Total digital workflow in the fabrication of a partial removable dental prostheses: A case report

Teresa Almeida Mendes[1,2] iD **, Duarte Marques[1,2]** iD **,**
Luis Pires Lopes[1] and João Caramês[1,2]

Abstract

This report describes a clinical and laboratory protocol used in the fabrication of a removable partial dental prosthesis with a digital workflow in a 73-year-old patient. The metal framework was produced with a selective laser melting technique. For quality assurance and discrepancy analysis, the framework was superimposed and compared to the respective digital design file, and the printed model was also compared to the digital impression and rendered as a 3D colour map. Differences were detected in the framework on the clasp of tooth 17 (upper right second molar) and on the printed model on the interproximal surfaces of the abutments, particularly on tooth 17 and palatine area. The use of this digital workflow allowed for the achievement of an removable partial dental prosthesis with a good fit and occlusion with minimal adjustments, with the reduction of both clinical and laboratory time. Further studies are needed to gain a better understanding of these techniques.

Keywords

Digital metal framework, removable partial dental prosthesis, selective laser melting

Introduction

The introduction of digital technologies in dental medicine has led to the implementation of new protocols and techniques. One of the areas that has developed most significantly has been the construction of metallic structures for prosthodontics. Digital technology computer-aided design (CAD) and computer-aided manufacturing (CAM) can be divided into two categories, defined as either subtractive or additive methods.[1] Subtractive material milling methods are used in fixed prostheses, but not in partial removable dental prostheses (RDPs). The milling of the materials can create fractures in narrow areas such as clasps.[2] More recently, the additive technique of selective laser melting (SLM) was developed for construction of RPD infrastructure.[1] SLM produces three-dimensional metal structures directly from a CAD model, with layers of powder materials which have been melted and layered over each other using a laser.[3] It allows for the creation of complex geometries with concave and thin zones at the base of the metal structure which are very difficult to achieve using subtractive methods.[3] It has the advantage of producing metal structures with lower porosity than the gold standard technique for obtaining metallic frameworks by eliminating several intermediary steps used in the lost wax method.[4] However, this technique has the disadvantage of utilizing complex and expensive equipment.[5]

To our knowledge, there are no case reports published with a digital workflow, including a metal framework produced by SLM, with further digital analysis of the digital impression and metal framework. This article thus aims to describe a clinical case where a removable partial prosthesis has been fabricated with a total digital workflow and a metal framework utilizing the SLM technique. The framework and digital impression were digitally analysed.
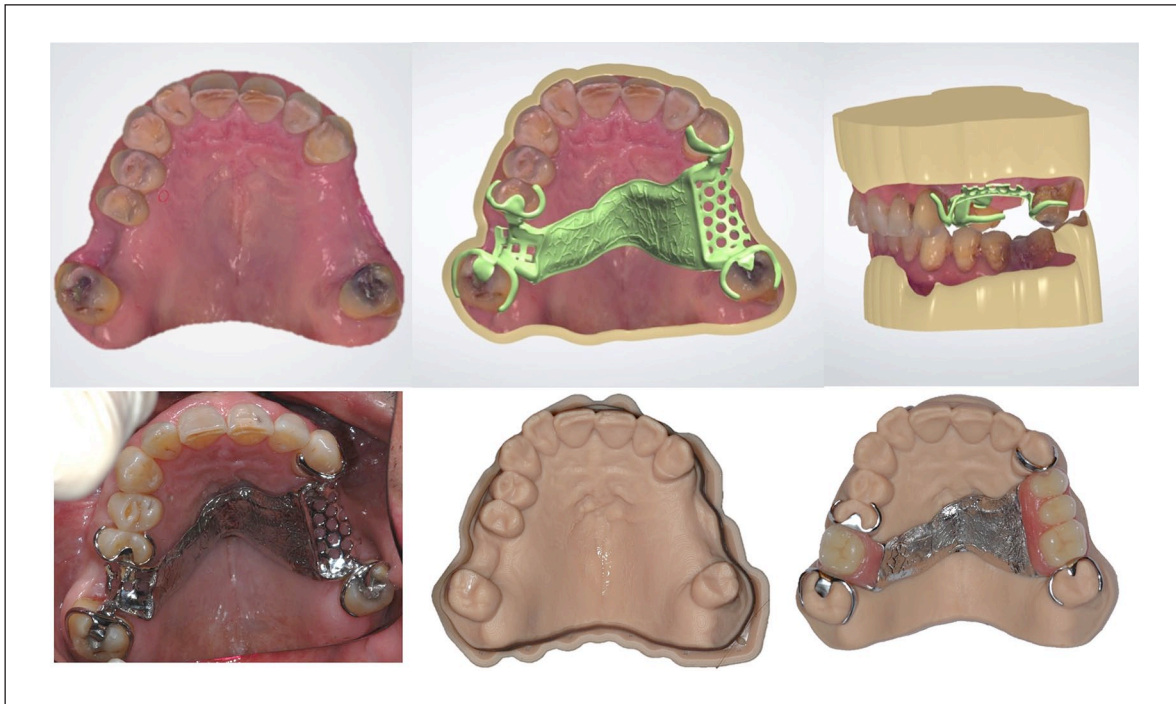
[1]Faculdade de Medicina Dentária, Universidade de Lisboa, Lisboa, Portugal
[2]Instituto de Implantologia, Lisboa, Portugal

Corresponding Author:
Teresa Almeida Mendes, Faculdade de Medicina Dentária, Universidade de Lisboa, Cidade Universitária, 1649-003 Lisboa, Portugal.
Email: teresa.gmendes@gmail.com

Figure 1. Digital impression and framework digital design, framework trial, and printed model with teeth arrangement.

Case

A 73-year-old male patient was seen by appointment at the Implantology Institute (Lisbon). The patient wanted to replace the missing teeth on the maxilla with an RDP. Clinical and radiological examination revealed the absence of dental decay, periodontal disease, and soft-tissue alterations. The patient had a Kennedy–Applegate Class III modification 1.[6]

The RDP was provided according a dual digital intra-oral impression with 3Shape (Trios®, Denmark) scanner.

The survey analysis on the first intra-oral digital impression was performed using 3Shape (3Shape Dental System 2018) software. The metal framework design was planned according to classic prosthodontic principles.[6] Minimal dental preparations were performed according to the design outlined on the diagnostic cast to produce guide plane (17M–upper right second molar, 27M–upper left second molar), occlusal rests (17M, 15D–upper right second premolar, 27M), and cingular rests (23–upper left canine).

Following preparation, the secondary impressions were undertaken. The STL (Surface Tessellation Language) file was imported to the 3Shape CAD design (Trios®, Denmark) where the metal framework was designed. The CAD design was imported into the SLM machine (EOS GmgH, Phibo, Barcelona), and the metal framework was fabricated directly with a cobalt chromium alloy powder (Phibo, Barcelona).

The intraoral metal framework try-on was performed, according to clinical criteria (Figure 1).[6] Tooth 17 on the mesial and palatal surface required adjustment to improve the fit.

The digital impressions were sent electronically to the laboratory to print the physical SLA resin master model[7] (Form 2; Formlabs, Berlin, Germany) with photopolymer resin (Detan models; Formlabs). The models were used to seat the metal framework and make the acrylic teeth arrangement (Ivoclar Phonaris, Schaan Liechtenstein).

Following the clinical try-in processing was completed with heat polymerizing resin (Probase Cold Ivoclar Vivadent, Schaan Liechtenstein).[8] The RDP was then placed in the mouth and adjusted for comfort and function (Figure 2). Following post-insertion appointments, the patient was recalled at every 6 months for check-ups. The patient was satisfied and reported excellent comfort.

Two digital comparisons were performed, the first between the metal structure (CAM) and its respective design (CAD file). The framework produced was digitized (3Shape D2000, Trios, Denmark), and the data obtained was exported to an STL file. This file was superimposed onto the STL file of the metal framework design (control) using Geomagic Control X64 (3D Systems, Canada),[9] with the tolerance limit of 100 microns. The pattern of three-dimensional deviations between the two models was observed by means of the colour difference, with the respective colour scale representing the deviations. No differences greater than 100 microns were observed in the larger connector area (green colour). The

Figure 2. Intra-oral photographs of the patient with the removable partial denture.
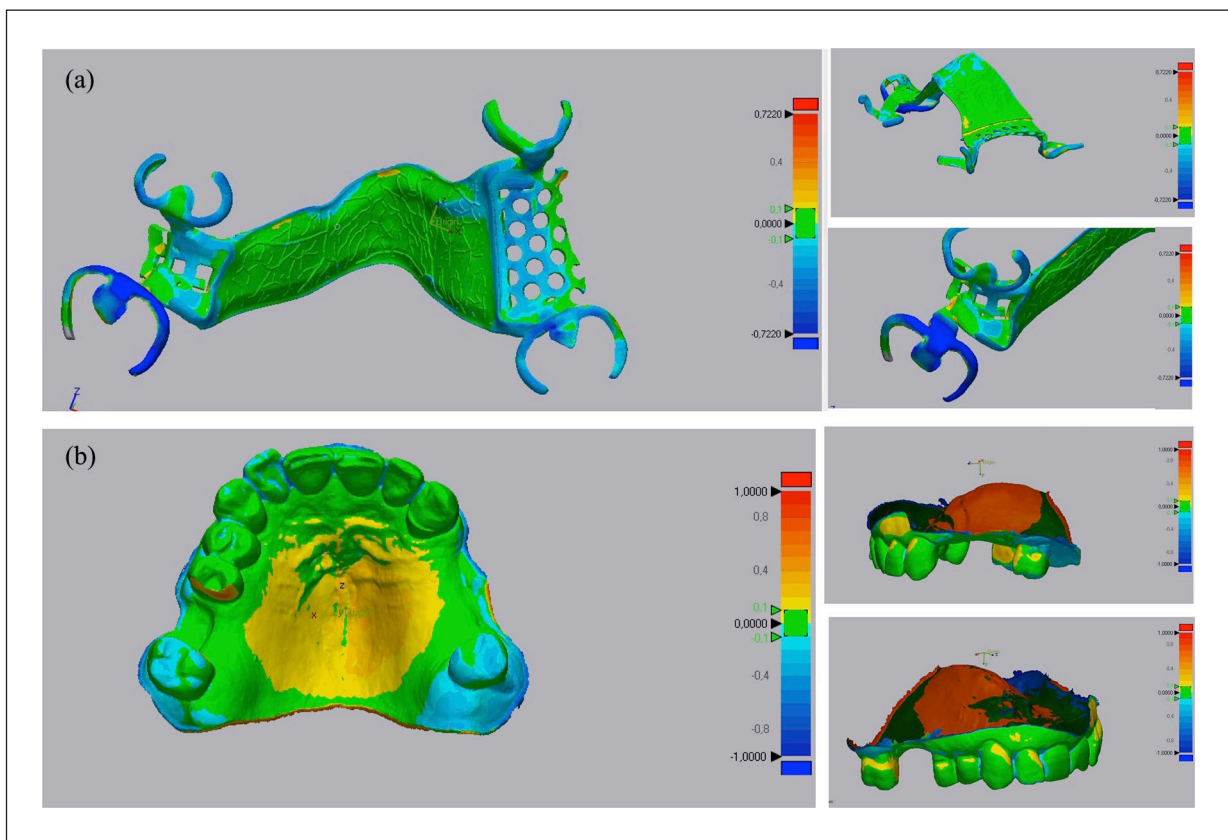
Figure 3. (a) 3D deviation of the superimposed digital framework design (CAD) and the metal framework produced (CAM) and (b) 3D deviation colour map of the superimposed digital impression and the printing model.

tooth support and other clasps showed some deviations, with the greatest differences on the clasp at tooth 17.

The second comparison was made between the physical model and the digital model. The physical model was scanned and the data were exported as an STL file. This file was superimposed onto the STL file of the digital model, to a tolerance limit of 100 microns (Figure 3). The figure shows deviations in the interproximal faces of abutments and the palatine area. The major difference was found on the mesial aspect of tooth 17.

Discussion

This article describes the production of an RDP from a digital workflow. The use of these digital technologies allowed for (1) acquisition of a good passive adaptation of the framework, requiring only a small adjustment of tooth 17; (2) fulfilment of clinical requirements without the need for adjustments; (3) improved comfort, since no materials capable of inducing vomiting reflexes were used; and (4) lower clinical and laboratory time in the execution of the framework.

In the production of metal structures the SLM technique, obtained by means of an intra-oral scanner, has distinct advantages since it avoids distortions associated with impressions and plaster materials. It also avoids the expense of materials and laboratory time. Currently, impressions obtained by means of intra-oral scanners are thus an alternative to conventional impressions, utilizing fully digital protocols for the construction of prosthetic structures.[10,11]

By superimposing the CAD file, we detected that the largest difference between the drawing and the structure produced occurred in the minor connectors and the clasps, particularly at tooth 17 (Figure 3). The printed model also showed deviations from the impression in the mesial aspect of tooth 17. Clinically, this corresponded to the zone where the tooth had to be adjusted. In other teeth the periodontal ligament movement, about $200\,\mu m$[12] compensated the differences between the drawing and the structure produced. Overlapping the digital model with the digital impression, it is possible to predict future clinical errors in frameworks. This methodology can be used prior to the design of the metal structure, indicating the points where adjustments will be needed.

In the future it may be necessary to adapt the design of these structures in the connector regions in order to eliminate the need for clinical modifications. Resin base and artificial teeth can also be made by means of 3D printing, although their mechanical and biological behaviours should be further assessed, which in the long term can save more time in the manufacture process.[13]

The results obtained are consistent with the results described in the literature. We can therefore conclude that this case may be considered as an example of the possible advantages of using this technique. However, it should be noted that this requires a considerable investment in equipment, and its sustainability must be considered within the individual clinical and laboratory environment.

Conclusion

The use of this digital workflow allowed for the achievement of an RDP with a good fit and occlusion with minimal adjustments, with the reduction of both clinical and laboratory time. More clinical and laboratory studies are needed with more significant samples regarding the clinical performance of the structures obtained by SLM.

ORCID iDs

Teresa Almeida Mendes https://orcid.org/0000-0001-6232-0251

Duarte Marques https://orcid.org/0000-0003-1966-8281

References

1. Al Jabbari Y, Koutsoukis T, Barmpagadaki X, et al. Metallurgical and interfacial characterization of PFM Co-Cr dental alloys fabricated via casting, milling or selective laser melting. *Dent Mat* 2014; 30: e79–e88.
2. Ye H, Ning J, Li M, et al. Preliminary clinical application of removable partial denture frameworks fabricated using computer-aided design and rapid prototyping techniques. *Int J Prosthodont* 2017; 30(4): 348–353.
3. Kajima Y, Takaichi A, Nakamoto T, et al. Fatigue strength of Co-Cr-Mo alloy clasps prepared by selective laser melting. *J Mech Behav Biomed Mater* 2016; 59: 446–458.
4. Koutsoukis T, Zinelis S, Eliades G, et al. Selective laser melting technique of Co-Cr dental alloys: a review of structure and properties and comparative analysis with other available techniques. *J Prosthodont* 2015; 24(4): 303–312.
5. Alifui-Segbaya F, Williams R and George R. Additive manufacturing: a novel method for fabricating cobalt-chromium removable partial denture frameworks. *Eur J Prosthodont Restor Dent* 2017; 25(2): 73–78.
6. Carr A and Brown D. *McCracken's removable partial prosthodontics*. 13th ed. St. Louis, MO: Elsevier, 2016.
7. Mansour M, Sanchez E and Machado C. The use of digital impressions to fabricate tooth-supported partial removable dental prostheses: a clinical report. *J Prosthodont* 2016; 25: 495–497.

8. Kattadiyil M, Mursic Z, AlRumaih H, et al. Intraoral scanning of hard and soft tissues for partial removable dental prosthesis fabrication. *J Prosthet Dent* 2014; 112(3): 444–448.

9. Sim J, Jang Y, Kim W, et al. Comparing the accuracy (trueness and precision) of models of fixed dental prostheses fabricated by digital and conventional workflows. *J Prosthodont Res* 2019; 63: 25–30.

10. Imburgia M, Logozzo S, Hauschild U, et al. Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. *BMC Oral Health* 2017; 17(1): 92.

11. Vögtlin C, Schulz G, Jäger K, et al. Comparing the accuracy of master models based on digital intra-oral scanners with conventional plaster casts. *Phys Med* 2016; 1: 20–26.

12. Papadopoulou K, Hasan I, Keilig L, et al. Biomechanical time dependency of the periodontal ligament: a combined experimental and numerical approach. *Eur J Orthod* 2013; 35(6): 811–818.

13. Lin W, Harris B, Pellerito J, et al. Fabrication of an interim complete removable dental prosthesis with an in-office digital light processing three-dimensional printer: a proof-of-concept technique. *J Prosthet Dent* 2018; 120(3): 331–334.