Resistance to dislodgement of zirconia copings cemented onto titanium abutments of different heights

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Statement of problem. For patients with limited interocclusal space, standard height implant abutments may not be usable. Shorter abutments may be desirable.

Purpose. The purpose of this study was to determine the effect of the height of titanium abutments on the tensile strength required to dislodge zirconia copings.

Material and methods. Two experimental groups of abutments were prepared: (1) 4.3-mm platform width implant abutment with a 6.5-mm height (control), and (2) a 4.3-mm platform width implant abutment with a 5.5-mm height (shorter). Each abutment had 5 zirconia copings (custom designed) fabricated through a 3-dimensional computer-assisted design (3-D CAD) process by scanning an identical wax pattern. The zirconia copings were designed to have a 6-mm projection above the titanium abutment to accommodate a 2-mm hole. A wire was inserted through this hole to attach the zirconia coping to a universal testing machine. Each abutment was placed onto an implant embedded in a brass base designed to fit onto the universal testing machine. The zirconia copings were cemented onto the abutments with a provisional luting agent (Improv), and a tensile force was applied at a crosshead speed of 0.5 mm/min. The removal force was recorded for each specimen. An unpaired *t* test was used for the statistical analysis (α=.05).

Results. The mean force (SD) necessary to remove the zirconia copings (Newtons) from the 6.5-mm titanium abutment (198.09 (28.83)) was higher (*P*=.0078) than for the 5.5-mm abutment (124.89 (36.388)).

Conclusions. By increasing the height of the abutment 1 mm and maintaining the diameter of the abutment, the resistance to tensile forces increased significantly between the 2 abutment dimensions evaluated. (J Prosthet Dent 2008;99:25-29)

Clinical Implications

For patients with reduced interocclusal space, the use of shorter abutments may decrease the retention of a cemented prosthesis. Careful presurgical planning through the use of diagnostic articulation and assessment of interocclusal space will lessen the need for shorter abutments and reduced retention.

The options for restoring edentulous areas have changed dramatically with the introduction of endosseous dental implants. Clinical decisions are not limited to the selection of the type of implant; there is also the need to choose the type of abutment (prefabricated or custom) and the type of cement.[1-3] Custom abutments made from several materials may be fabricated with computer-aided design/computer-aided manufacturing (CAD/CAM) systems, enabling the clinician to fabricate individualized implant components with the desired height, width, contour, and support to the adjacent tissue, thereby mimicking the properties of natural

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teeth.[4,5]

Over the years, those engaged in restoring implant-supported restorations have debated which type of retention mechanism is preferable. At present, the controversy remains as to whether to retain restorations connected to dental implants with cement or with screws. The retrieval of restorations covering the implant abutments is essential for the maintenance of the implants and repair of the prosthesis if complications occur.[6] There are many factors that can influence the amount of retention that can be achieved when luting a restoration to either an abutment or a natural tooth.[7] Factors affecting implant-supported restorations are similar to those affecting the luting of crowns to natural teeth, and include taper, height, width of the abutments, and the type of luting agent.

Covey et al[8] compared the effect of abutment dimensions and the type of luting agent on the retention of crowns. In that study, the specimens consisted of standard, wide, and experimental abutments, as well as 2 different luting agents: zinc phosphate definitive and zinc oxide eugenol provisional cement. Razzoog et al[9] fabricated 4 titanium abutments with different heights and taper using a CAD/CAM system (Procera; Nobel Biocare AB, Goteborg, Sweden). The abutments evaluated were 4 mm high with a 4-degree taper, 4 mm high with an 8-degree taper, 8 mm high with a 4-degree taper, and 8 mm high with an 8-degree taper. All aluminum oxide copings were luted onto the abutments using provisional cement (TempBond; Kerr, Romulus, Mich). The results showed that the least retentive abutment was the 4 mm with the 8-degree taper, while the most retentive abutments were 8 mm with the 4-degree taper. Michalakis et al[10] studied the difficulty in retrievability of the cement-retained implant-supported fixed partial dentures. The authors measured the retentive strength of noneugenol containing luting cements, Improv (Scientific Pharmaceuticals, Inc, Ponoma, Calif for Alvelogro Inc, Union, Wash), TempBond (Kerr), and TempBond NE (Kerr). The evaluation consisted of determining the failure loads of these 3 provisional luting agents on a fixed partial denture supported by 2 or 4 implants. The results showed that the cement that proved the most retentive was the provisional luting agent, Improv.

All-ceramic crowns are rapidly expanding in use as single- and multiple-unit prostheses and, while there are several ceramic substructure materials available, zirconia is arguably the most popular. The popularity of zirconia is generally attributed to its increased strength over other ceramic options.[11-13] A literature search revealed no studies of the retention of zirconia copings cemented onto titanium abutments. These ceramic crowns, when coupled with implants, may be cemented over either zirconia-based abutments or titanium abutments. The opaque nature of zirconia covers and masks the underlying metal color of the abutment, while still providing much of the enhanced esthetics attributed to all-ceramic restorations.[14,15]

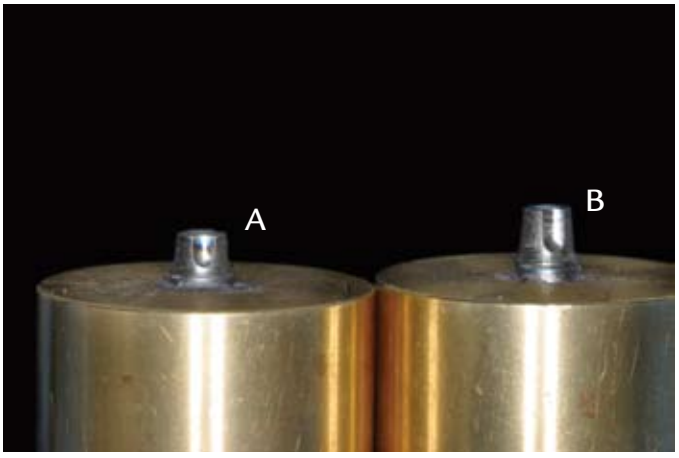
The objective of this study was to determine the effect of the height of a titanium abutment on the force required to dislodge a luted zirconia coping. The null hypothesis was that there would be no difference in removal force between the shorter (5.5 mm) and standard (6.5 mm) implant abutments with luted ceramic copings when using regular implant platforms.

MATERIAL AND METHODS

To determine the effect of height on the removal force of copings luted to implant abutments, 2 identically designed titanium abutments (Nobel Biocare AB) of different heights were fabricated (Fig. 1). Each abutment then had identical zirconia copings fabricated through the CAD/CAM process as described by Covey et al.[8]

The process of fabricating the zirconia copings consisted of waxing the coping form to full contour on the titanium abutment. Each coping was designed in a wax pattern to accommodate for a mechanism to attach it to the testing device. The copings required a height of 6 mm of zirconia above the abutment height to provide enough space to drill a hole with a #6 diamond rotary cutting instrument (018; Brasseler USA, Savannah, Ga).

After completion of the coping wax pattern, the abutments were scanned with a touch-probe scanner (Procera Piccolo; Nobel Biocare AB). The center of the abutment was centered on the scanning stage, and the abutment was digitized. The coping pattern was then placed onto the abutment and fixed with wax (Sticky Wax; Kerr) so that the wax pattern would not move during the scanning process. Then the

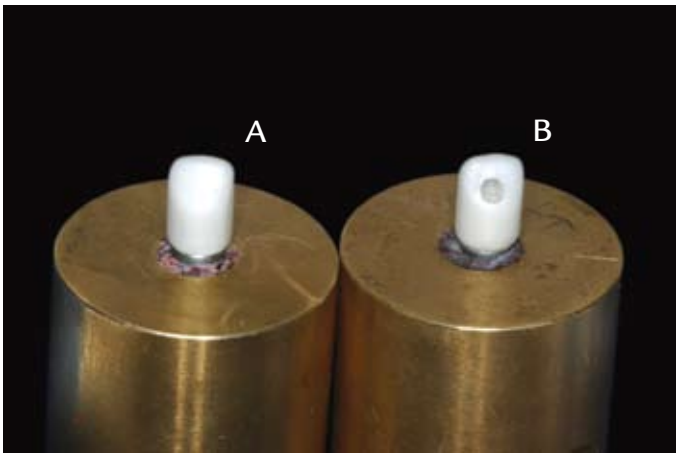


1 Titanium abutments. A, Shorter. B, Standard height embedded in base.

scanner was used to digitize the outer surface of the wax pattern. The abutment file and the coping wax pattern file were merged, and the delineation of the finish line was completed. All scanned data were sent, via Internet, to a Nobel Biocare production facility in Stockholm, Sweden, for fabrication of the test specimens. The zirconia copings were returned and placed onto the abutments prior to cementation (Fig. 2, A).

A hole was drilled in the 6-mm projection of the abutments to a diameter of 2 mm (Fig. 2, B) using a #6 round rotary cutting instrument (018; Brasseler USA) with copious water irrigation. The hole allowed for a wire to be used as an attachment from the zirconia coping to the universal testing machine (Series 5500, model #0122143910311; Instron Corp, Norwood, Mass), which exerted the tensile forces to separate the zirconia copings from the abutments during the testing procedure.

The titanium abutments (n=2) and zirconia copings (2 sets, n=5) previously fabricated had each of the bases and zirconia copings labeled according to its respective abutment: (1) 4.3 mm in diameter, standard height of 6.5 mm, and (2) 4.3 mm in diameter, shorter height of 5.5 mm. To hold the abutment/coping structure in the universal testing machine, implants were secured into 2 brass bases machined with identical dimensions, 1 for each of the implant replicas. The bases were designed to accommodate the lower component of the universal testing machine (Instron Corp). A hole was drilled into each of the bases to enable the engagement of the implant replicas. Each base was then mounted onto the universal testing machine and secured, using a cylindrical bar that passed through the brass base and the lower compartment of the machine. The implant replicas were connected to the upper member of the universal testing machine, using autopolymerizing acrylic resin (COE-Tray; GC America, Alsip, Ill) mixed according to the manufacturer's recommendation and poured into the hole of the base. Using the universal testing machine as a positioning device, the implant replica was lowered until it reached a level just below the implant platform and was embedded into the acrylic resin, ensuring that the replica was placed into the base at the same angulations. The replica was then released and made ready for the placement of the abutment. This procedure was repeated for each of the bases. Each base became the receptacle for 1 abutment. Both abutments were joined to the implant replicas using a supplied titanium screw (Nobel Biocare AB). The 2 abutment screws were torqued with a force of 32 Ncm, and the access opening of each of the abutments was filled with gutta-percha (Kerr). Each of the bases and zirconia copings was labeled according to the abutment received, and a new screw was used for each testing procedure. The custom zirconia copings were cemented onto the 2 different abutments, using a provisional luting cement (Improv; Alvelogro Inc). Improv was selected as the provisional cement to facilitate retrievability of the implant-supported fixed implant restorations[16] and because, with Improv, leakage is comparable to higher strength materials.[17]



2 A, Zirconia coping. B, Zirconia coping with 2-mm access hole.

The cement was mixed following the manufacturer's instructions and applied to the intaglio surface of the zirconia copings with a sponge applicator (Dungarvan Co, Grafton, Wis). Cementation of the copings simulated the clinical setting as much as possible by painting cement on the intaglio surface of each coping. Individual copings were seated on the abutments with firm finger pressure until hydraulic pressure was relieved, which, according to the manufacturer, was 5 minutes. A standardized force was not used in the study because when copings are cemented intraorally, the clinician generally uses finger pressure or occlusal force to accomplish the procedure. The excess cement was removed with a curette. After cementation, specimens were stored at 100% humidity for 24 hours prior to testing.

The copings were connected to the upper member of the universal testing machine by threading a 50-pound braided wire (Sealon Sevestrans Tackle Corp, Long Beach, Calif) through the hole drilled at the top of each coping. The wire was attached to a metal holder, which was also connected to the upper member of the testing machine and secured tightly in place. The abutment and the implant replicas were connected to the lower member of the testing machine by the base, which was fitted into place by a steel cylinder. The upper member of the testing machine was raised manually until initial tension was achieved on the wire. The retention of the zirconia coping was measured by applying

a tensile force sufficient to dislodge the coping from the abutment, using a tensile or pull load, with a crosshead speed of 0.5 mm/min. The removal force was applied in the long axis of the specimens, and the force in Newtons required to remove the copings was recorded.

After each testing period, the cement on the inner surface of the coping was removed using provisional cement remover (Henry Schein Inc, Melville, NY and L&R Manufacturing Co, Kearny, NJ), and any remnant on the abutments was also removed. A new set of screws replaced those used in the previous test. The next set of copings was cemented onto the abutments in the manner previously described, and the test was repeated with each of the 5 copings made for each abutment. Data were analyzed using an unpaired *t* test for tensile bond strength in Newtons (α=.05).

RESULTS

The mean tensile bond strength values (SD) or the force required to dislodge the coping from the abutment after cementation with a provisional cement for the standard and shorter abutments were 189.01 (28.9) N and 124.9 (36.4) N, respectively. The result of the unpaired *t* test with the abutment height of 5.5 mm and standard height of 6.5 mm as the grouping variable demonstrated a mean difference of -73.2 (df = 8; t value =-3.5; P<.001). The zirconia coping cemented onto the standard size abutments required a significantly (P<.001) higher force for dislodgement than that of the shorter abutments.

DISCUSSION

The null hypothesis, that there would be no difference in force required for removal between shorter (5.5 mm) and standard (6.5 mm) implant abutments with luted zirconia copings when using regular implant platforms, was rejected. This does not imply that shorter abutments are not appropriate for cemented restorations; rather, that at some level, the abutment height may become an issue if using provisional cement. Presurgical planning has always been recognized as important to the eventual success of implant restorative options. If the clinician and patient anticipate a cemented restoration, both the abutment height and implant angulation must be considered.

As treatment options and materials change, the basis on which those selections are made should also evolve. Most conventional wisdom regarding resistance form and retention of a dental prosthesis is based upon tooth preparations and cements no longer widely used in dental practices. Resistance form of a dental implant abutment is the shape given to it which is intended to afford a relationship with the restoration that will best enable it to withstand the stress brought upon it during the process of mastication. The retention form of a dental implant abutment is the provision in design intended to prevent the cemented restoration from being dislodged. Implant abutments are often formed with CAD/CAM technology and have little of the classic resistance form used for tooth preparations. The abutments are made from titanium or zirconia, which in no way mimics the natural prepared tooth, and are increasingly restored with CAD/CAM zirconia copings veneered with dental porcelain. The nature of CAD/CAM copings is that they are fabricated for a "passive fit". No undercuts are tolerated by the process, and an algorithm within the software provides for a cement space. Thus, the only contact the coping has when seated is at the margin of the die, abutment, or tooth.[9] Combine the material differences, the design differences, and the fabrication differences of the implant prostheses with the long-term use of provisional cements, and it is not surprising that clinicians would be confused about the best course of treatment for a patient. Some clinicians believe that the retrieval of restorations attached to implant abutments is essential for the maintenance of the implants and repair of the prosthesis if complications do occur. Johansson,[6] in a 9-year follow-up study, demonstrated that 22% of included patients had some type of complication ranging from screw fractures to framework fracture. Maintenance demands and office chair time for the situations Johansson reported depended upon the type of complication. Complications from the prostheses averaged 0.64 hours per prosthesis, per year for the clinician, and 1.0 hour per year for the dental laboratory technician. When the clinician places copings over teeth, increasing the retention is beneficial. However, when managing implant-supported restorations, increasing the retention may not always be convenient. The limitations of this study relate to the type of cement used, the material of the abutment, the internal surface and material of the coping, and the luting surface area of the abutment. All of these factors have been implicated in the retention of copings on natural teeth and may also impact retention on implant abutments.

The current in vitro study evaluated the effect of the titanium abutment height on the resistance of removal of zirconia copings under ideal laboratory conditions. The test used is only an indication of what the clinician may experience in clinical practice. No single in vitro test provides an accurate indication of the intraoral environment. A specific abutment taper, coping design, and luting environment were used, and the results are valid for these materials only. Caution must be used when generalizing the results directly to the clinical situation. Factors such as setting force, fluid on the abutment, and timing of insertion of the restoration after placing the cement were not evaluated. There was also no attempt to determine what effect long-term use of a restoration in the oral environment would have on the resistance to removal. Although finger pressure is

used clinically to cement restorations, the force used to seat the restorations was not standardized in this study.

Future studies should include other cement types, including provisional and definitive cements. Of interest would also be the wide variety of coping surfaces, which would influence the mechanical retention of the eventual coping. Cyclic loading and thermal cycling of the restorations prior to testing may also contribute to understanding how new dental materials should be used in the clinical setting. In this study, the coping margin followed a rather circular path with little variation in the height as would normally occur in the clinical setting. An actual measurement of the surface area provided for the luting of the coping may supply additional information as to when a cemented restoration must be replaced for a screw-retained restoration.

CONCLUSIONS

Within the limitations of this study, the height of the abutment tested significantly increased the resistance to removal of the zirconia coping.

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