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Research Article

Impact of Hole Modification in Cement-Retained Prosthesis on Mechanical Tensile Experiment

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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 (1mm) with lateral hole with a diameter (1mm) (OLH), the second is an occlusal hole with a diameter (2mm) for screw access (OH), the third is a lingual hole for releasing the excess adhesive (1mm) (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.

Key words: Retention time, Zirconia, Hybrid ceramic, Dental implant.

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INTRODUCTION

Dental implant use has increased greatly in the past few decades. This is caused by the ability of dental implants to replace missing teeth similar to real teeth, give good retention, good stability, and functional efficiency, comfort, and aesthetics.[1-5] Implant crowns can be retained with either a screw or cement. Each retention type has its advantages and disadvantages, and data has shown either no statistical difference between screw- and cement-retained implant crowns.[6]

The advantages of cement-retained prosthesis include a simpler operating procedure, easier passive fit, better esthetic results, and lower prosthetic costs than screw-retained prosthesis.[7-10] However, cement-retained prostheses are associated with several complications: cement residue at the gingival sulci around the abutment, especially underneath the gingival margin, is difficult to completely clean and can lead to peri-implant gingivitis, peri-implant inflammation, and ultimately implant failure.[10]

MATERIALS AND METHODS

Experimental Design: This in-vitro study consisted of 28 single-unit cement-retained implant restorations (7 specimens per group). Four groups were selected based on different cement-retained methods: the first group (OH group) (an occlusal hole for screw access), the second group (LH group) (a lingual hole for releasing the excess adhesive), the third group (OLH group) (an occlusal and lateral hole for screw access and releasing excess adhesive), and fourth group (control group) (no holes and no resin trial abutments). These groups were made first from two main study materials: the first one is from zircon and the other one is from hybrid ceramic (Vita Enamic).

Each is manufactured by (n=7) to test the retention of the cement-retained prostheses using dual-cure resin cement. These cement-retained methods are performed on two types of materials, Zirconia and Hybrid ceramic/Vita Enamic.

Specimens Preparation: In the laboratory. Each screw-retained abutment was attached to an implant analog with (35 N/cm) torque using a manual torque adapter prosthetic (Dentium, abutment D 4.5mm, L 2.5 mm/ Seoul, South Korea). The dental technician started the sample preparation with the aid of a lab scan/model scanner (Auto Scan DS-EX PRO/ Shining 3D, China), which was utilized to scan a scan body with the corresponding abutment which was administered into the software programs. The implant-supported, cement-retained zirconia and Hybrid ceramic copings were designed using EXOCAD (EXOCAD V2.4 GmbH, Darmstadt, Germany). A crown was designed with an intaglio surface that matches the abutment design and geometry.

The scanning file was exported to the EXOCAD software program in which the specimens were designed according to the shape of the abutment and the given ideal measurements (width, length, and height) as the cement gap (Cement gap was 0.05 mm).

The shape of the prosthesis was designed to be an inverted circular truncated cone. The taper of the upper clamping end was the same as that of the outer shape of the prosthesis.[11] The four groups' modifications (i.e. The holes in the crowns) are digitally measured and processed according to the demanded final shape of the specimens (Figure 1).

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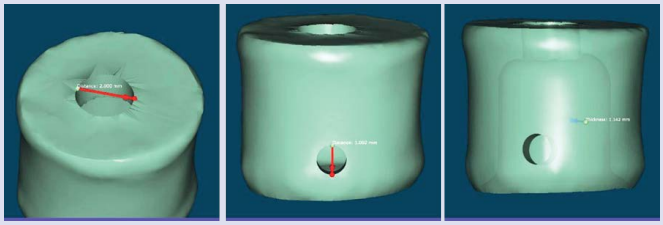

Figure 1: Measurements of hole from the EXOCAD OH=2mm, LH=1mm, thickness of crown = 1mm.

In the laboratory, the zirconia and Hybrid ceramic crowns were fabricated with computer-aided design and computer-aided manufacturing (CAD-CAM) technology (Aidite, Amd 500 dry milling for zirconia and Amw 400 wet for hybrid ceramic/ made in China)

The scanned master abutment was also used to fabricate 42-unit CAD/CAM zirconia restorations (Diamond, made in Canada) and 42-unit CAD/CAM hybrid ceramic restorations (Vita Enamic, Germany) with a 0.05mm space to accommodate the thickness of the cement film.

Analogs also after being scanned were inserted into AutoCAD software (AutoCAD 2022 V24.1) for allowing to design of a conical box in which the analog will be embedded in acrylic resin with the aid of dual-cure resin cement later. the acrylic resin conical box was digitally designed by using a 3D printer (Creality/ Halot one, 4K resolution, 50 µm). The upper and lower clamps are made from carbon steel by CNC machine according to the design made previously in AutoCAD

Cementation: After the preparation and processing stage is completed and the finished 4 subgroup abutments are ready, the following cementation stage starts. At this stage of work, we started by placing the analogs upright (90° angle) in the center of the acrylic resin conical box which was embedded and fixed with the dual cure resin cement until the analog was firmly fixed. Before cementation, Ti-Base abutments were torqued per manufacturer recommendations (32 N/cm) with a torque wrench onto individual analogs. Before continuing the fixation of the analogs, the abutment is covered by polytetrafluoroethylene (PTFE) tape to ensure its safety from excess resin cement.

When the seating of all the analogs is completed, a Teflon tape (PTFE sealing tape) is first placed as a pellet within the abutment screw access hole to seal and protect the screw head during cementation for each one then the interfaces between the crowns and the abutment finish line to check if each respective gap size allowed correct seating, where the crowns reached the intended finish lines. all crowns were set with a passive fit on the abutments and rotated by hand mesially and distally around the abutment's axis of rotation.

The chosen cement for this in-vitro study was self-adhesive resin cement (Totalcem dual cure, Itena, France), it was the same cement used to fix the analogs in their places within the acrylic resin conical box.

To standardize cementation, firstly cement was mixed following the manufacturer's instructions by using its mixing tips and the other thin intraoral tips.

After cement mixing started, the cement was applied on the intaglio surface of the crowns and started over crown insertion on the abutment and seated correctly,[12] An LED light was initially applied on each surface for 20 seconds (LED.F, Woodpecker, China). Then excess cement was removed from the abutment margin by a dental explorer.

A weight of 5 kg was used for 10 minutes at a room temperature of approximately 25°C. until cement curing, the assembly was stored in a moist environment at 37°C (±5°C) for 24 hours before testing.[13]

Pull-out Retention Test: The retentive strength of the specimen was evaluated by the tensile force required to separate the crown from the abutment. the assembly (i.e. crown cemented to the abutment which is screwed into the analog within the resin box) attached to the upper and lower metallic clamps, the whole is delivered to the universal testing machine (GT-UA03, GESTER, China).

The tensile force with a uniaxial pull-out load was applied parallel to the long axis of the specimens at a crosshead speed of 1 mm/min until the crown dislodged from the abutment; load–deflection curves were used to record the tensile force, and the tensile force applied to separate the specimen was obtained from the curve and recorded in Newton (N). All the specimens were tested in the same manner and The results were recorded in the software of the universal testing machine.

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 ($\alpha = 0.05$).

RESULTS

All the readings are obtained from the pull-off testing device and associated software, which are recorded and transferred to a statistical analysis application (IBM SPSS Statistical V.22) (Table 1). The units of these values in the tables are in Newton.

All the values obtained were subjected to the normality test (Kolmogorov-Smirnov & Shapiro-Wilk tests) (Table 2).

Descriptive statistics were made to the values of the four groups, according to the experimental design of this in-vitro study (Table 3).

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 4).

The Duncan test showed a significant difference between the OLH and the other three groups. The Occlusal-lateral hole group with a value of (257.4286 N) has better retention than the other three groups. There were also significant differences between the lateral hole with a value of (180.8571 N) and the occlusal hole group with a value of (138.5714 N) and fewer differences from the control group which had a value of (148.7143 N) (Figure 2A).

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 5).

Descriptive statistics were made to the values of the four groups, according to the experimental design of this in-vitro study (Table 6)

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 (Table 7)

The Duncan test showed a significant difference between the OLH and the other three groups. The Occlusal-lateral hole group with a value of (213.5714 N) has better retention than the other three groups. There were also significant differences between the lateral hole with a value of (162.5714 N) and the occlusal hole group with a value of (113.4286 N) and fewer differences from the control group which had a value of (155.8571 N) (Figure 2B).

DISCUSSION

The current study aimed to determine the differences in retention of the cement-retained implant prosthesis, produced by four techniques.

Table 1: Data results from pull-off test.

	Zirconia specimens				Hybrid Ceramic specimens			
No.	OH*	LH*	OLH*	Control	OH*	LH*	OLH*	Control
1	145	195	220	145	120	141	185	163
2	98	179	245	131	87	156	195	171
3	130	145	145	148	116	165	248	132
4	142	130	284	165	86	168	202	200
5	145	165	330	122	112	173	245	100
6	160	214	318	170	163	165	200	145
7	150	143	260	160	110	170	220	180

Table 2: Tests of normality for retention of zirconia.

Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
OH	0.282	7	0.097	0.847	7	0.115
LH	0.196	7	0.200*	0.954	7	0.767
OLH	0.136	7	0.200*	0.950	7	0.726
CONT	0.166	7	0.200*	0.949	7	0.723

Table 3: Descriptive Statistics for retention of zirconia.

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
OH	7	138.5714	20.01547	7.5654	98	160
LH	7	180.8571	19.02129	11.51544	130	214
OLH	7	257.4286	63.03929	23.82661	145	330
CONT	7	148.7143	17.73616	6.70364	122	170

Table 4: ANOVA test for retention of zirconia.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	61851.714	3	20617.238	14.681	0.0001
Within Groups	33704.286	24	1404.345		
Total	95556.000	27			

Table 5: Tests of normality for retention of hybrid ceramic.

Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
OH	0.256	7	0.182	0.871	7	0.19
LH	0.302	7	0.052	0.848	7	0.118
OLH	0.251	7	0.2*	0.887	7	0.258
CONT	0.157	7	0.2*	0.980	7	0.958

Table 6: Descriptive Statistics for retention of hybrid ceramic.

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
OH	7	113.4286	25.72844	9.72443	86	163
LH	7	162.5714	10.90653	4.12228	141	173
OLH	7	213.5714	24.81167	9.37793	185	248
CONT	7	155.8571	33.21359	12.55356	100	200

Table 7: ANOVA test for retention of hybrid ceramic.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	35386.429	3	11795.476	18.875	0.0001
Within Groups	14998.000	24	624.917		
Total	50384.429	27			

Also, this study aimed to evaluate which technique maintains the superior results. Several techniques have been applied to decrease the amount of cement residue at the abutment margin, including pre-seating, using polytetrafluoroethylene (PTFE) tape as a cement shield, and hole opening.[14-20]

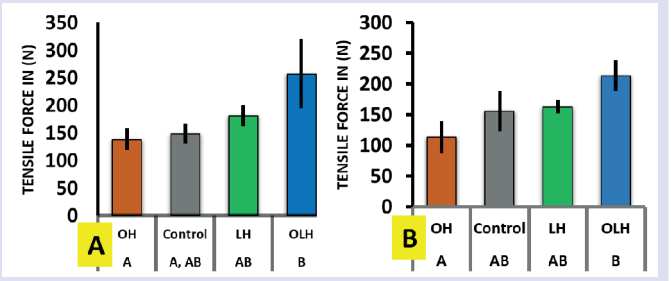

Figure 2: Retention test of zirconia (A) hybrid ceramic(B). Data expressed as mean±SD, same letter indicate no differences, different letter indicate significant difference at p<0.05 using Duncan test.

The technique of adapting PTFE tape around the abutment as a cement shield may interfere with the passive seating of the restoration.[17] Compared with other techniques, the hole opening technique does not require extra operating steps, which saves time and expense, making this technique practical and worthy of clinical promotion.[21]

However, the reduction of excess cement does not suffice if the technique used affects the tensile load resistance. Although it's desirable to achieve adequate retention levels without excess cement when cementing implant-retained restorations, both characteristics may be mutually exclusive. Many studies comparing the retention values of cement-retained implant prostheses have focused on the effect of cement types, changes in the surface roughness, height, and tapering features of the abutment. However, new studies are now aimed at new techniques such as using venting holes.

As shown in the results, this in-vitro study found that there is significantly higher retention calculated from crowns with the OLH group as well as from the crowns with the LH group with slightly lower values than the OLH group for both zirconia and hybrid ceramics.

This in-vitro study revealed significant disparities in the mean retentive force (N) of the different crowns over the same circumstances of the experimental study. The mean retentive force (N) of the OLH crowns was (257.4286) N and the mean retentive force (N) of the LH crowns was (167.2857) N while the mean retentive force (N) for the control was (148.7143) N.

As an explanation, we should start from the process of bonding, the air and cement inside the crown would get squeezed out; so if no hole exists, the only access to excess cement is through the crown margin (like, the control group), and the excess cement may be squeezed deep underneath the Peri-implant mucosa. The presence of a hole on the crown provides a path for cement and air extrusion rather than being only extruded from the margin, and then the cement fluid pressure at the margin of the abutment is reduced when the crown is seated in its position. this explanation is agreed with Zhou, *et al.*[22] Zhou, *et al,* showed in their studies that vent holes with smaller diameters (1 mm) can also have advantages for cement extrusion reduction without affecting the retention ability compared with crowns having a regular larger hole (2.5 mm).[22]

In these moments, due to the extrusion of air, the adhesive is extruded from the adhesive gap (marginal area), resulting in a large amount of overflow of the adhesive and insufficient filling with or without the formation of air trapping and air bubbles formation (in case of the control group). Also as the same as zirconia, the hybrid ceramic revealed significant disparities in the mean retentive force (N) of the sub-groups of study. The results show that the mean retentive force (N) of the OLH crowns was (213.5714) N and the mean retentive force (N) of the LH crowns was (162.5714) N while the mean retentive force (N) for the control was (155.8571) N.

Under the same conditions and standards that were conducted on zirconia, the results were close for both in the higher group of study (i.e., OLH group) and for the same reasons mentioned above in zirconia about the internal pressure during the placement over the abutment. When a hole is made in the occlusal surface of the prosthesis, the area with less pressure in the system will be the hole, and the air inside the prosthesis is preferentially discharged from the hole. The filling process of adhesives will not be significantly affected as we know that the Retention of fixed dental prosthesis depends on the total surface area of the abutment that is covered with sealer, in the case of the diameter, height and the surface area of the abutment used is the same.

During placement of the LH group prosthesis, air can be discharged from the hole. This explanation is agreed with the study of Sun *et al*,[11]

However, obstruction of air discharge appears on the other side without the hole. Therefore, the internal filling of adhesives is slightly insufficient and the amount of cervical overflow is slightly increased. To explain the difference in the amount of cervical overflow of adhesives between the OH group and the LH group in the present study. It is necessary to highlight this mainly because of the diameter of the hole. The diameter of the screw hole in the OH group was 2 mm, while the diameter of the overflow hole in the LH group was 1 mm.

The results of the current study showed that the presence of a hole on the crown, regardless of its size, could substantially reduce the amount of cement extruded at the abutment margin compared with no-hole crowns, which is consistent with the results of previous studies. For example, Zaugg *et al*. indicated that venting was the most effective method of reducing excess marginal cement. Jimenez *et al*. reported that a vent hole on the crown was more advisable than a pre-seating protocol for improving the performance in terms of reducing excess cement extrusion.[23,24]

The presence of a hole may also compromise the fracture resistance of the restoration: Saboury *et al*. reported that a central hole with a diameter of 2 mm on implant-supported zirconia restorations decreased fracture resistance.[25] Another study by Du *et al*. indicated that a full-contour crown with a 1-mm hole should be recommended over holes with diameters of 0-, 2-, 3-, and 4- mm in the posterior teeth region from the aspect of biomechanics by finite element analysis.[26] In contrast, Hussien *et al*. indicated that screw access channels on implant crowns did not affect the fatigue failure load of implant-supported crowns.[26]

This in vitro study cannot reflect the complex oral environment, and the clinical situation is affected by factors such as patient cooperation. This analysis may differ from the clinical procedure. For example, the adhesives are extruded out by the internal air pressure in the control group. However, in the clinical situation, slight deviation and rotation often occur when seating the prosthesis, and the adhesive coating cannot be completely uniform. All these factors may produce internal pores in the adhesives, reducing the internal air pressure.

CONCLUSION

The use of modified cement methods had a remarkable effect on both retention and marginal adaptation. The use of occlusal-lateral with (1 mm) hole (OLH) modification is more retentive than the other groups. The crowns' retention strength, don't gain good results with an increase in the diameter of the venting holes on implant cement-retained crowns.

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