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ZIRCONIA CROWN RETENTION ON CONVENTIONAL VERSUS SCREW CHANNEL CORRECTING ABUTMENTS

by

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DISCLAIMER

ABSTRACT

Zirconia Crown Retention On Conventional Versus Screw Channel Correcting Abutments

Angel J. Calvo, DMD, 2022

Directed by: Jeffrey J. Kim, DDS, PhD
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Introduction: Computer-aided design and Computer-aided manufacturing (CAD/CAM) systems are used to design and fabricate ceramic restorations. A common workflow to restore dental implants is cementing a monolithic zirconia crown to a prefabricated titanium abutment. Depending on the position of the implant, a conventional or screw channel correcting abutment can be utilized. Screw channel correcting abutments exhibit a design feature that introduces a window along the axial surface, reducing the abutment's surface area, and possibly compromising crown retention.

Objective: The purpose of this study is to evaluate and compare retention of monolithic zirconia copings designed using CAD/CAM software and cemented on either conventional or screw channel correcting abutments when subjected to pull out testing.

Methods: 20 screw retained titanium alloy surface-treated pre-market abutments; 10 screw channel correcting and 10 conventional were attached to implant analogs and torqued to 35 Ncm. Twenty zirconia copings were digitally designed and milled from pre-sintered yttrium-stabilized zirconium oxide disks. The copings were bonded to their respective Ti-bases with dual cured resin cement and subjected to pull out testing at a cross-head speed of 1mm/min with a universal testing system. A two-sample t-test was conducted to compare the mean Peak Loads (N) of conventional and screw channel correcting abutments.

Results: There was significant difference in Peak Loads with the conventional abutments have higher peak loads (Mean (M) = 704.6, Standard Deviation (SD) =115.9) than screw channel correcting abutments (M = 510.0, SD =173.9); p = .008).

Conclusions: Zirconia Crowns bonded with dual cure resin cement to conventional titanium abutments showed statistically higher retention than screw channel correcting abutments of the same height.

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LIST OF ABBREVIATONS

Abbreviation	**Term**
µm	microns
Al	Aluminum
C	Celsius
CAD	Computer-aided design
CAM	computer-aided manufacturing
Co	Cobalt
Cr	Chromium
DMA	N,N-dimethylacrylamide
GT	Gradient technology
Gpa	Gigapascal
HEMA	Hydroxyethyl methacrylate
M	Mean
mm	millimeters
MDP	10-Methacryloyloxydecyl dihydrogen phosphate
Mpa	Megapascal
N	Newton
Ncm	Newton Centimeter
3Y-PSZ	3-yttria partially stabilized zirconia
4Y-PSZ	4-yttria partially stabilized zirconia
5Y-PSZ	5-yttria partially stabilized zirconia

SD	Standard Deviation
STL	Standard Tessellation Language
RMGI	Resin-modified glass ionomer
Ti	Titanium

CHAPTER 1: Introduction

Several computer-aided design and computer-aided manufacturing (CAD/CAM) software and milling systems have been developed to design and fabricate ceramic restorations for natural teeth and dental implants.[1,2] Monolithic all ceramic materials have been extensively investigated with regards to marginal fit, esthetics, fracture strength, cement type and cementation protocol.[2] Different types of digitally designed monolithic restorations have been bonded to titanium bases and customized titanium abutments with different surface pretreatments.[3,4] One of the more commonly studied monolithic ceramic materials is zirconium dioxide (zirconia) which has demonstrated high fracture strength values when bonded to a titanium abutment for implant restorations.[5,6]

Zirconium dioxide is distinguished from other dental ceramics due to a unique phenomenon referred to as transformation toughening. When heated, three forms in its pure state have been identified: monoclinic (heating up to 1170 C), tetragonal (1170-2370 C) and cubic (above 2370 C up to melting point).[7,8] As a result of this temperature-dependent phase transformation process, zirconium ceramics exhibit a flexural strength of 900-1200 Mpa, compressive strength of 2000 Mpa, and a fracture toughness of 6 Gpa.[5] The polycrystalline structure of zirconia has less glass content, resulting in a less esthetic restoration with less translucency when compared to ceramics with higher glass content. [7] A more translucent zirconia was introduced to improve esthetics, 5-yttria partially stabilized zirconia (5Y-PSZ), which contains more cubic phase. In a study performed by

Alraheam and colleagues, the more conventional 3Y-PSZ has been shown to be more durable than 5Y-PSZ when exposed to fatigue testing and thermocycling.[8]

Zirconia abutments with a titanium base have been shown to be stronger than all-zirconia abutments.[5] The back taper design of the zirconia coping on the titanium base versus a shoulder or a chamfer has been found to be significantly more stable in resisting fracture between the zirconia and the titanium base.[9] The cementation protocol and type of cement used are important factors as well.[4,10] The highest retention was found to be with N,N-dimethylacrylamide/2-hydroxyethyl methacrylate (DMA/HEMA) based cements for luting implant abutments to titanium bases.[11] Mehl et al. studied the effects of cement film thicknesses (15, 50, 80 or 110 microns (μm)) and cement type on crown retention. They concluded that both cement film thickness and choice of cement are major contributors to the retentive strength of cement retained implant crowns, with 15 micron film thickness with a resin cement exhibiting the highest retentive strength.[12]

CAD/CAM technology can provide more accurate superstructures than those fabricated conventionally.[13] Marginal fit of zirconium dioxide copings with a chamfer margin have been reported to have mean values of 18.45 microns, which is well below the clinically acceptable threshold of 120 μm.[14,15] One important factor is the clinician's knowledge and familiarity with the software, as shown by Keunbada and colleagues in which they found that learning curves may differ according to the type of dental CAD software.[16,17] Abbo and colleagues found that when designing zirconia copings on titanium abutments, the resistance to tensile and dislodging forces improved with a 1 mm height increase while maintaining the same diameter.[18]

A study performed by Castillo-Oyague, et al. found no correlation between vertical marginal discrepancy or microleakage of implant supported crowns performed by laser sintering on cobalt-chromium (Co-Cr.)[19] At the same time, despite the framework alloy and manufacturing technique, resin-modified glass ionomer (RMGI) and acrylic urethane based cements provided better fit and less marginal leakage when compared to self-adhesive dual cure resin cements.[19] In another study, the marginal adaptation of all ceramic crown systems on implant abutments varied by the type of crown and cementation technique. Manually veneered zirconia demonstrated more favorable marginal fit on both titanium and zirconia implant abutments before and after cementation when compared to veneered and CAD/CAM fabricated lithium disilicate, but marginal discrepancies increased after cementation for all abutment/crown combinations. [20]

The objective of this study is to evaluate and compare the performance of monolithic zirconia copings from pre-sintered yttrium-stabilized zirconium disks designed using exocad CAD/CAM software (GmbH, Darmstadt, Germany) and cemented on either screw channel correcting Ti Base S-link or conventional L-Link Ti Base abutments (Mist, Seoul, South Korea) when subjected to pull out testing. The null hypothesis is that monolithic zirconia crowns made of a gradient (GT) material that combines 3Y-PSZ and 5Y-PSZ (IPS Emax, ZirCAD Prime, Ivoclar Vivadent, Schaan, Liechtenstein) cemented to S-Link and L-Link titanium bases will perform similar when subjected to pull-out retention testing with an MTS Insight electromechanical testing system (MTS Systems Corporation, Eden Prairie, MN).

CHAPTER 2: Materials and Methods

In the present study, 20 titanium alloy (Ti 6Al 4V) TiN surface-treated pre-market abutments; 10 screw channel correcting, 4.0 mm height (S-Link, Mist, Seoul, South Korea) and 10 conventional, 5.5 mm height (L-Link, Mist, Seoul, South Korea) were utilized (Fig. 1). Each L-link Ti Base was cut to 4 mm height and verified with a digital caliper. Each screw-retained abutment was attached to a 4.3 mm implant analog (Nobel Replace, Nobel Biocare, Gothenburg, Sweden) with 35 Ncm torque using a manual torque adapter prosthetic (Nobel Replace, Nobel Biocare, Gothenburg, Sweden). Implant-supported, cement-retained zirconia copings were designed using exocad (exocad GmbH, Darmstadt, Germany) after a model scanner (Freedom HD, DOF, Seoul, South Korea) was utilized to scan a scan body (Mist, Seoul, South Korea) with the corresponding abutment. A crown was designed with the intaglio surface that matches the L-link Ti base and another matching the S-link Ti base. The Standard Tessellation Language (STL) files of each crown were transferred to another CAD open software (Meshmixer) to modify the occlusal portion into a V shape in order to precisely fit in a custom printed titanium jig for testing (Fig. 2). Once the STL models were created from the coping design, they were be transferred to a CAM software (hyperDENT, Imagine Milling technologies, Chantilly, Virginia, USA) where their positions were arranged into two 98.5x20 mm A3 multilayered pre-sintered yttrium-stabilized zirconium oxide disks (IPS e.max ZirCAD Prime, Ivoclar Vivadent, Schaan, Liechtenstein). A computer-aided manufacturing 5-axis dry milling unit (CORiTEC350i, imes-i-core GmbH, Eiterfeld, Germany) was utilized to mill 20 zirconia copings from the two respective disks. To achieve the desired cement film thicknesses of 27 microns as specified in the CAD software, the internal surfaces of the copings were machined using high performance hard metal burs (T13, T14, and T15: imes-i-core, CORiTEC, Las Vegas, United States) capable of milling zirconium to precisely mirror the corresponding abutment shape. Once the copings were milled and de-sprued they were placed in a lightweight sintering furnace (Programat S1 1600, Ivoclar Vivadent, Schaan, Liechtenstein). The fit and marginal adaptation of the zirconia copings to titanium abutments was evaluated using a microscope and proper file thickness was verified using disclosing silicone (Fit-Checker, Kuraray, Tokyo, Japan).

Before cementation, the inner surfaces of all crowns were air-abraded with 50 µm aluminum oxide particles at 0.2 MPa pressure for 10 seconds. Specimens were cleaned in an ultrasonic bath with ethanol 96% for 5 minutes. Specimens were dried with pressurized air. Directly before cementing the copings, 10-Methacryloyloxydecyl dihydrogen phosphate (MDP) adhesive primer (Kuraray, Noritake, Tokyo, Japan) was applied and then air dried for 60 seconds. Dual-cure resin cement (PanaviaV5, Kuraray, Noritake, Tokyo, Japan) was applied with a thin film to the crown inner surface. Cement was light-cured per manufacturer instructions and the excess removed with a plastic curette (Universal implant deplaquer, Kerr, Bioggo, Switzerland). After cementation, specimens were stored in demineralized water at 37°C for 72 hours. All specimens were subjected to pull out testing at a cross-head speed of 1mm/min until crown displacement and load drop using MTS Insight electromechanical testing system (MTS Systems Corporation, Eden Prairie, MN) (Fig. 3). The peak load force was recorded in N.

CHAPTER 3: Results

An independent samples t-test was conducted to compare the mean peak loads of the two abutment types. There was a statistically significant difference in peak loads with conventional abutments having higher mean loads than screw channel correcting abutments. The mean force necessary to remove the zirconia copings (N) from the 4.00 mm conventional titanium bases (M = 704.6, SD = 115.9) was higher than for the 4.0 mm screw channel correcting titanium bases (M = 510.0, SD = 173.9); p = 0.008 (Fig. 4).

CHAPTER 4: Discussion

The initial null hypothesis, that there is no difference in tensile strength between (4.00 mm) conventional and (4.00 mm) screw channel angle correcting Ti-bases of the same height when cemented with dual cure resin cement, was rejected. If the clinician anticipates the need of screw channel correcting Ti-base to account for the position of the implant; one must be aware that this restorative option may be beneficial in certain cases but retention values are significantly lower. In this study, the unpaired samples t-test was used to compare the two means. Retention form and resistance form of an indirect restoration is usually based upon tooth preparations and cements. Resistance form of a dental implant abutment is the form given that will best enable the restoration to withstand stress during masticatory forces. Retention form of the abutment design is intended to prevent the cemented restoration to be dislodged. Since the screw channel correcting Ti-base has a chair like configuration, there is significantly less surface area when compared to the conventional straight Ti-base.

Abbo *et al*. found mean tensile forces of 198.09 N and 124.89 N on conventional 4.3 mm platform width abutments with 6.5 mm and 5.5 mm in height respectively, utilizing provisional luting cement. [18] This value is significantly lower than the one obtained in the present study even though they used taller abutments. Mahltzahn *et al*. reported retention of zirconia copings cemented to air particle abraded Ti-bases with different resin cements with mean values between 223 N and 598.6 N; samples that used a ceramic primer reported significant higher values, closer to the ones on the present study. [26] Gehrke *et al*. reported mean retentive strengths between of 650.7 N to 924.93 N from different resin cements cemented to 5.5 mm height Ti bases. The highest mean strength values were found when specimens were bonded with Panavia 21 cement, Ti bases and copings were air particle abraded and stored in distilled water for 60 days.[27] Linkevicius et al. obtained mean retentive values of 467 N, 665 N, 1338 N with 3 different resin cements on Ti-bases of 5 mm height with no air particle abrasion.[4] In both studies the values reported were higher than the present study but in both studies the Ti bases were higher; on the Linkevicius *et al* study 665N (RelyX U200, 3M ESPE) of tensile force was recorded with dual cured resin cement, 1338 N was recorded with a fluoroalumino silicate glass cement (G-CEM Link Ace (GC Co), the claim was the use of special ester phosphate monomers versus the methacrylate monomers on the RelyX cement helped in the retention of the copings.

This study evaluated the effect of both Ti-bases under ideal laboratory conditions. This test may indicate what the clinician might experience during a clinical scenario; not necessarily an accurate indication of the intraoral environment. Cyclic loading and thermocycling might give additional information and better understanding of the material tested. The values of the present study are consistent within the range of the previous studies made with MDP based resin cements despite the use of a shorter abutment and no air particle abrasion treatment on its titanium surface.

CHAPTER 5: Conclusions

Within the limitations of this in vitro study, based on the results the following conclusions were made. Zirconia copings bonded with dual cure resin cement to conventional titanium bases showed statistically higher retention than screw channel correcting abutments of the same height. The amount of surface area impacted significantly the tensile values even with the use of MDP based resin cements. The more parallel vertical walls of the screw channel correcting Ti bases did not compensate for the higher total occlusal convergence of the conventional abutments. In a clinical scenario were the need for angle correction to retrieve the restoration is deemed necessary, the retentive values for this option are slightly lower compared to that of conventional screw channel abutments when using a resin based dual cure cement.

Table 1. Conventional Ti Bases Raw Data

Table 1. Conventional Ti Bases Raw Data

Specimen	Peak Load (N)
1	691.773
2	647.216
3	680.35
4	721.369
5	850.772
6	711.531
7	437.855
8	771.765
9	690.442
10	843.225
Mean	**704.63**
Std. Dev.	**115.865**

Table 2. Screw Channel Correcting Ti Bases Raw Data

Table 2. Screw Channel Correcting Ti bases Raw Data

Specimen	**Peak Load (N)**
1	507.586
2	715.918
3	512.872
4	270.71
5	538.838
6	507.104
7	358.349
8	868.36
9	426.071
10	394.459
Mean	**510.027**
Std. Dev.	**173.951**

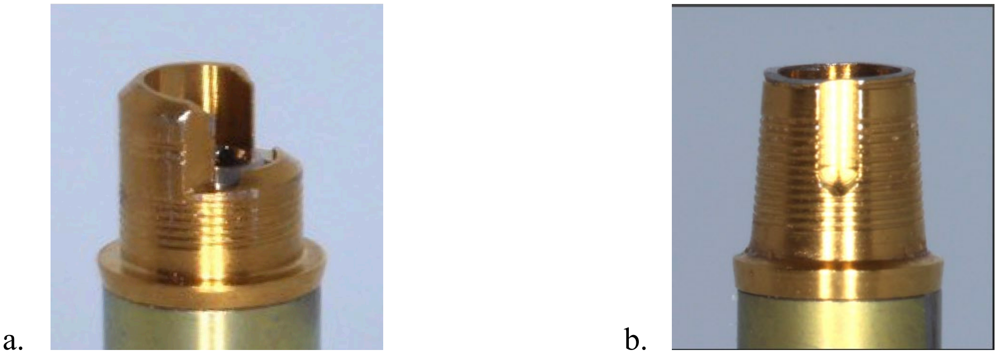

Figure 1. Titanium base types. (a) Screw channel angle correcting titanium base (aka S link). You can observe the chair like configuration. B). Conventional (aka L link) 4 mm titanium base after being cut.

Figure 2. CAD STLs. (a) Pre -molar crown STL prior to modification, (b) Zirconia coping modified STL lateral view, (c) Zirconia coping occlusal view with screw access channel.

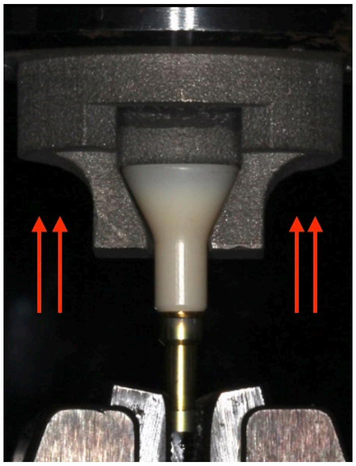

Figure 3. Zirconia specimen being held in place by a printed titanium jig on top (red arrows) and clamp holder on the bottom to hold the implant analog in place while performing the testing.

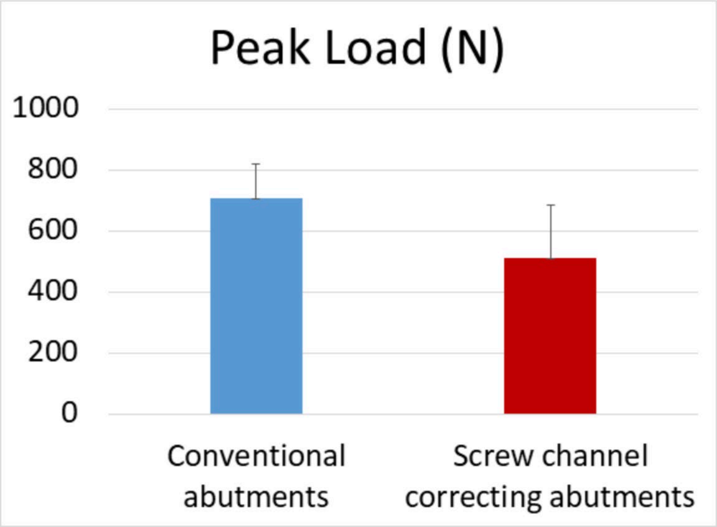

Figure 4. This graph represents the average peak loads measured from 10 conventional and 10 screw channel correcting abutments using MTS testing machine. Y-axis presents peak load values in Newtons (N). The mean force necessary to remove the zirconia copings (N) from the 4.00 mm conventional titanium bases (M = 704.6, SD = 115.9) was higher than for the 4.0 mm screw channel correcting titanium bases (M = 510.0, SD = 173.9); p = 0.008.

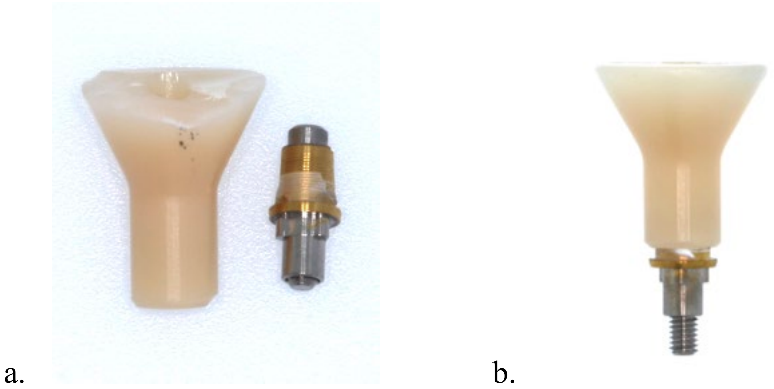

Figure 5. Post testing. (a) Conventional Ti base, (b) Screw channel correcting Ti base

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