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Evaluation of marginal adaptation of 4 different modified cement-retained implant prostheses: An *in vitro* study

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Abstract
Objectives: This *in vitro* study aimed to compare the adhesion strength of the adhesives of four modified cement-retained methods (MCRMs) that affect the retention of two types of materials (Zirconia and hybrid ceramic/VITA Enamic).
Methods: In this *in-vitro* study, four cement-retained methods were used: the first is an occlusal hole with a diameter (1 mm) with lateral hole with a diameter (1 mm) (OLH), the second is an occlusal hole with a diameter (2 mm) for screw access (OH), the third is a lingual hole for releasing the excess adhesive (1 mm) (LH), and the last one is a control group (no holes). Twenty-eight crowns (n=7) were fabricated for test with CAD-CAM system. The retention strength was examined by mechanical tensile experiments (MTE) *in vitro* using a universal testing machine, pull-off test.
Results: A statistically significant difference is seen in each material's retention strength (zirconia and hybrid ceramic). The OLH group in zirconia (257.4286 N), and in ceramic (213.5714 N). Had the highest values among the other groups, subsequently, the LH groups had slight differences from the other OH and control groups. (P=0.05).
Conclusions: The use of modified cement methods had a remarkable effect on retention. In this study, the use of occlusal-lateral with (1 mm) hole (OLH) modification is more retentive than the other groups.

Keywords: Retention time, zirconia, hybrid ceramic, dental implant

Introduction

The increasing aging of the population worldwide has led to a major proportion of patients who could develop complete edentulism and consequently need prosthetic rehabilitation, which can be an actual challenge for clinicians [1]. Dental implants have the most similarity to natural teeth in terms of mastication and aesthetics, as well as being biocompatible and requiring biocompatibility, masticatory features, and aesthetic follow-up [2, 3]. Screw-retained or cement-retained restorations are the most commonly used implant-supported prostheses retention. The benefits and drawbacks of both some clinical situations advocate for one method of retention over the other, which have been identified by numerous authors over the years, as well as following the development of technologies that have made them more and more suitable [4-6].

Fixed prosthodontics' marginal accuracy is heavily researched because it determines clinical success [7, 8]. The survival of fixed prosthodontics depends on the marginal adaptation's state. Marginal gaps can provide a favorable condition for biofilm deposition, aiding in caries and periodontal disease development. This will shorten the lifespan of the prosthetics restorations [9].

A clinical goal of a marginal gap ranging from 25 to 40 m for cemented restorations has been proposed, but it is difficult to achieve with conventional fabrication processes due to the various materials and clinical and laboratory procedures involved. However, the growing popularity of computer-aided design and computer-aided manufacturing (CAD/CAM) technologies, as well as the development of novel ceramic microstructures, has improved fixed prosthodontics practice, including the achievable marginal gap [10].

Previous research has discussed the methods developed for assessing marginal and internal fit. The cross-sectional method (CSM), The silicone replica technique (SRT), The triple scan method (TSM), Micro-computed tomography (MCT), Optical coherence tomography (OCT) [11-14].

Material and Methods

Specimens Preparation: The dental technician started scanning the original metallic abutment as attached to his dual analog with the aid of a lab scan/model scanner (Auto Scan DS-EX PRO/ Shining 3D, China), the scanned product was transferred to the software program (EXOCAD) for processing the digital model design and preparation of highly finished and detailed copy from the original one.

The digital model is printed by using a 3D printer (Creality/ Halot one, 4K resolution, 50 µm) into an acrylic resin model of abutment attached to the base, Which the late was checked for proper seating of the crowns on it.

The resin model is fixed to a cubic base from the same material at the level of the bone as shown in Fig (1A). The assembly of the abutment and its base is covered by a cubic cover with cutting guidelines for accurately sectioning the replica with minimal errors (Fig 1B).

Replica Technique in Marginal Adaptation Technique

To assess the marginal gap, the impression technique was selected. The method involves using low-viscosity material. The crowns were injected and filled up the fitting surface with light body silicone. The crown was then seated over the abutment and pressed for 3 min under a 5 kg load until the impression material was fully set according to the manufacturer's instructions (Fig 1C).

When the polymerization was completed, subsequently, the crown was removed leaving a light silicone impression on the abutment representing the thickness of the cement space. A putty silicone material (Zhermack, Zetaplus, Putty Impression Material, Zhermack S.P.A, Italy) was then applied over the remaining light impression on the abutment to overcome the difficulties in handling and cutting the thin thickness of the light body and to ensure that there are no spaces of irregularities would produce during placement of putty silicone, then quickly before starting the setting of putty silicone, The cover is placed over the heavy body with full engagement to the resin model to ensure a uniform final shape of silicone all around it (Fig 1D).

After the putty silicone was fully set according to the manufacturer's instructions, the silicone replica was removed and cut into two parts buccopalatally using surgical blade no. 15, then the readings on the cut parts would be two points on the buccal of the replica, and two points on the palatal side also. Every crown will produce four readings (Fig 1E).

The thickness of the light body was observed using a digital microscope (Koolerton LCD Digital USB Microscope, Hong Kong Karstone Technology Co., China) to evaluate the marginal gap. The sliced replica was placed under the digital microscope after accommodation of the best view, and a picture was captured for the replica then after that, we removed the replica and placed a ruler in the same place for the exact measurements achieved later. Each point was measured using (Image J) software (V 1.53A) (Fig 1F).

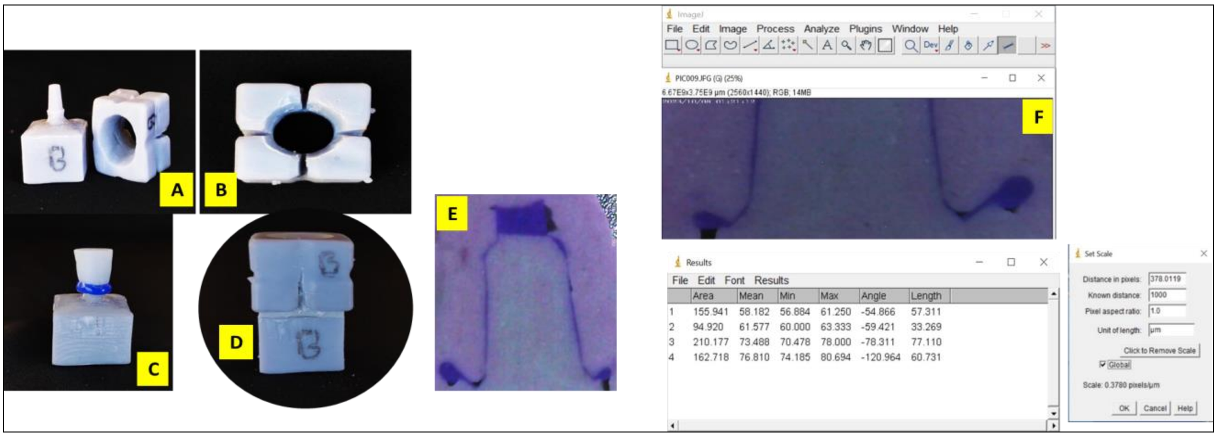

Fig 1: The designed model for marginal adaptation of cement-retained implant prostheses

A. Resin printed digital model of the abutment and the cubic cover.
B. The resin cubic cover with the cutting guide for the silicon replica.
C. The crown filled with a light body and seated on the resin model.
D. Resin Model covered with its cover with the heavy body within it.
E. The silicone replica cutting, ready for reading with a microscope.
F. Image J and the readings of a single crown.

Statistical Analyses

The collected data were transferred to the SPSS software (version 22.0) (IBM SPSS Inc., Chicago, IL, USA). Once the normality was tested, a parametric two-way Analysis of Variance was conducted to compare the mean marginal gap of each group. The post-hoc Duncan test was also performed to determine the statistical significance within groups for multiple comparisons (α = 0.05).

Results

Marginal Adaptation of Zirconia Test Data: Test of Normality for Marginal Gap Test for Zirconia: All the values obtained were subjected to the normality test (Kolmogorov-Smirnov & Shapiro-Wilk tests. The values were found to follow the normal distribution (Table 1).

Table 1: Tests of normality for the marginal gap of zirconia

	Kolmogorov-Smirnov			Shapiro-Wilk		
Groups	Statistic	DF	Sig.	Statistic	DF	Sig.
OH	0.280	7	0.103	0.851	7	0.125
LH	0.210	7	0.200*	0.956	7	0.781
OLH	0.194	7	0.200*	0.912	7	0.411
CONT	0.242	7	0.200*	0.855	7	0.136

Descriptive Statistics for Marginal Gap Test of Zirconia
Descriptive statistics were made to the values of the four groups, according to the experimental design of this *in-vitro* study. The table shows the means, standard deviations, standard of errors, minimum, and maximum (Table 2).

Table 2: Descriptive statistics for the marginal gap of zirconia

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
OH	7	100.8571	37.91406	14.33017	57	150
LH	7	68.8571	13.60672	5.14286	52	91
OLH	7	41.2857	10.48355	3.96241	30	61
CONT	7	153.4286	35.18928	13.30030	101	190

Analysis of Variance (ANOVA) for Marginal Gap test of Zirconia: The one-way analysis of variance was applied to the values. The ANOVA test result showed significance at $p<0.05$ in the retention values between groups. The Duncan multiple range test was performed to investigate this difference further (Table 3).

Table 3: ANOVA test for the marginal gap of zirconia

	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	48693.821	3	16231.274	21.854	0.0001
Within Groups	17824.857	24	742.702		
Total	66518.679	27			

Duncan Multiple Range Test of Marginal Gap Test for Zirconia: The Duncan test showed a significant difference between the OLH and the other three groups. The Occlusal-lateral hole group has better marginal adaptation with a lesser value of (41.2857 µm) than the other three groups. There were also significant differences between the lateral hole with a value of (68.8571 µm) and the occlusal hole group with a value of (100.8571 µm) and from the control group which had a value of (153.4286 µm) which was the highest in the results (Fig 2).

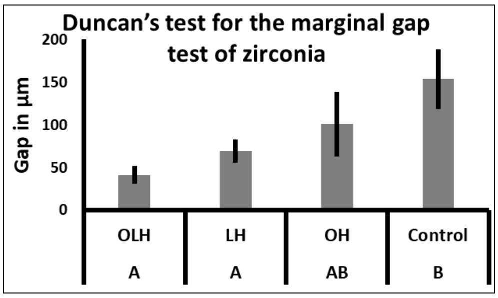

Fig 2: Duncan's test for the marginal gap test of zirconia

Marginal Adaptation of Hybrid Ceramic Test Data
Test of Normality for Marginal Gap Test for Hybrid Ceramic: All the values obtained were subjected to the normality test (Kolmogorov-Smirnov & Shapiro-Wilk tests. The values were found to follow the normal distribution (Table 4).

Table 4: Tests of normality for the marginal gap of hybrid ceramic

	Kolmogorov-Smirnov			Shapiro-Wilk		
Groups	Statistic	DF	Sig.	Statistic	DF	Sig.
OH	0.225	7	0.200*	0.874	7	0.201
LH	0.184	7	0.200*	0.932	7	0.570
OLH	0.262	7	0.158	0.906	7	0.370
CONT	0.362	7	0.006	0.720	7	0.006

Descriptive Statistics for Marginal Gap Test of Hybrid Ceramic: Descriptive statistics were made to the values of the four groups, according to the experimental design of this *in-vitro* study. The table shows the means, standard deviations, standard of errors, minimum and maximum (Table 5).

Table 5: Descriptive Statistics for the marginal gap of hybrid ceramic

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
OH	7	93.4286	20.71117	7.82808	52	118
LH	7	92.1429	27.34611	10.33586	57	128
OLH	7	60.1429	16.35470	6.18150	42	87
CONT	7	122.4286	32.92849	12.44580	97	194

Analysis of Variance (ANOVA) for Marginal Gap test of Hybrid Ceramic: The one-way analysis of variance was applied to the values. The ANOVA test result showed significance at $p<0.05$ in the retention values between groups. The Duncan multiple range test was performed to investigate this difference further (Table 6).

Table 6: ANOVA test for the marginal gap of hybrid ceramic

	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	13599.821	3	4533.274	7.171	0.001
Within Groups	15171.143	24	632.131		
Total	28770.964	27			

Duncan Multiple Range Test of Retention Test for Hybrid Ceramic: The Duncan test showed a significant difference between the OLH and the other three groups. The Occlusal-lateral hole group has better marginal adaptation with a lesser value of (60.1429 µm) than the other three groups. There were also lesser significant differences between the lateral hole with a value of (92.1429 µm) and the occlusal hole group with a value of (93.4286 µm) and from the control group which had a value of (122.4286 µm) which was the highest in the results (Fig 3).

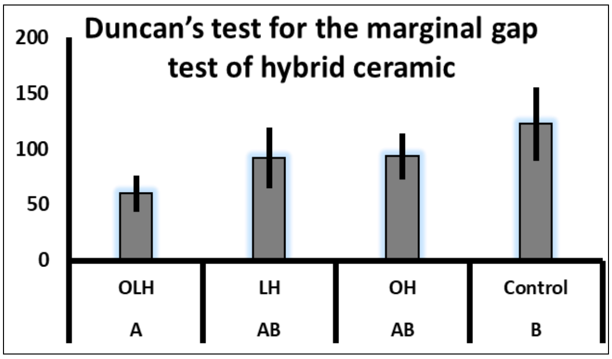

Fig 3: Duncan's test for the marginal gap test of hybrid ceramic

Discussion

Most implant abutments are made of metal, and the edge of the abutment is usually placed approximately 0.5^{-1} mm below the peri-implant mucosa to avoid unaesthetic metallic tints; a major drawback of cement-retained implant restoration is that the residual excess cement underneath the peri-implant mucosa cannot be removed completely, which may lead to peri-implant diseases [15, 16].

The marginal discrepancy is a key factor for the long-term function of implant-supported restorations in the oral environment because it promotes clinical success and prosthesis durability [17]. Thus, the presence of a marginal gap is one of the most important aspects to be considered when choosing the method for fabricating a dental crown, especially when new technologies are used [18].

The null hypothesis of this study stating that the placement, location, and diameter of a vent hole will have no significant influence on the amount of cement expressed at the margin of cement-retained implant prostheses was rejected. The lowest mean OLH of both zirconia and hybrid ceramic crowns examined in this *in-vitro* study was observed among the groups of study (30 µm in zirconia and 40 µm in hybrid ceramic), and this value is within the range of 120 µm as reported by McLean J. that clinically acceptable marginal discrepancies should be less than 120 µm [19].

Also, 120 µm has been reported by others to be the threshold for an acceptable marginal fit; however, others have stated that the acceptable marginal vertical misfit value should be 40 to 150 µm for implant-supported metal frameworks [12, 20, 21]. The other values of the study even the control with the highest mean supported by several studies which have evaluated the marginal gap between 100-200 µm and the internal gap from 200-300 µm for the cemented restorations [22-24]. These values are clinically acceptable. The findings of this study were similar.

In the present study, the PVS-replica method was used to assess the marginal discrepancy, which is known as a noninvasive and effective technique. The silicone replica technique replicates the complete cement space and it offers reliable results with the advantage of being used in both *in vivo* and *in vitro* studies as it is a non-destructive method as many authors have supported this in their research. [11].

The replica technique also allows measures to be repeated after any possible adjustments to the prosthesis, as well as to reassess the internal and marginal misfits. Such reevaluations can bring direct clinical benefits to the patient, without deleterious effects (control of quality) [25].

However, it is reported that the accuracy of the PVS-replica method may be affected by the type of silicone materials, the precision of the measuring procedure, and the number of measuring points [26]. And also there are some drawbacks can also be spotted in this technique: one of them is its difficulty in stabilizing the thin and fragile space between the crown and resin abutment [27].

This study evaluated the marginal gap of copings fabricated from hybrid ceramic (Vita Enamic) blocks and zirconia blocks.

Results indicated that there was a significant difference between the mean marginal gap values of the OLH group and the marginal gap values of the LH group from the mean values of the control. The mean of the OLH was (41.2857 µm) and the mean of the LH was (68.8571 µm), it falls within the acceptable limits which should be less than (120 µm) [19].

There are several reasons to consider as an explanation of the results of the study, the first one is that the significant effect of the crystallization cycle on marginal gap can mainly be due to the shrinkage of the material distorting the margins. CAD/CAM ceramic restoration can be affected by the fabricating technique [28]. In the heat-pressing technique, ceramic restorations can encounter changes during the investing and sintering process, which can lead to non-noticeable distortions.

Also, other reasons to consider as an explanation of the results of the study, is that the crown prostheses of zirconia were dry milling and the standardization of the CAD/CAM differs according to the parameters given for making the prostheses and the number of axis and age of burs used for shaping the prostheses, as many studies mentioned that by comparing marginal adaptation of different CAD/ CAM systems. They conclude that CAD/CAM systems, software, and parameters within a given software may interfere with marginal adaptation [29]. Some other studies assessed only the system's milling machine [30]. They show significant differences in marginal adaptation depending on the type of milling machines, due mainly to the number of axes and thickness of burs.

CAD/CAM milling is a mature technology that has been widely used because of its standardized, repeatable, and efficient manufacturing process [31]. But the only variables that were not kept consistent for the samples were the burs used for the milling unit. This could be a possible explanation for the gradual increase of marginal gap values within a group. Therefore, because bur wear can affect the cutting efficiency.

Wear on the milling burs during consecutive milling could play a role in the efficacy of their cutting ability and therefore may have resulted in discrepancies in the marginal area of the copings even within the same groups.

In addition to the standardization of CAD/CAM, we need to take into consideration several aspects when working with a CAD/CAM system. Some of these aspects are the accuracy and precision of the scanning. Dental restorations with great marginal and internal fitness are the results of accurate scanning.

Also, Besides the scanning stage, CAD/CAM ceramic restoration can be affected by fabricating techniques [28]. In the heat-pressing technique, ceramic restorations can encounter changes during the investing and sintering process, which can lead to distortions.
Greater gaps in the occlusal area compared to other areas (marginal and axial) can be explained by the limitation of the scanner resolution, which may produce rounded edges [32]. Another explanation can result from the planar occlusal reduction compared to the flat occlusal reduction design used in other studies as this type of design can produce more occlusal gaps due to scanning. These findings are in agreement with those in previous studies [33].
According to the manufacturer, this ceramic hybrid promises marginal integrity, strength, and more conservative tooth preparation in the posterior region of the mouth (especially where minimum interocclusal space is available).
The mean marginal discrepancy within the hybrid ceramic group was significantly within the limits that the previous studies revealed with it which was (>120 µm). The mean of the OLH was (60.1429 µm) and the mean of the LH was (92.1429 µm). It could be explained by considering the difference in their physical properties. Hybrid ceramic blocks are soft (dual network of ceramic and composite) CAD/CAM blocks they can be milled faster and cause less wear to the milling burs.
In the present study, the cement space was designed digitally for the CAD-CAM restorations during the computerized design process. However, the question remains as to whether the CAD-CAM devices can transfer the cement space range from the milling unit to the restoration with the same precision. Parameters of the milling unit (bur use times, milling material, and drill diameter) [34].
In addition, Hybrid ceramics do not require a crystallization phase; this distinguishing feature may have affected the results. To acquire more accurate results.
This study showed that the location of the vent hole does affect the proportion of cement expressed at the margin. There was a statistically significant difference in the proportion of cement expressed at the margin when comparing OLH holes to both LH and OH holes. (As shown in the Fig 8).

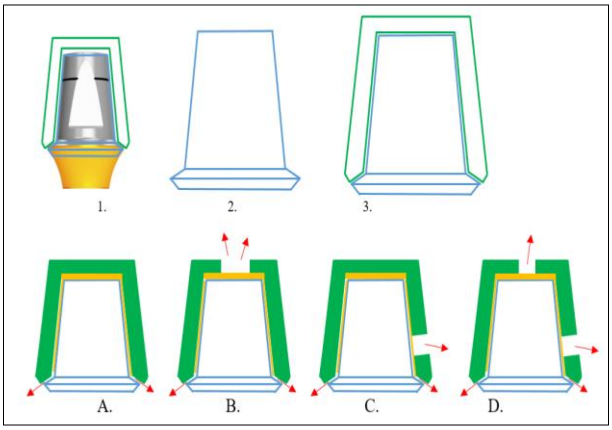

Fig 8: Section of a pattern of the abutment. 2. Sketch of simplified abutment. 3. Sketch of simplified prosthesis. And Schematic diagrams of the simulation results of each group. A; control group. B, OH group. C, LH group. D, OLH group. (LH, lingual hole; OH, occlusal hole; OLH, occluso-lateral hole)

Most of the studies reporting an inverse relationship between the cement gap or die spacer and MG (marginal gap) should be valid only to a certain limit, as the cement gap not only affects the MG but also affects the retention and fracture of restorations, especially with ceramics.
This relationship was conducted on natural or artificial tooth-supported crowns that may have different taper and finish line configurations than implant abutments. [35, 36].
In summary, for both, zirconia and hybrid ceramic the impact of venting holes on the cement distribution inside the crown during functioning because they adapt flow, hinder particle stacking, and release residual intracoronal pressure corresponding rate of flow of cement compensates for the change in vent hole diameter with formation of sealing of marginal area with a minimal amount of cement introduced or expressed from the margin into the gum.

Conclusion

The use of modified cement methods had a remarkable effect on marginal adaptation. Using occlusal-lateral with (1 mm) hole (OLH) modification has higher marginal adaptation than other groups. Using OLH had effectiveness in diminishing the marginal residual excess cement into the periodontal tissue, which indeed would have less production of peri-implantitis and bone defects.

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