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Hybrid-Abutment-Crown with Offset Implant Placement: Effect of Different Machinable Crown Material on Torque Loss

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ABSTRACT

Background: The purpose of the current study was to assess the impact of three esthetic CAD/CAM materials (zirconia, Lithium disilicate and polymer infiltrated ceramic network material) on the torqueloss of a hybrid-abutment-crown.

Materials and Methods: A total of 21 hybrid-abutment crowns with identical external geometries were designed in CAD software to fit ti-base abutment (4 mm height). Samples were grouped into 3 groups (n=7), according to CAD/CAM crown material, Zirconia (Z), Lithium disilicate (L_2) and Hybrid ceramic (V). A universal primer and an adhesive resin cement were used for cementation. Artificial aging in form of water storage (30 days), thermal cycling (5000 cycles at 5-55°C) and chewing simulation (75000 cycles, 49 N, 1.67 Hz) were applied.Specimens were initially torqued to 30 Ncm using a digital torque meter before aging then unscrewed with the same device after aging procedures. Torque loss was prescribed as tightening torque minus device reading. The statistical analysis involved using one-way ANOVA, followed bypost hoc test for pairwise comparison.

Results: The lowest mean torque loss valuewas observed in group Vwhich was 4.31±1.91Ncm, then group L_2 that was 5.88±1.66Ncm, then group Z that was 7.74±1.72.one-way ANOVA test showed astatistically significant result (P<.05).

Conclusion: Abutment-crowns made of polymer infiltrated ceramic network material and lithium disilicates may act as potential stress breakers, and possibly booster screw joint stability. While zirconia greatly affects the underlying screw joint causing higher torque loss.Further clinical studies are needed to assess if these materials also withstand relevant loads in-vivo.

Key words: hybrid-abutment-crown, torque loss, ti-base, ceramics, CAD/CAM

I. INTRODUCTION

The placement of dental implants may be considered as an optimal treatment option to restore a single posterior tooth, owing to its notable success rate.[1] The efficacy of this therapeutic approach is contingent not only upon the achievement of successful osseointegration, but also upon the appropriate superstructure.[2]

In the case of posteriorly placed implant-supported single crown, thefixture should be positioned accurately and cautiously.[3] Horizontal offset position should bedetermined by considering the occlusal force distribution.[4]Clinically, the optimal horizontal offset positiona distally placed implant-supported restorations isone of the key factors underlying implant success, in terms ofpreventing failure and the mechanical complications caused byan unfavorable cantilever effect and bending movements.[5,6]However,various factors make it difficult to reduce the horizontal offset, such as thedegree of root divergence, occlusion with the antagonist teeth,esthetic issues, interproximal bone resorption, and certain practical difficulties encountered during the surgery.[7]Anitu and Orive found a distal offset position (relative to implant diameter) would help in stress reduction around implant. **Lee et al (2016)[8]**investigated the relationship between the horizontal offset and the presence of mechanicalcomplications for a single-tooth implant in the posterior regionof the jaw. Their findings indicated that the probability ofexperiencing mechanical complications increased with a horizontal offset ofmore than 3.7 mm.

To achieve optimum functional and esthetic rehabilitation, implant abutments, which represent a link between the dental implant fixtures andtheir superstructures, must be chosen carefully.[9] The hybrid abutment concept is a relativelyrecently introduced concept yet widely growing in implant supported single crown rehabilitations.Ti-base is a prefabricated abutments with a hybridconcept of cemented and screwed fixation in the sameprosthesis where the implant-abutment connection is usedwith the precision provided by the manufacturer.[10] Implantabutments that are adapted for CAD/CAM use, such as the ti-base, allow the digital design and milling of customizedrestorations to be extra orally cemented and screw-retainedto the implant.[11] Furthermore, currently the most commonCAD/CAM systems have a growing database library for rapidfabrication of prostheses on ti-base abutments.[12] The advantages of this technique include customization of the emergence profile, time efficiency with cost reduction, hybridretention mechanism (cemented and screwed) that allowsremoval of excess cement, and improved

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light curing of therestoration margins before screwing.[13.14]

Today, there are numerous options for restoring implants as implant-supported single crowns using esthetic glass, polymer-based glass, or high-strength zirconia ceramics.[15]Regardingrestorative material, research found that all-ceramic implant-supported single crowns prosthesis survival rates ranged from 93 percent to 97.6 percent after 5 years.[16]Chairside manufacturing of esthetic implant-supported prostheses is now a widely available service in dental practices owing to CAD/CAM technologies.[17]

Hybrid-abutment-crowns manufactured from monolithic zirconia and lithium disilicates exhibited highclinical success rates over an observation period of up to 10 years[18,19] and displayed less ceramic chipping and fractures than veneered ceramic crowns on implants [20]. When failures cannot be prevented, a major concern should be determining “favorable failure patterns”; that is, choosing a technical complication of the prosthetic superstructure over a moresevere complication at the implant itself that might result in biological secondary complications or even catastrophic failures.[21]A study by **Güngör et al(2019)[22]** suggested a favorablefailure mode in the case of occlusal overloads: a lithium disilicate superstructurefractured before the implant-abutment interface damage became visible, supposedly protecting the osseo-integrated implant from fatal damage. Hybrid-abutment-crowns fabricatedfrom 3 mol% yttria-stabilized tetragonal zirconia polycrystalline ceramic (3Y-TZP) did not exhibit this favorable failure pattern.[23,24] Lithium disilicate ceramics and resin matrix ceramics materials could also represent interesting alternatives for hybrid-abutment restorations.[25] Initial in vitro testing indicated that all these restorationsendured relevant masticatory forces and mightbe suitable for clinical use.[26,27]Three different CAD/CAM restorative materials were used in this study namely; 3Y-TZP zirconia, lithium disilicate ceramic and polymer-infiltrated ceramic network material

Mechanical complications of the implant-prosthetic system include loosening and fracture of the prosthesis retaining screw, micromovements, fracture of the abutment, fixture fracture, and super- structural fracture.[28]One of the most critical mechanical complications is the loosening of abutment or prosthesis screw.[29] Currently, the incidence of screw loosening extends between 7 to 39%. Screw loosening can cause unbalanced distribution of occlusal forces, screw and implant fracture, micro-gab space between abutment, and implant that can allow bacterial ingress that will affect the osseointegration.[30,31] Screw loosening can be attributed to variety of factors such as insufficient tightening force, improper placement of the implant, excess mechanical loads than normal, and changes in temperature in the oral cavity.[32]There has been limited research conducted on the effect of restorative material and height of ti-base abutment on torque maintenance.

II. MATERIALS AND METHODS

Additive manufacturing technology by using 3D printer (AccuFab-D1, Shining 3D, Zhejiang,China) was used to make 21 identicalPMMA (NextDent, AV Soesterberg, Netherland) boxes with dimensions 22 x12 x15mm.Dental surveyor (Marathon-103, Saeyang company,Daegu, South Korea) was used as a positioning device. The surveyor carried a fixed handpiece (MNL-S Nakanishi international, Tochigi, Japan) to which implant was attached. Implant fixture (V Plus Implant 4.2*10, Vitronex Elite Implant, Flotecno SRL, Milano, Italy) was clamped to the handpiece using implant driver from the surgical kit (3D Diagnostix,Boston,MA,USA).

Customized silicone base using a putty impression material (Zetaplus Putty, Zhermack SpA, Italy) was fixed to a surveyor plateau to ensure precise positioning of the printed PMMA box in same place.Then self-cured acrylicresin material (St Cold Cure, Acrostone Dental & Medical Supplies, Cairo, Egypt)was mixed according to manufacturer instruction, poured around the fixture which is held in position using the surveyor and was left for complete setting.

Restorations fabrication

An implant scan body (Lot20005314, vitrinox Elite Implant, FlotecnoSRL, Italy) was attached to the implant. Laboratory scanning was done using desktop scanner(Medit T310, Medit corporation, Seoul, South Korea). STL file of this optical scan was then exported toCAD software (Dental CAD 3.0 Galway, Exocad Dental DB software, Germany)**.** The operator replaced the mesh of the scan body with the matching titanium base from the corresponding library (V plus implant, Vitronix Elite,Flotecno SRL).A virtual abutment-crown structure was designed with11.0 mm mesio-distal dimension (average of human mandibular first molar).

A total of 7 zirconia abutment-crownwere dry milled from zirconia disk (ceramill zolid HT+, Amann Girrbach, Pforzheim, Germany)using (K5 plus milling machine,vhf camfacture

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AG,Ammerbuch, Germany). Restorations were 20% over-sized to compensate for sintering shrinkage, sintered in furnace (TABEO-1/M/ZIRKON-100, MIHM-VOGTDental-Gerätebau,Germany), left to cool to room temperature and was then finished and polished using zirconia Finishing & Polishing Kit (ZiLMasterHP, SHOFU INC, Kyoto, Japan) according to the manufacturerinstructions.

Accordingly, Restorations from Polymer-infiltrated ceramic network(Vita Enamic VITA Zahnfabrik, Bad sackingen, Germany) and Lithium disilicate ceramic (IPS e.max CAD, Ivoclar- Vivadent, Liechtenstein) were wetmilled in (Cori-tec 150i-pro,imes-icore GmbH, Eiterfeld Hessen, Germany) milling machine. For each material, A total of 7 abutment-crown were made. Following the milling process, IPS e-max CAD restorations were crystalized in a ceramic furnace at 880°C (Programat ep3010, ivoclar Vivadent, Liechtenstein) for 30 mins. After firing, the restorations wereglazed at 700°C. Vita Enamic restorations were and finished and polished for the outer surface of restorations by using a polishing set (Vita Enamic polishing kit, VITA Zahnfabrik, Bad sackingen, Germany).

Abutment-crowns cementation to ti-ibases

All ti-bases were air-particle abradedwith 50 µm aluminum oxide powder (COBRA50 White,Renefert, Germany) using sandblasting machine (Renefert basic eco, Renefert, Germany)at pressure 2.5 bar and 10 mm distance for 20 seconds according to manufactures instructions, then cleaned utilizing an ultrasonic cleaner (CD-4820 digital ultrasonic cleaner, Codyson, China) for3 minutes on 99% isopropanolsolution, after which they were dried with oil-free air steam.

The sandblasted outer surface of the ti-bases was coated with a universal primer (Monobond plus, Ivoclar Vivadent,Liechtenstein). A single coat of the primer was gently rubbed onto the ti-base surface for 20 seconds, and then left fora self-reaction period of 60 seconds.

zirconia crowns intaglio surfaces were air-borne particle abraded using 50 µm Al_2O_3 particles with pressure of 2.5 bar for a duration of 20 seconds, at a distance of 2 cm in a circulating motion to roughen the surface evenly. Subsequently, a single coat of the universal primer (Monobond plus, Ivoclar Vivadent, Liechtenstein) was applied, agitated for 20 seconds, allowed to react for 1 minute, and then gentle air-dried with a compressed air free of oil and water.

The intaglio surfaces of the remaining 14 restorations (IPS e.max CAD and Vita Enamic) were conditioned with 9.5% buffered hydrofluoric acid (Porcelain etchant, Bisco, Anaheim, CA, USA) for 30 seconds. The surfaces were then irrigated with water for 60 seconds and ultra-sonically cleaned (CD-4820 digital ultrasonic cleaner, Codyson, China) in 99% isopropanol for 3 minutes. The surfaces were then thoroughly dried with a compressed dry air stream for a duration of 10 seconds. Then, a single coat of universal primer (Monobond plus, Ivoclar Vivadent) was applied to the screw channel intaglio using a micro brushand allowed to set for 60 seconds.

All the restorations were bonded to ti-bases using a self-curing adhesive resin cement (Multilink Hybrid-abutment, Ivoclar Vivadent, Liechtenstein). The restoration was then tightly pressed against the ti-base. The sample was kept under static load of a 5 kg offered by specially designed cementation device for 15 minutes until complete setting of the resin cement, thenexcess cement at restoration periphery was precisely removed with a sharp scalpel (no 15), the restoration margin was then finished and polished using a polishing kit (EVEComposoft Polishing Kit, EVE Ernst Vetter GmbH,Keltern,Germany).

Torquing the hybrid-abutment-crown to the fixture

A digital torque meter device(TSD-50 Torque Screwdriver, Electromatic EquipmentCo. Inc,USA)was used to tighten the abutment screw.A 1.25 mm screwdriver was soldered to the stock device tip for precision engagement of abutment screw tip.

The torque meter device waskept with the longitudinal axis ofthe restoration, and turned clockwise until the screw wastightened to 30Ncm as instructed by the manufacturerfor 5 seconds. After 15 minutes,each screw was retightened to minimize thesettling effect.Screwaccess channels were then packed with PTFE tape and top-sealed with 2 mm-thick increment oflight cured composite resin (Beautiful II,SHOFU INC, Kyoto, Japan).

Storage and artificial aging:

To simulate the intraoral conditions, all specimens were soaked in a 37°C water bath on a closed plastic container for one month**.** Then, cyclic loading was done forall specimens using a four-station dynamic loading cycler (Chewing Simulator CS-4; SD-Mechatronik, Westerham, Germany. Each sample wasplaced and secured in a custom-made positioning acrylic holder. The samples were loadedwith 49 N (5 kg) at a rate of 1.6 Hz for 75,000 cycles. Asteatiteball with 6 mm diameter serving as a cusp of antagonist molarwas used to exert axial loading in central fossa of the crown at a descending speed of 40 mm/sec.Additionally, all restorationswere thermal aged (SD Mechatronic Thermocycler) inwater for 5,000 thermal cycles between 5°C and 55°C with a dwelling time of 15 seconds.

Measuring torque loss

Sealing composite in the screw channel was removed with a slow speed handpiece, Additionally, PTFE tape was removed with a small excavator. The digital torque meter was used in a counterclockwise direction to untighten the abutment's screw. Device reading was recorded as reverse torque value

Torque loss was calculated from the equation:

Torque loss= tightening torque – reverse torque

Statistical Analysis

The statistical analyses were performed using the Social Package for Statistical Science (SPSS) software, specifically version 25.0. The normality test was performed usingKolmogorov-Smirnov test for factors and groups. The test showed that the sampling distribution of data didn't deviate from normality (p>0.05), therefore, the following tests of significance will be performed following parametric statistics.

The analysis involved using one-way ANOVA, followed bypost hoc test for pairwise comparison. Statistical significance was established by considering a p-value below 0.05 (P<0.05).

Univariate One-Way ANOVA for Crown Material

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Torque Loss	Between Groups	41.572	2	20.786	8.688	0.002
	Within Groups	43.066	18	2.393		
	Total	84.638	20			

Post Hoc Tests

Multiple Comparisons

Dependent Variable				Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Torque Loss	Bonferroni	Zirconia	Lithium Disilicate	1.85714	0.82679	0.112	-0.3249	4.0392
			Vita Enamic	3.44286*	0.82679	0.002	1.2608	5.6249
		Lithium Disilicate	Zirconia	-1.85714	0.82679	0.112	-4.0392	0.3249
			Vita Enamic	1.58571	0.82679	0.213	-0.5963	3.7677
		Vita Enamic	Zirconia	-3.44286*	0.82679	0.002	-5.6249	-1.2608
			Lithium Disilicate	-1.58571	0.82679	0.213	-3.7677	0.5963

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*. The mean difference is significant at the 0.05 level.

III. DISCUSSION

The objective of the present study was to assess andcompare the impact of the height of ti-base and restorative material type onthe torque maintenance of abutmentscrews with screw-retained implant-supported single prostheses. Research hypotheses assumed that thehybrid-abutment crown materialstypecould influence torque maintenance of CAD/CAM fabricated hybrid-abutment-crown. The hypothesis has been accepted.

Crown fracture and loosening of retaining abutment are alternatively the first and second common mechanical complications of the implant-prosthetic system.[33]An updated meta-analyses states that the incidence of screw loosening is currently prevalent in varying degrees, ranging from 7% to 39% depending on implant-abutment connection design, screw material and design, occlusal table, friction coefficient, design of the restoration, passivity, implant number and diameter, and occlusal loads.[34,35]

Repetitive screw tightening and loosening was necessary duringlaboratory procedures and surface treatment of the hybrid-abutment-crowns this typically causestresses in the screw, which could lead to their loosening.[36] Consequently, a new screw was used each time before the hybrid-abutmentstorqued onto the implant fixture with the digital torque meter.

In the present study, 30Ncm was applied (according to the manufacturer’s instructions) as the tightening torque for the hybrid-abutment-crown retaining screws. Additionally,the screws were retightened after 15 minutes to compensate for the settling effect.[37] The loosening torqueis predicted to be the same as tightening torque at perfect conditions.Nevertheless, this actually doesn’t happen.[38,39]

The present study revealed that the reverse torque valuefor hybrid-abutmentretaining screw of the tested samples was lowerthan the initial tightening torque. This finding supportsthe results of other studies. In the present study, theloosening torque was evaluated after artificial aging. Screw loosening can cause unbalanced distribution of occlusal forces, screw and implant fracture, micro-gab space between abutment, and implant that can allow bacterial ingress that will affect the osseointegration.[40]

The hypothesis couldn’t be rejected based on the results of this study. The reverse torque values of hybrid abutment crowns are variably affected by the type of restorative material used. Samples restored with zirconialose 26.261 ± 5.22% of their initial preload, while restorations made from lithium disilicate lose 21.2 ± 4.64% of initial torque.polymer-infiltrated-ceramic-network material appears to be effective in preload retention explaining that their restorations had only 15.33 ± 5.46% of torque loss. Pair wise comparison show a statistically significant difference between torque loss values among the three materials ($p<0.05$).

Regarding the effect of abutment material on screw joint stability, finding of the present study are in agreement with previous studies.[41-43]**Jo et al (2014)**[42] compared the stability of the joint ofthree abutments made of commercially pure grade 3 titanium, commercially pure grade 4 titanium, or titanium alloy Ti-6Al-4V. It was found that preload and compressive bending strength valueswere significantly higher in the group made from titanium alloy in contrast other groups.According to **Dhingra et al (2013)**[41] the torque loss of the zirconia abutment was higher than that of the titanium abutment after cyclicloading.**Ožiūnas et al(2023)**[43] observed that the highest reverse torque values were found in Polyetheretherketone group while zirconia group showed the lowest values, yielding a conclusion that post-load loosening torque values varied significantly depending on the hybrid-abutment material.

In implant rehabilitations with hybrid-abutment, stress transfer to underlying structures vary greatly according to abutment restorative material. Results of the finite element analysis study by **Tribst et al (2019)**[44] showed more stress concentration occurred with zirconia abutment at cervical region. Lower stresses had been concentrated with polymer infiltrated ceramic material and lithium disilicate. Authors also observed that more stress concentration in the cervical region occurs directly proportional tothe elastic modulus of the hybrid abutment material.

The results of this study disagree with the results **Al-zordk et al (2020)**[45] who investigated the effect of hybrid-abutment-crown material type of three different machinable restorative materials (zirconia, lithium disilicate, and PEEK) on torque maintenance. This would be attributed to difference in aging procedures as Al-zordk et al (2020)[40] study depended only on thermal cycling. Additionally, premolar size of restoration in the latter study would be a cause for difference.

There exists certain limitations for the current study, including dynamic loading and thermal cycling don't completely mimic oralcircumstances, limited artificial aging simulation period, other implant positions would be possible for testing, and other aspects that can potentially influence the preload loss of the hybrid-abutment prostheses which include the type of connection, and texturization of the ti-base, the type of cement used, the fit of the superstructure, and the surface treatment.

IV. CONCLUSIONS

Within the limits of this in vitro study, it is possible to say the following:

1. There is no statistically significant variation in the reverse torque values of hybrid-abutment-crowns that are bonded to titanium bases with varying heights.
2. The type of ceramic restoration affects the torque loss of hybrid-abutment-crowns.
3. Zirconia greatly affects the underlying screw joint causing higher percentage of torque loss.
4. Abutment-crowns made of polymer infiltrated ceramic network material and lithium disilicates may act as potential stress breakers, and possibly booster screw joint stability. Further clinical studies need to assess if these materials also withstand relevant loads in-vivo.

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