Cantilever Protocol Bars in Acrylated Polyetheretherketone (Peek): A Mechanical Compression Assay

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Abstract

Aim and Objective: To assess the mechanical behavior of acrylated protocol bars made of polyetheretherketone (PEEK) in different designs. Materials and Methods: Using the CAD/CAM, 3 types of bars were designed. Eighteen bars went through a milling cut process, being 6 of each type, and then acrylated. The bars were screwed to the prosthetics pillars of the matri× and submitted to the mechanical compression assay. The resistance data were submitted to two-way analysis of variance and Tukey's test. Results: The modified T-type bar showed significantly higher resistance to compression at the left cantilever, whereas the squared bars were significantly more resistant at the right. There was no significant difference amongst the three designs when the load was applied at the Centre. Conclusion: All three designs showed similar behavior to the compression load applied at the Centre.

Key Words: Prostheses and implants, Dental implants, Biomedical and dental materials

Introduction

Dental prostheses of the cantilever type protocol have shown lower stress level in their infrastructure due to the size of the support bar as well as it shape, which yields a more stable and solid system [1].

The bars lead to an implant splinting and may assist the stabilization and distribution of the occlusal loads. This type of prosthesis causes modification of the strength distribution in the surrounding bone tissue [2]. Several bar designs as well as confection materials and techniques have been described in the literature [3].

The PEEK (Polyetheretherketone) is a semicrystalline polymer of high performance used as protocol bars [4] due to its mechanical properties, stability in high temperatures, and chemical resistance – the PEEK is in intimate contact with the saliva without reacting intraorally– in addition to getting great aesthetic results, having low weight, and being an alternative to patients who are allergic to metals [5-7].

The PEEK represents a suitable biomaterial not only capable of replacing the conventional polymers, but also metals and ceramics in the odontology field [8].

Given the aforementioned regarding PEEK, the aim of the present study was to assess the mechanical resistance of three different designs for protocol bars made with PEEK by means of the system CAD/CAM after being acrylated.

Materials and Methods

The study was approved by the research ethics co mmittee (REC) of São Leopoldo Mandic School of Dentistry and Dental Research Centre, under the protocol number 2017/6767.

Initially, an aluminium matri× containing four parts was developed (Precisão Poços Tec., Poços de Caldas, Brazil). The base had four equidistant holes placed at a distance of 21 mm from the centre, in which the straight mini-pillar analogues were fi×ated (Neodent, Curitiba, Brazil) simulating the actual position of the implants. The mini-pillar analogues functioned as support for the bars at the moment the compression was applied. On the same base, positioned in parallel and from behind the holes, two protrusions were placed for a tight fit in the middle part – or body – of the matri× (*Figure 1A*). The body of the matri× has two holes in order to fit the two protrusions from the base. It has the intended shape of the bar and will be used for the insertion of the piece (*Figure 1B*). The lid has four holes coincident with the location of the mini-pillar analogues of the base (*Figure 1C*). Finally, the last part is an over-lid with a screw thread in order to avoid any displacement of the matri× during insertion (*Figure 1D*).

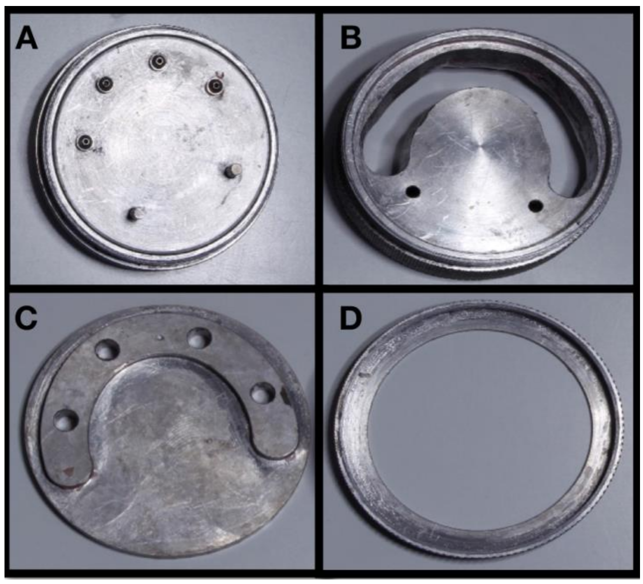

***Figure 1.** Aluminium matri× (A) base, (B) body, (C) lid, (D) over-lid.*

Titanium prosthetic pillars with dimensions of 4.5 mm × 10.0 mm (Derig, São Paulo, Brazil) were developed in order

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to connect the bars to the mini-pillar analogues just as a clamping key in stainless steel and clamping component in titanium (Derig, São Paulo, Brazil). These clamping components were used to fi×ate the bar to the titanium prosthetic pillar once the acrylization procedure was carried out.

Using a delineator, the mini-pillar analogues were positioned and then fi×ated with Duralay acrylic resin (Reliance Dental CO, Worth, USA). Subsequently, the prosthetic pillars were screwed.

Ne×t, the prosthetic components positioned at the base of the matri× were pulverized with Ainsworth Scanner metallic powder and scanned using the scanner D900L (3Shape, Copenhagen, Denmark) for the production of a virtual model. The project was developed using the CAD Software 3Shape (3Shape, Copenhagen, Denmark). The bars were projected from three drawings of different sections, namely, rounded, squared, and modified T-type. For the production of the bars, PEEK Victre× discs were used (Poliflúor, São Paulo, Brazil), with dimensions of 98.0 mm × 16.5 mm and machined using a 5-a×es milling machine DW× 51D (Roland DG, São Paulo, Brazil).

Eighteen bars with dimension of 3.5 mm × 5.0 mm and a cantilever of 10.0 mm were obtained, being 6 bars of rounded section, 6 bars of squared section, and 6 bars of modified T-type section (*Figure 2*). One bar of each group was used for the pilot test.

Figure 2. *Bar types produced with milling cut.*

The prosthetic pillars were fi×ated to the bars using a 20N torque. After that, each bar was fi×ated with the clamping component (*Figure 3A*) before getting wa×ed. Dental wa× number 7 Lysanda (Lysanda Produtos Odontológicos Ltda., São Paulo, Brazil) was used.

Before wa×ing, the holes of the titanium prosthetic components were covered with dental silicon Zeta Labor (Zhermack, Turin, Italy) in order to avoid penetration of the melting wa×. Once the wa×ing was finished, four straight mini-pillar analogues were fi×ated and screwed in each wa× test model, and acrylization of the bars were conducted.

The finishing and polishing of the bars took place using high cutting drills and polishing file. The final polishing was done using pumice stone and Universal Polish polishing paste (*Figure 3B*).

Figure 3. *(A) Fitting of the bar with the aluminium matri× for posterior insertion, and (B) finished bars.*

For the mechanical compression assay, it was used the DL 2000 universal testing machine (EMIC Ltda., São Jose dos Pinhais, PR, Brazil). For strength application, the e×act mean points in the application zone were stipulated using a pachymeter, being the location of these points at 5 mm from cantilevers and 5 mm at the centre of the bar. The bars were fi×ated to the matri× with a 20N torque.

Based on the pilot test, the machine was calibrated with a load cell of 2000N and actuator speed of 5 mm/min during one minute. This sequence was applied in three regions: centre, right cantilever, and left cantilever, in that order.

Results

The data of the resistance to compression were submitted to two-way analysis of variance (ANOVA) in order to investigate the influence of the bar design and the location of load application, as well as any interaction between these two variables. Tukey's test was used for multiple comparison correction. The statistical calculations were done using the software SPSS 23 (SPSS Inc., Chicago, IL, USA) at 5% significance level.

Table 1. *Mean and standard deviation of the resistance to compression, in kgF, based on the design of the PEEK bar and location of the load application.*

Location	**Rounded**	**Modified T-type**	**Squared**
Right	154.91 Bb (27.50)	189.75 Bc (162.55)	344.94 Ab (184.58)
Centre	424.57 Aa (67.83)	463.33 Ab (113.44)	492.19 Aa (169.62)
Left	246.90 Bb (122.34)	656.25 Aa (318.84)	272.12 Bb (133.20)

The two-way ANOVA showed that the resistance to compression was significantly affected by the interaction between the bar design and the location of load application ($p = 0.007$, test power = 87.9%).

Tukey's test indicated that when the load was applied to the right, the squared bar presented significantly higher resistance to compression than the one observed for the rounded and modified T-type design groups – which did not significantly differ between one another. On the other hand, when the load was applied to the left, the modified T-type bar showed significantly higher resistance to compression than the other two groups (with no significant difference between them). When the load application was at the centre, there was no significant difference amongst the three types of bar design regarding the resistance to compression (*Table 1 and Figure 4*).

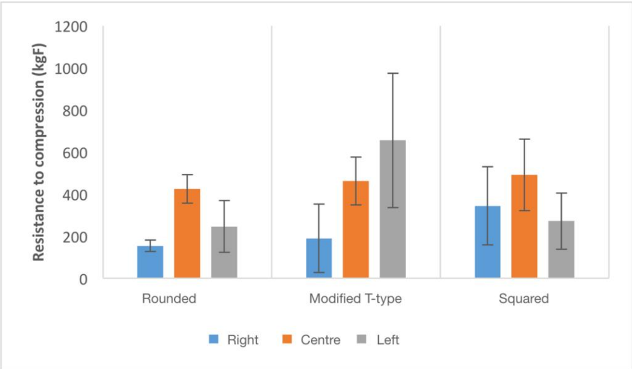

Figure 4. *Histogram (mean ± standard deviation) of the resistance to compression values based on the design of the PEEK bar and location of the load application.*

For the bars with rounded and squared designs, the highest values of resistance to compression were obtained when the load was applied to the centre, with no significant difference when the load was directed to the right or to the left. For the modified T-type bar, the resistance was significantly higher when the load was applied at the left in comparison to the load directed to the centre. However, at this location, the load was superior than that found when the load application was at the right.

Discussion

At the beginnings of dental implantology, the major faced problems were related to biological issues such as hypertrophy, hyperplasia, and infla mmation of the peri-implant tissues. Nowadays, with the improvement of techniques and materials, the most frequent challenges are fractured screw, fracture or abrasion of the acrylic coating, and the fracture of the prosthesis infra-structure [9].

The region of the molars or that of the cantilever is the place of the highest overload of bar strength [10]. In the present study, the strength application was at the region of the cantilevers and at the centre of the bars according to the works of Waddell et al. [11] Dunnen et al. [12] found fracture in the infra-structure of the cantilever, however, the acrylic coating fractured at the three locations of strength application, which is in accordance with the results observed in the present study.

One of the main causes of protocol success is the precise design of the bars [13]. The design depends upon the geometry and on the characteristics of the prosthesis material [14]. The must have at least 3.0 mm of thickness [15]. The bars used in the present work had the dimensions of 3.5 mm × 5.0 mm. Mericske-Stern et al. [16] suggest that the design of the prosthesis depends upon the quantity and location of the implants, being proper between 4 and 6 implants. Taking this into account, in the present research, the bars were projected over 4 implants.

Designs with 'I' and 'L' shapes are great clinical options and the 'I'-shaped bar is the one with higher resistance at the region of the cantilever. Rasmussen et al. [17], Staab and Stewart [18] reported no difference between the test results for the oval e elliptic bars. Mericske-Stern et al. [16] recommend bars of 'U'-type because of a larger transversal area to promote a better bonding at welding. De Carvalho et al. [4] tested the resistance to compression of the 'T' bar, inverted 'T' bar, and rectangular bar, all made of PEEK, and concluded that the most resistant design was the rectangular bar. On the other hand, Zarb and Jansson [19] reported that the infra-structure design would not significantly affect the biomechanical behaviour of the prosthesis.

The size of the cantilever is also important and they should not e×ceed 20 mm [15]. In the present study, they had 10 mm.

There are several techniques for the manufacture of infra-structures, such as the lost wa× method, prefabricated titanium bars, and casting monoblock with cylinders rectification [20].

The interest in the technology CAD/CAM for restorations over implants has increased for several reasons, including the fact that the protocol bars and the abutments can be produced with milling cut from solid pure discs, being for this reason, more homogeneous. CAD/CAM-fabricated bars demand less time in manufacturing, show higher precision, and the physical properties of the material are not affected in comparison to other methods [5,13]. By contrats, other study found similar clinical and radiographic results between CAD/CAM-fabricated and gold alloy infra-structures [21]. In the present work, the CAD/CAM was used due to the vantages presented by the system.

On choosing a material for infra-structures, the professional must take into account its properties and characteristics [22]. Amongst the used materials, the polyetheretherketone (PEEK) has outstood as a feasible alternative for having properties as chemical and radioactive resistance, high stability in temperatures higher than 300 degrees Celsius, and greater resistance than some metals [23]. In addition, the PEEK is a biocompatible, non-conducting, and thermally insulated material. Even with low modulus of elasticity and rigidity, the resistance to abrasiveness is similar to that of metal alloys [5,24]. The PEEK is a polymer with colouration similar to the tooth, and it is used as biomaterial in orthopaedics [7,25]. Authors have suggested the use of PEEK bars due to the ease in manufacturing using the CAD/CAM technology as well as its comfort and low weight of the infra-structure when compared to metal bars [6]. Moreover, it was observed greater stability, absence of noise, and premature contacts [5].

There is the possibility to strengthen the PEEK using other materials, such as glass or carbon fibres, which improve the PEEK properties [23]. Based on results of fle×ural resistance tests, authors suggested that the PEEK is far more resistant that several plastic materials used in dentistry [7]. In the present study, pure PEEK was used, without any mi×ture or reinforcement with other type of materials.

One study was conducted to evaluate the behaviour of the implant-supported prosthesis having an infra-structure of PEEK and a cantilever design, in a mastication simulation up to 5 years. The results showed that 4393N would fracture the resin coated infra-structures whereas 2553N would fracture the uncoated ones. Since the average load at molars zone is around 500N, both options are valid [26]. In the present work, all compression resistance results were obtained at a force superior to 500N with a purpose of enabling the bars to have an eventual clinical use. Nevertheless, the present research was not able to demonstrate a representative advantage amongst the assessed bar designs.

Conclusion

We conclude that the acrylated modified T-type bars showed higher resistance to compression at the left cantilever, whereas the acrylated squared bars presented higher resistance to compression at the right cantilever. Nevertheless, all three designs of the acrylated bars showed similar behaviour to the compression load applied at their centre.

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