

Research Article

Comparison of tensile bond strength between implant abutments and all ceramic restoration luted with four luting agents-An in-vitro study

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Abstract: The choice of luting agents contributes a significant role in retention of cement retained implant restorations and their precise tensile behaviour needs to be investigated further. The aim of present study is to estimate and compare the difference in tensile bond strength between implant abutments and all ceramic restorations luted with four luting agents. An experimental, single blinded, in-vitro study design was employed. A total of 40 machined, conventional commercially pure titanium abutments were divided into four groups of ten each and attached to the implant fixtures. Full coverage all ceramic restorations were fabricated, luted with four cements (Group A–Zinc phosphate, Group B–Glass ionomer, Group C–Resin cement, Group D–Zinc oxide eugenol) and evaluated for tensile bond strength in the universal testing machine set at 0.5 mm per minute cross head speed following immersion in artificial saliva with pH 7 at 37°C and thermocycling. Statistical analysis was done by Independent sample T test and One-way ANOVA at 0.5 level of significance. The four luting cements used in this study had the following tensile bond strength values. Group A (Zinc phosphate cement) 222.5 +/- 6.498 N, Group B (Glass ionomer) 93 +/- 3.28 N, Group C (Resin cement) 373 +/- 6.68 N and Group D (Zinc oxide eugenol) 44 +/- 2.02 N respectively. Both the Independent sample T test and ANOVA showed statistically high significant difference (p<0.001) between all the four experimental groups. The highest tensile bond strength was exhibited by the resin luting cements followed by zinc phosphate, glass ionomer and Zinc Oxide Eugenol respectively following luting the all ceramic restorations with implant abutments and the clinicians could choose the appropriate cement based on their clinical requirement and judgement of the existing clinical situation.

Keywords: Tensile bond strength, Luting cement, Implant abutment, All-ceramic restorations.

INTRODUCTION

One of the crucial factors determining the success in fixed prosthodontics is retention. Several parameters like tooth preparation, the choice of restoration and luting cement play a major role in contributing retention in fixed restorations[1]. Tooth preparation with minimal taper offers a greater retention than convergent preparations[2]. The degree of axial taper and surface area of the abutments is directly proportional to the amount of retention obtained [3].

However, implant abutments and natural teeth used as abutments in fixed restorations possess innate differences between them. The taper of implant abutments are more exaggerated and the surface area of the implant is comparatively lesser than the natural teeth abutment and this might affect the retention sufficiently[4]. The other factors contributing to the retention in implant abutment include the platform size, screw access filling method and the finish of the abutments. The screw retention was originally advocated because it enabled retrievability which allowed survival of implant components. Screw

loosening is one of the common problems associated with fixed implant screw retained restorations[5]. The cement-retained implant restorations are associated with advantages viz. comfortable familiarity with the clinical and laboratory techniques of conventional fixed dental prostheses, particularly to practitioners. Other advantages include enhanced posterior esthetics, ability to correct minor casting discrepancies between superstructure and abutments, and reduced technique sensitivity both in the clinic and laboratory. Additionally, the cement retained restorations become the prime modality of management when confronted with malaligned implants.

The other advantages of cemented implant restorations include superior occlusion and esthetics, cement retained prostheses have a higher degree of passive fit. The cement space can compensate for minor discrepancies in the framework [6]. Clinicians desiring retrievable restorations may still achieve them through progressive cementation. Increasingly stronger cements were advocated, rather than screw retention, until the desired retention is reached[7]. The disadvantage of the

cement retained implant restoration is the lack of a reliable means of retaining and then retrieving the superstructure for routine care and maintenance. However, retrievability is highly desirable for cleaning, and it facilitates evaluation for mobility of ailing implants. In addition, treatment for peri-implant bone loss can be enhanced by removing the superstructure and re-submerging the implant. Mechanical failures are also rectified by retrieving the superstructure. Another drawback of cement retained implant restoration is the reported potential for damage due to the inability to retrieve excess cement from implant margins, leading to adverse periodontal problems [8].

Nevertheless, de-cementation of restoration is a commonly observed clinical phenomenon in implant supported cement retained prosthesis and it poses a serious threat of aspiration of the prosthesis by the patient which could be a huge clinical risk. The adhesive behavior developed between commercially pure titanium implant abutment and all ceramic restoration after luting with various luting agents is a complex phenomenon that has not been studied extensively and needs to be investigated to evaluate clinical performance. The excessive taper of 16° and reduced cross sectional area [when compared to natural tooth abutment] of commercially pure titanium implant abutments may influence adhesive ability of luting agents used for all ceramic restorations and can influence retentive behavior of the cemented prosthesis[9].

Hence, this study has attempted to evaluate the tensile bond strength between implant abutment and all ceramic restoration with various luting agents. The null hypothesis formulated for this study is that there is no significant difference in tensile bond strength between implant abutment and all ceramic restoration luted with various luting agents.

Aim

To estimate tensile bond strength between implant abutments and all ceramic restoration luted with four luting agents. To compare and evaluate the difference in tensile bond strength in implant abutment and all ceramic restoration luted with four luting agents.

Study Design

Experimental, single blinded, in vitro study

Inclusion Criteria

- 3.75mm commercially pure titanium, non-coated, endosseous, internal hex, tapered, root form implants with straight platforms.
- Machined conventional commercial pure titanium abutment with 16° taper and surface area of 0.1302 cm².
- Abutment height of 4mm.

Exclusion Criteria

- Commercially pure titanium angulated abutment.
- Ceramic implant abutment.
- Custom made machined / Milled abutments.
- Metal / Metal ceramic restorations for implant abutment.
- Friction fit abutments.
- Ball headed abutments for over dentures.

Sample Size Estimation

A pilot study was initiated with five samples each in four experimental groups and the results were obtained and sample size was reworked to ten samples in each experimental group to establish 90% power using G*power statistical software.

GROUPS

The specimen was distributed into four groups of 10 each (n=10) and cemented with four specific luting agents, immersed in artificial saliva at 37° for one week and thermocycled and tested for tensile bond strength with instron universal testing machine (thermocycled 1000 times in 5°C and 55°C water).

Group 1- Implant abutment luted to all ceramic restoration with zinc phosphate cements. De Trey, Dentsply, Germany.

Group 2- Implant abutment luted to all ceramic restoration with glass ionomer cement. GC Gold label – GC Corporation Tokyo, Japan.

Group-3- Implant abutment luted to all ceramic restoration with resin bond cements. Ivoclar Vivadent – Variolink, Liechtenstein - Switzerland.

Group 4- Implant abutment luted to all ceramic restoration with zinc oxide eugenol cement. 3M ESPE – Rely XTM Temp NE – USA.

METHODOLOGY

A total of 40 implant fixtures were embedded in square shaped auto-polymerizing resin blocks (2*2cm). All the fixtures were 3.75mm diameter, non-coated, internal hex and root form implants with straight platforms. Machined conventional, commercially pure titanium abutments with 16 degree taper and surface area of .1302cm were torqued to 25Ncm into the implant fixtures.

The 40 specimens were divided into four groups of 10 each. An optical impression of abutments in each specimen was made with CEREC 3D (Sirona Dental Systems) intra oral camera. Full coverage restorations was designed with morphological occlusal surface which served to secure the restoration into a brass jig and were to be tested for tensile bond strength in the universal testing machine. A spacer thickness of 25microns were set in the software and the blocks were subjected to milling. 40 restorations were designed and were milled in the CEREC 3D unit. The two burs used in each unit were 1.6mm flat cylinder diamond and 1.6mm cone shaped cylinder diamond. The burs were

changed after 5 millings to standardize the wear down of burs. E max ceramic milling blocks were used to fabricate the restoration. Following milling, the intaglio surfaces of the crowns were cleaned using air abrasion.

Implant abutments were cleansed with ethyl alcohol and allowed to dry for a period of 2 minutes prior to cementation. The cements were mixed according to the manufacturer’s recommendation and the all ceramic restorations were seated with finger pressure on to their respective abutments. Excess cement were removed using a plastic scaler. All ceramic restoration were then loaded along the long axis with the 5 kg load to ensure complete seating. The cementing procedure were carried out at room temperature by one investigator.

Following cementation, all the specimens were immersed in artificial saliva at 37 degree with a pH of 7. This was followed by thermo-cycling 1000 times in 5°C and 55°C. Following this, the specimen were transferred and mounted in the universal testing machine (Instron) set at .5 mm per minute cross head speed and the pull out test for tensile bond strength was performed to evaluate the retention of individual restoration. The load required to remove each All-ceramic restoration was recorded and the nature of cementation failure was determined and categorized into adhesive, cohesive or combined failures. The retention values expressed as tensile bond strength values were obtained and analyzed using independent samples T test and ANOVA at .05 level of significance.

RESULTS

The results of the study were as follows-

In all the four groups of specimen tested, the nature of cementation failure was of adhesive nature between implant abutment and cement interface. Adhesive failure between restoration and cement interface was not observed in any of the specimens. Cohesive failure within the cement was not observed in all the four groups.

Table 2 showed the tensile bond strength values expressed in Newtons for four groups. The four luting cements used in this study had the tensile bond strength values viz.222.5±6.498 N for zinc phosphate group 1, 93±3.28 N for glass ionomer group 2, 373±6.68 N for resin cements group 3 and 44±2.02 N for zinc oxide eugenol cement group 4 respectively

Independent sample t test to compare two mean values given in table 3. The t value was 56.21 between group A and B, t value was 51.155 between group A and C, t value was 82.75 between group A and t value was 118.96 between group B and C, t value was 39.95 between group B and D, t value was 148.85 between group C and D.A highly significant difference with p<.001 was observed in all the group comparisons.

Table 4 A and 4 B shows the one way ANOVA table to compare the mean value between the groups. The ANOVA results shows statistically high significant difference p (< .001) between all the four groups: Group A, Group B, Group C, Group D.

Table 1: Cements used in the study

Groups	Cement Name	Cement Type	Manufacturer
Group A	De Trey	Zinc phosphate cement	DENTSPLY, GERMANY
Group B	GC Gold label	Glass ionomer cement -	GC CORPORATION TOKYO, JAPAN
Group C	Variolink N	Resin cement	IVOCLAR VIVADENT LIECHTENSTEIN SWITZERLAND.
Group D	3M ESPE – Rely XTM Temp NE – USA	Zinc oxide eugenol cement	Rely XTM Temp NE – USA

Table 2: Tensile Bond Strength Values Obtained After Thermocycling

Tensile bond strength values (Newtons)				
Samples	Group A	Group B	Group C	Group D
SAMPLE 1	229.063	90.11	360.128	39.4688
SAMPLE 2	206.813	85.012	372.128	45.2031
SAMPLE 3	218.178	95.14	365.119	46.6094
SAMPLE 4	218.766	92.97	380.275	45.231
SAMPLE 5	226.728	95.74	378.104	45.122
SAMPLE 6	226.121	94.18	375.642	45.714
SAMPLE 7	224.031	94.24	379.216	43.214
SAMPLE 8	225.468	93.62	379.824	43.412
SAMPLE 9	224.028	95.48	370.912	44.602
SAMPLE 10	226.214	94.82	372.616	45.706
MEAN ± SD	222.541±6.498117	93.1312±3.280471	373.3964±6.688772	44.4282±2.024923

Table 3: Independent Samples T-Test to Compare Two Mean Values

Groups compared	F	t	Df	Significant P-Value
Group A vs Group B	2.871	56.219	18	<0.001
Group A vs Group C	0.062	-51.155	18	<0.001
Group A vs Group D	5.944	82.753	18	<0.001
Group B vs Group C	4.457	-118.965	18	<0.001
Group B vs Group D	0.982	39.950	18	<0.001
Group C vs Group D	0.008	148.856	18	<0.001

Table 4 A: One Way ANOVA to Compare Mean Values Between Groups

Group	N	Mean	Std. Dev	Minimum	Maximum	P-Value
Group A	10	222.54	6.50	206.81	229.06	<0.001
Group B	10	93.13	3.28	85.01	95.74	
Group C	10	373.40	6.69	360.13	380.28	
Group D	10	44.43	2.02	39.47	46.61	
Total	40	183.37	129.28	39.47	380.28	

Table 4 B: ANOVA Table

	Sum of Squares	Df	Mean Square	F-Value	P-Value
Between Groups	650922.563	3	216974.188	8523.248	<0.001
Within Groups	916.443	36	25.457		
Total	651839.006	39			



Fig-1: Implant fixture with all ceramic restoration mounted on acrylic base



Fig-2: Testing the samples in Instron machine

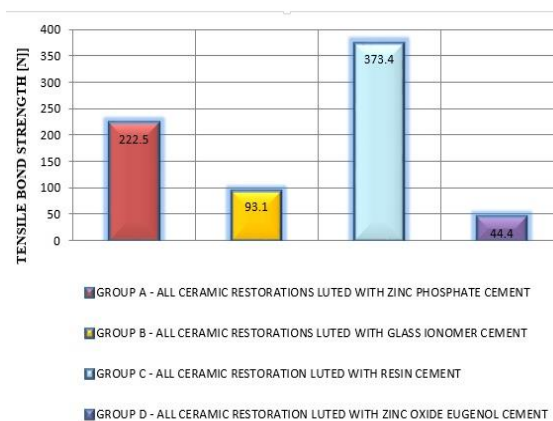


Fig- 3: Comparison of Tensile Bond strength between luting cements

DISCUSSION

De-cementation of restoration due to cementation failure is a commonly observed clinical complication in implant supported cement retained prosthesis. Apart from the esthetic emergency, it poses a serious threat of aspiration and swallowing of the prosthesis by the patient which could be a huge clinical risk. The factors inducing cementation failure are complex and the type of materials used for restorations and the behavior of luting cements themselves may influence the rate of cementation failure in implant supported restorations.

The null hypotheses that proposed there is no significant difference in tensile bond strength between implant abutment and all ceramic restoration luted with various luting agents was negated after the study. The four luting cements used in this study had the tensile bond strength values viz. 222.5 ± 6.498 N for zinc phosphate, 93 ± 3.28 N for glass ionomer, 373 ± 6.68 N for resin cements and 44 ± 2.02 N for zinc oxide eugenol cement respectively, following immersion in artificial saliva and thermocycling and a statistically highly significant difference $p < 0.001$ was observed between the four group of cements studied.

De boever et al [10] reported 36% of cemented restoration required recementation, whereas 38% of screw retained restoration required retightening. Duncan et al [11] reported no cementation failures of the restoration in a prospective clinical trial of single stage implant at 36 months.

Jebren et al [12] reported decementation of restoration to be 2.13% in a multicentered retrospective study of ITI implant supported posterior partial prosthesis.

Levine et al [13] concluded that 98.2% of cemented restoration were free of complications in a multicentered retrospective analysis of solid screw ITI implants for posterior single tooth replacement.

Wannfors et al [14] reported few prosthetic complication were observed with cemented all ceramic constructions in a prospective clinical evaluation of different single tooth restoration designs on osseo-integrated implants.

Sailer et al [15] reported no biological problems associated with cement retained zirconium and titanium abutments in randomized control trial of customized zirconia and titanium implant abutments for canine and posterior single tooth implant reconstruction.

Krennmair et al [16] reported 9.9% of re-cementation in cement retained restorations in there retrospective clinical analysis of 146 implants with single tooth replacement.

McMillan AS et al [17] reported 3.9% of single tooth restoration required re-cementations in their retrospective multicentered evaluation of single tooth implants.

Breeding et al [9] as reported when removal of the provisionally cemented superstructure from a cemented abutment becomes necessary, the retentive strengths of the abutment / fixture and superstructure / abutment luting agents become important considerations.

Pan et al [18] reported few data exist regarding cement failure load and marginal leakage of castings cemented to implant-supported abutments subjected to load and thermal cycling, especially with newer cements.

Covey et al [19] reported permanent luting cement produced uniaxial retention forces approximately 3 times greater than provisional cement. The increase in surface area provided by a wide abutment did not result in an improvement in retention strength over the standard abutment. Mansour et al [20] reported the retention values of castings cemented to ITI solid abutments and have ranked the retentive ability of luting cements.

Pan et al [18] also reported luting agents designated by the manufacturer as provisional cements demonstrated lower resistance to removal, regardless of material type. Luting agents described by manufacturers as "permanent" differed in resistance, with resin cements being most resistant, followed by zinc phosphate and polycarboxylate cements. Provisional cements demonstrated leakage comparable to higher-strength materials.

The luting cements are categorized into provisional and permanent types based on their longevity, compressive and tensile strength and ability to resist dissolution by the intra oral fluids and precise indication and contra indication for their usage remains unclear. Under function with prolonged time intervals, a few biological and mechanical complications are observed which include peri-implantitis, perforation of the restoration and partial or total chipping of veneering material. These could warrant retrieval of restorations for examination and repair and retreatment. Retrieval of restorations is often accompanied by unexpected chipping of ceramic and damage to the margin of the restoration especially when multiple units and long span prosthesis are involved. In lieu of above mentioned difficulties the clinicians preferred to use provisional luting cements for the same. Provisional cements offer easy handling and retrievability, fairly reduces chair side working time, minimizes patient and clinician discomfort during retrieval procedure and very considerable minimization of expenditure to the patient

as the restoration can be removed without damages and need not be repaired or re-fabricated after the underlying treatment is completed.

Implant supported cemented fixed restoration can be of single crowns and cantilever, short span and long span fixed partial dentures. In implant supported restorations the abutment is metal or ceramic unlike a natural teeth in conventional bridges. The occlusal scheme for implant supported restorations follows the implant protected lingualised occlusal scheme. The role of luting agents for implant supported fixed restorations is purely mechanical unlike chemical adhesion exhibited by glass ionomer cements over natural teeth. Hence there appears to be no marked priority between the provisional and permanent cements used for luting implant restorations. The predominant difference between provisional and permanent luting cements is by virtue of better compressive strength and tensile strength offered by the permanent cements as inferred from this study.

The cementation failure can either be adhesive or cohesive in nature. Adhesive failure can occur at intaglio crown surface and cement interface or adhesive failure between implant abutments and cement interface. In this study the mode of cementation failure was adhesive failure in all the specimens tested. Thermo-cycling was done in this study to simulate the fatigue that occurs in clinical conditions. Implant abutment taper could be another important factor influencing cementation failure. The normal recommended taper is 6° whereas implant abutment has exaggerated taper of 16° to 20° which could alter the retentive ability of luting cements. The data regarding implant abutment taper is very obscurely stated in literature. Another important factor influencing failure is surface preparation in implant abutments. Implant abutments have mechanical grooves, vertical and horizontal provided by manufactures. In additions to these implant abutments can be acid etched and sand blasted to provide more retention. The intaglio preparation of crowns and restorations influence cementation failure. The intaglio surface can be sand blasted, adhesive coupling agents can be used to minimize the adhesive cementation failure.

The ideal requirement of luting cements is that it should be strong enough to retain the restoration and also allow easy removal if required. The commonly used cements in cemented fixed implant restorations were zinc phosphate, glass ionomer and resin cements as permanent cements and zinc oxide and IRM as provisional cements. Zinc phosphate cement tends to reduce loss of retention significantly and also permits reasonable ease during removal. As zinc oxide eugenol cement does not adhere strongly to metallic surface of the implant abutment as compared to zinc polycarboxylate cement, glass- ionomer cement and resin cements it ensures easily retrievability of

restoration when required clinically. Hence it is probable that provisional cement may be considered as permanent cement for implant supported single crown restoration. The clinician should carefully consider the choice of luting cement by evaluating the surface area taper of abutment, degree of abutment, type and nature of luting cements, inter-occlusal spaces and occlusal consideration. Several factors should be carefully evaluated and considered while preferring cement retained restorations. The various factors in this assessment involved number of implants are position, occlusion, cost of pre fabricating a restoration and possible complications. The principle of progressive cementation can also be advocated thereby stronger cements are progressively used until adequate retention is achieved. Furthermore the retrievability of the restoration could be most possibly maintained by implicating modification in the design of the restoration for easy removal without damaging the cement super structure. The luting cement used in such restoration exhibit variability in compressive and tensile strength, varying levels of dissolution in salivary and gingival crevicular fluid, unpredictable soft tissue response and thus contributes a very important role in determining the success of implant therapy.

The highest tensile bond strength was observed for resin cements followed by zinc phosphate, glass ionomer and zinc oxide eugenol respectively in this study. Hence this study offers a guideline for the clinicians to select the choice of luting agents based on their preference and judgment appropriate for the clinical situation. When frequent inspection of peri-implant tissues were deemed necessary the clinicians can prefer zinc oxide eugenol and glass ionomer cements. Glass ionomer offers less tensile strength in implant abutments contrary to the natural teeth abutments. The possible reason could be retention is purely mechanical in implant abutments unlike natural teeth where glass ionomer has additional chemical adhesion. When superior retention is preferred and frequent re-inspection not preferred then the clinicians could choose between resin cements and zinc phosphate cements based on their preference and familiarity with the cements.

CONCLUSION

Within the limitations of this study the following conclusions were drawn. Among the four luting cements tested in this study to lute all ceramic restorations to implant abutments,, the highest tensile bond strength values were observed for resin cements (373 ± 6.68 N) followed by zinc phosphate (222.5 ± 6.498 N), glass ionomer (93 ± 3.28 N) and zinc oxide eugenol (44 ± 2.02 N) respectively, after immersion in artificial saliva and thermo-cycling. A statistically highly significant difference ($p<0.001$) was observed for tensile bond strength between the four group of cements studied and the clinicians could choose the

appropriate cement based on their clinical requirement and judgement of the existing situation.

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