An in vitro assessment of circumferential grooves on the retention of cement-retained implant-supported crowns

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Statement of problem. Crowns cemented on short implant abutments may have insufficient retention.

Purpose. The purpose of this study was to evaluate the effect of circumferential grooves on the retention of cemented cast copings on implant abutments.

Material and methods. Sixty similarly-shaped implant abutments were divided into 4 groups (n=15): without grooves, with 1 groove, with 2 grooves, and with 3 grooves. Fifteen identical NiCr cast copings were prepared to fit all 60 abutments. The castings were cemented to each group of abutments with a noneugenol provisional cement (Tempbond NE) and a zinc phosphate cement (Harvard). After thermal cycling and storage for 6 days in a water bath, retention tests were conducted with a tensile testing machine (Instron) (5 mm/min) and retentive forces were recorded. Data were subjected to 1 way-ANOVA, Tukey's (HSD) test, and repeated measures ANOVA (α=.05).

Results. For the noneugenol temporary cement, group retention values were increased according to the number of grooves (P<.001). For the zinc phosphate cement, the first groove increased the retention by approximately 60% (P<.001). The retentive values were higher for the zinc phosphate cement than the provisional cement. The influence of the grooves depended on the type of cement used (P<.001). Cement remnants were found primarily on the castings for provisional cement and for the plain abutments cemented with zinc phosphate cement. Remnants were found primarily on the abutments for the grooved abutments cemented with zinc phosphate cement.

Conclusions. The addition of circumferential grooves to implant abutments increased the retention of cement-retained castings. For zinc phosphate cement, 1 groove was as effective as several, whereas for the provisional cement, the retention increased gradually with additional grooves. (J Prosthet Dent 2011;106:367-372)

Clinical Implications

Circumferential grooves on implant abutments may help to increase the retention of cement-retained castings.

Factors that may affect the retention of cast restorations include geometry of abutment preparation, abutment taper, surface area, abutment height, surface roughness, retentive grooves, and the luting agent used.[1-6] Surface roughness, grooves, and luting agents are factors that can be controlled by the clinician. Surface roughness increases retention because of the resulting microretentive ridge and groove patterns.[7-10] Surface roughness has been reported to enhance crown retention as much as 31%.[6] Grooves can be either vertical or horizontal to create cement keys.[11]

The advantages and disadvantages of restoring dental implants with a cement-retained superstructure have been well documented.[12-14] Cement selection, classified as definitive or provisional, is of primary importance for cement-retained implant-supported crowns.[15] Studies have demonstrated

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that composite resin, zinc phosphate, and glass-ionomer luting agents significantly enhance the cement failure loads of the prostheses luted to titanium abutments in comparison to provisional luting agents.[16-18] For cement-retained implant-supported restorations, the choice of cement is one of the most important factors controlling the amount of retention attained.[19,20] The need for restoration retrievability has increased the use of provisional cements for implant-supported crowns.[21] In a recent study, it was shown that zinc oxide-based cements (provisional cements) and zinc phosphate cements are commonly used for the definitive cementation of implant-retained restorations.[22] The retentive strength of provisional luting agents is another influencing factor on retention.[23-24] Various provisional luting agents have been reported to have different values of retentive strength for implant-supported restorations.[16-18,20,21,25-27] However, in certain situations, the retention of crowns is inadequate, especially when a short implant abutment is used because of inadequate interarch space.

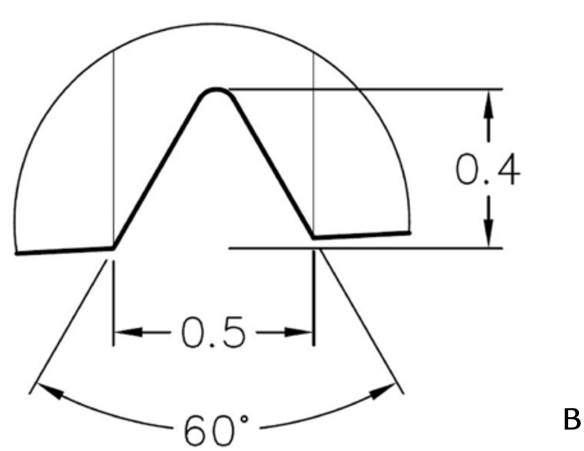
The purpose of this study was to introduce the use of circumferential grooves on implant abutments as retentive promoters and to evaluate the effect of the circumferential grooves on the retention of castings cemented to implant abutments with provisional and definitive cements. The null hypothesis was that the circumferential grooves would not affect the retention of the cemented castings.

MATERIAL AND METHODS

Sixty straight shoulder type titanium abutments (MDcpk61; MIS Implant Technologies Ltd, Misgav, Israel) (height 6.0 mm and 6-degree taper with 0.5 mm shoulder width) with abutment screws and corresponding 12 mm-long stainless steel laboratory implant analogs were used (MIS Implant Technologies Ltd). The abutments were divided into 4 groups of 15 abutments each: without grooves, with 1 groove, with 2 grooves, and with 3 grooves (Fig. 1). Other than the number of grooves, the abutments were identical. Each groove was 0.5 mm wide and 0.4 mm deep with an interwall angle of 60 degrees. The grooves were specially prepared by the manufacturer (MIS, Implant Technologies Ltd) upon request.

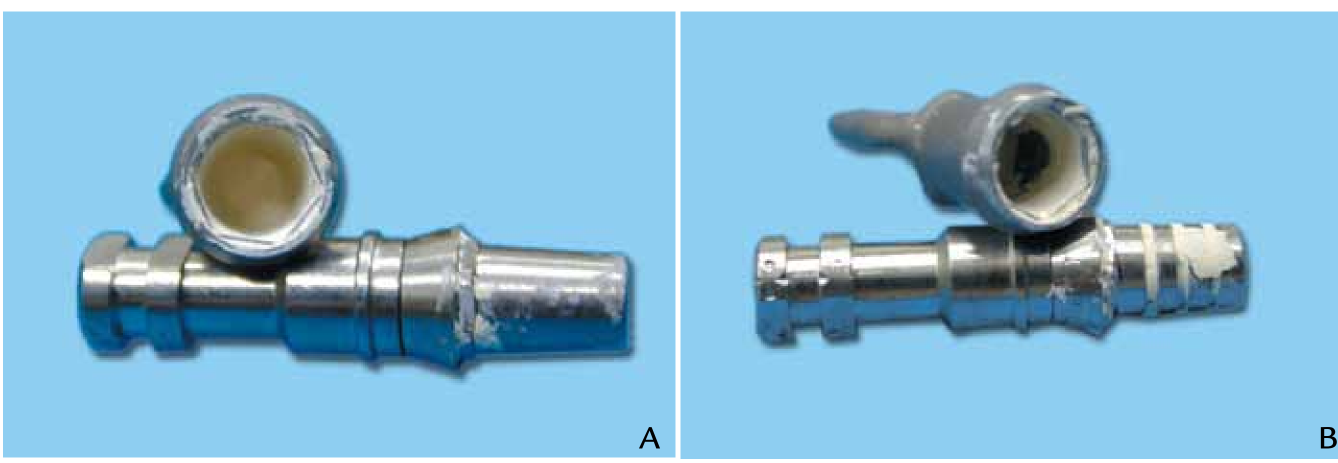
Crown patterns were fabricated with prefabricated burn-out plastic copings (MD-IC040; MIS Implant Technologies Ltd) with a wax ring attached to the occlusal portion. The patterns were sprued, invested, and cast with NiCr alloy (Remanium; Dentaurum, Ispringen, Germany) in a vacuum casting machine (Easycast; Zubler Geratebau Gmbh, Ulm-Jungingen, Germany). All cast copings were inspected for accuracy and fit with calipers and a ×16 magnification microscope (Model X, Stereoscopic Microscope; Olympus, Tokyo, Japan). The copings were numbered 1 to 15 for identification during testing and assigned to correspondingly numbered abutments. Finally, the intaglio of all copings was airborne-particle abraded for 20 seconds with 110µm aluminum oxide particles (Renfert, Hilzingen, Germany) at a pressure of 0.2 MPa, washed with water, and dried with compressed air before initial testing. Laboratory analogs were paired with numbered abutments (and cast crown copings) and connected to the encased abutment screw.

The implant abutment screws with the abutments were tightened to the analogs with a screwdriver and a torque control device (MT-RIO40; MIS Implant Technologies Ltd) to a torque of 20 Ncm. To cement the copings onto the abutments in a repeatable manner, a base was fabricated in a plastic ring (25 mm in diameter) filled with acrylic resin (Orthoplast; Vertex-Dental, Zeist, Netherlands) with a vertical hole prepared in the center. The analog with its abutment was placed in the hole while the cast coping was cemented. The castings were cemented to each group of abutments with a zinc oxide-based provisional cement, ZO (TempBond NE; Kerr, Romulus, Mich) or a zinc phosphate definitive cement, ZP (Harvard cement; Harvard Dental International GmbH, Hoppegarten, Germany). Cements were mixed according to the manufacturer's instructions and were



1 A, Abutments with and without grooves. B, Cross-section of groove.

2 Retention test with testing machine.



3 Cement failure mode: A, Plain abutment with adhesive type failure. B, Grooved abutment with mixed failure.

applied in a thin, 3 mm wide, layer to the cervical margin of the inner surface of the copings.[16]

Each coping was seated on the abutment 30 seconds after the start of mixing, and a static load of 50 N was applied for 10 minutes. After setting, excess cement was removed with a plastic curette (Universal Implant Deplaquer; KerrHawe, Bioggio, Switzerland). Cementation was performed at an ambient temperature of 23 ±1°C. Specimens were stored in 100% humidity at 37°C for 1 hour, thermocycled 500 times between 5°C and 55°C with a dwell time of 10 seconds and then stored in 100% humidity at 37°C for 6 days. This limited aging protocol was used in a previous study where provisional cements were tested.[24]

The specimens were assembled in the universal testing machine (Model 4502; Instron Corp, Norwood, Mass) and subjected to a pullout test (retention) at a crosshead speed of 5.0 mm/min (Fig. 2). The forces required to remove the copings were recorded in newtons.

After the retention test, the copings and abutments were evaluated for failure mode according to the location of the residual cement (Fig. 3) with ×16 magnification (Stereoscopic Microscope; Olympus). Full thickness residues on the abutment or casting were denoted as adhesive failure. Cohesive failure was denoted when the failure was within the cement and partial thickness residues were seen on the abutment and the opposing surface of the casting. A combination of adhesive and cohesive failure was considered a mixed failure.

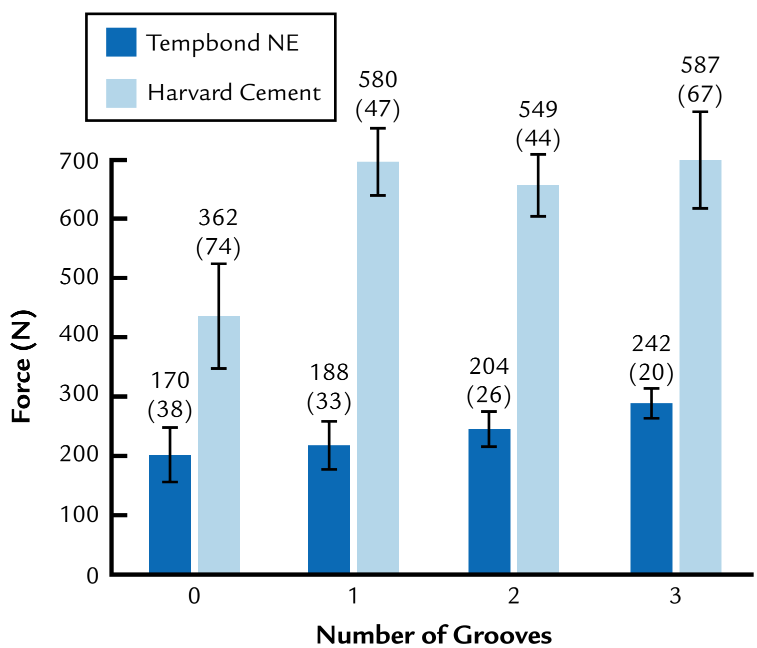
After the pullout test (of the specimens cemented with provisional cement), cast copings and abutments were placed in an ultrasonic cleaner for 5 minutes, followed by mechanical cleaning with a plastic curette and cotton appli cators soaked in petroleum-ether. It was assumed that the cleaning procedures had no relevant effect on the retention and cementation and retention tests of the next group were then performed similarly with the same castings. A 1-way ANOVA with post hoc Tukey's Honestly Significant Difference (HSD) test and repeated measures ANOVA were performed. All tests were conducted at the 95% level of confidence (α=.05).

RESULTS

The mean tensile force required to separate the castings from the abutments is seen in Figure 4. It was apparent that the circumferential grooves increased the retention of both cements. The 1-way ANOVA indicated that for each cement type, the additional grooves significantly increased the retention of the castings ($F=15.6$, $df=3$, $P<.001$ for ZO provisional cement and $F=48.5$, $df=3$, $P<.001$ for ZP cement). The repeated measures ANOVA (Table I) showed an interaction between the cement type and the number of grooves ($P<.001$). Therefore, the effect of the number of grooves depended on the cement type. The retentive values of ZP were more than 2 times higher than for ZO. For ZO, there was a gradual increase in the retention values in accordance with the number of grooves. The mean retentive force (SD) increased from 170 (38) N for no-groove to 242 (20) N for 3-grooves. For ZP, the addition of grooves increased retention values. The addition of 1 groove increased the retention from a mean of 362 (74) N to 580 (67) N. The additional grooves made no significant contribution to retention. Table II presents comparisons with Tukey's HSD test. Groups not significantly different at the .05 level are presented as a subset.

An estimation of the percentage contribution of the grooves may indicate that for ZP, the first groove increased the retention approximately 60%, while the second and third grooves had no cumulative effect. For ZO, each additional groove gradually increased the retention, whereas the third groove increased the retention approximately 42% ($P<.05$).

Castings cemented on plain abutments also exhibited adhesive type failure for both ZO and ZP. For these specimens, the cement remnants were



4 Mean (SD) of retention force (N) versus number of grooves for zinc oxide noneugenolprovisional cement (Tempbond NE) and zinc phosphate cement (Harvard Cement).

Table I. Two-way ANOVA with repeated measures for cements and grooves

Source	Type III Sum of	*df*	Mean Square	F	*P*
Cement	3045816	1	3045816	1405	.001
Cement × Retentive Force	173287	3	57762	27	.001
Error	121446	56	2169	-	-
Retentive Force	379384	3	126461	57	.001
Error	124989	56	2232	-	-

Table II. Tukey's HSD test for zinc oxide provisional and zinc phosphate cement (n=15). Means for group in homogeneous subsets

Subset for alpha = .05			No. of Grooves	Cement Type
3	2	1		
		170.4	0	Zinc Oxide
	187.6	187.6	1	Provisional
	203.8		2	
241.9			3	
		361.7	0	Zinc Phosphate
	549.0		1	Cement
	580.3		2	
	587.3		3	

found primarily (more than 50%) over the inner-surface of the castings. For ZO, the grooved abutments exhibited mixed (adhesive/cohesive) type failures with greater than 50% of remnants being found on the castings. However, when ZP was used with grooved abutments, the mixed type failure was evident, while the remnants were found primarily on the abutments.

Discussion

Cement-retention has become, in many situations, the method of choice for implant-supported prostheses. Provisional cements are used primarily to facilitate the removal of interim restorations. Since there is no risk of decay on the abutments, provisional cements can also be used for the cementation of implant restorations as they are much weaker than the definitive cements and permit retrievability of the restorations.[18,21] Therefore, the ideal cement should provide adequate retention while also enabling retrievability.[13,21]

The null hypothesis that the use of circumferential grooves would not have any effect on the retention of the cemented copings was rejected. The results of the present study show that the use of circumferential grooves increased the retention of the cement-retained copings. Therefore, circumferential grooves can help provide retention control while still maintaining retrievability.

The findings of this study suggest that the addition of 1 groove increased the retention of both ZO and ZP cements. The mean retentive forces with no grooves were 170N for ZO and 362N for ZP. The addition of 1 groove increased the retention to 188N for ZO and 580N for ZP. However, for ZP, 1 groove was as effective as several, whereas for ZO the retention increased gradually with additional grooves. Since the experimental conditions of other studies were not exactly the same, the basis of comparison for the results is questionable. However, Walfart et al[27] investigated the retention of various cements without thermocycling, The authors found retentive forces of 400N for ZP (Harvard Cement; Harvard Dental International GmbH) and 180N for ZO (Freegenol; GC Europe NV, Leuven, Belgium), which are similar to the current findings. Squire et al[16] examined the retention of cemented specimens with 5 types of cements subjected to 24 hours of thermocycling (approximately 1000 cycles). The authors found approximately 300N for ZP (Fleck's Cement; Mizzy/Keystone Industries, Cherry Hill, NJ) and 30N for ZO (ZONE; Cadco Dental Products, Inc, Oxnard, Calif). The low retention values for the ZO provisional cement can be attributed to the different thermocycling conditions. In the dental literature, there is no consensus on the thermocycling protocol needed for testing provisional cements.

The cement failure mode was generally adhesive in nature, although some cohesive and mixed failure was observed. Cement remnants were found mostly on the casts for ZO and on plain abutments cemented with ZP. Remnants were found mostly on abutments for the grooved abutments cemented with ZP. This pattern of failure may indicate that the circumferential grooves create a local lock, which affects the failure mode and the location of the remnants.

It may be that this local lock increases the length of the fracture-line (plane) and has a greater effect on cements with a high modulus of elasticity such as zinc phosphate cements (ZP). Clinically, the circumferential grooves can be effective for increasing the retention of fixed dental prostheses in situations where short abutments are used because of small interocclusal distance.

The cross sectional shape of the grooves in the present study was chosen arbitrarily. Therefore, the optimal geometry, including the groove's depth and the wall's angulation, should be studied and defined in further studies.

The limitations of this study should be noted. The study tested the retention force of only 2 types of cements. The pullout test of the cemented castings was performed after limited aging without cyclic loading. This protocol did not simulate long-term oral conditions. Therefore, additional studies are needed to quantify the effect of grooves on the retention of other cements under long-term simulation, which may assist clinicians in cement selection. The desire for retrievability dictates the use of long-term provisional cements for implant-retained fixed prostheses. Since they differ from definitive cements, special protocols are needed for testing such provisional cements.

Conclusions

Within the limitations of this study, the following conclusions were drawn:

1. The retention of cast copings cemented on plain abutments with zinc phosphate cement was about 2 times greater than those cemented with zinc oxide provisional cement.

2. The addition of 1 circumferential groove on the abutments increased the retention of cast crowns cemented with zinc phosphate cement approximately 60% and was 3 times higher than those cemented with zinc oxide provisional cement.

3. The surface modification of an implant abutment by means of circumferential grooves is an effective method of improving the retention of cast crowns cemented either with zinc oxide provisional cement or zinc phosphate cement.

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