ORIGINAL RESEARCH

Effect of Surface Modifications on the Retention of Implant-supported Cement-retained Crowns with Short Abutments: An *In Vitro* Study

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Abstract

Aim: The study aimed to evaluate and compare the effect of incorporating one circumferential groove and bur modification on retention of cast copings on implant abutment cemented with glass ionomer cement.

Materials and methods: Fifteen straight shoulder implant abutments casted of height 6 mm used with corresponding 12 mm long stainless steel implant analog. The abutments were divided into three groups of five abutments in each group. Group I: Control group, without any surface modification, Group II: Milling of a circumferential groove, and Group III: Bur modification by creating punches of size whole round bur diameter 5 per axial surfaces. Glass ionomer definitive cement was used to adhere the cast copings to each group of abutments. After thermocycling, the specimens were evaluated for retention using the Instron Universal Testing Machine's pull-out test. The data were analyzed using One-way ANOVA, followed by the Tukey *post-hoc* test to compare the load among the three groups.

Results: According to the findings, the inclusion of a circumferential groove (Group II) increased the retention of glass ionomer cement maintained implant-supported crowns by 44.58%. The bur modification (Group III) boosted glass ionomer cement maintained implant-supported crown retention by 110.69% while retaining retrievability. Results were statistically significant.

Conclusion: Bur modification revealed more retention when compared to the groove and control group.

Clinical significance: Short abutments are used in the clinical situation where interarch space is less. To achieve adequate retention of the implant crowns, surface modification of the abutments is necessary while selecting a cement-retained prosthesis.

Keywords: Bur modification, Cement-retained restoration, Circumferential groove, Glass ionomer cement, Implant-supported, Short abutments.

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Introduction

The practice of dental implantology has changed dentistry's outlook and is considered the best treatment option for oral rehabilitation. The osseointegration of the implant and the integrity of the implant prosthesis are critical for the success of implant therapy.[1] Screw-retained, cement-retained, and combined implant restorations are the most common types, each with its own set of benefits and drawbacks.[2]

A screw-retained implant restoration has a well-documented history of successful application. It has excellent marginal integrity, used efficiently in the areas of limited inter arch space and retrievability.[3] However, there are drawbacks, such as increased stress concentration around the implants, which causes lateral and horizontal tipping and elongation forces, resulting in loosening or breakage of the screws, necessitating prosthesis repair or replacement, and an open screw axis hole, which compromises the occlusion and stability of the veneering material. The prosthesis phase is technique-dependent, involving sophisticated clinical and laboratory procedures that could drive up treatment costs.

The cement-retained prosthesis has become a therapy option to circumvent these disadvantages. Compared to screw-retained prostheses, a cemented restoration has several advantages, including equal stress distribution, passive cast, superior occlusion, enhanced aesthetics, economical and less chair-side time, better loading characteristics, minimal risk of component fractures, reduced component complexity, and laboratory procedures.[4]

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The fundamental disadvantage of a cemented prosthesis is its irreversibility,[5] and susceptibility for peri-implantitis due to cement extrusion and seepage, bond failure at the implant-abutment interface, and decreased stability where interocclusal space is limited.[6]

As a result, selecting the right cement for an implant-supported repair is crucial. It is determined by the need for retrievability of the prostheses, the amount of retention required, the ease with which cement can be removed, cost, variability in compressive and tensile strength, unpredictable soft tissue response, and differing levels of dissolution in saliva as well as gingival crevicular fluid.[7–9]

Provisional and permanent luting cements are the two types of luting cement. Provisional cementation is far more suitable for restorations supported by multiple implants because it facilitates easy handling, retrievability, reduces chairside working time, minimizes patient and clinician discomfort during the retrieval procedure, and is cost-effective for the patient because the restoration can be removed without causing damage and does not need to be repaired or refabricated; however, compromised abutment preparation may affect the retention of implant-retained crowns.[10]

Chemical bonding occurs in resin cement, which helps to keep restorations in place. The definitive luting cements, which improve the retention of cement-retained implant-supported restorations, include glass ionomer cement, zinc phosphate cement, zinc polycarboxylate, and resin cement.[8] When more force is required to remove the prosthesis, retentive cement may cause damage to the implant, abutment, and prosthesis.[7] The intaglio surface of the restoration might be treated before cementation to improve bond strength.[8] To strengthen the adhesion capacity between metal and cement, chemical treatments such as silicoating, tin plating, or metal primer application might be used.

For implant-supported fixed restorations luted with provisional cement, the long-term cementation failure rates were 12.66% for single crowns, 5.08% for cantilever crowns, and 10.29% for multiple crowns. When luted with provisional and permanent cement in implant-supported fixed restorations for more than 5 years, there is no difference in the longevity of the restorations.[10]

In cement-retained implant-supported restorations, certain factors like abutment surface modifications, abutment taper, width, height, surface roughness, and retentive grooves are important to gain adequate retention.[11,12]

The abutment's surface morphology can be modified to increase the prosthesis' retention. Mechanical and chemical methods are two types of surface modifications. Mechanical methods include roughening the surface with rotary, grooving circumferentially, and sandblasting. Chemical methods involve etching the surface with 48% sulfuric acid at a temperature of 60° for 1 hour. Surface roughness proved to enhance the retention of a cement-retained crown as much as 31%.[13]

The abutment configuration and height are dictated by the clinical situation and cannot be changed at the clinician's discretion. The type of luting agent utilized and the abutment surface alterations are the parameters that can readily be altered to determine the amount of retention required.

The purpose of this study is to compare and evaluate the effect of implant-abutment surface modifications (circumferential groove, bur modification) on the retention of implant-supported cement-retained crowns with short abutments cemented using glass ionomer cement.

Materials and Methods

The present *in vitro* study was conducted in the Department of Prosthodontics, Sree Sai Dental College and Research Institute, Srikakulam. The pull-out bond strength testing was carried out using a universal testing machine.

The null hypothesis proposed is that the circumferential groove, bur, and sandblasting modification would not affect the retention of the cemented cast coping.

Sample Size and Design

For this *in vitro* study design, 15 straight, narrow-diameter implant abutments (IMPACT) were used with corresponding implant analogs. The abutments were divided into three groups of five abutments in each group, where implant analogs were taken and have been mounted with acrylic resin onto which abutments were placed. Here the sample size was five per group.

Placement of Abutments onto the Implant Analogs

To keep the analogs in place, chemically cured acrylic resin (DPI RR COLD CURE) was poured around them. The abutments were then torque to 25 N cm using a Universal Torque Ratchet and Hex drove. Crowns made of the nickel-chromium alloy were placed on these abutments. Tin platinum foil with a thickness of 0.001 inches was adapted and polished onto the abutment surface as a die spacer. Three 20 × 20 × 20 mm auto polymerizing acrylic blocks with implant abutment attached to the implant analog were prepared (Fig. 1).

Fabrication of Wax Pattern

Wax patterns for copings were made using blue inlay wax, and all samples must be identical. The coping had been given a loop design on the occlusal portion used inlay wax and sprue wax. This occlusal loop helped to hold the cast coping to the Instron Machine Jig.

Investment and Casting

Wax sprues had been attached and invested in phosphate bonded investment (METAVEST). After heating to 950° for wax elimination, copings had been cast in Ni-Cr alloys using a conventional casting technique.

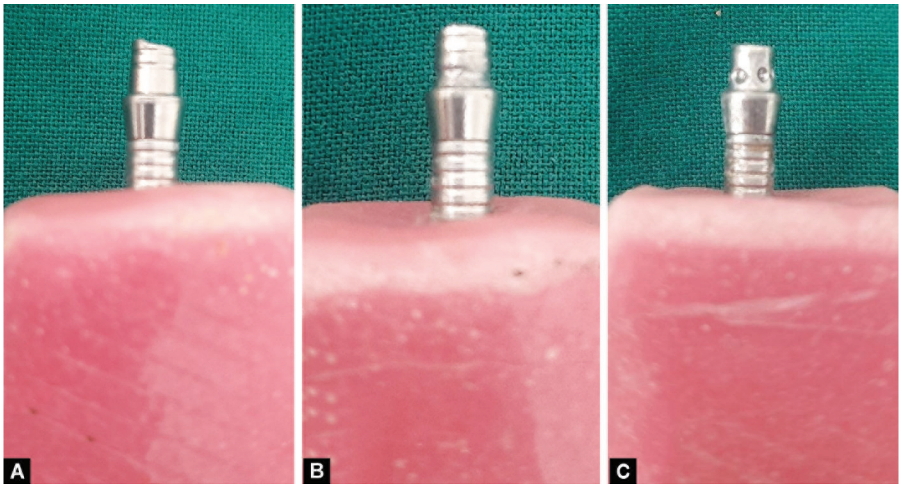
In centrifugal casting, the alloy was melted in a crucible by a torch flame. The mold hydrostatic pressure gradient develops along the length of the casting once the metal fills.

To get a clean casting, castings had been divested from investment and sandblasted with aluminum oxide particles to get a clean casting. All casted copings were trimmed and inspected for accuracy and fit.

Fit of Metal Copings

Fit-checker disclosing media was used to evaluate the fit of metal copings. When applying finger pressure vertically to the crown, stability was determined to have been acceptable if no rotational movement was seen.

Fig. 1: Implant analog embedded in acrylic block



Figs 2A to C: Sample groups (A) Group I—control group; (B) Group II—circumferential groove modification; and (C) Group III—bur modification

Surface Treatments

Specimens were divided into three equal groups with a metal loop attached to them. Three different types of surface treatments include:

- **Group I:** Control group, without any surface modification (Fig. 2A).
- **Group II:** Milling of a circumferential groove of 0.5 mm wide and 0.4 mm deep (Fig. 2B) was placed on the abutment surface, which was later roughened by sandblasting with 110-µm aluminum oxide particles pressure of 0.2 MPa for 20 seconds. The abutments were cleaned in water and dried with compressed air before initial testing.
- **Group III:** Bur modification (Fig. 2C) was achieved by punching five axial surfaces of abutments with full round bur diameter and then sandblasting with 110-µm aluminum oxide particles at a pressure of 0.2 MPa for 20 seconds. The abutments were cleaned in water and dried with compressed air before initial testing.

Cementation of Crowns

Glass ionomer cement (Ivoclar Vivadent) was used to cement the cast copings to each group of abutments. Cement was mixed according to the manufacturer's directions and applied to the cervical margin of the inner surface of the copings in a thin, 3 mm wide layer.

After 30 seconds of mixing, each coping was seated on the abutment, and a static load of 50 N was applied for 10 minutes. The extra cement was removed using a plastic curette once it had been set. The cementing process was carried out at a temperature of 23 ± 1°C. Specimens were kept at 37°C for 1 hour in 100% humidity and then thermocycled 500 times between 5 and 55°C with a dwell time of 10 seconds before being kept in 100% humidity for 6 days.

Measurement of Retentive Strength

The specimens were subsequently assembled in the INSTRON universal testing machine and pulled out at a crosshead speed of 0.5 mm/minute until the metal coping debonded from the abutment (Fig. 3). In Newton, the tensile bond strength of polymer-based cement was measured. The retentive strength of all frameworks was assessed in the same way.

Fig. 3: Instron universal testing machine with sample (pull out test)

Statistical Analysis

The following statistical procedures were carried out:

The data were collected in a Microsoft Excel 2013 spreadsheet systematically, and a master table was created. The data set was segmented and distributed in an appropriate manner. The data were proofread before being presented in graphs and tables.

The Statistical Package for Social Sciences (SPSS) software was used to conduct the statistical analysis (SPSS version 19). The statistical significance of the acquired results was determined by applying appropriate statistical tests to the data.

The one-way analysis of variance (ANOVA) and Tukey honestly significant difference (HSD) tests were used to assess the data statistically.

The one-way analysis of variance test (ANOVA) was used to analyze the data, followed by the Tukey *post hoc* Test for multiple comparisons.

The one-way analysis of variance (ANOVA) is performed to see if the means of two or more independent (unrelated) groups differ significantly. With the addition of bur modification, the load gradually increased. There was a significant discrepancy between the two groups.

Results

Mean values of the maximum load were determined for all the three groups along with their standard deviations using descriptive statistics (Table 1).

Table 1: Mean values of maximum load across the three groups

Group	*Sample size (n = 15)*	*Mean ± SD*
I	5	66.12 ± 6.205
II	5	66.88 ± 7.694
III	5	166.04 ± 11.247

A total of 15 crowns were included for the experimental analysis. Table 1 represents the mean values of maximum loads across the three groups. Five crowns were cemented on the control group abutments, while another five crowns were cemented on the circumferential groove modification abutments, and the rest five crowns onto the bur modification abutments.

Tensile bond strength values ranged between 66.12 ± 6.205 for the control group (Group I) and 166.04 ± 11.247 for the bur modification group (Group III). Significant statistical differences in tensile bond strength were concluded between different surface modifications and the control group. The bur modification (Group III) displayed the highest tensile bond strength with a statistically significant difference of 99.16 ± 3.67 when compared to circumferential groove modification (Group II) (p <0.001) and 99.12 ± 5.75 when compared to the control group (Group I) (p <0.001). On the contrary, the control group (Group I) had the least tensile bond strength mean among the three groups (p <0.001) and performed statistically significant differences with the bur modification group (Group III). No statistically significant difference was observed between the control group (Group I) and the circumferential groove modification (Group II) concerning their maximum load values.

Table 2 represents the comparative mean of maximum loads across the three study groups. There was a significant difference between the three groups of which surface modification was done for the retentive strength [$F(2, 12) = 221.245$, $p = 0.001$]. The Tukey *post-hoc* test revealed that the maximum retentive force was statistically higher for Group III (166.00 ± 11.247, p <0.001), followed by Group II (66.80 ± 7.694, p <0.001) as compared to the control group (66.00 ± 6.205, p <0.001). Thus it was seen that maximum retentive force for Group III.

Thus it was seen that maximum retentive force for Group III (166.00 N), i.e., almost two times when compared to the control group (66.00 N).

Among all, Group III (bur modification) showed the highest retentive force.

Table 2: Comparison of mean values of maximum load across the three groups

	Sum of squares	*Degree of freedom (df)*	*Mean square*	*F*	*p*
Between groups	33022.105	2	16511.0525		
Within groups	920.570	12	76.71416	221.245	0.001*
Total	33942.675	14			

*p value shows highly statistically significant difference using one-way ANOVA test (p <0.001)

Discussion

Dental implants are an excellent treatment option to restore the missing teeth in a functionally important or aesthetic zone. The two therapeutic options that are available for implants are either screw-retained restorations or cement-retained restorations. The screw-retained restorations have merits, such as ease of retrievability, lack of cement, or cement-induced complications. With the introduction of cement-retained implant restorations, there has been an increase in cement-retained prostheses. Some studies report that less than 10% of implant restorations were screw-retained in general practice restorations, moving away from the screw-retained alternative.[14] Porcelain fracture, screw loosening, loss of the prosthesis, aesthetics, and lab costs are the disadvantages of screw-retained when compared to the cement-retained restorations.[15,16] Cement-retained prosthesis, on the other hand, have benefits such as superior occlusion, aesthetics, passivity, low porcelain fracture due to the lack of a screw accessible hole, comfort in the posterior region, and loading characteristics.[17] Saleh Saber et al. concluded in their study that minimum height of the abutment leads to lack of retention for an implant-supported cement-retained restoration.[18]

Some aspects of implant dentistry, such as the abutment height and implant configuration, cannot be changed by a clinician and must be determined based on the clinical situation, whereas the alloy used for the prosthesis, the type of cement used, and the surface modifications of the abutment can all be easily changed to improve retention.[19,20]

To improve retention, many procedures are available to modify the surface of short abutments. The addition of circumferential grooves, sandblasting, bur modification, and alloy primers is easily available on the chairside.[9] Sandblasting generates roughness on the abutment surface, increasing surface area and mechanically removing debris, boosting cement bond strength. Circumferential grooves lengthen the fracture line, generating a local lock, and have also been shown to improve retention.[1]

Hence the alloys used for manufacturing the prosthesis, the presence of bur modification on the abutment, and the extension of cement into the punches created by round bur delayed the crack propagation and increased the retention of coping cemented to short abutments when compared to abutments without any surface modification.

This property can be utilized in areas of limited occlusal space where short abutments are required. Even though adding a circumferential groove in abutments and sandblasting with 110-µm aluminum oxide showed increased retention of coping cemented to short abutments compared to the control group; this was less retentive compared to copings on abutments with bur modification, luted with glass ionomer cement.

When luted with temporary cement, there may be a chance of repeated dislodgement of the prosthesis. Choice of cement is important but keeping the retrievability of the cement-retained crowns in mind, semi-permanent cement can be used which would not compromise the retention.[9] Glass ionomer cement is chosen in this study because of its good retention, acceptable strength, working time, and biological features. Even when mixed in large quantities, it is simple to handle.

The effects of standard machined, sandblasted, and grooved implant abutments on the retentive strength of cemented complete crowns were compared in a study by de Campos et al. According to the study, the sandblasted and grooved surface groups had 2.4 times stronger mean uniaxial retentive strength than the machined surface group.[21]

Surface treatment, height, and airborne abrasion, according to Cano-Batalla et al., are different parameters in enhancing retention that varies depending on the patient's needs. After airborne-particle abrasion, a maximum increase of 90 N in retention force was reported for the 5 mm abutments cemented with acrylic urethane cement, according to the study. Significant differences between 4- and 6-mm abutments were also discovered, with the 6-mm abutments being more retentive. In this investigation, 6 mm abutments were employed to offer maximal retention with a reduction in typical abutment height, and sandblasting improved retention for these abutments.[22]

The studies conducted by Keum et al.[23] on 40 implant fixture analogs and abutments airborne particle abrasion technique have increased the retention of the provisional cement as well as definitive cement-retained prostheses, while the studies done by Sahu et al. proved that there is an increase in retention of abutments with the milled and sandblasted surface with 110-μm aluminum oxide achieve the maximum retention followed by abutments with retentive grooves and then by abutments with a milled surface when cast copings were cemented to implant abutments with polymer-based cement. The present study shows that as the above studies have mentioned the relevance of sandblasting has increased the retention of the provisional and resin cement.

According to Nejatidanesh et al., research on the retentiveness of implant-supported metal copings utilizing various luting agents, Fuji Plus, and TempSpan had the highest and the least retentive strength, respectively (320.97 ± 161.47, 3.39 ± 2.33). There was no significant difference between Fuji Plus, Fleck's, Ploy F, and Panavia F2.0. These cements were superior to all the other provisional cements and Fuji I which showed statistically the same retentive strength.[24]

The bond strength of the abutment might varies greatly depending on the type of cement used and the abutment's surface modification. The level of resistance to dynamic lateral loading increased by sandblasting varies depending on the cement employed.[12]

Modifications are made to allow retrieval when necessary, while also ensuring sufficient retention during function and preventing frequent dislodgement from the abutment. Modifications can be made on the clinical side solely, requiring no additional laboratory work and being cost-effective for patients.

The results of this investigation showed that roughening the abutment surface with a diamond bur improves the retention of metal copings on titanium abutments. This is extremely useful in clinics because physicians require a technology that allows them to cement crowns on titanium abutments with long-term stability. Because many different investigations employed expensive procedures for it, we focused on mechanical modifications rather than chemical adjustments or different cement varieties in this study. The major purpose is to give people almost identical services at no additional cost.

Depending on the need for retrievability and the amount of retention required, the types of cement and modifications in the abutment can be individualized for each patient. Reviewing all the studies, circumferential groove modification and bur modification on the short abutments were chosen, and the metal copings were cemented using glass ionomer cement. Upon testing the pull-out bond strength using the universal testing machine, it was noted that the bur modification group is more retentive when compared to the groove and control group. This study shows that the bur modification (Group III) increased the retention of glass ionomer cement retained implant-supported crown by 110.69% while maintaining retrievability compared to the control group (44.08%).

Limitations of the Study

The abutment surface modifications were done using disc and round bur and made standardized for this study. The variations in the standardization might be attributed to the difference in the retention of cement-retained crowns. Additionally, the use of different cements results in different retention values. The studies in the future should be directed to analyze the long-term retention of various cements and also on different abutment surface modifications.

Conclusion

Within the limitations of this study, the following conclusions are drawn, i.e., surface modification of short abutments by addition of circumferential groove and bur modification increased the retention of the glass ionomer cemented abutment to coping. The addition of bur modification and abutment surface air abrasion with 110-μm aluminum oxide particles increased the retention of glass ionomer cement retained implant-supported crown by 110.69%. In extremely demanding clinical situations where the only short implant is the only choice, the combination of bur modification and surface air abrasion gives excellent retention with glass ionomer cement.

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