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INTERNAL IMPLANT-ABUTMENT INTERFACE OF CAD/CAM MILLED BARS FABRICATED WITH DIFFERENT MATERIALS

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ABSTRACT

Purpose: The increased use of customized abutments develops with the evolution of CAD/CAM. The importance of fitting accuracy between implant components has been documented. The purpose of the present study was to evaluate the fit of implant-abutment interface for CAD/CAM milled bar over two implants constructed by Poly Ether Ether Ketone (Bio-HPP PEEK), Cobalt Chrome (Co-Cr), Titanium (Ti) and Zirconia using scanning electron microscopy (SEM).

Material and Methods: Two parallel implants with a 14 mm distance from each other were embedded in clear epoxy resin molds. Forty-eight custom milled bars were constructed and were divided equally into four groups: Group (A) Bio-HPP Poly Ether Ether Ketone (PEEK) bar, group (B) Cobalt Chrome (Co-Cr) bar, group (C) Titanium (Ti), and group (D) Zirconia (Zirc) bar. The marginal fit at the implant-abutment interface was scanned and measured under scanning electron microscope.

Results: There was a significant difference between the four studied groups regarding marginal fit the between implant and customized bars. The highest value of micro-gap distance was found in Zirconia bar 17.57 μm ± 1.83 followed by Bio-HPP Poly Ether Ether Ketone bar 9.72 μm ± 3.52. In Titanium bar the micro-gap was 4.02 μm ± 1.19 and the lowest value of micro-gap was recorded in Cobalt Chrome bar 3.22 μm ± 0.75.

Conclusion: CADCAM milled bars fabricated with Chromium Cobalt, Titanium, or PEEK, possesses better internal fit than zirconia milled bars. All the previous milled bars were within the clinically acceptable range of misfit.

Internal Implant-Abutment Interface of CADCAM Milled Bars Fabricated with Different Materials.

KEYWORDS: CADCAM milled bars, Titanium, PEEK, Implant abutment fit, zirconia

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INTRODUCTION

Implant-abutments interface plays an essential role in the health and esthetics of the soft and hard tissues around dental implants [(1)]. Abutments can be divided into prefabricated stock and custom fabricated abutments. Although prefabricated abutments are machine produced with high accurate fitness, they lack versatility since they are fabricated into standardized limited configurations. "One size to fit all" is an inherent drawback of prefabricated abutments when challenged with a diversity of clinical scenarios such as different implant angles, emergence profiles and gingival margin morphology. Prefabricated abutments are typically manufactured from titanium alloys, that can be visible as an aesthetic metallic discolored band at the patient's crown cervically [(2)].

Therefore, satisfying the aesthetic demands and functional requirements can be a hard task when using a prefabricated abutments. On the other hand, customized abutments can be tailored to fit different heights, angles, and morphology and provide better support of soft tissue around dental implants. The evolution of computer-aided design/computer-aided manufacturing (CAD/CAM) had allowed for the increased use of customized abutments and bars of improved fit in implant prosthodontics [(3,4)]. The complete fit of the abutment and bars after the final tightening of the abutment screw can be achieved when all the opposing surfaces of both the implant and the abutment are in maximum three-dimensional closeness and contact without any strain of the components [(5, 6)].

The importance of fitting accuracy between implant components has been reported by several authors[(7-14)]. The abutment–implant interface is considered one of the areas where occlusal force is concentrated and transferred to the implant. Consequently, long-term firmness is essential for reducing clinical complications and prolonging the dental implant service life [(15)]. The incompatibility and misfit at the implant-abutment interface can lead to prosthetic complications including mechanical and technical adverse procedures affecting the meso-structure or the superstructure. These complications include lack of passivity, increase of occlusal overload, micro-Pump effect, peri-implantitis and mucositis, repeated screw loosening, irretrievable screw fractures, wear and deformation of the implant index, wear of the abutment connection and the destruction of implant osseointegration [(16-21)].

Many materials are used in the CAD/CAM fabrication of implant framework restorations, such as Cobalt Chromium alloy, Titanium, Zirconia, and high-performance polymers. Titanium (Ti) is widely used and became the standard implant substructures' material of use due to its favorable biomechanical properties [(22)]. On the other hand, Chrome-Cobalt (Cr-Co) was broadly utilized in several aspects in dentistry because of its strength, low cost, resistance to corrosion when compared to other alloys. The scientific research regarding the use of Co-Cr alloy for implant restorations is limited [(23)] .

The need for aesthetic alternative material yet possessing superior mechanical and biomechanical features has led to the introduction of zirconia use in implant framework fabrication[(23)]. The high-performance polymers such as Poly Ether Ether Ketone (PEEK) are other alternatives to both metallic and ceramic implant frameworks that are being recently introduced. PEEK are semi-crystalline polymers with improved mechanical properties by the addition of 20% ceramic fillers (Bio-HPP PEEK)[(24)]. Studies examined and compared the implant-abutment interface using PEEK are scarce in literature.

There is a lack in the literature comparing the degree of fitness of implant supra-structures made of the above-mentioned materials. The aim of this in-vitro explorative study is to evaluate the fit of implant-abutment interface of customized CAD/CAM screw-retained milled implant framework (bar) over two implants constructed in four different materials: Poly Ether Ether Ketone (Bio-HPP PEEK), Cobalt Chrome (Co-Cr), Titanium (Ti), and Zirconia. Implant-abutment interface gap were measured under scanning electron microscopy (SEM). The null hypothesis was that there is no difference exists in the fit and gap distance between the four different milled materials.

MATERIALS AND METHODS

Preparation of Specimen

Forty-eight clear epoxy resin molds (8 mm width, 18 mm height, and 8 mm thickness) were prepared and used in the study for the four test groups. Cone Beam Computed Tomography (CBCT) (parameters 85 KVP, 5 MA) was recorded for the epoxy resin molds. A standard tessellation language file (STL file) of the model was also obtained using desktop scanner (D850, 3Shape, Copenhagen, Denmark). The STL file was superimposed on the DICOM file using the best-fit algorithm. A surgical guide was constructed by an implant planning software (real guide; 3diemme, Italy). The surgical guide was printed using clear surgical guide resin (EPAX Clear Resin; EPAX 3D). The resultant surgical guide was finished and cleaned with alcohol to remove excess monomer. Two dental implants, 4mm in diameter and 10 mm in length, (Neobiotic, IS-II active, Korea) with conical 11-degree and 2.5 mm internal hex internal connection were used. The two implants were inserted 14 mm distance from each other by the aid of the constructed surgical guide in each mold, leaving only 3 mm of implant surface exposed following the ISO 14801:2007 standard. Implants were scanned using a desktop scanner (D850, 3Shape, Copenhagen, Denmark) after the placement of scan abutments (Neobiotic, IS scan body, D4, SCRP, South Korea) tightened at 10-N using a torque wrench. STL files were imported and digital designing of a primary bar supra-structure using the Exocad software program (Exocad GMPH Dental CAD Software) was made.

Forty-eight milled bars (2 mm in height and 1 mm width) were constructed in different materials that were equally divided into four groups (n =12) as follows: Group (A) Bio-HPP Poly Ether Ether Ketone (PEEK) (Bredent Gmbh, Germany), group (B) Cobalt Chrome (Co-Cr) (MoguCera C Disc, Scheftner Dental alloy, Germany), group (C) Titanium (Ti) (Scheftner Dental alloy, Germany), and group (D) Zirconia (Zirc) (Yeti Dental , Germany). The milled bars (Figure 1) were fabricated utilizing a computed milling machine (CAM) (ED5X, Emar, Egypt). A new placed cutting tools removed the excess material gradually and shaped the bar according to the planned design (CAD). The constructed bars were then mounted into the implants engaging their internal connection with an abutment screw tightened at 30-N using a torque wrench. Each group had 12 milled bars screwed into the resin embedded implants for a total of 24 interfaces per group (n=24). Fig (1)

Vertical sectioning of all implants was performed by water jet-powered sectioning equipment (Germany). Copious rinsing was done with distilled water followed by ethyl alcohol to remove any clogged debris that could interfere with accurate visualization of the implant–abutment interface. All the samples were cleaned inside ultrasonic bath for 12 minutes (Beijing Ultrasonic Co., Beijing, China) before finally the test specimens were thoroughly washed with ethyl alcohol and dried.

Evaluation of Fit

The vertical marginal gap distance at the implant-abutment interface of each prepared sample was scanned using high resolution scanning electron microscope (SEM), FEI Quanta FEG 250 (Thermo Fisher Scientific, Netherlands). Three allocated points (top, middle, and bottom) on each side per single sectioned implant were measured, with a total of six measured areas at each implant–abutment interface. The horizontal gap distances at each point between sectioned abutment and internal implant interface was measured. Fig (2).

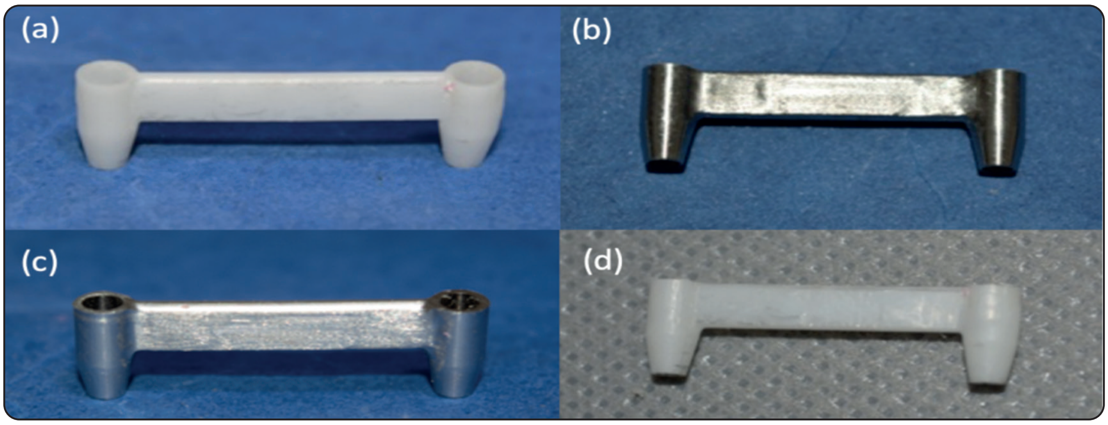

Fig. (1) The four test milled bar groups supra-structures with their customized abutments; (a) PEEK, (b) Chrome-Cobalt, (c) Titanium, and (d) Zirconia

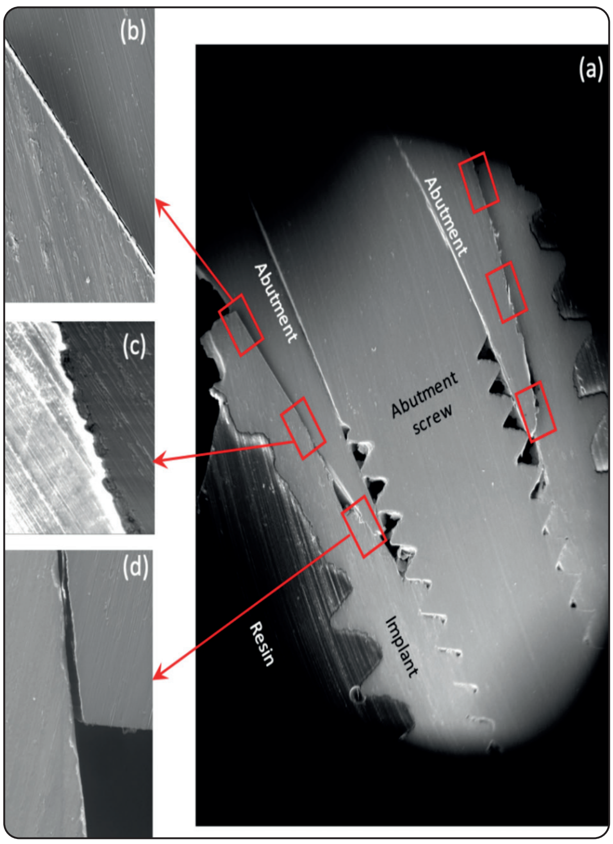

Fig. 2 (a) Vertical cross section of customized bar-implant interface and the three (top, middle, and bottom) on each side measuring areas as illustrated by the red boxes with SEM at 52x magnification (b), (c), and (d) are sample electronic photomicrographs at 800x magnification for measuring gap distance

The working parameters for each sample were at 800× magnification and the photomicrographs were collected in separate images to aid in the accurate measurement of the fit. The interface gap distance was calculated on the scanning electron microscopic images taken for each test sample using an image measuring pixel counting software (Image J, National Institutes for Health). The gap distance in μm was measured on the SEM images by the aid of the linear measuring scale of the software.

Sample size calculator and Statistical Analysis

A sample size of 12 bars which yields 90% power to detect significant differences, with number of four groups (n=4) were needed to reach a significance level at 0.05. Data were collected, revised, coded, and entered onto the Statistical Package for Social Science (IBM SPSS) version 23. Data were described as mean, standard deviations. Using one-way analysis of variance ANOVA test, the comparison between groups were made followed by post hoc analysis using least significance difference LSD. The confidence interval was set to 95% and the margin of error accepted was set to 5%. The p-value was considered significant at the level of < 0.05. Table (1)

TABLE (1) Studied groups, number of readings and mean gap distance from SEM taken for each bar.

Group	Material	Number implant/abutment interface	Total number of readings	Mean ± SD	P-value
A	PEEK	24	24 × 6 = 144	9.72 μm ± 3.52	<0.001
B	Cr-Co	24	24 × 6 = 144	3.22 μm ± 0.75	
C	Ti	24	24 × 6 = 144	4.02 μm ± 1.19	
D	Zirc	24	24 × 6 = 144	17.57 μm ± 1.83	

RESULTS

There was a significant difference between the four studied groups regarding marginal fit between implant and customized bars with p-value <0.001. The highest value of micro-gap distance was found in group (D) Zirconia (Zirc) bar 17.57 μm ± 1.83 followed by Group (A) Bio-HPP Poly Ether Ether Ketone (PEEK) bar 9.72 μm ± 3.52. In group (C) Titanium (Ti) bar the micro-gap was 4.02 μm ± 1.19 and the lowest value of micro-gap was recorded in group (B) Cobalt Chrome (Co-Cr) bar 3.22 μm ± 0.75. Table (1)

DISCUSSION

The development of computer-aided design/ computer-aided manufacturing (CAD/CAM) accelerated developments in dentistry and allowed the use of wide range of different materials in implant prosthodontics. Information regarding the accuracy of fit of customized abutments and bars made from different materials is scarce in the literature. The present study examines the fit of four different customized bar materials constructed by one single technique; that is, milling procedure. Although, it has been affirmed that the occurrence of gaps and discrepancies at the junction of implants and abutments is inevitable [7, 8], an optimum fit with the least micro-gap is crucial and should be considered the goal when designing and fabricating implant components [9].

There is no existing guideline on how to accurately record the fit for implant abutment interface either in-vitro or in-vivo. Inconsistency in methodology explains the discrepancies reported among authors. Furthermore, statistical results are challenging to interpret because of variations in sample size, number of measurements per specimen, and measuring protocols employed. Some investigators measured the implant abutment interface in non-sectioned specimens [7, 13, 25], while others recommended to measure sectioned specimens [8, 9, 26]. In addition, various techniques for assessing the fit and measuring of micro-gap at the implant–abutment interface have been described, such as direct observations performed by radiography[27], scanning electron microscopy (SEM) [19, 28, 29], scanning laser microscopy [7], optical microscopy [30], 3D microtomographic technique [31], and optical coherence tomography [32]. Each technique has its inherent differences, advantages and disadvantages, and possible flaws; hence care consideration should be kept in mind when interpreting results. The implant abutments and bars could be customized in a variety of techniques including milling, casting, and laser sintering 3D printing. The different techniques of customization can result in surface irregularities that play a major role to increase the gap and form discrepancies at the implant-abutment interface [28].

Since early studies [33, 34] in implant dentistry, the described adequate marginal gap between the prosthetic framework and the implant has been varying over time and ranging between 30 μm to 150 μm. Currently, there is a shortage of conformity of "what is the acceptable gap between implant and abutment?"[35]. Various studies considered a tolerable gap distance should not exceed 49μm[36,37,38]. Considering those studies, the gap distance of all studied specimens in the present study were within an acceptable range. However, other reports described the acceptable gap to be less than 10μm[39,40,41]. Considering those reports, only the custom bars made of PEEK, Ti and Co-Cr were within the acceptable range while the zirconia abutments were not. Therefore, it can be interpreted that different materials of construction can influence on implant–abutment interface gap distance. It is worth noting that three tested material groups (Co-Cr, PEEK, and Ti) were milled directly from fully sintered blocks, while (Zirc) group was soft milled from partially sintered blocks which was subsequently fired to its final form. Sintering shrinkage is a factor that should be kept in mind.

Queiroz et al., [14] evaluated the initial and final fit of external hexagon custom zirconia and metal abutments upon cyclic loading. They concluded that different materials and fabrication techniques could develop different levels of a marginal misfit at the implant-abutment interface. The mechanical cyclic loading provoked the misfit regardless of fabrication process or the material used. Zirconia custom abutments showed increased wear and misfit that could result in long-term instability at the implant-abutment interface. Barbosa et al.,[42] examined the vertical fit between abutments and prosthetic platform, prosthetic screw loosening torque, and screw stress distribution among two groups of custom abutments (titanium and zirconia). The titanium fit was better than that's of the zirconia before and after cycling loading, indicating the superiority of titanium when compared to zirconia material. Baldassarri et al.,[43] evaluated the gap between customized zirconia and Titanium abutments for different implant systems with conical connections. The Titanium abutments connections showed significantly superior fit compared to zirconia abutments, which exhibited mean gaps that were approximately three to seven times greater than those in the titanium abutments. All previous agreed with our study where zirconia customized bars exhibited the worse misfit. The possible cause of inferior fit and wider gap distance in custom zirconia abutment might be related to sintering shrinkage that could reach up to 20% of their initial volume. [44] On the other hand, other study showed opposing results. Butignon et al., [45] in their study had compared the level of vertical fit between custom Titanium and zirconia abutments against the fit of pre-machined gold-alloy abutments. The gold-alloy group showed the highest value of vertical misfit (14.93 μm ± 0.78), followed by the Titanium group (8.53 μm ± 0.44) while the zirconia group showed the least amount of vertical misfit (5.64 μm ± 0.73). Cyclic loading did not significantly change the level of vertical misfit.

There is very few in the literature about the micro-gap fitness of customized PEEK abutments and bars in comparison to other materials. Sundar et al.,[28] showed that there was a significant gap difference between the CAD/CAM PEEK abutment and zirconia abutment. Zirconia abutments showed greater vertical gap values than PEEK abutments. In their study, the vertical gap between PEEK abutment and implant ranged between 6.7 to 7.8 μm.

The assessment of the effect of technique and material on gaps is still a current and a valid research topic in implant prosthodontics. However, additional comparative studies evaluating the misfit among different methods using original and third-party abutments are needed. The limitation of the present study was utilizing the vertical cross-section technique to measure the gap distance and the fit. As a result, the precision was assessed only at a few defined areas per each implant, and this might not totally demonstrate the complete geometry of internal fit. Cross sectioning procedure by itself could cause some damage to the specimens. Also, the effect of cyclic loading on the precision of fit was not included in the study. More clinical short and long terms in-vivo research should focus on the durability of using different custom abutments' materials utilized for different kinds of implant prostheses.

CONCLUSION

Based on the findings of this in-vitro study, the following conclusions were drawn: CADCAM milled bars fabricated with Chromium Cobalt, Titanium, or PEEK, possess better internal fit than zirconia milled bars. The implant frameworks milled using those three materials not only fitted within the clinically acceptable range of misfit but also had mean values of gap distance less than 10 μm. The zirconia abutments showed the worst internal fit.

Deceleration Authors declare that there is no conflict of interest.

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