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Research Article

Role of Circumferential Grooves in Improving the Retentive Properties of Cemented Implant Supported Crowns-An *In-vitro* Evaluation

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Abstract

Introduction: Short implant abutments which have less than 6mm height pose a problem of limited retention and the present study evaluates the effect of circumferential grooves in improving the retentive quality. A comparative evaluation of Zinc phosphate cement and Non eugenol provisional cement in providing adequate retention for implant crowns is also undertaken

Methodology: 80 implant analogues with abutments were fabricated and they were grouped into four. In group 1 no groove was milled and in the other three groups circumferential grooves were fabricated in the order of 1, 2 and 3. Cobalt chromium copings with loops were fabricated and cemented with phosphate and non eugenol cement in equal number of specimens in each group. Retention test was conducted with Instron universal testing machine using a pullout method. The retention values, tensile stress and tensile strain were calculated and subjected to statistical analysis – One way ANOVA.

Results: Retention values of phosphate cement were higher when compared to those of non eugenol cement. When luting was done with non eugenol cement, on incorporating one groove, the retention value increased by 73%, with two grooves by 181% and with three grooves by 242%. With phosphate cement, the retention values increased by 35%, 70% and 120% with each groove. The values obtained were statistically significant (<0.001).

Conclusions: 1. Phosphate cement exhibited superior retention, stress and strain values when compared to non eugenol cement. But this does not deny the usefulness of non eugenol cement in cemented implant crowns because of its facilitation of retrievability.

2.Circumferential grooves definitely improve the retentive qualities of cemented implant crowns irrespective of the luting agents used.

Keywords: Cemented Implant Supported Crowns; Retention; Circumferential Grooves; Luting Cements; Retrievability; Short Abutments

Introduction

Cement-retained implant prostheses got recognised in the field of dentistry during the 1990s. The versatility of these crowns increased along with the introduction of angulated and customisable abutments. This combination allowed the connection of non parallel implants using fixed dental prosthesis. Presently clinicians practising dental implantology whole heartedly endorse the use of cemented restorations.

The luting cement used along with the implant prosthesis should provide retention for a reasonable period of time and at the same time should ensure the feasibility of removal when required [1,2]. In other words, the luting cement for implant prosthesis should be strong enough to provide retention and at the same time weak enough so that the clinician can retrieve it when it is necessitated [3,4]. The retrievability makes the clinicians opt for temporary cements for luting implant prosthesis but its capability to serve as a definitive luting agent remains a questionable issue [5]. Cement retained implant restorations do have less failure rate when compared to screw retained restorations both in short term as well as in long term evaluations. [5-7].

The retentive principles of cemented crowns related to teeth as well as implants are almost similar. Abutment dimensions especially the height and the geometry of convergence have important role in determining the retention. Incorporating surface roughness improve the retention to some extent. Making of vertical grooves either on the abutment or on the intaglio surface of the restoration, do not have much effect in increasing the retention even though there is a marked increase in the surface area. Horizontal grooves made on the abutment surface and on the internal surface of the restoration enhances retention because of the cement key formed by the luting agents [8,9]. Horizontal grooves incorporated on the abutments in varying numbers have a role in situations where short abutments are preferred because of the paucity of clinical space. Cemented crowns on mandibular premolars and molars especially in advancing ages pose a challenge in obtaining retention.

Abutments with less than 6mm height are usually considered as short and cemented crowns made for them require additional retentive elements such as horizontal grooves with 0.5mm width and 0.4mm depth. The present study was designed to evaluate the retention capabilities of horizontal grooves made on the implant abutments with conventionally used luting cements like zinc phosphate cement and zinc non eugenol cement with the following objectives.

- To find out the effect of circumferential grooves incorporated on short implant abutments in improving the retention of cemented restorations.
- To compare and evaluate the retentive capability of two luting cements viz. Zinc phosphate cement and Zinc non eugenol cement.

Methodology (Figure 1a)

The present study was conducted to determine the resistance to dislodgement of casted copings cemented on short implant abutments of 4mm height and 4.8mm diameter. Circumferential grooves were incorporated to evaluate their effect on retention.

80 single piece implant analogues were milled in stainless steel with abutment height of 4mm and diameter 4.8mm with 6^0 taper (Figure 1). The analogues were divided into 4 groups, each containing 20 specimens. Circumferential grooves with 0.5mm width and 0.4mm depth were incorporated on the abutments. The distribution of groups is as follows

- **Gr. 1:** 20 implant analogues with no groove on the abutment
- **Gr. 2:** 20 implant analogues with one circumferential groove placed in the middle of the abutment
- **Gr. 3:** 20 implant analogues with two circumferential grooves placed on the abutment
- **Gr. 4:** 20 implant analogues with three circumferential grooves placed on the abutments (Figure 1).

Figure 1: Implant abutments.

Figure 1a: Schematic diagram of implant abutments

Fabrication of specimens

All the wax copings were fabricated on dental stone duplicates of Gr.1 specimens. A loop was attached on the occlusal portion of the wax coping (Figure 2). The patterns were casted in cobalt chrome alloy (Bego). All casted copings were inspected for accuracy of fit under 16x magnification (Figure 3). The intaglio surfaces of the castings were blasted with aluminium oxide particles (110μm) for 20 seconds.

Figure 2: Wax pattern of coping with loop.

Figure 3: Casted coping.

The specimens in each group were subdivided into two consisting of 10 in each. The sub groups were designated as A and B. The castings were cemented on subgroup A specimens with Zinc oxide eugenol free cement - Relyx Temp NE (3M). The mixing time was limited to 30 seconds and the cement was loaded on to the fitting surface of the coping. After seating, 50 newton (5.09858 kg) static load was applied for 10 minutes. Once the cement was set, the excess was removed and the specimens were stored in hundred percent humidity at 37^{0}C for one hour. Sub group B specimens were cemented with Zinc phosphate cement – Detray Zinc (Dentsply). All other procedures carried out were similar to those followed in subgroup A specimens (Figure 4,5).

Figure 4: Rely X Temp NE - non eugenol cement.

Figure 5: De Tray Zinc- Zinc phosphate cement.

Retention test

The specimens were subjected to pullout test (Retention test) using universal testing machine (Model 3365, Instron corporation). Pulling force was applied through the loop present on the casting, at a cross head speed of 0.5mm per minute. Load application was continued till the copings were separated (Figure 6).

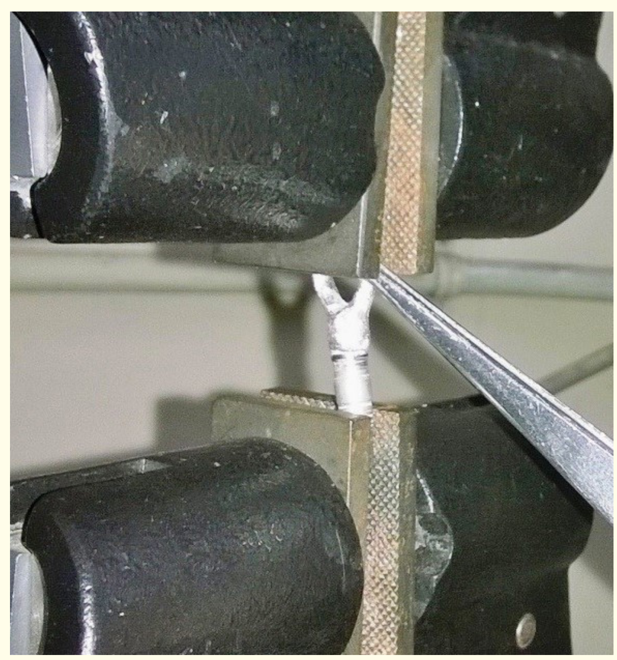

Figure 6: Pull out test of the coping was done with Instron universal testing machine.

Values of maximum load applied for removal of casting, tensile stress and tensile strain were recorded.

Determination of failure mode

After the retention test, both the abutment surface and the intaglio surface of the copings were examined under magnification (Binocular stereo microscope at 20x) (Figure 7). Failure mode was determined by the quantity of the residual cement present on the abutment and the coping. Full thickness cement residues on the abutments or the coping was considered as adhesive failure (Figure 8). When the failure is within the cement and partial thickness residues were seen both on the abutment and on the intaglio surface of the casting was considered as cohesive failure. A combination of adhesive and cohesive failure was designated as combined failure (Figure 9).

Figure 7: Stereo microscope.

Figure 8: Adhesive failure.

Figure 9: Mixed failure.

Following the pullout test, cast copings and abutments were subjected to ultrasonic cleaning for 5 minutes. The metallic surfaces were further subjected to mechanical cleaning with a plastic instrument followed by petroleum ether soaked cotton pellet. The cleaning process did not alter the metallic surfaces and the assembly could be reused for the testing of other groups.

Values of tensile stress, tensile strain and maximum load were recorded with the Instron after the pullout test done at a crosshead speed of 0.5 mm/min. The forces required to remove the copings were recorded in newtons.

Statistics

Results were tabulated and subjected to statistical tests – ANOVA and Sheffe multiple comparisons test.

Results

Mean values of maximum load, tensile stress and tensile strain measured during the pullout test for each group are given in table 1. The recorded values were statically evaluated using one way ANOVA and Schiffe Multiple Comparison test.

Two types of cements were compared viz. Zinc oxide non eugenol and Zinc phosphate cements by obtaining maximum load values, tensile stress and strain calculated at maximum load. In all the four groups of specimens and in all the three tests, the values were higher for Zinc phosphate cement significantly when compared to those of Zinc oxide non eugenol cement (Table 1).

The presence of circumferential grooves had significant role in enhancing the pullout load, tensile stress and the strain. The pattern of progression of enhancement of values were similar with both the cements on the effect of the number of grooves. Incorporation of grooves per se as well as the number of grooves had significant role in increasing the pullout force required. The stress and strain experienced at maximum load also increased along with the number of grooves. Multiple comparisons also endorse the finding that group 4A and 4B shows maximum values for the load, tensile stress and strain. In other words, incorporation of three grooves has significant effect in enhancing the retentive properties (Table 2-7).

Both abutments and copings were examined for the remnants of cements after the pullout tests. Copings cemented with zinc phosphate and non eugenol cement showed very little cement remnants on abutments where there was no circumferential groove, indicating adhesive failure. In abutments with grooves, cement remnants were found on both the grooves and the intaglio surfaces of the

Group	1A	1B	2A	2B	3A	3B	4A	4B
Max Load(N)	38.7 ± 3.7	334.5 ± 5.0	66 ± 2.5	451.1 ± 3.4	107 ± 3.1	571.4 ± 3.1	130.7 ± 1.8	735.4 ± 7.5
Tensile Stress (MPa)	2.9 ± 0.3	25.7 ± 1.2	3.7 ± 0.3	38.2 ± 1.1	5.8 ± 0.3	55.3 ± 1.7	11.1 ± 0.3	67 ± 1.4
Strain (%)	2.4 ± 0.4	22.7 ± 2.0	2.9 ± 0.4	34.4 ± 1.8	5.4 ± 0.3	51.7 ± 2.4	9.6 ± 0.4	62.6 ± 1.8

Table 1: Mean values of maximum load, tensile stress and strain found out with pullout test.

- **A:** Copings cemented with Zinc oxide eugenol free cement
- **B:** Copings cemented with Zinc Phosphate cement
- **Gr.1:** Implant analogue with no groove
- **Gr.2:** Implant analogue with one circumferential groove
- **Gr.3:** Implant analogue with two circumferential grooves
- **Gr.4:** Implant analogue with three circumferential grooves.

Group	Mean	SD	N	F	Sig.	Scheffe multiple comparison	
						Pair	F`
Gr.1A (a)	38.7	3.7	10	1940.25**	0.001	a and b	148.6**
Gr.2A (b)	66.0	2.5	10			a and c	929.61**
Gr.3A (c)	107.0	3.1	10			a and d	1598.47**
Gr.4A (d)	130.7	1.8	9			b and c	334.87**
						b and d	790.51**
						c and d	106.18**

Table 2: Scheffe multiple comparisons based on maximum load (Gr. 1A,2A,3A,4A).

** denotes significance.

Group	Mean	SD	N	F	Sig.	Scheffe Multiple Comparisons	
						Pair	F`
Gr.1B (a)	334.5	5.0	10	11421.91**	0.001	a and b	880.73**
Gr.2B (b)	451.1	3.4	10			a and c	3635.6**
Gr.3B (c)	571.4	3.1	10			a and d	10411.63**
Gr.4B (d)	735.4	7.5	10			b and c	937.51**
						b and d	5236.01**
						c and d	1742.35**

Table 3: Scheffe multiple comparisons based on maximum load (Gr. 1B,2B,3B,4B).

** denotes significance.

Group	Mean	SD	N	F	Sig.	Scheffe Multiple Comparisons	
						Pair	F`
Gr.1A (a)	2.9	0.3	10	1319.73**	0.001	a and b	11.36**
Gr.2A (b)	3.7	0.3	10			a and c	146.28**
Gr.3A (c)	5.8	0.3	10			a and d	1104.73**
Gr.4A (d)	11.1	0.3	9			b and c	76.1**
						b and d	897.39**
						c and d	460.77**

Table 4: Scheffe multiple comparisons based on tensile stress - MPa (Gr. 1A,2A,3A,4A).

**denotes significance.

Group	Mean	SD	N	F	Sig.	Scheffe Multiple Comparisons	
						Pair	F`
Group 1B (a)	25.7	1.2	10	1826.48**	0.001	a and b	142.44**
Group 2B (b)	38.2	1.1	10			a and c	803.78**
Group 3B (c)	55.3	1.7	10			a and d	1556.65**
Group 4B (d)	67.0	1.4	10			b and c	269.49**
						b and d	757.33**
						c and d	123.29**

Table 5: Scheffe multiple comparisons based on tensile stress - MPa (Gr. 1B,2B,3B,4B).

**denotes significance.

Group	Mean	SD	N	F	Sig.	Scheffe Multiple Comparisons	
						Pair	F`
Group 1A (a)	2.4	0.4	10	629.85**	0.001	a and b	2.49
Group 2A (b)	2.9	0.4	10			a and c	92.12**
Group 3A (c)	5.4	0.3	10			a and d	508.92**
Group 4A (d)	9.6	0.4	9			b and c	64.31**
						b and d	441.95**
						c and d	174.69**

Table 6: Scheffe multiple comparisons based on strain at maximum load % (Gr. 1A,2A,3A,4A).

**denotes significance.

Group	Mean	SD	N	F	Sig.	Scheffe Multiple Comparisons	
						Pair	F`
Group 1B (a)	22.7	2.0	10	785.51**	0.001	a and b	57.18**
Group 2B (b)	34.4	1.8	10			a and c	349.05**
Group 3B (c)	51.7	2.4	10			a and d	661.7**
Group 4B (d)	62.6	1.8	10			b and c	123.67**
						b and d	329.84**
						c and d	49.57**

Table 7: Scheffe multiple comparisons based on strain at maximum load % (Gr. 1B,2B,3B,4B).

**denotes significance.

copings which indicated a combined failure. This was more with zinc phosphate cement than with zinc non eugenol cements. In copings luted with non eugenol cement, more than 70% of the remnants were found on the copings than on the abutments with and without grooves. This shows that noneugenol has less adhesive property compared to zinc phosphate cement (Figure 8,9).

Discussion

Cemented implant restorations

Cement retained implant crowns are easily accepted by the clinicians because of the similarity with the tooth supported crowns in the clinical and laboratory steps followed. In contrast to the screw retained crowns, cement retained ones are less technique sensitive and are kind to minor casting misfits. An added advantage is that cemented crowns are better suited for designing fixed prosthesis for misaligned implants. Retrievability is the most highlighted favourable point of cemented implant crowns because it facilitates periodic evaluation [10-12].

Luting cements

There is a wide range of luting cements available in the market viz. zinc oxide eugenol, Zinc phosphate, Poly carbonate, Glass ionomer and Resin cements. Retention provided by the luting cements is influenced by other factors like the number, height and geometry of the abutments along with the physical and mechanical properties and chemistry of the luting cements [13,14].

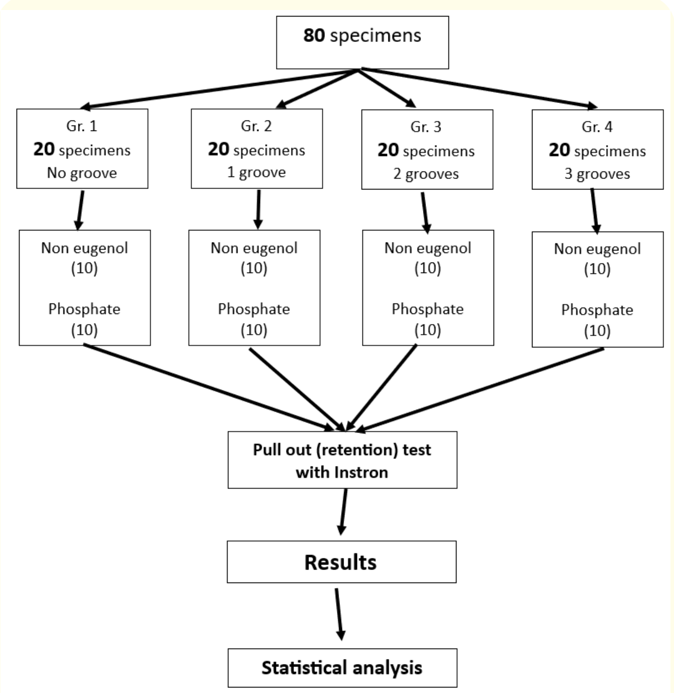

Figure 10: Flow chart on methodology

In the present study two cements were included - Zinc phosphate and Zinc oxide non eugenol. These are commonly employed in clinical practice. With non eugenol cement, the maximum force required for the crown removal was 38.7 ± 3.7N whereas with the phosphate cement the value was 334.5 ± 5. N. Similarly the tensile stress and the strain at maximum loading also showed a significant increase. Mansour., *et al.* and Sheets., *et al.* also have made similar observations but brand variations have caused changes in the values marginally (Table 1) [15,16].

Based on the retentive values obtained, the cements need not be branded as superior or inferior because maximum retention may not always be required in cemented implant crowns. The retention values should be optimum so that the crowns should remain serviceable for a reasonable period of time and the crowns should be retrieved for periodic checkup or for addressing emergencies like screw loosening, fracture of components or for treatment of peri implant diseases.

The survival rates of implant supported restorations are in fact very high - 97% after five years and 95% after ten years. But peri-implantitis do appear after two years of placement of the restoration – 34% at patient level and 21% at implant level. In other words, one third of patients and one fifth of all implants experience peri-implantitis and it is attributed to ill designed and ill fitting cemented restorations. This grave situation is a major health burden justifying the concern that retrievability of the cemented implant restoration cannot be overlooked because controlling plaque accumulation is the only way to restrict peri-implantitis [17,18].

Short abutments

Multiple factors influence the retention of cemented implant restorations other than the luting agents. Dimensions, taper, surface roughness and grooves incorporated have found to enhance the retentive properties [8]. On tooth preparations, dentists have the freedom of choice to incorporate the appropriate retentive elements. In the case of implant abutments, the manufacturers dictate the design and the clinicians have very limited choice. Grooves were the most popular retentive designs incorporated by the dentists or technicians. Vertical (axial) grooves were first tried but not with satisfactory results. Horizontal grooves were tried next which have shown remarkable improvement in retention [19]. The cement keys that extended into the grooves, strength of the cement and the adhesiveness of the luting agent to the crown ensure the improvement in retention. The present study was designed to find out the effectiveness of horizontal grooves incorporated on implant abutments especially in the short ones which have less than 6mm height [20].

The present in vitro study was taken up to evaluate the effectiveness of horizontally placed grooves on the implant abutments. Four groups of specimens were made of which Gr.1 had no groove and the other three groups had grooves in the order of 1, 2 and 3. Zinc phosphate cement and non eugenol temporary cement were selected for the experiment. A pull-out test was conducted with Instron universal testing machine and three properties were calculated viz maximum load required for removal of the cemented crown, Tensile stress and strain experienced at the application of maximum load (Table 1).

When luting was done with non eugenol cement, on incorporating one groove, the retention value increased by 73%, with two grooves by 181% and with three grooves by 242%. The stress values increased by 27%, 100% and 282% and the strain measured at maximum loading increased by 20%, 125% and 300% respectively.

When the luting was done with phosphate cement, the retention values increased by 35%, 70% and 120% with each groove. The stress values increased by 48%, 115% and 160% and the strain values by 51%, 127% and 178% along with the incorporation of each groove. Each groove had a cumulative effect both for the non eugenol cement and for the phosphate cement. This is in contrast to the findings of Lewinstein., *et al.* [21].

The values obtained in each test were subjected to one way ANOVA and Scheffe multiple comparisons test and the differences observed with the luting cements and the incorporation of grooves were found to be highly significant (<0.001). (Table 1-7).

Mode of failure of the luting agents

After the pullout test, the abutments and the copings were examined for the cement remnants to ascertain the mode of failure. With no circumferential groove, both the cements did not leave remnants on the abutments indicating an adhesive failure. In abutments with grooves, cement remnants were found both on the grooves and on the intaglio surface of the copings indicating a mixed (adhesive/cohesive) failure but more with the phosphate cement. With non eugenol cements, more of the remnants were found on the copings indicating the poor adhesive nature. Similar pattern of mode of failure was reported by other authors also [21]. The major limitations of the study are that the specimens were not subjected to thermo cycling and cyclic loading. These processes would have improved the realistic perceptions of the results. The authors are planning to have a second phase of the study including more number of cements and where thermos cycling and cycling loading could be included.

Conclusions

- Phosphate cement exhibited superior retention, stress and strain values when compared to non eugenol cement. But this does not deny the usefulness of non eugenol cement in cemented implant crowns because of its facilitation of retrievability.
- Circumferential grooves definitely improve the retentive qualities of cemented implant crowns irrespective of the luting agents used.

Author Contributions

Conceptualization-Pradeep Dathan, Nimy R L, *Lab experiments*-Nimy R L, Pradeep Dathan, *Review of articles*-Nimy R L, K.Chandrasekharan Nair; *Initial draft preparation*-Nimy R L, Smitha Raveendran; *Review and editing*- K. Chandrasekharan Nair, Pradeep Dathan, Shyam Mohan; *Supervision* – Pradeep Dathan, Shyam Mohan

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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