Research Article

Marginal discrepancy and retention post-cementation of unretentive crowns in conometric systems: An in vitro comparative study

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Abstract: Background: This *in vitro* study was carried out to determine the marginal discrepancy (MD) and retention force (RF) values in the conometric systems (CSs) having poor retention after cementation using two distinct cements and procedures. Materials and methods: This study used 24 monolithic zirconia crowns that were cemented into 24 conometric caps and 24 conometric abutments attached to implant analogues. The researchers repeated the pull-out test until they achieved the RF values <40N. All samples were classified into two categories (n=12): grooved and ungrooved crowns. Every group was separated into 2 subgroups (n=6) depending on the cement type that was used i.e., either zinc phosphate cement (ZPC) or resin-modified glass ionomer cement (RMGIC). After cementation, the researchers calculated the MDs with a stereoscopic microscope, and the RFs were calculated with the help of pull-out tests. The researchers statistically analysed the data using a two-way analysis of variance (ANOVA) test with a significance level <0.05. Results: They noted that the ungrooved crowns that were cemented using RMGIC (163±17.13µm) and ZPC (173.16±23.13µm) exhibited the highest average MDs. On the other hand, the grooved crowns that were cemented with RMGIC displayed the lowest average MD (38.16±22.85µm). Also, RMGIC showed a higher RF value (355.54±102.23N, 373.48±46.33N) compared to that shown by ZPC (199.79±114.01N, 189.86±21.33N). Conclusions: Both the cement groups in this study showed a higher and acceptable retention. Furthermore, it was seen that the incorporation of grooves in the crowns during the cementation procedure decreased the MD. Additionally, RMGIC-cemented grooved crowns displayed the best post-cementation MD and RF values.

Keywords: Conometric system, Marginal discrepancy, Retention force, Zinc phosphate, Resin-modified glass ionomer.

Introduction

Conometric systems (CSs) employ friction retention instead of cement or screws to preserve implant-supported restorations [1-5]. Conometric abutments and caps with anti-rotational characteristics were devised for use in single-unit restorations [6]. This mechanism may wear because of repetitive crown insertion-removal and ageing [7]. The wearing of the CS reduces the frictional retention force (RF) occurring between the conometric abutments and cap. In some cases, the doctor may need to replace both the crown and cap to acquire satisfactory retention [8]. The knowledge regarding high costs and time requirements involved in traditional crown replacement strategies was the purpose of conducting this study. Therefore, to increase the crown's RF, the doctor might be required to make adjustments and use cementation as a different therapeutic strategy [8].

One of the key elements in the long-term performance of implant-supported restorations is seen to be marginal adaptation. Extended lifespan and the clinical success of prosthetic restorations require a proper adjustment between implant abutment and restoration [9]. The absence of marginal adaptation can cause a variety of mechanical and biological issues, including plaque collection, pain, marginal bone loss, osseointegration loss, increased periodontal pocket depth and gingival index, and implant failure [10-12].

Several factors can influence the retention of cemented implant-based restorations, such as abutment height, abutment geometry, surface roughness, abutment taper, retentive grooves, and luting agents that were employed [13-17]. The clinician can only control a few factors such as surface roughness, grooves, and luting agents. The CS is based on the notions of frictional retention and did not incorporate cementation as a standard procedure. Very few studies have determined the marginal discrepancy (MD) and RF values after the cementation of CS. As a result, this report was carried out to evaluate the MD, RF, and results of introducing changes, particularly the insertion of grooves, in addition to the application of 2 different cement types as a different technique for CS.

Materials and methods

Specimen preparation

In this study, computer-aided design and manufacturing technology were employed to design and produce 24 mandibular first molar monolithic zirconia crowns. These were cemented into 24 conometric caps (4.5mm diameter) using resin-modified glass ionomer cement (RMGIC) (GC FuciCEM Evolve, Tokyo, Japan). After vertically placing 24 implant analogues (Ankylos; Dentsply Implants) in the autopolymerizing acrylic resin, the researchers tightened 24 conometric abutments (having a 4.5mm diameter) into the implants. Following that, all the samples were analysed with the pull-out test using a universal testing instrument (Instron 3345, USA) at the 2mm/min crosshead speed. This test was repeated until the abutments and caps showed RF values were <40N, indicating an inadequacy state.

Twenty-four samples were categorised into 2 groups containing 12 samples each, i.e., ungrooved and grooved crowns. A round-end diamond bur (with a 1.4mm diameter) was used to create one groove (escape channel) on the inner surface of conometric caps (Figure 1). Every group was categorised into 2 groups (n=6) based on the type of cement used in the study. Out of these 2 groups, one of them was cemented using RMGIC, while the other group used zinc phosphate cement (ZPC) (Kulzer, GmbH, Almanya). The ZPC was mixed based on the manufacturer's instructions and plastered on the inner walls of all crowns (caps) using a disposable brush. Thereafter, the crowns were cemented on the general abutments for 10 mins at the standard pressure of 5kg. After the cementation procedure, the researchers removed the extra cement, and placed the samples in distilled water at 37°C for 24 h.

Marginal discrepancy (MD) and retention force (RF) measurements

The MD of every sample in the 4 groups was assessed after 24 h of cementation at 4 different crown positions (i.e., mesial, distal, buccal, and lingual). Several studies [9, 18, 19] recommended the assessment of MD at ×50 magnification with a stereoscopic microscope (Leica 4.5; Leica Microsystems GmbH, Almanya). The MDs were computed by subtracting the average distance between 2 reference points in the cemented crowns from the values measured before cementation based on similar reference points (Figure 2). The pull-out test was performed using a universal testing instrument (Instron 3345, USA) with a 2mm/min crosshead speed. The force used to dislodge the cemented crowns from conometric abutments were measured in Newtons.

Statistical Analyses

The researchers analysed all the data using a statistical software (SPSS ver. 20.0, SPSS Inc). They employed the two-way analysis of variance (ANOVA) to assess the MD and RF values after the cementation of grooved and ungrooved crowns using RMGIC and ZPC at the significance level <0.05.

Figure 1: A. The preparation of the groove and B. Ungrooved and grooved crowns.

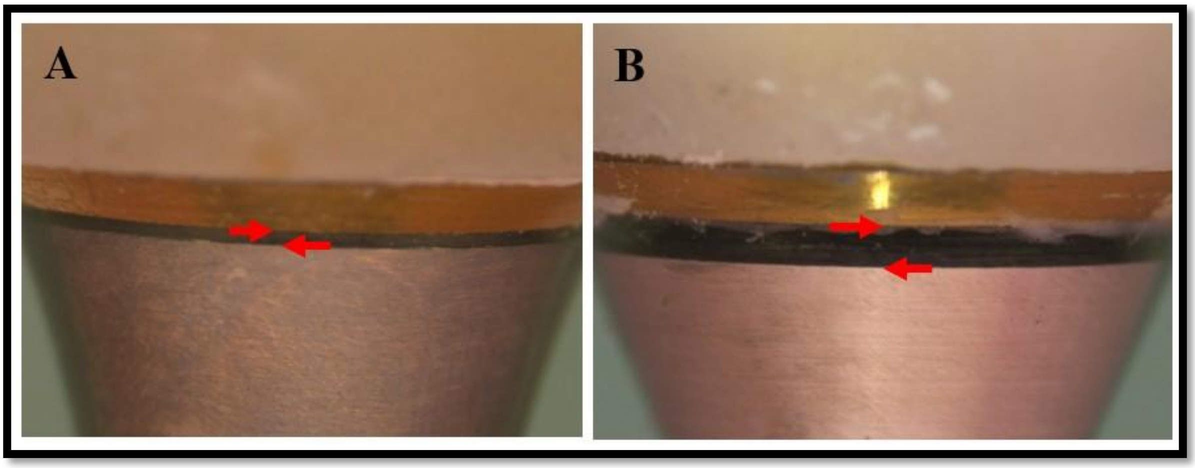

Figure 2: The results of the MD measurements using a stereomicroscope. (A) The reference points pre-cementation of the crown and (B) the same reference point post-cementation of the crown.

Results

Table 1 presents the average RF value that is needed to dislodge the crowns from conometric abutments, in addition to the average MD after the cementation of CS. The findings of the two-way ANOVA test for MD revealed that factors like grooves and cement type showed a significant effect ($P<0.05$); while the interaction between the above components was also seen to be significant ($P=0.003$) (Table 2). The maximum average MDs were noted in ungrooved crowns that were cemented using RMGIC (163±17.13μm) and ZPC (173.16±23.13μm). The lowest average MDs were seen in grooved crowns that were cemented using RMGIC (38.16±22.85μm). With regards to the RF, the results of the two-way ANOVA revealed that the grooves and cement type showed no significant effect on RF, and no interaction was noted ($P=0.677$) (Table 3). The RMGIC-cemented crowns showed significantly different mean RF values compared to the ZPC-cemented crowns ($P<0.05$). ZPC showed a lower RF than RMGIC.

Table 1. The means and standard deviations of the RFs and MDs of the cemented CS.

Groups	n	Marginal discrepency Mean±SD (μm)	Retention forceMean±SD (N)
Ungrooved crowns with RMGI	6	163±17.13	355.54±102.23
Grooved crowns with RMGI	6	38.16±22.85	373.48±46.33
Ungrooved crowns with ZP	6	173.16±23.13	199.79±114.01
Grooved crowns with ZP	6	102.66±16.00	189.86±21.33

Table 2: The results of the two-way ANOVA of the MDs of the cemented CS.

	Type III Sum of Squares	df	Mean Square	F	P
Corrected Model	70023.500[a]	3	23341.167	58.070	.000
Intercept	341293.500	1	341293.500	849.094	.000
Cement	8362.667	1	8362.667	20.805	.000
Groove	57232.667	1	57232.667	142.388	.000
Cement* Groove	4428.167	1	4428.167	11.017	.003
Error	8039.000	20	401.950		
Total	419356.000	24			
Corrected Total	78062.500	23			

[a]R^2 = 0.897 (Adjusted R^2 = 0.882).

Table 3: The results of the two-way ANOVA of the RFs of the cemented CS.

	Type III Sum of Squares	df	Mean Square	F	P
Corrected Model	174017.904[a]	3	58005.968	8.906	.001
Intercept	1877161.820	1	1877161.820	288.203	.000
Cement	172756.299	1	172756.299	26.523	.000
Groove	96.360	1	96.360	0.015	.904
Cement * Groove	1165.245	1	1165.245	0.179	.677
Error	130266.596	20	6513.330		
Total	2181446.320	24			
Corrected Total	304284.500	23			

[a]R^2 = 0.572 (Adjusted R^2 = 0.508)

Discussion

Incomplete seating is a typical issue noted during the cementation of implant-supported restorations. Restoration seating can be enhanced by a variety of cementation procedures, including die spacing, venting, and escape channels [(20–22)]. Furthermore, the viscosity and cement film thickness affect seating [(23)]. The venting method is difficult and includes extra stages that may weaken and fracture the zirconia restoration [(24)]. The selected process must be carried out at the chair within a short time. Hence, in this report, the researchers preferred using an internal groove as the cement escape channel within the inner crown surface instead of drilling a vent hole. The findings of this study showed that the first null hypothesis (that neither the inclusion of the groove nor cement type would affect the MD) was rejected.

Clinically acceptable MD values after cementation for restorations were <120µm [25, 26]. In the past, a few studies regarded the MD values ranging between 50 and 100µm as the clinically appropriate limit [27, 28]. In their study, McLean and von Fraunhofer proposed that the clinically-acceptable MD value was 120µm [29]. Based on the findings of this study, irrespective of the type of cement, the formation of grooves within the inner crown surface was seen to decrease the MD values. The results indicated that the mean MD values (163±17.13 and 173.16±23.13) noted for the ungrooved crowns were clinically unacceptable while the MD values for grooved crowns lay in the acceptable range (38.16±22.85 and 102.66±16.00). The researchers believe that these grooves could improve the crown seating by increasing the drainage of excessive cement which decreases the subsequent hydrostatic pressure.

This study showed statistically significant differences in the values when the different types of cements were used. As a result, the researchers should consider the cementing agent type that is used to determine an acceptable MD after cementation. The variance in MD can be attributed to the thickness of the cement films, which ranges between 25 and 100µm [30, 31]. Alofi displayed that the use of RMGIC showed the lowest thickness of the cement film at differing temperatures, followed by glass ionomer and ZPC [32]. The grooved crowns that were cemented with RMGIC exhibited an acceptable MD value after cementation (38.16±22.85µm). Sutherland et al. observed that the average MD of all-ceramic crowns that were cemented using ZPC on implant abutment was seen to be 168.8±23µm [33], similar to ungrooved ZPC-cemented crowns (173.16±23.13µm) in this study.

In this study, the researchers also aimed to assess the RF of cemented CS. The second null hypothesis (that states that there is no variation in the RF values of both types of cements after the groove addition) was accepted as the results in this study showed no significant variation in RF values of the grooved and ungrooved crowns. In the past, many *in vitro studies* [34–36] evaluated the RF of luting cement under varied experimental settings. Similar to earlier studies [34, 37], the results in this study showed that all groups that used RMGIC as a cementing agent showed a higher RF value in comparison to the groups using ZPC. However, contrary results were presented by Kapoor et al. [35], who noted that RMGIC showed a lower RF compared to ZPC [35]. A different study that investigated the retention of base metal copings with the dental implants indicated that RMGIC and ZPC displayed a similar RF [38]. Thus, it was concluded that the RF values for the implant-supported restorations may vary based on the protocol and implant systems used. Furthermore, unique ageing procedures, such as mechanical stress, constant-temperature water storage, and thermal cycling, in addition to different pretreatment procedures, can influence the RF [39, 40]. Hence, it is not easy to directly compare the results noted in this study with those seen in other *in vitro* studies.

This study was clinically significant as it showed that addition of grooves helped in achieving acceptable MD values. Evaluation of MDs and RF post-CS can help the clinicians determine the optimal approach and methodology based on the existing case study to adjust the system and use it as a temporary solution. Based on the findings of this study, the researchers have recommended the addition of grooves and application of RMGIC to achieve appropriate MD and RF values post-cementation of CS. However, a few limitations were noted. This is an *in vitro* study that did not take into consideration some parameters like saliva, long-term ageing, or intraoral occlusal factors that change the physical characteristics of the luting cement. Therefore, long-term *in vitro* studies should use the chewing simulation technique to assess the MD and RF values of CS after cementation.

Conclusion

The results of this *in-vitro* investigation showed an increase in retention in both the cement groups. These groups also showed an acceptable RF value. The incorporation of grooves in the crowns during the cementation technique reduces the MD. However, no effect was observed on the RF values of cemented CS. Furthermore, this study discovered that the grooved crowns that were cemented with RMGIC exhibited the best post-cementation MD and RF results.

Conflict of interest

There are no disclosed conflicts of interest for the authors.

Authors'contributions

SHT; leadership responsibilities include research activity planning, reviewing, editing, and supervising. ZSA; data organization, investigation, methodology, and writing—first draft. Both authors reviewed and approved the final version of the paper for publication.

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تباين الحافة والاحتفاظ بعد لصق التيجان غير المستقرة في الأنظمة الكونومترية: دراسة مقارنة في المختبر

زينب صباح الجلبي، سليمان هاكان تونا

المستخلص:

الخلفية: تم إجراء هذه الدراســة في المختبر لتحديد قيم تباين الحافة (MD) وقوة الاحتفاظ (RF) في الأنظمة الكونمترية (CSs) التي تمتلك قوة احتفاظ غير كفاية بعد اللصــق باســتخدام تقنيتين وأســمنتين مختلفين. المواد والطرق: تم اســتخدام 24 تيجان زركونيا متجانســة مثبتة في 24 غطاء كونوميتري، بالإضــافة إلى 24 دعامة كونومترية متصلة بنظائر الزرعة، في هذه الدراسة. كرر الباحثون اختبار السحب حتى وصلوا إلى قيم RF < 40 نيوتن. وتم تقسيم العينات إلى مجموعتين رئيسيتين (العدد = 12): التيجان غير المحززة والمحززة. تم بعد ذلك تقسيم كل مجموعة إلى مجموعتين فرعيتين (العدد = 6) بناءً على نوع الأسمنت المستخدم، أي إما أسمنت فوسفات الزنك (ZPC) أو الأيونومر الزجاجي المعدل بالراتنج (RMGIC) . بعد اللصق، تم تقييم MDs باستخدام مجهر مجسم، وتم قياس RFs بمساعدة اختبارات الســحب. قام الباحثون بتحليل البيانات إحصــائياً باســتخدام اختبار تحليل التباين ثنائي الاتجاه (ANOVA) بمســتوى دلالة < 0.05. النتائج: لاحظوا أن التيجان غير المحززة التي تم لصــقها باســتخدام RMGIC (163±17.13 µm) و ZPC (173.16±23.13 µm) أظهرت أعلى متوســط MDs. من ناحية أخرى، أظهرت التيجان المحززة التي تم لصــقها بـــــ RMGIC أدنى متوســط MD (38.16±22.85 µm). أيضًــا، أظهر RMGIC قيمة RF أعلى (355.54±102.23 N, 373.48±46.33 N) مقارنة بتلك التي اظهرتها ZPC (199.79±114.01 N, 189.86±21.33 N). الخلاصــة: كلا المجموعتين الأســمنت في هذه الدراســة أظهرت احتفاظ أعلى ومقبول. علاوة على ذلك، فقد لوحظ أن دمج إن إضــافة الأخاديد إلى التيجان في اثناء عملية اللصــق يقلل من MD. بالإضـافة إلى ذلك، أظهرت التيجان المحززة الأسمنتية RMGIC أفضل قيم MD وRF بعد اللصق