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Case report

Esthetic rehabilitation for a Kennedy Class IV patient using detachable 3D printing diagnostic denture and removable partial denture with polyetheretherketone framework

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ABSTRACT

For patients with high aesthetic expectation, using removable partial dentures (RPDs) to restore the missing teeth in the aesthetic area rapidly and obtain the patients' approval is challenging. This case described an alternative digital protocol to solve this situation. A detachable 3DP diagnostic denture was involved in the procedure, which not only allowed patient to evaluate the possible outcome of the RPD, but also can be duplicated to form a definitive RPD, by bonding a milled PEEK framework and a customized PMMA dentition containing posts, using a thermoplastic compression molding (CM)process.

1. Introduction

Nowadays, digitalization technology advanced in dentistry makes it possible to fabricate removable partial dentures (RPDs) with computer-aided design/computer-aided manufacture (CAD/CAM) procedure [1]. This procedure can simplify the difficulty of RPD fabrication, and reduces costs, labor and the time of the entire treatment [2]. Metal materials have long been used as a standard material to fabricate the RPD framework due to its desirable mechanical properties [3]. But there are some notable disadvantages of metal, including an esthetically unacceptable display, metallic taste, potential biofilm production and hypersensitivities [4]. As a response, non-metallic framework materials have been introduced into RPD. Polyetheretherketone (PEEK), which has been used in orthopedics for many years, possesses excellent mechanical characteristics, high chemical stability, high temperature resistance and high biocompatibility, and can be milled digitally [5, 6, 7, 8]. It has been considered as a promising material for dental applications [9]. Recently, some studies suggested that PEEK can be used to fabricate RPD frameworks, providing metal-free esthetics, and good outcomes were obtained in a short-term follow-up [10, 11, 12].

In prosthodontics, sometimes patients may be anxious, because of fearing the failure to achieve the desired outcome, especially who has failed treatment experience. Though there is no report on how to restore missing teeth for such patients, given the causes of patients' anxiety, utilizing diagnostic waxing may be beneficial, as diagnostic waxing often performs as visualizing and planning the restoration effect of a denture before it is finalized [13]. However, there was the absence of diagnostic waxing trial in the PRD fabrication of digital process [3, 10, 14], which was considered as a disadvantage of digital technology [15].

In this article, we described an integrated digital rehabilitation procedure used for a patient with missing lower anterior teeth, who has high aesthetic requirements and can't tolerate the presence of metal in her mouth. According to her requirements, we fabricated a 3DP diagnostic denture that can be split into two parts, the dentition and the denture base with framework. After the try-in, the patient expressed satisfaction with its appearance. Then a customized PMMA dentition was inserted into the base of the detachable 3DP diagnostic denture to replace the 3DP dentition, finally a milled PEEK framework and thermoplastic were used to replace the rest of the detachable 3DP diagnostic denture with a compression molding process to form the definitive RPD. The patient was satisfied with the definitive prosthesis.

2. Case report

A 53-year-old female presented multiple missing teeth, including 4 s molars, upper left first molar, four lower incisors and lower right canine. Embrasure clasp grooves had been prepared on lower left canine and lower left first premolar and a rest fossa was on the lower right first

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premolar (Figure 1 A, B). Her main concern is to restore the lower anterior teeth without any implant involved, due to fear of the surgery, and long-span edentulous space of 5 teeth was not suitable for FDP [16]. Previously, the missing teeth had been restored with a RPD in other clinic to the stage of waxing try-in. The waxing consisted of a cobalt-chromium (Co–Cr) alloy framework and 5 commercial resin teeth (Figure 2 A), but the expected outcome couldn't be achieved after 3 adjustments of the waxing. The patient expressed anxiety because she worried about the treatment effect may be as same as before. Complaints (Figure 2 B–D): (1) The shapes of artificial teeth were narrow; (2) The midlines of the upper and lower dentition were irregular; (3) Poor aesthetics, especially a display of metal components when smiling; (4)The framework with metallic taste was irritating to her, non-fit with abutment teeth causing poor tongue feeling; (5) The gingival margin curves of the waxing were inharmonious; (6) The movement of tongue was limited, resulting in poor pronunciation. In addition, she complained that the previous treatment wasted too much time, so she wanted to complete the treatment as soon as possible to back to normal social interaction. Her aesthetic expectation before treatment and satisfaction with the waxing was scored using a visual analog scale (VAS) in the range of 0–10 [17], then 9 and 2 were recorded respectively. In order to shorten the treatment time and remove the metal, a digital restoration of PEEK framework RPD was adopted which was divided into 2 stages. Foremost, the entire treatment plan was clearly explained and discussed with the patient. Then, an informed consent was signed by the patient form authorizing for treatment and publication of this case report.

2.1. Stage 1: RPD design

An intraoral scanner (TRIOS 3, 3Shape A/S, Copenhagen, Denmark) was used to obtain the digital impressions of the upper and lower dentitions, which were saved as standard tessellation language (STL) files. Then the STL files were uploaded into EXO CAD (exocad Dental CAD; exocad GmbH, Germany) to design a diagnostic denture, which was fabricated using a 3D printer (ProJet MJP 3600, 3D Systems, USA). The above 3DP diagnostic denture could be disassembled into two parts that were the dentition with posts (2 mm in diameter and 3 mm in length) on the ridge lap and the denture base with framework (Figure 3 A–C). Compared with the waxing, 4 customized teeth were neatly arranged on the 3DP diagnostic denture and the clasps were moved 1 tooth distally. To coordinate the gingival margin curve, the labial denture base was expanded to wrap the neck of the adjacent teeth. At second visit, the 3DP diagnostic denture was placed in her mouth (Figure 3 D–F). She was satisfied with the contour of the denture and the pronunciation was basically normal. Then we scored her satisfaction with the 3DP diagnostic denture using VAS, scoring 6.

2.2. Stage 2: RPD fabrication

1. Respectively, a PEEK disk (BioPAEK, Sino-dentex Co., Ltd., Changchun, China) and an A2 shade polymethyl methacrylate (PMMA) disk (Aidite (Qinhuang DAO) Technology Co., Ltd., Qinhuangdao, China) were milled into framework (Figure 4 A) and artificial dentition (Figure 4 B), with a 5-axis milling machine (Cameo, Aidite (Qinhuang DAO) Technology Co., Ltd., Qinhuangdao, China).
2. The virtual 3D models of the PEEK framework and the 3DP diagnostic denture were obtained using an intraoral scanner (TRIOS 3, 3Shape A/S, Copenhagen, Denmark) (Figure 5 A, B). The deviation between them was compared in Geomagic Qualify 2013 (Geomagic, Morrisville, NC, USA), and 10 reference points closely related to abutment teeth were selected, which showed that the absolute value deviation was no more than 90 μm except for one point of 170 μm (Figure 5 C). The gap between 50 and 311 μm was defined as a clinically acceptable fit [18], so it can be considered that the PEEK framework can be fitted well as the 3DP diagnostic denture in the patient's mouth. Therefore, the PEEK framework can be used directly for definitive PRD fabrication without a visit for try-in.
3. Replaced the 3DP dentition with the milled dentition to form a combined denture (Figure 6 A).
4. Dental stone was poured into the tissue surface of the combined denture to form a bottom cast (Figure 6 B).
5. The above combination was embedded in the lower part of a flask filled with gypsum to the edge of the combined denture (Figure 6 C).
6. Wrapped the combination with silicone impression material (Zetalabor, Zhermack, Badia Polesine, Italy), but exposed the incisal margins (Figure 6 D), to prevent milled dentition movement during the CM process.
7. Installed the upper part of the flask filled with gypsum. After opening the flask, the milled dentition was left in the tooth sockets (Figure 6 E). Then the PEEK framework was mounted on the bottom cast (Figure 6 F).
8. The PEEK framework was filled with acrylic resins (QC-20 Denture Base Polymers, Dentsply Dental (Tianjin) Co., Ltd, Tianjin, China), then a CM process was performed. After polishing, the denture was delivered (Figure 7 A). With slight adjustments, the RPD was successfully fitted for the patient (Figure 7 B–D). The patient was satisfied with the aesthetics of this RPD. Finally, she scored 8 for satisfaction with the RPD.

3. Discussion and conclusions

Patients' satisfaction is a critical factor in determining the outcome of dental treatment [19]. In this case, the patient was extremely worried about the outcome of the RPD. Enable patient to have a more intuitive understanding of the outcome as soon as possible, so as to calm her anxiety about the effect of the restoration, a 3DP diagnostic denture was used in our case, which was designed according to her expectations. Correspondingly, the satisfaction scores increased from 2 to 6. More importantly, the 3DP diagnostic denture without metal that gave her a different feeling from try-in of the waxing with Co–Cr framework, which corrected her bad impression of the RPDs and anxiety about the outcome, so she actively cooperated with the operation of 3DP diagnostic denture trial. Compared with the traditional waxing, the fabrication of a 3D printing diagnostic denture was faster and more convenient, thus

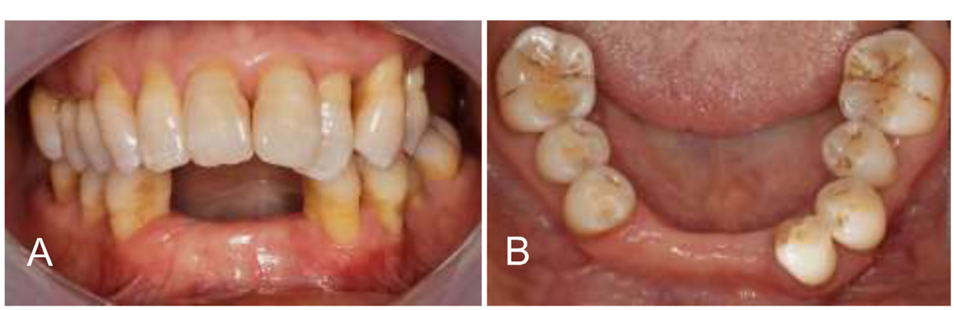

Figure 1. Preoperative photographs. Front view (A) and occlusal view (B).

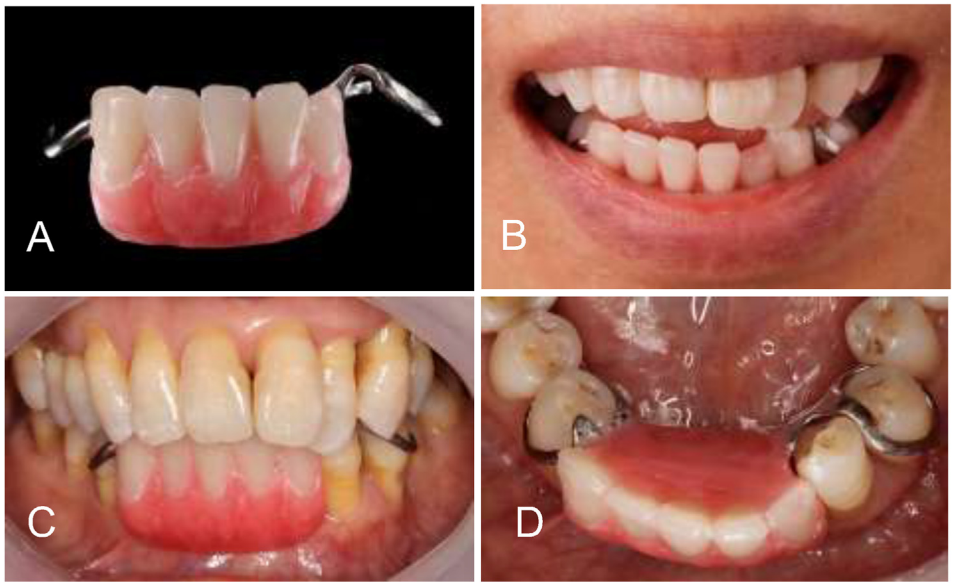

Figure 2. Waxing try-in. The waxing with metal framework (A), smiling view (B), front view (C), and occlusal view (D).

reducing the time of the whole treatment. Moreover, the step of PEEK framework try-in was replaced by the method of using digital scanning technology to compare deviations between PEEK framework and the framework of the 3DP diagnostic denture, which reduced the entire treatment time. To sum up, a high satisfaction was finally obtained (8 points).

Because the undercut of artificial dentition, once embedded, it was difficult to take it out from the embedded material. Therefore, in order to rapidly and accurately duplicate the 3DP diagnostic denture, a split and combined structure was adopted in our 3DP diagnostic denture. After embedding, the milled dentition was left in the silicone sockets, and the other part can be taken out directly. A mean of tooth arrangement of 18

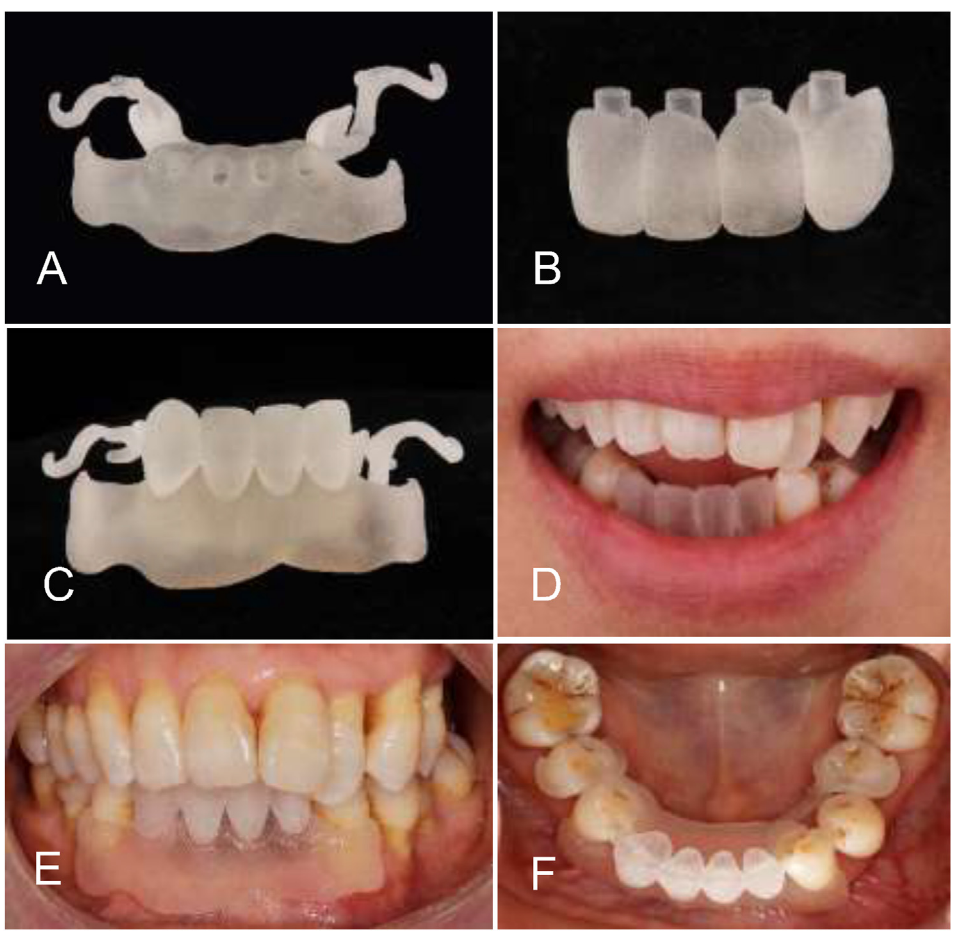

Figure 3. Trail of the 3DP diagnostic denture. The base and framework (A). The dentition (B). The two parts were combined together (C). Smiling view (C). Front view (D). Occlusal view (E).

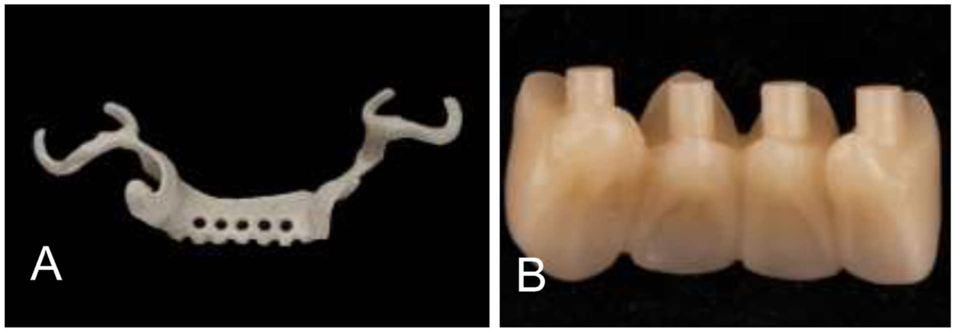

Figure 4. The milled PMMA dentition (A) and the PEEK framework (B).

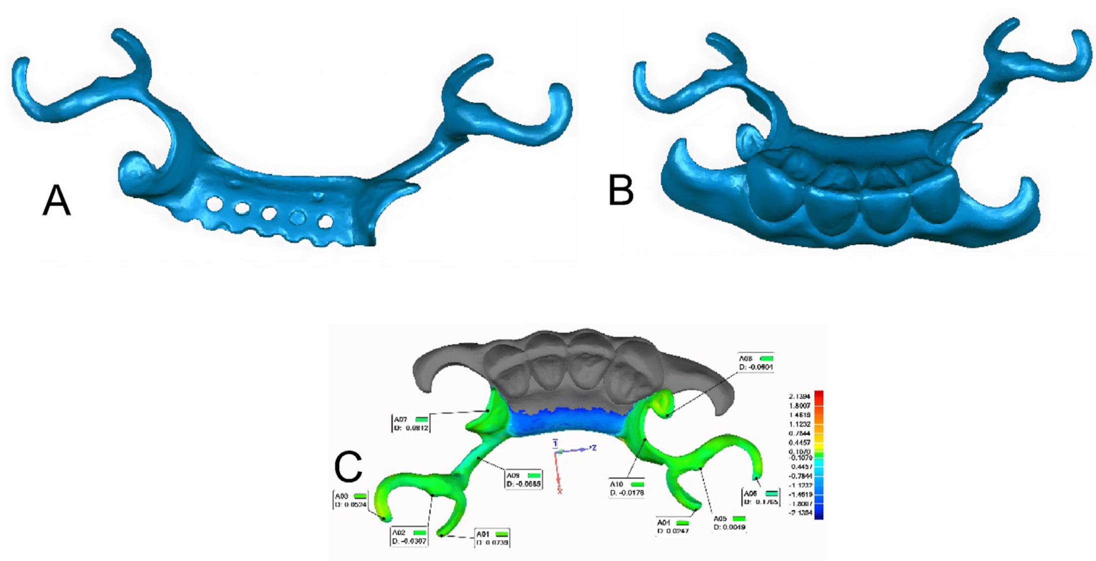

Figure 5. Digital model of the PEEK framework (A). Digital model of the 3DP diagnostic denture (B). Deviation annotations at points of interest on framework. Absolute value deviation: 5–176 μm (C).

μm on the incisal direction (Figure 8), comparing the trueness of teeth displacement between 640 μm for digital dentures and 1000 μm for conventional injection molding [20].

It had been suggested that the design of grooves on the ridge lap of artificial teeth could improve the bond strength to the denture base [21, 22], but the holes didn't significantly improve the bond strength, due to the air trapped in the holes when the PMMA dough was pressed [23]. Therefore, we designed posts at the ridge lap of milled dentition. Compared with grooves, the posts are convenient for assembling and disassembling between milled dentition and 3DP diagnostic denture base during RPD fabrication, and can also play a role in expanding the contact area between milled dentition and thermoplastic, which is conducive to the improvement of bond strength. In addition, the modality of resins wrapping posts may be good for avoiding air trapped at the bonding interface, thus improving the bond strength, but this hypothesis needs to be proved by further research.

The retention of clasp is proportional to the thickness, width, undercut of the its arms and the elastic modulus of the material, while the elastic modulus of PEEK is 4 Gpa, which is much lower than the 240 Gpa of Co–Cr [24, 25]. Under the premise of not affecting the aesthetics and occlusion, the thickness, width and the undercut of the PEEK arms need to be appropriately increased to obtain a suitable retention. Tannous et al. [25] suggested that a PEEK clasp with an undercut of 0.5 mm could provide sufficient retention for clinical use.

It should be emphasized that PEEK has only recently been used to fabricate RPD frameworks, so studies evaluating its long-term clinical behavior are lacking. Although in vitro studies of Mayinger et al. [26] indicated that the PEEK clasps after artificial aging, which simulated a 2-year clinical period, could still have sufficient retention for clinical usage, there is not enough scientific evidence of how it performs under fatigue stress when used as an RPD framework. This, coupled with the absence of research on what size and type of RPD frameworks can be fabricated with PEEK, it is recommended to use PEEK as an alternative material for RPD frameworks only in some special cases, such as the patients with metal allergies or high aesthetic requirements. Another matter of concern is the retention can't be adjusted by bending the PEEK clasps at delivery.

Moreover, some deficiencies may be encountered with the detachable 3DP diagnostic denture. It can only evaluate the contour of the RPD, except the color. There are significant differences in physical properties between 3DP diagnostic denture and the definitive PRD, especially the framework, so it can't evaluate the retention accurately. The additional cost of the scanning equipment, CAD software, 3D printing materials, training and special designing. Therefore, future studies will focus on solving these deficiencies and seeking out some 3D printing materials with color and physical properties closer to the definitive RPD for fabricating diagnostic dentures to provide more accurate information for the design and fabrication of RPDs.

In this report, we presented a digital process for aesthetic area restoration using RPD with PEEK framework. The detachable 3DP diagnostic denture with full structural elements used in this case served as a bridge for communication between doctor and patient, eliminated the

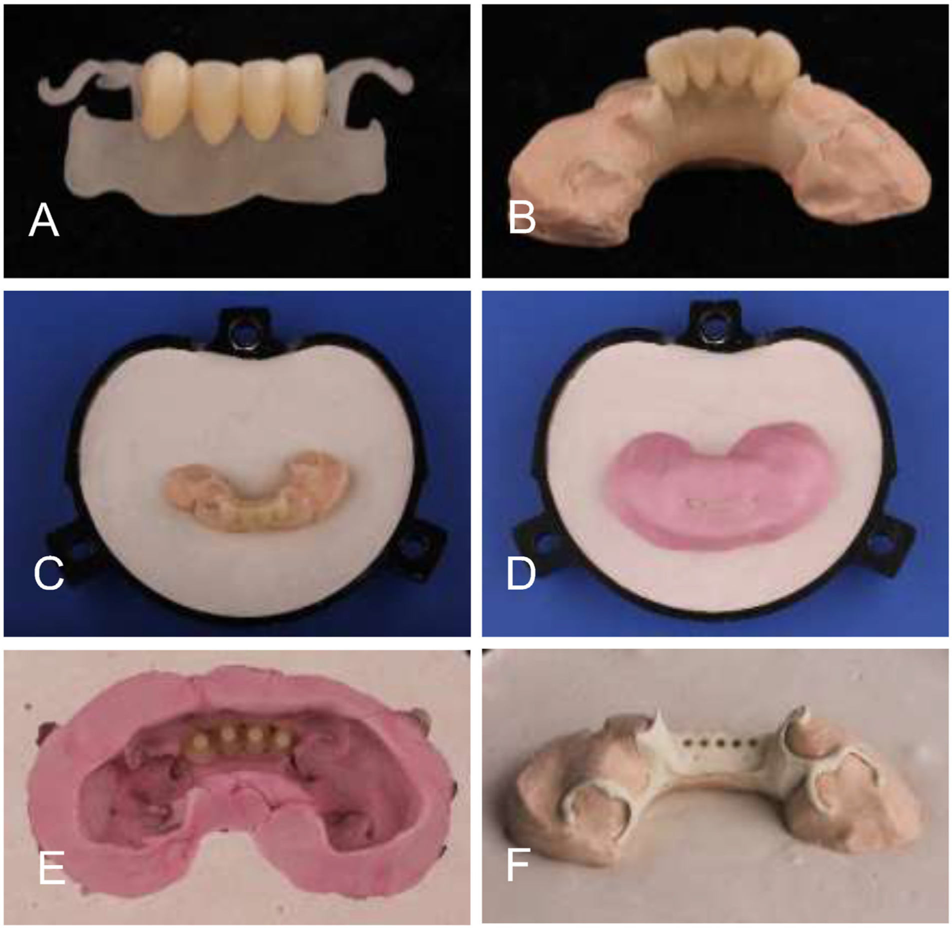

Figure 6. Fabrication of the RPD. The combined denture, assembled by milled dentition on the 3DP diagnostic denture base (A). The combination containing bottom cast and the combined denture (B). The combination was embedded in the lower part of a flask filled with gypsum (C). Wrapped the combination with silicone impression material (D). The milled dentition was left in the tooth sockets (E). PEEK framework was mounted on the bottom cast (F).

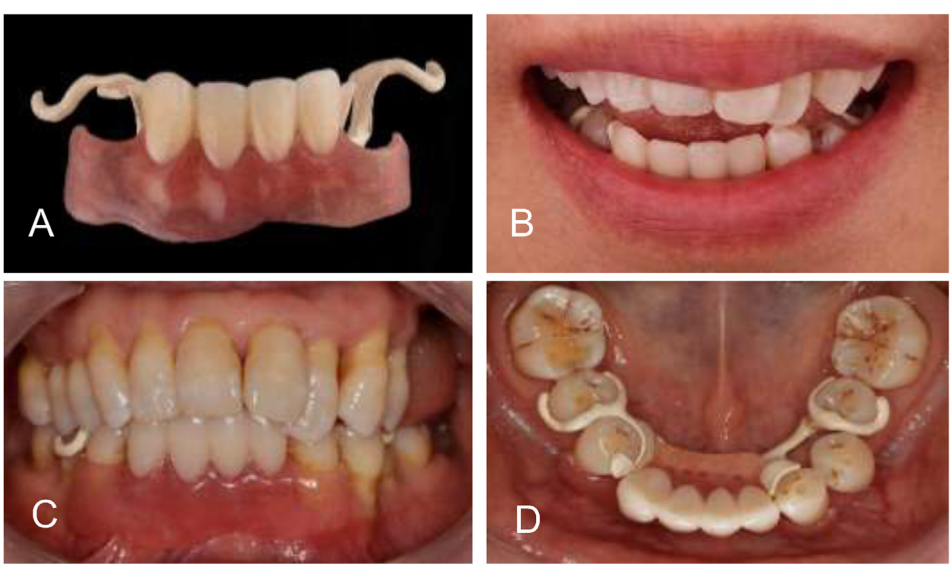

Figure 7. Delivered the definitive RPD. The definitive RPD (A). Smiling view (B). Front view (C). Occlusal view (D).

patient's anxiety caused by excessive concern about the restorative effect. Secondly, it also played a positive guiding role in design and fabrication of the definitive RPD between doctor and technician. Finally, during the 11-month clinical follow-up, the above RPD exhibited good clasp retention without any breakage. The PEEK framework fitted well, except the high-gloss surface seems to have lost some of its shine. Further short-term and long-term clinical follow-up are required to keep track of its service status, to consolidate the scientific evidence.

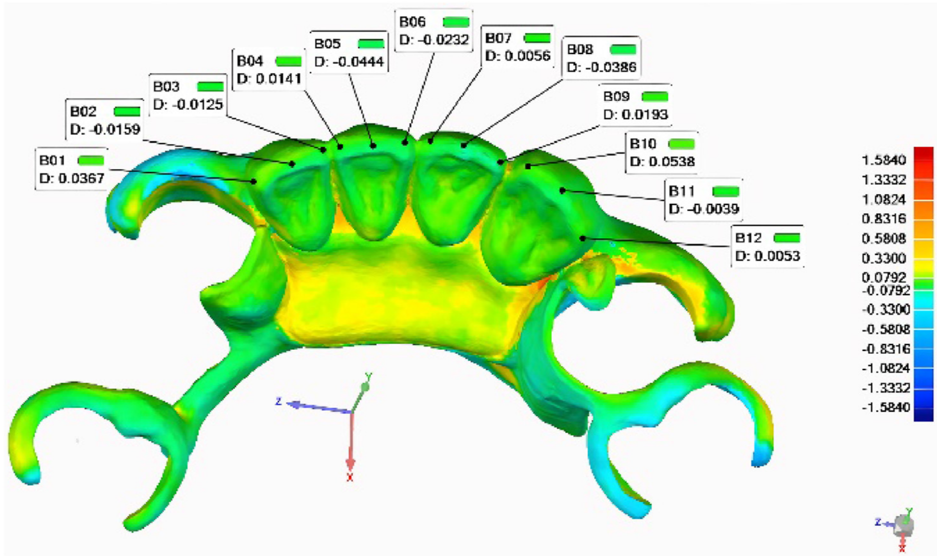

Figure 8. Dentition arrangement in incisal direction. Deviation annotations at 3 points selected on incisal margin of each tooth. The mean:18 μm.

Declarations

Author contribution statement

All authors listed have significantly contributed to the investigation, development and writing of this article.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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References

[1] M.S. Bilgin, E.N. Baytaroğlu, A. Erdem, E. Dilber, A review of computer-aided design/computer-aided manufacture techniques for removable denture fabrication, Eur. J. Dermatol. 10 (2) (2016) 286–291.

[2] F.I. Gentz, D.I. Brooks, P.C. Liacouras, A. Petrich, C.M. Hamlin, D.O. Ellert, et al., Retentive forces of removable partial denture clasp assemblies made from polyaryletherketone and cobalt-chromium: a comparative study, J. Prosthodont. 31 (4) (2022) 299–304.

[3] H. Nishiyama, A. Taniguchi, S. Tanaka, K. Baba, Novel fully digital workflow for removable partial denture fabrication, J. Prosthodont. Res. 64 (1) (2020) 98–103.

[4] P. Zoidis, I. Papathanasiou, G. Polyzois, The use of a modified poly-ether-ether-ketone (PEEK) as an alternative framework material for removable dental prostheses. a clinical report, J. Prosthodont. 25 (7) (2016) 580–584.

[5] A.D. Schwitalla, T. Spintig, I. Kallage, W.D. Müller, Flexural behavior of PEEK materials for dental application, Dent. Mater. 31 (11) (2015) 1377–1384.

[6] L.M. Wenz, K. Merritt, S.A. Brown, A. Moet, A.D. Steffee, In vitro biocompatibility of polyetheretherketone and polysulfone composites, J. Biomed. Mater. Res. 24 (2) (1990) 207–215.

[7] T. Wimmer, A.M. Huffmann, M. Eichberger, P.R. Schmidlin, B. Stawarczyk, Two-body wear rate of PEEK, CAD/CAM resin composite and PMMA: effect of specimen geometries, antagonist materials and test set-up configuration, Dent. Mater. 32 (6) (2016) e127–e136.

[8] M.G. Wiesli, M. Ozcan, High-performance polymers and their potential application as medical and oral implant materials: a review, Implant Dent. 24 (4) (2015) 448–457.

[9] S. Najeeb, M.S. Zafar, Z. Khurshid, F. Siddiqui, Applications of polyetheretherketone (PEEK) in oral implantology and prosthodontics, J. Prosthodont. Res. 60 (1) (2016) 12–19.

[10] I.E. Harb, E.A. Abdel-Khalek, S.A. Hegazy, CAD/CAM constructed poly(etheretherketone) (PEEK) framework of kennedy class I removable partial denture: a clinical report, J. Prosthodont. 28 (2) (2019) e595–e598.

[11] T. Ichikawa, K. Kurahashi, L. Liu, T. Matsuda, Y. Ishida, Use of a polyetheretherketone clasp retainer for removable partial denture: a case report, Dent. J (Basel) 7 (1) (2019) 4.

[12] S.A. Sadek, Comparative study clarifying the usage of PEEK as suitable material to be used as partial denture attachment and framework, Open Access Maced. J. Med. Sci. 7 (7) (2019) 1193–1197.

[13] J.W. McLean, Aesthetics in restorative dentistry: the challenge for the future, Br. Dent. J. 149 (12) (1980) 368–374.

[14] L. Lo Russo, E. Lo Muzio, G. Troiano, L. Guida, Cast-free fabrication of a digital removable partial denture with a polyetheretherketone framework, J. Prosthet. Dent S0022–3913 (21) (2021), 317-6.

[15] S. Pillai, A. Upadhyay, P. Khayambashi, I. Farooq, H. Sabri, M. Tarar, et al., Dental 3D-printing: transferring art from the laboratories to the clinics, Polymers (Basel) 13 (1) (2021) 157.

[16] T.J. McGarry, A. Nimmo, J.F. Skiba, R.H. Ahlstrom, C.R. Smith, J.H. Koumjian, Classification system for complete edentulism. The American College of Prosthodontics, J. Prosthodont. 8 (1) (1999) 27–39.

[17] M. McCunniff, W. Liu, D. Dawson, L. Marchini, Patients' esthetic expectations and satisfaction with complete dentures, J. Prosthet. Dent 118 (2) (2017) 159–165.

[18] A.L. Carneiro Pereira, A.K. Bezerra de Medeiros, K. de Sousa Santos, É. Oliveira de Almeida, G.A. Seabra Barbosa, A. da Fonte Porto Carreiro, Accuracy of CAD-CAM systems for removable partial denture framework fabrication: a systematic review, J. Prosthet. Dent 25 (2) (2021) 241–248.

[19] J. Dudley, L. Richards, M. Mahmud, The use of a psychological testing instrument as an indicator of dissatisfaction with aesthetic dental treatment - a preliminary study, BMC Psychol. 8 (1) (2020) 24.

[20] C. Wang, Y.F. Shi, P.J. Xie, J.H. Wu, Accuracy of digital complete dentures: a systematic review of in vitro studies, J. Prosthet. Dent 25 (2) (2021) 249–256.

[21] H.S. Cardash, B. Applebaum, H. Baharav, R. Liberman, Effect of retention grooves on tooth-denture base bond, J. Prosthet. Dent 64 (4) (1990) 492–496.

[22] P.K. Vallittu, Bonding of resin teeth to the polymethyl methacrylate denture base material, Acta Odontol. Scand. 53 (2) (1995) 99–104.

[23] G.R. Zuckerman, A reliable method for securing anterior denture teeth in denture bases, J. Prosthet. Dent. 89 (6) (2003) 603–607.

[24] J.A. Chrystie, Principles of clasp retention: a review, Aust. Dent. J. 33 (2) (1988) 96–100.

[25] F. Tannous, M. Steiner, R. Shahin, M. Kern, Retentive forces and fatigue resistance of thermoplastic resin clasps, Dent. Mater. 28 (3) (2012) 273–278.

[26] F. Mayinger, D. Micovic, A. Schleich, M. Roos, M. Eichberger, B. Stawarczyk, Retention force of polyetheretherketone and cobalt-chrome-molybdenum removable dental prosthesis clasps after artificial aging, Clin. Oral Invest. 25 (5) (2021) 3141–3149.