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RESEARCH AND EDUCATION

Comparative evaluation of BioHPP and titanium as a framework veneered with composite resin for implant-supported fixed dental prostheses

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ABSTRACT

Statement of problem. High rates of veneering chipping are a common prosthodontic complication of restorations with a titanium framework. A new bio high-performance polymer (BioHPP) based on polyetheretherketone (PEEK) has been introduced for denture superstructures. Clinical reports suggest that BioHPP could be used as an alternative framework material to support complete-arch restorations. However, peer-reviewed information is lacking regarding the performance of BioHPP as a framework material for implant-supported screw-retained fixed dental prostheses (FDPs) veneered with composite resin.

Purpose. The purpose of this in vitro study was to evaluate and compare the bond strength of modified PEEK (BioHHP) and titanium with a veneering composite resin and compare the marginal fit and fracture resistance of implant-supported screw-retained FDPs fabricated by using computer-aided design and computer-aided manufacturing (CAD-CAM) frameworks veneered with composite resin.

Material and methods. A composite resin was bonded to 2 framework materials (n=20/group): pure titanium (Ti) and BioHPP (Bi). The shear bond strength (SBS) was determined after 24-hour wet storage. Furthermore, 20 3-unit CAD-CAM BioHPP and titanium frameworks were fabricated (n=10/group). The marginal fit between frameworks and abutments was evaluated by scanning electron microscopy by using the single-screw test. After thermocycling and mastication simulation, the fracture resistance of FDPs veneered with the composite resin was examined. The independent sample t test was used to evaluate differences (α=.05).

Results. Significantly higher shear bond strengths were obtained in group Bi (31.1 ±3.5 MPa) than in group Ti (20.5 ±1.8 MPa). The mean marginal gap width was 19 ±4 µm in group Bi and 16 ±6 µm in group Ti. Statistical tests showed no significant differences (P>.05). After loading, veneering chipping was observed at a load of 1960 ±233 N in group Ti. Although the BioHPP frameworks fractured at 1518 ±134 N, no chipping occurred.

Conclusions. The bond strength of BioHPP with the composite resin was greater than that of titanium. CAD-CAM BioHPP frameworks exhibit good marginal fit and fracture resistance. BioHPP may be a suitable alternative to metal as a framework to be veneered with composite resin. (J Prosthet Dent 2019;122:383-8)

Complete-arch fixed implant-supported prostheses (CAFIPs) have served as a successful treatment for edentulous jaws.[1,2] Titanium is commonly used for computer-aided design and computer-aided manufacturing (CAD-CAM) implant-supported fixed dental prosthesis (FDP) frameworks because of its excellent mechanical properties.[3] CAFIPs and supporting implants have been reported to have relatively high survival rates.[4] However, prosthesis success was defined as the restoration remaining intact without damage during the entire follow-up period. Prosthetic complications have been reported to be relatively often, with the most common being fracture of the veneering material.[1,5,6] These veneering materials include porcelain, polymethyl methacrylate

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Clinical Implications

Veneered with composite resin, a nonmetallic material appears to be a clinically promising framework material, especially as veneer chipping is less likely than with titanium.

(PMMA), and composite resin. To help dissipate impact stresses, decrease denture weight, and reduce treatment expense, composite resin, especially for long-span FDPs and CAFIPs, has been used as a suitable alternative to porcelain. Composite resin has better esthetics and color stability than acrylic resin. However, the relatively low shear bond strength between veneering composite resin and the metal framework remains a major weakness of metal-resin restorations.[7] Failure at the metal-resin interface due to poor bonding to metal may cause significant clinical complications.[8,9]

Titanium frameworks may cause esthetic complications because of their grayish color and the possibility of corrosion and degradation.[10-12] Moreover, they may induce metal allergy.[13] Therefore, the demand for metal-free dental prostheses has led to the development of esthetically biocompatible metal-free materials.

Recently, a bio high-performance polymer (BioHPP) based on polyetheretherketone (PEEK) has been introduced as a dental framework material.[14,15] Because of its excellent characteristics, including outstanding physical properties, good dental esthetics, low specific weight, low plaque affinity, and high biocompatibility, BioHPP can be used for a number of applications in dentistry,[14-21] including interim abutments, implant-supported bars, and dental implants. It has also been considered as a framework material for FDPs.[19] Clinical reports have suggested that BioHPP could be an alternative framework material for complete-arch restorations to address many metal-resin–related problems.[20,21] However, long-term clinical evidence is lacking, and the characteristics of BioHPP are not well defined.

In view of the low bond strength between the veneering composite resin and titanium, the bond strength of this nonmetallic framework to composite resin should be assessed by a shear bond strength (SBS) test.[22] In addition, marginal fit should be evaluated.[23-26] BioHPP can be milled by CAD-CAM techniques,[27] which have expanded the application of this material to implant-support prostheses.

A previous study reported that fracture loads of 3-unit reinforced PEEK FDPs without a veneer and fabricated by different methods ranged between 1738 N and 2354 N and that CAD-CAM FDPs had higher fracture load values.[27] To reflect the clinical application, the fracture load and modes of 3-unit FDPs with veneer and supported by different frameworks should also be assessed.

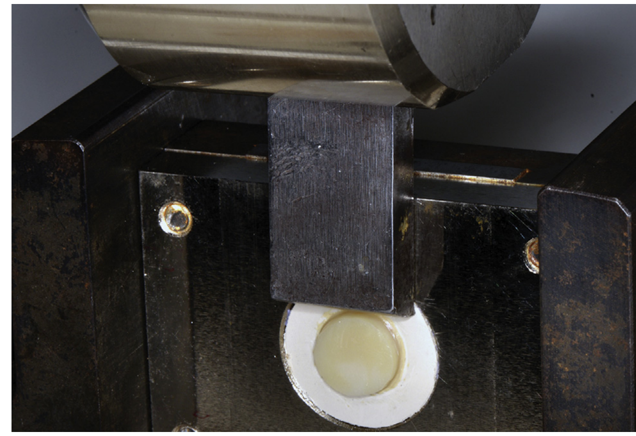

Figure 1. Shear bond strength testing in universal testing machine.

Accordingly, a series of in vitro studies were performed to test the bond strength to composite resin, the marginal fit, and the fracture resistance of implant-supported FDPs fabricated with different CAD-CAM frameworks and veneered with composite resin. The research hypothesis was that the use of BioHPP veneered composite resin would result in greater bonding strength than the use of titanium. In addition, the marginal fit and fracture resistance of implant-supported FDPs fabricated by CAD-CAM and with a BioHPP framework could meet the requirements of clinical application.

MATERIAL AND METHODS

A total of 40 titanium (Ti) and BioHPP (Bi) disks (25 mm in diameter and 4 mm in thickness) were machine-milled by CAD-CAM from commercially pure titanium (Ti Target; Japan Metal Service Co Ltd) and modified PEEK (BioHPP; bredent GmbH & Co KG). All specimens were fabricated by 1 dental technician following a standard bonding procedure. Adhesive selection was based on the manufacturer's recommendations. For group Ti, the titanium surfaces were abraded with 110-μm aluminum-oxide particles at a pressure of 0.25 MPa. After the excess alumina had been removed, an adhesive (SR Link; Ivoclar Vivadent AG) was applied to the titanium surface.

For group Bi, after abrasion with 110-μm aluminum-oxide particles at 0.25 MPa pressure and placement in an ultrasonic bath with deionized water for 5 minutes, an adhesive (visio.link; bredent GmbH & Co KG) was applied to the BioHPP surfaces and light polymerized for 90 seconds. A thin, uniform layer of opaque resin (SR Nexco Opaquer; Ivoclar Vivadent AG) was brushed on all the surfaces of the 2 groups. For reproducibility and uniformity, a cylindrically shaped Teflon mold (14 mm in diameter and 2 mm in thickness) was used to apply the

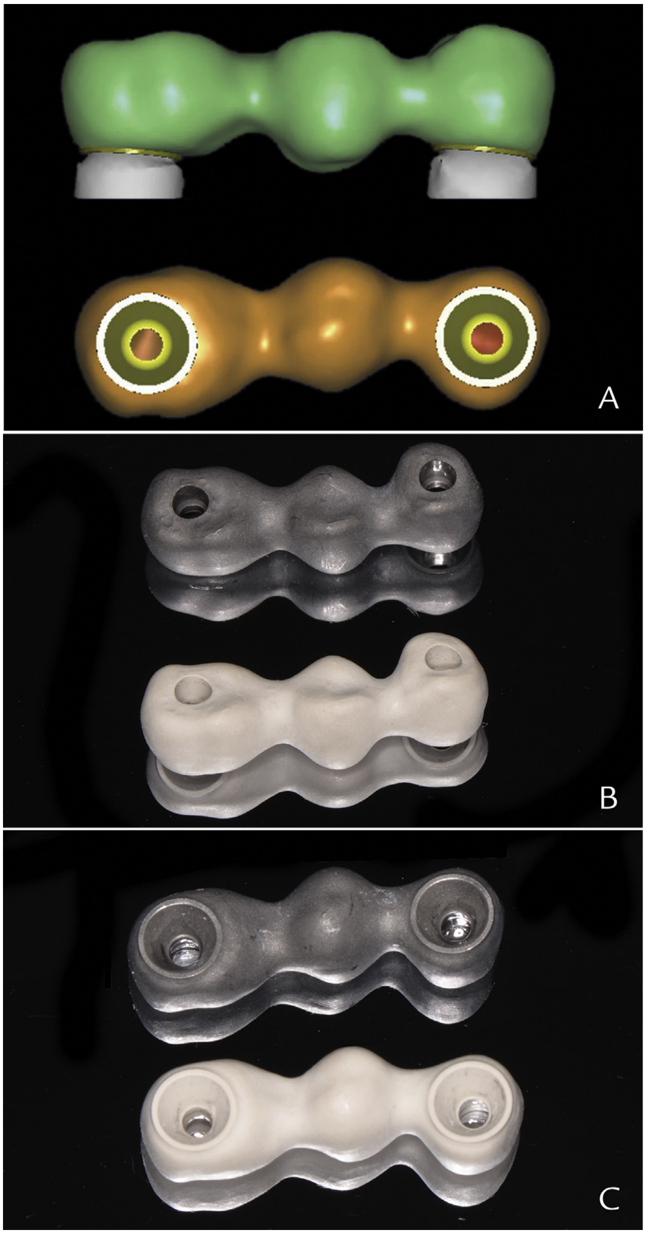

Figure 2. Anatomic 3-unit FDP frameworks. A, Designed. B, Manufactured in titanium and biologically acceptable high-performance polymer, occlusal view. C, Gingival view.

composite resin (SR Nexco Paste; Ivoclar Vivadent AG) by the layering technique. Finally, veneered specimens were polymerized using the same polymerization unit for 180 seconds and placed in distilled water for 24 hours at 37 °C. Afterward, the SBS was measured by using a universal testing machine (AGS-J; SHIMADZU), and a loading head was used on the specimens at a speed of 0.5 mm/min (Fig. 1). The SBS values were calculated as follows: shear stress (MPa)=load (N)/area (mm^2).

To produce standardized FDPs, 2 WEGO implants (Jericom Dental Implant System; Weihai WEGO Jericom Biomaterials Co, Ltd) were inserted in the first premolar

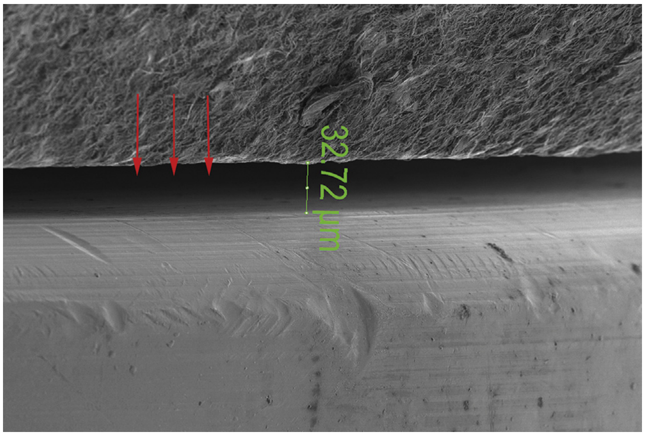

Figure 3. Scanning electron microscope image showing interface between framework and multiabutment of one implant. *Red arrows* indicate interface. Original magnification ×800.

and first molar region of a model fabricated with epoxy resin. After installing 2 multiabutments (Jericom Dental Implant System; Weihai WEGO Jericom Biomaterials Co, Ltd.), the master model was scanned (D800 3D Scanner; 3Shape) to design an anatomic 3-unit FDP framework (exocad Dental 2015; exocad GmbH) (Fig. 2A). Based on this master design, a total of 20 frameworks (n=10/group) were milled (308B; Willemin-Macodel) from titanium and BioHPP disks (Fig. 2B, 2C).

The screw at one implant was tightened to 20 Ncm by using a calibrated hand wrench (Jericom Dental Implant System; Weihai WEGO Jericom Biomaterials Co, Ltd), and the other screw was removed. Subsequently, under a calibrated scanning electron microscope (SEM) (Quanta 250 FEG; FEI), the vertical distance from framework to multiabutment in the master cast was measured for all the unretained interfaces. SEM images of the whole implant-FDP complex and focused close-ups of the buccal, mesial, and distal interfaces were made at a magnification of up to ×800 (Fig. 3). The mean misfit per implant was calculated from mesial, buccal, and distal measurements.[28,29]

A silicone mold was produced based on the waxing on the master model, allowing for a standardized and reproducible anatomic shape. With the help of the silicone mold, the occlusal thickness of the veneering material was set at 2 mm. All specimens were fabricated following a standard bonding procedure based on manufacturing recommendations by 1 dental technician. The veneered FDPs were finished and polished (Fig. 4). Then, all FDPs were thermocycled (Thermocycler THE 1100; SD Mechatronik) from 5 °C to 55 °C with a dwell time of 20 seconds for 5000 cycles.[7] A standardized load of 4.9 N was applied for 10 minutes, and the FPDs were stored in distilled water at 37 °C for 24 hours. The FDPs were then positioned and loaded (AGS-J; SHIMADZU) with a ball (5 mm in diameter) at the center of the pontic

Figure 4. Resin-veneered prostheses from 2 framework materials.

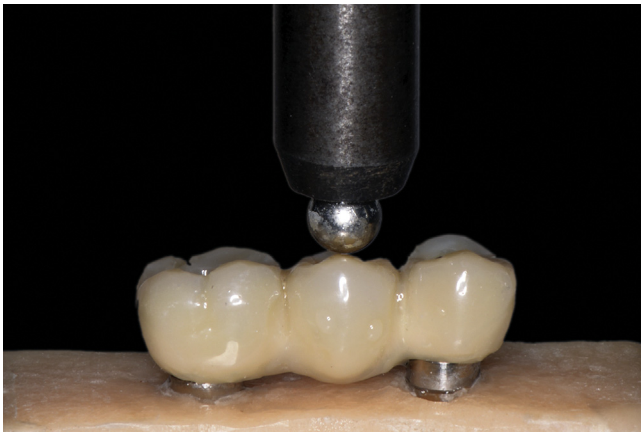

Figure 5. Prostheses loaded with 5-mm-diameter ball at center of pontic.

from the occlusal-gingival direction at a speed of 1 mm/min (Fig. 5). The fracture load and the fracture modes were recorded.

The data were analyzed by using a statistical software program (IBM SPSS Statistics, v21; IBM Corp). The independent sample *t* test was performed to test the differences between the 2 groups (α=.05 for all the analyses).

RESULTS

The mean SBS values obtained for each specimen are presented in Figure 6. The SBS in group Ti was significantly lower than that in group Bi (t=11.86, *P*<.001).

Mean vertical misfit values, standard deviations (SDs), minimum, maximum, and median, for the different frameworks, are presented in Table 1. All vertical microgap measurements were less than 35 μm (Table 1). Total vertical microgaps were 16 ±6 μm for the Ti group and 19 ±4 μm for the Bi group. No significant difference was found between the 2 groups (t=1.958, *P*>.05).

The results of fracture load and fracture mode testing are listed in Table 2. Statistically significant differences were found between the 2 groups (t=5.190, *P*<.001). However, veneer fracture occurred in 100% of group Ti (Fig. 7), and direct fracture of frameworks occurred in 100% of group Bi (Fig. 8).

DISCUSSION

This study investigated the bond strength of a veneering composite resin to BioHHP and titanium. The SBS in group Bi was significantly higher than that in group Ti. Moreover, as a framework material, BioHPP had clinically acceptable fracture resistance and marginal fit. Therefore, the research hypothesis was accepted.

Durable bonding to veneering materials is required to ensure an adequate functional outcome and long-term stability. Binding force can be obtained by chemical adhesion, mechanical interlocking, or a combination thereof, depending on the composition of the materials used and their interactions.[19,22] The present study focused on the bond strength between framework materials and the veneering resin and revealed a comparatively high value for the shear bond strength between BioHPP and veneering resin. This demonstrates that BioHPP, as a nonmetallic material, has stronger bonding ability with composite resins than titanium. The low shear bond strength between the composite and metal remains a challenge. Limitations of mechanical retention, such as a bulky framework, differences in physical and chemical properties, and microleakage in the interface, result in insufficient bond strength between veneer resin and metal.[9]

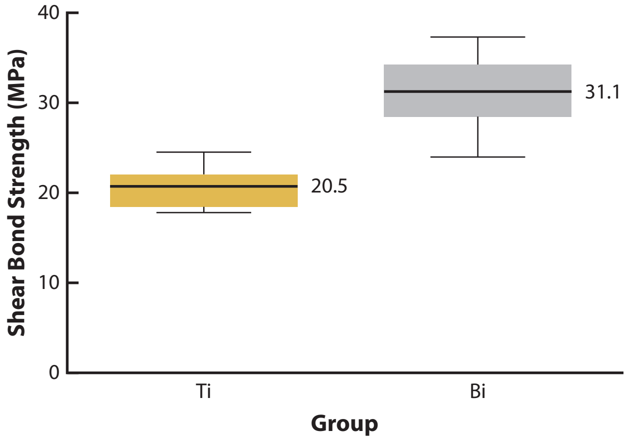

Figure 6. Mean shear bond strength values.

The adhesive system affects the chemical bond between the framework materials and veneering composite resin.[19] The PEEK has been modified by surface treatments, and different bonding systems have been used to improve bonding by increasing mechanical retention and chemical interaction. A recent study has shown that visio.link has a high capacity to modify the PEEK surface

Table 1. Values of vertical microgap (μm) of implants (n=40)

Gap Widths (μm)	Ti (n=20)	Bi (n=20)
Mean ±SD	16 ±6	19 ±4
Minimum	8	11
Maximum	32	33
Median	15	19

Bi, bio high-performance polymer; SD, standard deviation; Ti, titanium.

Table 2. Fracture load value (N) and percentage of fracture mode

					Fracture Mode	
Groups	Mean ±SD	Maximum	Minimum	Median	V	F
Ti	1960 ±233	2323	1598	1945	100%	0
Bi	1518 ±134	1797	1340	1504	0	100%

Bi, bio high-performance polymer; F, framework fracture; SD, standard deviation; Ti, titanium; V, veneer fracture.

to increase the bond strength.[30] The 2 framework materials exhibited different bond strengths when bonding to the same composite resin, although the adhesive methods were different. Further studies are needed to optimize their bond strengths.

This study preliminarily tested the fracture resistance of veneered implant-supported FDPs. Differences were found in the compressive strength between the 2 veneered framework materials. The BioHPP frameworks fractured at a mean load of 1518 ±134 N, with lower compressive strength than that of group Ti. However, the value was still higher than the reported maximum molar masticatory force of 600 to 920 N.[31,32] This suggested that veneered BioHPP FDPs exhibited acceptable resistance to fracture for posterior use. Expanding the surface area of the connector might have increased the fracture load.

The fracture modes of the 2 designs were different. After loading, chipping of the veneering material was observed in all specimens of group Ti but without framework cracking, whereas the main fracture mode of group Bi was direct fracture of the framework rather than veneering chipping. The result revealed that the fracture of BioHPP frameworks appeared to occur earlier than the veneer chipping when the FDPs were subjected to vertical pressure. The fracture strength may be associated with the internal tensile stresses within the FDPs, the strength and thickness of the veneering composite resin, and the bond strength of the framework with the veneering material. Owing to the complexity of affecting factors, the different results still lack accurate and scientific explanation.

The clinically acceptable fit of implant-supported dental prostheses has been reported to be less than 120 μm.[23] A misfit in the framework is likely to cause fewer technical complications such as screw loosening, screw fracture, or occlusal inaccuracies.[24,25] Furthermore, bacteria in the microgaps at the abutment-framework interface may negatively affect peri-implant tissues.[26]

Figure 7. Veneer fracture in group Ti.

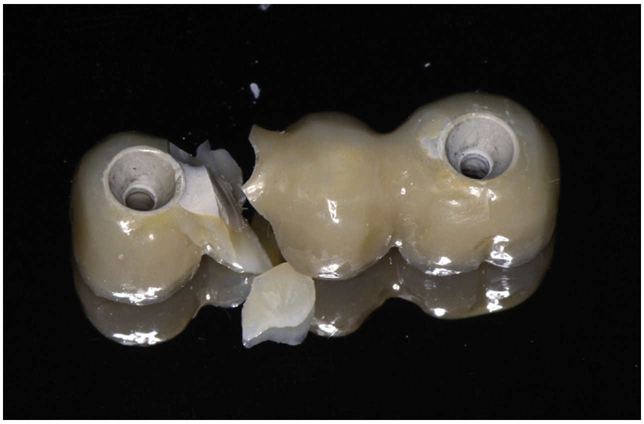

Figure 8. Direct fracture of framework in group Bi.

Owing to the advances in CAD-CAM and restorative materials, better accuracy of long-span and large-volume restorations can be achieved.[28,29] No statistical differences were detected between the CAD-CAM BioHPP and titanium frameworks, and mean vertical misfit values were no more than 35 μm, further indicating that BioHPP could meet the requirements for CAD-CAM frameworks in clinical practice.

This study found that BioHPP, as a framework material, exhibited relatively good properties, especially high shear bond strength with composite resin, suggesting that this nonmetallic framework material may serve as an alternative for implant-supported FDPs and even CAFIPs. Nevertheless, limitations of this in vitro study should be considered. Longer-span and larger-volume restorations need to be simulated and tested. During the simulation of aging, distilled water rather than artificial saliva was used. The stress situation of dental prostheses is complex, and the loading conditions adopted will not simulate the complex 3D situation in the mouth. Thus, clinical trials are needed to support the use of this modified PEEK for long-term restorations under oral conditions.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The bond strength of BioHPP to composite resin was greater than that of titanium.
2. CAD-CAM BioHPP frameworks exhibited good marginal fit and fracture resistance.
3. BioHPP may be a suitable alternative to metal as a framework to be veneered with composite resin.

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