

*Statistically significant at p ≤ 0.05
**Highly Statistically significant at p ≤ 0.01

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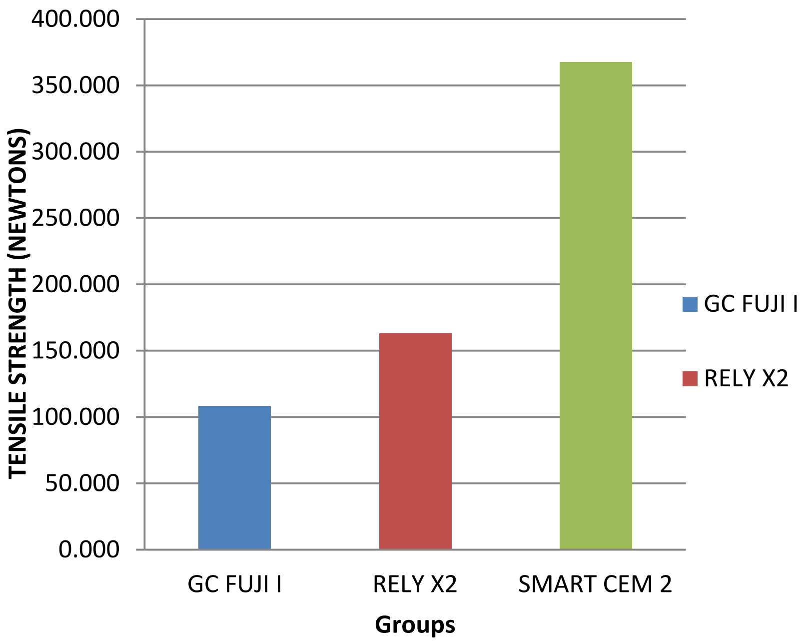
Table 3. Descriptive statistics of mean tensile bond strength of cements (Newton, N).

GC Fuji I cement (G_T)	Rely X™ luting 2 cement (R_T)	Smart Cem™2 cement (S_T)
Mean ± SD 108.58 ± 7.81	Mean ± SD 163.06 ± 6.48	Mean ± SD 367.63 ± 14.30

Table 4. Pair wise comparison of tensile bond strength of cements using tukey's post hoc test.

Variable	Interventional group	Interventional group	Probability value (p)
Tensile strength	GC Fuji I cement (G_T)	RelyX™ luting 2 cement (R_T)	<0.0001**
		Smart Cem™ 2 cement (S_T)	<0.0001**
	Rely X™ luting 2 cement (R_T)	Smart Cem™ 2 cement (S_T)	<0.0001**
*Statistically significant at $p \leq 0.05$ **Highly Statistically significant at $p \leq 0.01$			



Graph 1. Mean tensile bond strength of the cements.

DISCUSSION

Stainless steel crowns are widely recognized as a durable alternative to extensive, multisurface fillings, which are known to have a poor prognosis and often need to be repaired or replaced [15].

Although SSCs have a high clinical success rate, a key reason for its clinical failure is loss of crown due to cementation failure [16,17]. This is mainly due to the fact that they are subjected to repeated loads and temperature changes in the oral environment during function [9] and microleakage between the tooth wall and the crown [18].

Microleakage

The presence of microleakage may lead to postoperative problems such as bacterial accumulation, fluid flow in the gap and detachment of the restoration [19].

Luting cements play an important role in obtaining a suitable marginal seal and reducing microleakage through the crown margins [1].

As all dental materials are subjected to variety of temperature changes in the oral cavity, thermocycling procedure can simulate the same in laboratory settings [20,21].

So the samples were subjected to thermocycling. According to Harper et al. a dwell time 30 s was appropriate since patients cannot tolerate the direct long-term contact of vital teeth with too cold or hot materials [22]. Accordingly, water bath duration for thermocycling was set at 30 s in this study.

Dye penetration method is the most widely used method to assess microleakage because of its sensitivity, ease of use and convenience [23]. The leakage was assessed in this study by the linear penetration of dye from the external margin of the luting agent with a stereomicroscope (LEICA WILD M 3 Z) at 40x magnification using scoring given by Mirkarimi and Bargrizan criteria [14].

In the present study, smallest degree of microleakage, was obtained with the self-adhesive resin cement, i.e., Smart Cem2 cement (mean value 11.57, **Table 2**) which was statistically highly significant when compared with Resin modified glass ionomer cement ($p<0.002$**, **Table 3**) and Glass ionomer cement ($p<0.0001$**, **Table 3**) which is in agreement with the results obtained by Piwowarczyk et al. who had zincphosphate cement, conventional glass–ionomer cement (Fuji), one resin-modified glass–ionomer cement (Fuji Plus), resin cements (RelyX ARC, Panavia F), and one self-adhesive universal resin cement (Rely X Unicem) [24].

The smallest degree of microleakage of Smart Cem2 cement could be due to the organic matrix consists of newly developed multi-functional phosphoric acidic methacrylates. The phosphoric acidic methacrylates can react with the basic fillers in the luting cement and the hydroxyapatite of the hard tooth [25]. Apparently, therefore, this agent is capable of generating an effective seal at the interfaces between restorative alloy, cementing agent and dental tissue [24].

The microleakage of Resin modified glass ionomer cement with (mean 25.67, **Table 2**) was not statistically significant ($p<0.134$, **Table 3**) when compared to Glass ionomer cement. This result was in agreement with previous study [13]. This is due to penetration of the polymer into the demineralized dentin and entrance into the dentinal tubules, stronger micromechanical bonding can be achieved, which in turn results in diminished microleakage compared to Glass ionomer cement [13].

Tensile Strength

During function in the oral environment, SSC are subjected to repeated loads and temperature changes [18] with luting agents maintaining their integrity during the stress transfer of SSC for teeth support [26].

In the current study, the highest retention values were observed with self- adhesive resin cement, i.e.,: Smart Cem2 cement, (mean ± SD 367.63 ± 14.30 and **Table 4**) which was statistically highly significant ($p<0.0001$**) than Resin modified glass ionomer cement and Glass ionomer cement. This is in accordance with the results reported by Yilmaz et al. [12].

The highest degree of tensile bond strength of Smart Cem2 cement could be due to presence of 4-META and PENTA in its matrix. 4-META which has been shown too chelate the calcium ions of hydroxyapatite crystals [27] and exhibits better imbrication on to the irregularities of the metal surfaces [9]. Other advantages are insolubility in the oral environment, adequate consistency and film thickness, [28] superior mechanical properties, optimal bonding to dental structures and reduced micro-leakage.

In the present study, the tensile strength of Resin modified glass ionomer cement (mean ± SD 163.06 ± 6.48, **Table 4**) was more when compared to Glass ionomer cement (mean ± SD 108.58±7.81, **Table 4**) which was statistically highly significant ($p<0.0001$**). This is in accordance with the results reported by Yilmaz et al. [29].

This is due to fact that Resin modified glass ionomer cement consists of 2-HEMA and unconverted monomer in the set cement. 2-HEMA has an ability to quickly balance the network flexibility after curing of methacrylate groups bonded to polycarboxylate chains. Thus, the rapidly formed polymer network between 2-HEMA and the methacrylate groups of ionized and unionized fractions of polyacrylic acid decreased the rate of the acid-base reaction [30].

Resin modified glass ionomer cement have greater compressive and diametrical strengths as compared to glass ionomer cements. This increase in strength is mainly attributable to their lower elastic modulus and the greater amount of plastic deformation that can be sustained before fracture occurs [31].

In the present study, the low values obtained with respect to tensile bond strength, for glass ionomer were in accordance with the findings of earlier studies [32]. The two inherent drawbacks of glass ionomer cements are moisture sensitivity and low early strength due to the result of slow acid-base setting reactions. Therefore these cements are more susceptible to hydrolytic degradation. Rosenstiel et al. stated that solubility plays an important role in the success of the cements to prevent failure in the retention [33].

In the present study, tensile strength was evaluated considering the prepared tooth surface area. This procedure is very important to determine the real tensile strength because when the prepared tooth area is increased higher retention values are expected. The retention of artificial crowns varies according to the mechanical properties of luting agents, geometric relationship of prepared tooth surface and definitive restoration, because these factors may influence the stress distribution within the cement layer and at surface-cement interface [34].

Hence, it can be concluded that crowns cemented with Smart CemTM2 cement had least microleakage and highest tensile bond strength. Further *in vivo* studies using these cements will accurately determine their clinical effectiveness.

CONCLUSION

Stainless steel crowns cemented with Smart CemTM2 cement (self-adhesive cement) had the least microleakage and highest tensile bond strength followed by Rely XTM luting 2 cement (RMGIC) and GC Fuji 1(GIC).

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