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In vitro comparison of marginal and internal fit between stainless steel crowns and esthetic crowns of primary molars using different luting cements

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ABSTRACT

Background: This study was to assess and compare the marginal and internal fit of stainless steel crowns (SSCs) with those of preveneered SSCs and zirconia crowns using different luting cements. **Materials and Methods:** In this *in vitro* study, 36 primary first molars were divided into three groups (n = 12) each prepared to receive different crowns (SSCs, preveneered SSCs, or zirconia crowns). Each group was further subgrouped (n = 4) according to the luting cement (resin cement, glass ionomer cement [GIC], or resin-modified GIC [RMGIC]). After cementation, the teeth were sectioned in the buccolingual direction to assess the marginal and internal fit. The results were analyzed using ANOVA and Bonferroni statistical tests. The level of significance was set at $P < 0.05$. **Results:** Zirconia crowns, especially those cemented with resin cement, were associated with the lowest marginal and internal gap width. Regardless of the luting cement, no significant difference was observed between all three crowns tested in terms of marginal gap ($P > 0.05$); however, zirconia crowns cemented with resin cement had significantly lower internal gap than preveneered SSCs and SSCs cemented with resin cement. In addition, those cemented with RMGIC had significantly lower internal gap than preveneered SSCs cemented with that cement ($P < 0.05$). **Conclusion:** Zirconia crowns cemented with resin cement were the most accurately fitted internally, while marginally, they were not significantly different from the rest of crown-luting cement combinations tested.

Key Words: Internal fit, marginal fit, stainless steel crowns, zirconia crowns

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INTRODUCTION

Crowns are recommended for restoring primary teeth in many occasions, and posterior teeth (molars) are particularly given importance as they are vital in the mastication and development of occlusion; therefore, it is important that they receive the most durable restoration to retain them until exfoliation.[1] Crowns for the primary molars are preformed and come in a variety of sizes and materials to be placed over decayed or developmentally defective teeth.[2] They can be made completely of stainless steel crowns (SSCs) or stainless steel with a white veneer cover, usually composite resin, bonded onto the facial surface in a laboratory procedure (preveneered SSCs) or made wholly of a white ceramic material (zirconia crowns). All of these are held onto the molar teeth by luting

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cements,[2-4] which in turn play a significant role in the retention of the crowns.[5]

Internal gap has been defined as the perpendicular measurement from the internal surface of the crown to the axial wall of the preparation, whereas marginal gap has been defined as the same measurement at the margin of the crown.[6] The presence of marginal gap (discrepancy) exposes the luting cement to the aggressive oral environment. Consequently, the larger the marginal gap, the more rapid will be the expected rate of cement dissolution.[7,8] In permanent teeth prepared to receive ceramic crowns, it is important to have low marginal gap width because of polymerization shrinkage of resin composite cements.[9] Most authors agree that a marginal gap between 100 and 150 µm appears to be in the range of clinical acceptance with regard to crown longevity.[10] However, unfortunately, this cannot be achieved in the primary teeth due to preformed nature of primary molar crowns. Shifflet and White[11] found that optimal marginal adaption is difficult with SSCs due to the limited ability to adjust their prefabricated shapes and dimensions by contouring and crimping. Proper contouring and crimping are crucial for crown retention and reducing marginal gap width. The marginal gap can also be influenced by the luting cements as these can elevate the crown after cementation.[12]

The marginal fit of SSCs was assessed in one study using resin cement, glass ionomer cement (GIC), and polycarboxylate cement. This study found that a clear marginal gap was present in all sampled teeth regardless of the luting cement. In addition, none of the luting cements demonstrated uniform thickness levels along the margins due to the different crown adaptation rates in different marginal locations.[13] Marginal fit and internal fit were never assessed previously in esthetic pediatric molar crowns (preveneered SSCs and zirconia crowns) and compared to SSCs. Therefore, the aim of this study was to assess and compare marginal and internal fit of SSCs with those of preveneered SSCs and zirconia crowns using different luting cements. The tested null hypothesis was that marginal and internal fit would not be related to the crown type or luting cement.

MATERIALS AND METHODS

Sample collection and preparation

This *in vitro* study was approved by the Ethical Committee of College of Dentistry, Qassim University. A convenience sample of 36 human primary first molars sound or with proximal caries and resorption rate lower than two-thirds were collected, kept in distilled water at room temperature (23°C ± 1°C) for no more than 3 weeks, and used in the study. Teeth which had buccal or lingual caries were excluded from the study. Carious teeth were cleaned leaving intact caries-free buccal and lingual surfaces. In case of pulp exposure teeth, pulp remnants were removed and the pulp chamber was filled with GIC (Ketac™ Fil Plus Aplicap A2, 3M ESPE, St. Paul, MN, USA) and the cavity was restored to its original form with composite resin (Filtek Z250 A1, 3M ESPE, St. Paul, MN, USA) after 7 s etch-and-rinse technique (Scotchbond Universal Etchant, 3M ESPE, St. Paul, MN, USA) and bonding (Adper™ Single Bond 2 Adhesive 3M ESPE, St. Paul, MN, USA). Polymerization steps were 20 s for the adhesive and 40 s for each layer of resin composite using a light-emitting diode (LED) visible light-polymerizing unit (SmartLite® Max LED Curing Light Dentsply/Caulk, Milford, DE, USA).

The teeth were then embedded in clear cold-cure acrylic resin blocks (Eco Cryl Cold, Protechno, Spain) up to 2 mm below the cement enamel Junction in an upright position utilizing a mold obtained from 19 mm diameter cylindrical polyethylene pipe and they were randomly divided into three groups (A, B, and C) (n = 12 each).

Crown preparations

All tooth preparations were performed by the same operator. Standardized tooth preparations for SSCs (3M™ ESPE™ SSCs, 3M ESPE, St. Paul, MN, USA) were performed for teeth in Group A. The mesiodistal dimension of each tooth was determined using a periodontal probe before the most appropriate SSC was selected. The occlusal surface was then reduced 1.0–1.5 mm with a diamond coarse shoulder bur (836KRS-014C-FG, NTI-Kahla GmbH, Germany). Mesial and distal surfaces were prepared using a needle diamond bur (859 L-010F-FG, NTI-Kahla GmbH, Germany) and all line angles were rounded. The selected precontoured and pretrimmed SSC was fitted and crimped with pliers (No. 800112 and 800417, 3M ESPE, St. Paul, MN, USA).

Teeth in Groups B and C were prepared according to the manufacturer's instructions to receive preveneered SSCs (NSCs; NuSmile® Ltd., Houston, TX, USA) and full-ceramic crowns (NZCs; NuSmile® Ltd., Houston, TX, USA), respectively. In both groups, a coarse football diamond bur (379-023C-FG, NTI-Kahla

GmbH, Germany) was used to prepare the occlusal surface of the teeth by 1–1.5 mm. A coarse tapered diamond bur (858-012C-FG, NTI-Kahla GmbH, Germany) was used for proximal, buccal, and lingual reductions by 0.5 mm. The preparation margin was carefully extended and refined to a feather edge on all surface using a fine-tapered diamond bur (858-014F-FG, NTI-Kahla GmbH, Germany) and all line angles were rounded.

Crown cementation with the luting cements

In each group, the teeth were subgrouped by cementation using different luting cements as follows (*n* = 4 per group): Group 1: Conventional GIC (Ketac Cem Aplicap™, 3M ESPE, Seefeld, Germany); Group 2: Resin-modified GIC (RMGIC) (NuSmile BioCem®, NuSmile Ltd., Houston, TX, USA); and Group 3: Self-adhesive resin cement (Rely X™ Unicem Self Adhesive Universal Resin Cement Aplicap™, 3M ESPE, Seefeld, Germany).

Each luting cement was prepared according to the manufacturer's instructions. Then, the crowns in each group were filled with the respective luting cement and positioned on the preparations using finger pressure. The crowns were loaded axially with 5 kg with a loading apparatus until 10 min after the cement mix was initiated to hold the crowns in place in a standardized manner until the cement had set and excess cement was removed with a sharp curette.

The embedded crowns were sectioned in the buccolingual direction using a diamond disk (Super Diamond Disk No. 800.104.355.524.190; NTI-Kahla GmbH, Germany). A digital photograph of each section was obtained under a stereomicroscope (Hamilton, Hamilton International s.r.l. Lazio, Italy) at an original magnification of ×20.

Marginal and internal gap measurements

Thirteen measurements were made at 13 different sites on the digital photographs of the sectioned surfaces of the specimens using a modified method to that adopted by Korkut *et al*.[14] The measurement sites were selected as follows: (1) buccal and lingual finishing points of the crowns, (2) buccal and lingual cusp tips, (3) deepest point of the occlusal surface, (4) buccal and lingual midpoints between the cusp tip and the finishing points, and (5) another location exactly in-between the initial ones [Figure 1]. In each measurement, the perpendicular distance between the tooth structure and internal surface of each crown was measured digitally by employing computer software (Lucia G on Meteor, Version 4-51 for Nikon Laboratory Imaging, Tokyo, Japan). The mean of the measurements obtained from the buccal and lingual finishing points represented the marginal gap width, while the mean of the remaining 11 measurements of the same specimen represented the internal gap width.

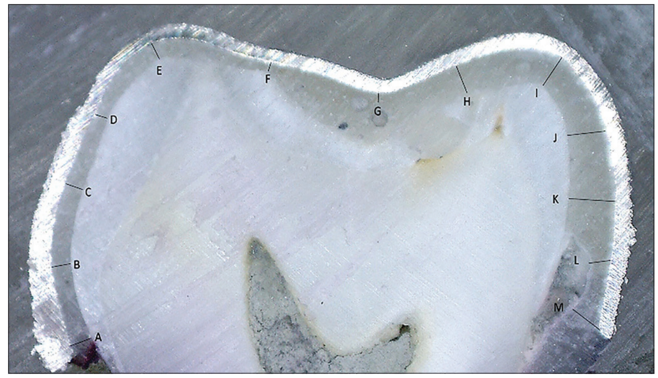

Figure 1: Buccolingual section showing the measurement sites (A-M) on a stainless steel crown cemented with resin cement.

Statistical evaluation

Data were analyzed using the SPSS computer software (SPSS Version 20, Chicago, IL, USA). Marginal and internal gap data were analyzed with two-way ANOVA to disclose any statistical significance of the differences between the groups, and pairwise comparisons were made using Bonferroni *post hoc* test. The P value was set at $P < 0.05$.

RESULTS

A clear marginal and internal gap was observed in all of the tested crown types, and different gap widths were observed across the assessed measurement points. The descriptive statistics (mean and standard deviation) of the marginal and internal gap width data for the tested crown type and luting cement combinations are presented in Table 1. The least marginal and internal gap width means were obtained from zirconia crowns cemented with resin cement (0.09 ± 0.00 mm). While no significant difference was observed in terms of marginal gap width between all crown-type and luting cement combinations ($P > 0.05$), zirconia crowns cemented with resin cement were associated with significantly lower internal gap width mean than preveneered SSCs and SSCs cemented with resin cement ($P < 0.001$). In addition, zirconia crowns cemented with RMGIC were associated with significantly lower internal gap width mean than preveneered SSCs cemented with that cement ($P = 0.013$) [Figure 2]. The rest of the differences of internal gap width measurements were insignificant ($P > 0.05$).

Overall, among the tested crowns, the crowns which had the lowest marginal and internal gap width means measured were zirconia crowns (0.17 ± 0.09 mm and 0.19 ± 0.12 mm, respectively). On the other hand, among luting cements, GIC was associated with the greatest marginal and internal gap width means (0.38 ± 0.16 and 0.37 ± 0.09, respectively) [Table 2].

DISCUSSION

Literature reports lack the presence of a standardized method to measure the marginal and internal fit of cemented crowns, in general. Those methods which were reported in the literature on permanent teeth crowns include assessment of cross-sectional views, direct view of the crown on a die, impression replica technique, and clinical examination.[12] In the current study, the sectional method was used to measure the marginal and internal gap of the tested crowns, which enables the measurement of cemented crowns. In addition, a stereomicroscope was preferred for measurement over the scanning electron microscope (SEM) which has been used for SSCs cemented on prepared primary molars in one report[13] as no significant difference was found between the results obtained by these two methods in a previous report.[15] In addition, SEM imaging measurements are based on visual determination of the measurement areas which can lead to less standardized measurements.[6] Buccolingual sectioning of the crowned teeth was done, and then, measurements of cement thickness were recorded using image analysis software. The limitation of using such technique is that it gives a two-dimensional (2D) view for measuring the thickness of gap in a single section and does not examine 3D adaptation.[16]

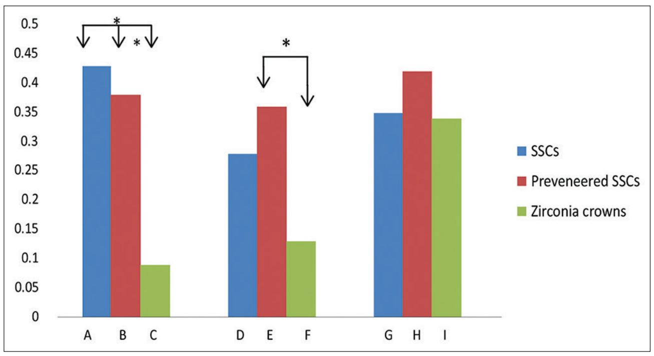

Figure 2: Mean internal gap of each crown type and luting cement combination. A-B-C: Crowns cemented with resin cement, D-E-F: Crowns cemented with resin-modified glass ionomer cement, G-H-I: Crowns cemented with glass ionomer cement. *$P < 0.05$. SSCs: Stainless steel crowns.

Table 1: Descriptive statistics for marginal and internal gap width measurements (mm) with different crown type and luting cement combinations

Gap	Crown type	Luting cement (mean±SD)		
		GIC	RMGIC	Resin cement
Marginal	SSCs	0.51±0.23	0.26±0.09	0.34±0.11
Internal		0.35±0.06	0.26±0.03	0.43±0.20
Marginal	Preveneered SSCs	0.33±0.09	0.39±0.29	0.3±0.29
Internal		0.42±0.14	0.36±0.13	0.38±0.11
Marginal	Zirconia crowns	0.29±0.02	0.14±0.01	0.09±0.00
Internal		0.34±0.09	0.13±0.01	0.09±0.00

SSCs: Stainless steel crowns; GIC: Glass ionomer cement; RMGIC: Resin-modified glass ionomer cement; SD: Standard deviation

In this study, a clear marginal and internal gap was observed in all of the tested crowns. Different gap widths were observed across the assessed measurement points. This finding is in part in agreement with Erdemci *et al*.[13] Furthermore, in this study, it was observed that among the 11 measurement points which were used to measure the internal gap, the occlusal measurement points which were in the middle between the buccal and lingual cusp tips and the deepest point of the occlusal surface had the greatest measurements in most of the tested crown samples regardless of the luting cement. In addition, axial measurements were generally lower. This is not surprising as primary molar crowns are performed; consequently, a clinician selects the crown size which is deemed most appropriate. In addition, occlusal surface preparation of primary molars is

Table 2: Descriptive statistics for marginal and internal gap width measurements (mm) with different crown types and luting cements

Gap	Luting cement			Crown type		
	GIC	RMGIC	Resin cement	SSCs	Preveneered SSCs	Zirconia crowns
Marginal	0.38±0.16	0.26±0.18	0.24±0.20	0.35±0.17	0.34±0.22	0.17±0.09
Internal	0.37±0.09	0.26±0.11	0.29±0.20	0.34±0.12	0.38±0.12	0.19±0.12

SSCs: Stainless steel crowns; GIC: Glass ionomer cement; RMGIC: Resin-modified glass ionomer cement not commonly anatomic; crown adaptation was found to be better on the anatomical occlusal surface preparations compared to the semi-anatomic and nonanatomic occlusal preparations.[16]

In this study, the tested null hypothesis was rejected as surprisingly, compared to all tested crowns, zirconia crowns, especially those cemented with resin cement, had the lowest internal gap widths with statistically significant differences from both preveneered SSCs and SSCs cemented with the same cement. This probably indicates that the heterogeneity in gap width which was observed in this study was least in zirconia crowns, especially those cemented with resin cement, which is important so that retention and resistance forms are not compromised as ceramic restorations tend to be fragile.[17] In addition, zirconia crowns seemed to be the most accurately fitted internally and somehow marginally when compared to SSCs and prevenereed SSCs although the differences in marginal gap measurements were not significant from the rest of the crown-luting cement combinations tested and despite that contouring and crimping were performed for SSCs before cementation. Contouring and crimping of 3M SSCs were found to significantly reduce the marginal circumference of 3M SSCs and improve their marginal adaptation.[18] However, it seems that SSCs did not achieve their maximum adaptation in this study; this may be related to the crown morphology of sampled teeth (first primary molars) since crown morphology plays an important role in the marginal adaptation of the crown. First primary molars have crown bulges particularly cervically on the buccal surface which can create areas of undercuts that may compromise SSC adaptation despite the contouring and crimping since the buccal surface is not commonly involved in SSC preparation.[19] As opposed to SSC preparations, zirconia crown preparations are significantly more aggressive, and as per the manufacturers' instructions, they involve all tooth surfaces; consequently, any coronal bulge will be removed and crown adaptation will be improved.

On the other hand, the findings that the least marginal and internal gap widths were associated with zirconia crowns cemented with the luting cement resin cement are not surprising as Ganapathy *et al*.[20] found that resin cements exhibited greater reduction in the marginal discrepancy than RMGIC following luting in all ceramic complete veneer crowns. Few authors also found that self-adhesive resin cement has good marginal integrity and low microleakage when compared to RMGIC and GIC and that it is easily applicable.[21,22] On the contrary, the finding that GIC had the greatest measurements in this study can be explained by the differences in viscosity of the cements.

It is important to mention the limitations of this study as despite the effort which was made through axial loading following crown cementation to simulate bite force in clinical conditions in this study, the force generated from a child biting down on a preformed crown or on a bite stick could be higher which can improve crown adaptation and allow for more accurately adapted crowns which consequently reduces marginal and internal gap values as bite force in children is not fixed and can be affected by age or malocclusion.[23] In addition, future studies should include a larger number of sampled teeth and preferably apply functional loading to mimic the oral environment. These studies can also incorporate 3D modeling as it may provide more precise data on the marginal and internal fit of the crowns due to the ability to measure from various directions. Clinical studies should also be carried out in an attempt to update what would be the clinically acceptable in terms of marginal and internal fit of preformed crowns of primary molars.

CONCLUSION

Within the limitations of this *in vitro* study, the following can be drawn:

1. Zirconia crowns cemented with resin cement were the most accurately fitted internally
2. With regard to marginal fit, no significant difference was observed between zirconia crowns, preveneered SSCs, and SSCs regardless of the luting cement used (resin cement, RMGIC, or GIC).

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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