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Cantilever Feasibility in Hybrid Prosthesis with Esthetic Framework Materials an *in vitro* Study

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Abstract

The increase in demand for metal-free implant-supported prosthesis led to the development of new esthetic and biocompatible dental materials used as frameworks. The All-on-four implant-supported complete denture framework can be fabricated from a variety of materials. Traditionally framework material was cast from noble metal (gold) or base metal alloys (i.e Chromium-cobalt) veneered with heat-cured acrylic resin The advent of Computer Assisted Design (CAD) and Computer Assisted Milling (CAM) allowed milling of a substructure free from defects and distortions, passively fitting on the implant platform.

Keywords: Biomedical dental materials • Zirconia • PEEK • Cantilever

Introduction

This technological advancement also allowed for the fabrication of more complex substructures to provide support for stronger material such as zirconia. Zirconia is an aesthetic alternative to metal for implant-supported frameworks, one which offers biocompatibility, low bacterial surface adhesion, and good mechanical properties. On the other hand, zirconia frameworks are of a rigid material having a high modulus of elasticity (210 GPa), which is considered a disadvantage in the masticatory shock absorbance of the prosthesis [1]. Also fully customized zirconia abutments showed a high wear at the implant-abutment interface. It is interesting to note that it is the titanium implant that showed higher wear at the implant interface when connected to a one-piece zirconia abutment compared to a titanium abutment.

Recently Polyetheretherketone (PEEK) frameworks applied to the All-on-four concepts have also been reported. This material enjoys similar strength to that of the dentin and cortical bone, and it has excellent biological compatibility. In addition, it is compatible with aesthetic veneering materials. It is as elastic as a bone with a GPa modulus of elasticity and with an ability to reduce stresses transferred to the abutments. Overloading of the implants could result from the high modulus of elasticity; hence, the transfer of forces to the bone-implant interface is limited in the case of PEEK framework [2]. Few studies have been reported to evaluate the performance of the PEEK frameworks for the rehabilitation of the edentulous patient using the All-on-four concept, especially the behavior of this material in distal cantilevers that are essential components of an All-on-four® restoration to preserve decent functional capabilities of the patient.

Cantilever's length appears to be an important element in designing and fabricating full-arch prosthesis. Moreover, the height and width of the cantilever are crucial in minimizing the amount of deformation of the prosthesis. Today, a large number of materials are available to produce a prosthesis infrastructure. It is recommended that metallic alloys exhibit high tensile strength (>300 MPa) and elastic modulus (>80,000 MPa) sufficient to prevent deformations and cantilevers fractures. Still, guidelines for designing or implementing tooth-colored material frameworks with distal cantilevered segments have not been established yet. PEEK has an elastic modulus that is close to human bone, suggesting homogeneous stress distribution to surrounding tissues. Its radiographic radiolucency and low density (1.32 g/cm^3) makes it suitable for medical applications. PEEK is an inert material with high compatibility to the surrounding tissues and do not reveal any toxicity. Therefore, it is ideal for patients allergic to titanium and other metals. PEEK isn't like metal; its color is beige with a touch of grey and has more aesthetic appearance than the metal.

Limited studies have evaluated the load to fracture of cantilever in Implant Complete Fixed Denture (ICFD) or hybrid implant prosthesis frameworks. This study was designed to investigate the behavior of PEEK implant prosthetic frameworks and adds more information about the length of the distal cantilever, the design and dimensions of the framework. This study aims to assess PEEK distal cantilever reliability in implant supported infrastructure by comparing it to zirconia's resistence to load with two different cantilever loading distances (10 mm, 15 mm). As our study is clinically oriented, we have provided substructures of both materials (PEEK and Zirconia) with maximum possible dimensions specific to each material individually in order to achieve better the functional role of the prosthesis.

Literature Review

Parallel vertical drilling was performed on two sites of the bloc for the first two-implant analog locations, and a 30 degree tilted drilling was performed for the most distal implant analog. All the drilling sites were made 8mm apart from each other. The three analogs were fixed in place with epoxy resin cement and the abutments were fitted in the analogs and tightly screwed on. Twenty frameworks were milled and divided into 4 groups (n=5), according to material type PEEK, zirconia and to the cantilever loading distance (10 or 15 mm). The first epoxy test apparatus (M1) was scanned by (Arum 3D scanner, Arum Europe GmbH Frankfurt, Germany). PEEK frameworks (CopraPEEK Medium, White Peak Dental System Essen, Germany), were milled using Arum 5 × -200 milling unit (Arum Europe GmbH Frankfurt, Germany). In addition, the second epoxy test apparatus (M2) was scanned and 10 zirconia frameworks (Copran Zri, White Peak Dental System Essen, Germany). All the zirconia frameworks were sintered according to the manufacturer instructions in a sintering furnace (ARUM HTS-2, Arum Europe GmbH Frankfurt, Germany)

The frameworks were designed using Exocad software (Exocad GmbH, Darmstadt, Germany), and the cross-section of the frameworks was a rectangular shape with a full length of 40 mm. The frameworks section dimensions were decided, as suggested by the fabricants, to be 6×6mm for PEEK, 4×4mm for zirconia for the inter-abutment space , a 2mm increase of vertical height in all the frameworks was applied at the distal cantilever connection will result in: 8x6 mm for PEEK, 6x4 mm for zirconia. Abutment wall thickness was 3 mm for PEEK, 2 mm for zirconia.

At the level of each cantilever of each framework, two dimples with 2 mm diameter and 0.5 depths were created on the upper surface of the cantilever at 10 and 15 mm from the distal implant to facilitate the loading rod positioning. Finally, the Variobase abutments were cemented on each bar by resin cement (Variolink Esthetic dual-curing luting cement, Ivoclar Vivadent, Schaan, Liechtenstein). The frameworks were kept to rest for 24h before the loading experimentation. Each framework was then mounted on the implant analogs, secured with abutment screws, and torqued to 35 Ncm with a manual torque wrench. Moreover, a mini stainless steel clamp was attached to each framework at the level of the first abutment to hold steady the whole apparatus together (framework and epoxy model), and avoid any disengagement of the cement during the load application.

Testometric M350-10KN was used. The application of an axial load performed at a crosshead speed of 2 mm/min until complete breakdown. The traditional load-to-failure test was performed in this test, which uses a static load that was increased incrementally with a 2 mm/min crosshead speed until the occurrence of the specimen. All specimens were loaded from 0 Newton (N) until fracture occurred. The load was applied on the dimples located at 10 mm or 15 mm distance from the posterior implant. The load value at the cantilever's fracture was automatically recorded by the software.

Sample's Description

The sample contained 20 frameworks divided into two equal distinct main groups according to Framework Material (Zirconium Group and PEEK Group). Each one of the main groups was divided into two equal distinct subgroups according to Cantilever Loading Distance (10 mm Group, 15 mm Group).

The highest load-to-fracture values were found for the zirconia group with 817.66 N for 10 mm and 555.34 N for 15 mm cantilever loading distance, and the lowest values were found for the PEEK group with 651.16 N for 10 mm and 375.88 N for 15 mm cantilever length. Effects of Framework Material and Cantilever Loading Distance on load to fracture (in newtons) were studied.

Both P-values were much lower than 0.05, so we can conclude at 95% of confidence level that there were significant differences in the load to fracture values (in newtons) Zirconia Group and PEEK Group whatever the Cantilever Loading Distance was the sample [3]. Positive Algebraic sign of mean differences indicates that load to fracture values (in newtons) in Zirconia Group were greater than those of PEEK Group whatever the Cantilever Loading Distance was in the sample. Independent Samples T test was applied to know if there were significant differences in load to fracture values (in newtons) between 10 mm Group and 15 mm group.

Discussion

A study was conducted on fracture resistance of the cantilever in All-on-four frameworks with two different materials and different cantilever lengths. The load to fractures was the highest for the Zirconia frameworks, and the lowest loads were sufficient to fracture the PEEK frameworks. It is also noted for all the categories the load to fracture was the highest for the shortest cantilever.

Both esthetics materials namely Zirconia and PEEK used in the present study scored values within those ranges mentioned above which are enough to resist masticatory forces in just the 10mm cantilever group.

Specimens with 10 mm length and 3 × 5 connection area mm fractured at a mean load of 923.7 N and other specimen with same cross section area but with 7mm length cantilever failed at 1011.7 N for 7 mm, while specimens with a connector 3 × 4 mm failed at 474.8 N and 700.9 N for 10 and 7 mm of cantilever length, respectively. The authors suggested that cantilever in zirconia frameworks might be best limited to a single cantilever unit [4]. Values reported in the present study with a 10 mm cantilever length of zirconia material and a cross-sectional area of 4 × 6 mm showed lower loads to fracture in comparison with the same cantilever and smaller cross-sectional area (3 × 5 mm). This variation could be due to the difference in the framework designs, in this experiment the frameworks were cemented on the Variobase abutments, while in Chong study the frameworks were screwed directly into the implant analogues which gave them strength and resistance to fracture.

Another *in-vitro* study evaluated the load to fracture of zirconia frameworks, zirconia All-on-four frameworks loaded at 10 mm cantilever length, and with 10 mm2 cross sectional dimension using failed at 905 N. On the other hand the zirconia framework in the present study loaded at the same cantilever length and with 16 mm^2 cross-sectional area using failed at a lower load of 817 N. This discrepancy can be explained by the concentration of the force at the end of the cantilever in contrast to de Fransco who interposed a silver foil of 1 mm thickness between the pressure gauge and the framework to better distribute the force on the entire cantilever.

A study also compared different specimens according to the cantilever length (7 mm, 10 mm, and 17 mm) and connector dimensions (6 × 6 mm, 6 × 8 mm, and 6 × 10 mm). The highest load-to-fracture value was found for the group with the highest occlusal-cervical thickness (10 mm) and the shortest cantilever length (7 mm). The results from this study showed that increased vertical dimension at the connector level provided improved fracture resistance. This is in agreement with the results reported. One of the critical factors for the long-term success of the fixed implant-supported prosthesis is the framework design. The design depends primarily on the geometry and characteristics of the material. The height should have a minimum of 4 mm. Posterior wall thickness should be a minimum of 6 mm and anterior wall thickness, a minimum of 5 mm. The abutment wall thickness should be a minimum of 1 mm. For tooth-supported zirconia-based restorations, the minimal recommended dimension of connectors is 4 × 4 mm; this was applied to the design of implant-supported frameworks, preserving 16 mm2 of section area, at the level of connectors. The load to fracture of PEEK frameworks; their study was designed to investigate the behavior of a PEEK implant-supported prosthesis with a cantilever design in a five-year chewing simulation. The fracture values after 5 years of simulated chewing were 4393 N for the fully anatomic PEEK denture and 2553 N for the PEEK framework with composite veneering.

The mean fracture strength of the PEEK restorations was considerably lower (1430 N) than zirconia, but considerably higher than that of the reported physiological maximum posterior masticatory force of 880 N. They concluded that PEEK restorations fabricated in excessive crown height space can potentially withstand physiological occlusal forces. One of the main shortcomings of PEEK restorations is their low bonding to the veneering materials [5]. Several studies showed adhesive failures or crown popping of PEEK frameworks; others showed different bonding techniques to avoid failures such as sandblasting and laser treatment, among others. This fact can be explained by the deformation of the PEEK frameworks under load before the complete fracture as observed during the experimental procedures in this study where the PEEK frameworks bended under load before complete fracture. The frequent disengagement of the veneering material from the framework can be explained by this bending phenomenon.

Due to its low elastic modulus PEEK provides a cushioning effect on occlusal forces. When it is combined with low elastic modulus materials such as poly (methyl methacrylate) (PMMA) or composite resin, it will further reduce occlusal forces to the restoration and the opposing dentition. Therefore, the use of PEEK can be advantageous for implant supported prosthesis where there is no proprioception on implant interface. Screw loosening and veneer complications are reduced to minimum. On the other hand, the use of rigid frameworks fabricated by metal or zirconia could lead to plastic deformation of the implant shoulder and screw fractures.

Conclusion

This study explored the cantilever feasibility in hybrid implant prosthesis with two esthetic framework materials namely Zirconia and PEEK. A load-to-fracture test was conducted on two different framework materials (PEEK and zirconia) that were used for hybrid implant prosthesis with two different cantilever loading distances (15 mm or 10 mm). The highest load-to-fracture values (817.66 N) were found for the zirconia framework with 10mm cantilever length and the lowest load (375.88 N) was needed to fracture the PEEK frameworks with 15 mm of cantilever length.

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