Fabrication of a removable partial denture of injectable poly (ether-ether-ketone) (PEEK) made partially by a digital workflow: case report

Fabricação de uma prótese parcial removível de poli (éter-éter-cetona) injetável (PEEK) feita parcialmente por um fluxo de trabalho digital: relatório de caso

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ABSTRACT
The introduction of computer-aided design and computer-aided manufacturing in rehabilitation with removable partial denture, enabled the emergence of new methods of fabrication of the framework and materials. In view of this, polyether-ether-ketone appears as an alternative to Cobalt-Chromium, due to its aesthetic properties, high resistance and for being non-allergic. In this sense, the present study aimed to report a clinical case where the framework of a removable partial denture was manufactured from a digital workflow, using polyether-ether-ketone as the

material of choice, compared to a removable partial denture made with a cobalt-chromium framework. In this case, it was possible to perceive that the use of computer-aided design and computer-aided manufacturing technology for the construction of a removable partial denture framework of polyether-ether-ketone resulted in a denture with adequate adaptation and good aesthetics. Patient satisfaction, comfort, retention, number of follow-up sessions, masticatory performance and quality of life were evaluated. Compared with the conventional denture, the polyether-ether-ketone framework denture provided better satisfaction and comfort. Both prostheses showed similar results in terms of masticatory performance and in terms of quality of life, however the polyether-ether-ketone framework denture showed better results. In conclusion, polyether-ether-ketone proved to be a viable material for making removable partial denture framework. However, controlled and randomized clinical trials are needed to demonstrate the benefits of this treatment as an alternative in relation to the conventional denture.

Keywords: removable partial denture, biomedical and dental materials, polymers, technology, computer-aided design.

RESUMO
A introdução do desenho assistido por computador e a fabricação assistida por computador em reabilitação com prótese parcial removível, permitiu o surgimento de novos métodos de fabricação da estrutura e dos materiais. Em vista disso, o poliéter-éter-cetona aparece como uma alternativa ao cobalto-cromo, devido a suas propriedades estéticas, alta resistência e por ser não alérgico. Neste sentido, o presente estudo teve como objetivo relatar um caso clínico onde a estrutura de uma prótese parcial removível foi fabricada a partir de um fluxo de trabalho digital, utilizando o poliéter-éter-cetona como material de escolha, em comparação com uma prótese parcial removível feita com uma estrutura de cobalto-crômio. Neste caso, foi possível perceber que o uso de desenho assistido por computador e tecnologia de fabricação assistida por computador para a construção de uma estrutura de prótese parcial removível de poliéter-éter-cetona resultou em uma prótese com adaptação adequada e boa estética. Foram avaliados a satisfação do paciente, o conforto, a retenção, o número de sessões de acompanhamento, o desempenho mastigatório e a qualidade de vida. Em comparação com a dentadura convencional, a estrutura de poliéter-éter-cetona proporcionou melhor satisfação e conforto. Ambas as próteses apresentaram resultados semelhantes em termos de desempenho mastigatório e em termos de qualidade de vida, porém a prótese de estrutura de poliéter-éter-cetona apresentou melhores resultados. Em conclusão, a prótese de poliéter-éter-cetona provou ser um material viável para a confecção de dentaduras parciais removíveis. Entretanto, são necessários ensaios clínicos controlados e randomizados para demonstrar os benefícios deste tratamento como uma alternativa em relação à dentadura convencional.

Palavras-chave: dentadura parcial removível, materiais biomédicos e odontológicos, polímeros, tecnologia, desenho assistido por computador.

1 INTRODUCTION

The conventional Removable Partial Denture (RPD) is a type of denture made from a metallic alloy framework (with cobalt-chromium as the most used alloy), in combination, with the replacement of artificial teeth, aiming to reestablish function and aesthetics. However, this type of denture has disadvantages, such as poor aesthetics due to the metallic coloring of the framework and its components, such as clamps and supports.[1]

As an alternative to metal alloys, the use of polymers in the manufacture of RPD framework was introduced with the aim of adding more aesthetics to this type of rehabilitation. Among the high-performance polymers used in dentistry, polyether-ether-ketone (PEEK) stands out. This material can be manufactured by various techniques. The most common methods are injection molding or computer-aided design/computer-aided manufacturing (CAD/CAM) milling techniques. Some authors[2, 3] have described the clinical use of RPD's made of machined PEEK, justifying its use through the mechanical properties presented by this material, among them the fact that it is biocompatible and allows a reduction of the stresses transferred to the abutment teeth, due to its high modulus of elasticity.[4, 5]

However, comparative studies regarding the clinical performance between PEEK and Cobalt-Chromium framework are scarce, but the available studies present it as a promising material in the manufacture of RPD's framework.[6] In addition, there are reports of studies comparing milled PEEK and injectable PEEK framework, where the injectable method was evaluated as more promising when compared to the milling method of the CAD/CAM technique.[7]

In this sense, the present study aimed to report a clinical case where the framework of a RPD was manufactured from a digital workflow, using injectable PEEK as the material of choice, compared to a RPD made with a cobalt-chromium framework (Cr-Co). Patient satisfaction, comfort, retention, number of follow-up sessions, masticatory performance and quality of life were evaluated. The null hypothesis assumed there is no difference between the two materials used in making the RPD.

2 CLINICAL REPORT

2.1 ETHICAL CONSIDERATIONS

This clinical case was submitted to the Research Ethics Committee of the Federal University of Rio Grande do Norte and was approved with the following opinion number: 5.191.014.

2.2 ANAMNESIS AND CLINICAL EXAMINATION

The present clinical case is a female patient, 72 years old, who attended the Dentistry Department of the Federal University of Rio Grande do Norte (UFRN) for clinical evaluation.

During the anamnesis, the patient reported a previous diagnosis of Sjögren's Syndrome, and the following main complaint: “replace lost teeth”.

In the extraoral clinical examination, no abnormal clinical changes were observed. Intraorally, the absence of elements: 18, 17, 14, 24, 25 and 28 was evidenced, and the need for restorative treatment as a result of a carious lesion in tooth 15. Due to the reported dental absences, the patient's upper arch was classified as Class II, Kennedy modification.[2]

2.3 REHABILITATIVE PLANNING

The patient was oriented about the possibilities of treatment and instructed to sign the Free and Informed Consent Form to begin the planned steps. Oral hygiene and diet guidelines were discussed, and the mouth preparation stage began, which consisted of periodontal treatment and restoration of tooth 15. For the rehabilitative treatment, a Removable Partial Denture (RPD) was planned. As a way of evaluating the performance of the PEEK framework, two prostheses were planned and manufactured: (1) RPD in Cr-Co, performed by the conventional laboratory process of cast alloy; and (2) RPD in PEEK, manufactured by the injection method.

All the usual clinical procedures that lead to prosthetic rehabilitation with RPD were performed from obtaining the study model to making the acrylic RPD. The first step consisted of making study impressions to make the preliminary models of both arches. The molds were poured to obtain the study models using type IV plaster (Dentsply, New York, USA).

2.4 STUDY MODEL DESIGN

The study model was designed using a B2 parallelometer eyeliner (Bio-Art, São Paulo, Brazil). This procedure was performed with the objective of acquiring information about the shape and contour of the abutment teeth and adjacent tissues. Such information made it possible to plan the preparations of RPD abutment teeth (guide planes, retentive areas, interferences, esthetics and adequacy of the prosthetic equator).[1]

Subsequently, the working model was scanned using the Generation Red bench scanner (3shape, Copenhagen, Denmark) to perform the surveying using Dental CAD software (Exocad – GmbH, Hesse, Germany) (Figure 1). This second design was carried out in order to check the accuracy of the parameters found in the conventional design. It was observed that the retentive regions highlighted in green and blue were in accordance with those observed in the conventional design.

2.5 MOUTH PREPARATION

After defining the trajectory of insertion and removal of the RPD, niches were planned in the abutment teeth (16 - Mesial; 13 - Mesial; 23 - Mesial; 26 - Mesial) in Dental CAD software (Exocad – GmbH, Hesse, Germany). It is important to emphasize that element 15 had a milled crown with a niche located in the occlusal-distal region. No adjustments to the prosthetic equator were necessary. After tooth preparation, the patient was molded using condensation silicone, Putty Profile (Coltene, Rio de Janeiro, Brazil), and the working model was made using type IV plaster (Dentsply, New York, USA).

2.6 PLANNING OF CR-CO AND PEEK FRAMEWORK

Planning was carried out for the construction of two framework for the RPDs. Both, based on the design of the twin clamps (15 and 16), circumferential clamp (26), modified MDL (23) and the single palatal plate major connector. The Co-Cr framework was obtained from the plaster working model, while the PEEK framework was made digitally, using Dental CAD software (Exocad – GmbH, Hesse, Germany) (Figure 2).

2.7 CONSTRUCTION OF THE FRAMEWORK IN CR-CO

After completion of the planning, the construction of the framework of the RPDs was carried out. It started with Cr-Co (Laboratório Siso, Rio Grande do Norte, Brazil), by duplicating the working model in a coating model. Next, the metal framework was waxed; inclusion to obtain the mold for later casting and injection of the metal in the coating mold; disinclusion of the metallic framework, and the final stage of finishing and polishing (Figure 3A).

2.8 FABRICATION OF THE PEEK FRAMEWORK

The fabrication of the framework in PEEK, OverPeek (Celmat, São Paulo, Brazil) was initially carried out by printing the castable patterns in 3D Smart Print Try-in Castable resin (Smart Dent, São Paulo, Brazil). For this, a MiiCraft 125 Ultra 3D printer (Smart Dent, São Paulo, Brazil) was used with an accuracy of ± 32.51 µm in the XY plane.

The 3D model for adapting the PEEK frameowrk was printed on the Anycubic Photon Mono X 4K SLA/LCD 3D printer (Anycubic, Shenzhen, China). Subsequently, the printed model was inserted into the Anycubic Wash & Cure Plus washing and curing machine (Anycubic, Shenzhen, China) in order to improve the material properties.

Subsequently, the castable resin patterns were coated using Bellavest HS (Wilcos, Rio de Janeiro, Brazil) and Begosol HE (Wilcos, Rio de Janeiro, Brazil) products.

When the coating was finished, the metal ring was placed in a Vulcan 3-550 oven at 900 °C (Dentsply, New York, USA) in order to create a mold for PEEK injection. Sequentially, after 60 minutes, the ring was removed from the oven and placed in the OverPress device (Gold Icel, São Paulo, Brazil) to inject OverPeek (Celmat, São Paulo, Brazil) at 370 °C for 20 minutes. After the injection, the metallic ring was inserted in the OverCooler device (Gold Icel, São Paulo, Brazil) to be cooled and opened.

Subsequently, the metal ring was opened to remove the PEEK framework, and then the framework was finished and polished using a kit from OdontoMega (São Paulo, Brazil) (Figure 3B).

2.9 TESTING OF FRAMEWORK MADE OF CR-CO AND PEEK

In the test-in-mouth phase of the Cr-Co and PEEK framework, it was observed that their insertion and removal, that is, the supports on the niches, coincided with the predetermined trajectory in the conventional and surveying (Figure 4A e B). It is important to note that the PEEK framework weighed 176 grams, while the Cr-Co framework weighed 964 grams (Figure 5). In addition, adaptation, retention, stability and occlusion were also evaluated. Subsequently, the color selection of the artificial teeth was performed, according to the Biotone Scale (Dentsply, New York, Brazil), as well as the gingiva, based on the Tomaz Gomes System Scale (Vipi, São Paulo, Brazil).

2.10 ASSEMBLY OF TEETH AND ACRYLIZATION OF FRAMEWORK MADE OF CR-CO AND PEEK

After checking the items mentioned above, the Cr-Co and PEEK framework were sent to the Dental Prosthesis Laboratory, for assembly of the models in a semi-adjustable articulator (Bioart®2000, São Carlos, SP, Brazil) and acrylization of artificial teeth in both framework.

2.11 INSTALLATION AND FINAL ADJUSTMENTS OF PRRS MADE OF CR-CO AND PEEK

In the installation phase (Figure 6), the quality of the surface finish and settlement of the RPDs were evaluated, with the same being oriented to make the initial use for 15 days, only of the RPD made with PEEK framework and, later, the use of RPD with a conventional metallic framework for another 15 days.

2.12 APPLICATION OF THE ORAL HEALTH IMPACT PROFILE (OHIP-14) QUESTIONNAIRE

After each period of use was established for each RPD, the level of patient satisfaction was also evaluated, since the quality of life is directly related to the dental condition. In this sense, a 14-question questionnaire called OHIP-14 (Oral Health Impact Profile) was applied. This questionnaire is based on the OHIP-49 initial assessment instrument, a 49-question questionnaire that aims to analyze the perception of the impact of oral conditions on the well-being, based on Locker's theoretical model of oral health. It is worth mentioning that the OHIP-14 includes the impact of oral health, taking into account seven dimensions, functional limitation; physical pain; psychological discomfort; physical disability; psychological disability; social disability and impairment/disadvantage. The OHIP-14 questionnaire response score ranges from 0 (never), 1 (rarely), 2 (sometimes), 3 (sometimes) and 4 (almost always). To calculate the severity of the impact, the values are added together (additive method). Higher values indicate a worse quality of life.[8]

The patient reported adaptation with the PEEK and Cr-Co framework after 15 days of use. In the answers to the OHIP-14 questionnaire, the patient mentioned that she had no difficulty in eating with the use of both prostheses and had never had speech difficulties, being satisfied with the treatment. The score found according to the pre-established sum of the OHIP-14 questionnaire was 0, showing that the patient was satisfied with her oral conditions and well-being. The one difference that was noted by the patient was her aesthetic and functional satisfaction in relation to the denture of the PEEK framework, as it is a lighter material and easier to use.

3 DISCUSSION

The digital systems of virtual planning in Dentistry that are currently available on the market are capable of handling the data obtained through digital scans made on plaster models or directly from the patient.[9] The CAD/CAM system also allows for agile communication between prosthetic laboratories, the possibility of merging intraoral digital models with 3D facial scan data and greater efficiency in the patient's treatment plan.[10] The advantages of using digital impressions are numerous, but the comfort offered to the patient is the greatest advantage, as there is no discomfort caused by conventional impression materials, such as nausea.[11]

However, these intraoral scanning systems have disadvantages: training is required to operate the system so that measurements are accurate and fast.[11, 12] The operating field must be dry, as the presence of gingival fluid can cause error due to optical refraction.[13, 14] The registration of the mandibular position is fixed, not being able to perform dynamic occlusion on the patient, however some CAD software packages have a virtual articulator that allows mandibular movement. Certain providers charge users optical printing fees and have closed systems. In addtion, purchasing an intraoral scanner is still expensive.[14, 15] In our study, the indirect scanning method was used, using the model previously molded and poured in plaster, with subsequent bench scanning, given that this type of scanning is still the most accurate system as compared to intraoral scanners.[16]

Digital technology can be implemented in several areas of dentistry, and using it to fabricate removable partial dentures would be no different. RPDs are devices designed to replace lost teeth and restore the function and aesthetics of patients with partially edentulous arches. This rehabilitation presents, the stock teeth that replace the lost teeth and also a framework that is commonly metallic, where Cr-Co is the material of choice most often used.[17]

The reason why CR-Co is such a widely used material is due to its relatively low cost, biocompatibility, as well as its mechanical and physical properties, and it has predictive characteristics that are well documented.[4, 17] Although Cr-Co is the gold standard, with regard to the material for making RPD's, it has some limitations: (1) aesthetic problems, especially if the ends of the staples are located in the anterior area; (2) discomfort felt by patients; (3) deleterious effects on abutment teeth; (4) fracture of the staples; (5) formation of microporosities following its manufacture due to material shrinkage.[6]

In view of this, studies with the aim of reducing the disadvantages, caused by the use of metal alloy in the manufacture of RPD's, present PEEK (Poly(ether-ether-ketone)) as a more aesthetic and comfortable alternative.[6] In the present study, a comparative analysis was performed between the use of Cr-Co and PEEK in the manufacture of RPD's in order to assess the acceptability of the patient and the level of satisfaction. It was observed that the PEEK framework was well accepted, especially with regard to aesthetics and comfort. The main reason for this increased level of acceptability and comfort comes from the comparison of the weight of the two frameworks. Despite the Co-Cr framework being considered a light framework among the other metal options, the PEEK framework presented a considerably lower weight (176 vs. 964 grams).

For the fabrication of the PEEK framework there are several techniques. The most common methods are injection molding or computer-aided design/computer-aided manufacturing (CAD/CAM) milling techniques. The fabrication technique can affect the adaptation of the framework influencing retention. The injection technique is economically favorable compared to the machined technique, allowing the use of PEEK for framework in the case when the patient has financial difficulties. In addition, a study from the retention point of view, these frameworks manufactured by the injection molding technique were considered a promising method in relation to the milled method of the CAD/CAM technique.[7]

The degree of patient satisfaction was analyzed using a 14-question questionnaire validated in the literature, called OHIP-14. This assessment instrument uses parameters that measure the quality of life related to the oral health of individuals, based on scores to define the degree of satisfaction. The OHIP-14 questionnaire response score may vary, with higher values indicating a worse quality of life.[8] In the present study, the patient had a score of 0, meaning that she was satisfied with the offered treatment, especially with regard to the PEEK framework due to its aesthetics and comfort.

To date, there are still relatively few studies in the scientific literature that describe the applicability of PEEK and its physical-mechanical properties when used to make skeletons for RPD's. In previous studies, it has been determined that using milled PEEK to obtain prosthetic framework through CAD/CAM, as performed in our report, allowed for greater fracture resistance when compared to other methods,[18] in addition to being a material promising in the making of RPD's framework.[6] Therefore, the results obtained in this report demonstrate the potential of making RPD by the CAD/CAM system using PEEK.

4 CONCLUSION

PEEK is a viable material for making RPD's framework. However, controlled and randomized clinical trials are needed to reveal the real benefits of this treatment alternative in relation to the conventional denture.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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LEGEND OF FIGURES

Figure 1. Surveying using Dental CAD software.

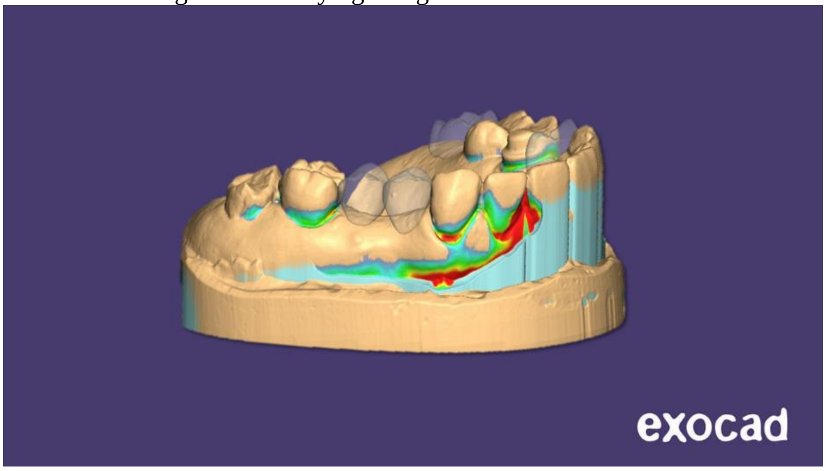

Figure 2. Digital planning of the PEEK framework.

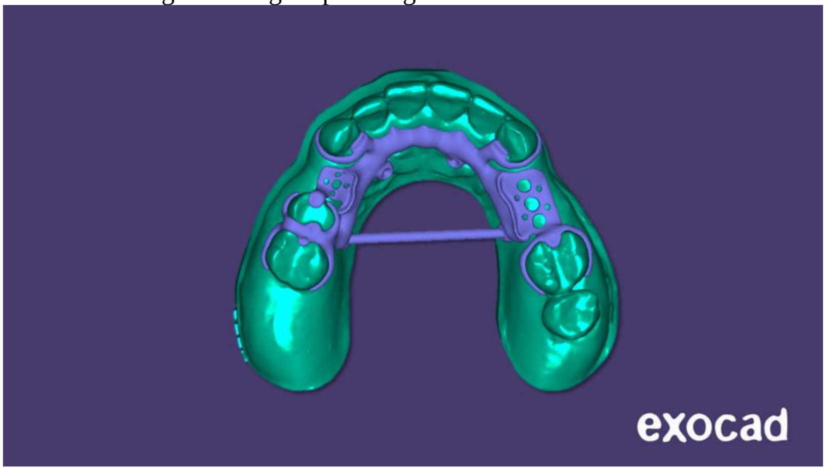

Figure 3. Completed PPEK framework. (A) Framework in Cobalt-Chromium. (B) PEEK framework.

Figure 4. Proof of RPD framework. (A) Framework in Cobalt-Chromium. (B) PEEK framework.

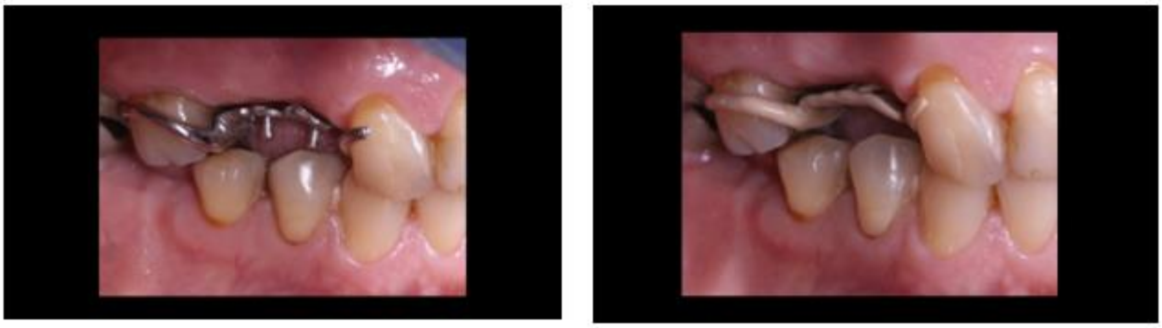

Figure 5. Weight of RPD framework. (A) Framework in Cobalt-Chromium. (B) PEEK framework.

Figure 6. Finished RPD. (A) Framework in Cobalt-Chromium. (B) PEEK framework.