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Patient Satisfaction and Accuracy of Partial Denture Frameworks Fabricated using Conventional and Digital Techniques

Keywords

Framework
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ABSTRACT

This case report compares a conventional and a digital workflow for manufacturing metal frameworks for maxillary and mandibular removable partial dentures (RPDs). Two sets of maxillary and mandible RPDs were produced. The metal framework of one set of RPDs was produced conventionally using the lost wax casting technique. Intraoral-scanning and computer-aided designing (CAD) were used to fabricate the metal frameworks of the other set of RPDs using direct metal laser sintering (DMLS) technology. The accuracy of fit of the two sets of RPDs was evaluated after 3 months using replica models. Patient satisfaction was assessed. Two years later, the fit accuracy of the DMLS prosthesis and patient satisfaction were re-evaluated. The accuracy of fit in the maxillary RPD with the DLMS manufactured metal framework showed better results in all areas except areas of rests (457 vs. 421 µm) and the major connector (850 vs. 512 µm). The mandibular RPD with DLMS manufactured metal framework showed only in the areas of the reciprocal arm and major connector better fit accuracy compared to the conventional RPD. The patient satisfaction with the DLMS manufactured RPDs was rated equally to the conventional one. The use of digital technologies in manufacturing RPDs seems promising regarding accuracy and patient satisfaction.

INTRODUCTION

Dental digital technologies, such as digital scanning, computer-aided design (CAD) and manufacturing and 3D printing, revolutionized dental rehabilitations, as they enhance efficiency and precision while providing more durable treatment outcomes and reduced chairside time. Digital technologies are also implemented in the field of removable prosthetics more frequently in the clinic. The digitalization of manufacturing metal frameworks of the removable partial dentures (RPD) is expected to reduce the number of treatment steps, improve the accuracy of fit and minimize the manufacturing costs. For these technologies to be widely implemented in general practices, several clinical examinations as well as the development of protocols for the respective manufacturing processes are essential.

Complete digital methods or a combination of conventional-digital techniques are described in a few clinical studies as alternatives to conventional manufacturing procedures.[1-3] Conventional-digital methods use conventional impressions. Thereafter, the stone casts are scanned using

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an extraoral scanner.[1-4] In the complete digital manufacturing procedure however, the impressions are made using an intraoral scanner and manufactured using additive techniques according to the digital framework design.[1]

Lee, J.W. *et al*. described the indirect way of manufacturing the metal frameworks using the sacrificial patterns, which were then invested and casted.[3] In other studies, the metal frameworks were fabricated directly using one additive CAM technique, such as selective laser melting (SLM) or selective laser sintering (SLS).[1-3] There are few clinical studies that evaluate the accuracy of fit of digitally manufactured metal frameworks and compare them to conventionally casted ones.[1,3,4] The accuracy of fit of the metal frameworks is either analysed visually by the dentist or with the help of various methods, such as the pressing test or by fabrication of replicas. The focus of the analysis is placed on different areas of the construction elements of the metal framework or of the RPD.[1,3-5] To the author's best knowledge, there is currently only one study that compares patient satisfaction of conventionally and digitally manufactured RPDs.[2]

This case report describes a clinical case in which two sets of RPDs with metal frameworks for maxilla and mandible were manufactured for one patient using conventional and digital workflows. The aim of this case report study was to evaluate accuracy and patient satisfaction after 3 months for both RPDs and two years of function for the digitally with DMLS manufactured RPDs frameworks *(Figure 1)*.

MATERIALS AND METHOD

A partially edentulous 51-year-old patient with periodontitis was treated in the student course at the University of Zurich. Two dental students performed the prosthetic treatment and were supervised at each clinical step by an experienced prosthodontic specialist. Before the start of the prosthetic treatment phase, the patient underwent preprosthetic treatment. During this time, all old or inadequate fillings were replaced. Caries and periodontitis were treated and he was provided with removable partial dentures in the maxilla and mandible. The dentition of the maxilla according to the Kennedy classification corresponded to class III2 and the mandible to class I2.

For diagnostic purposes, at the beginning of the prosthetic treatment, maxillomandibular relationships were recorded and the acrylic resin teeth (Candulor, Condyloform II NFC+) in the posterior area and porcelain teeth (Candulor, Physioset CT) in the anterior area were setup in wax *(Figure 2A)*. The setup was tried in on the patient and all necessary adjustments were made.

The situation models of the maxilla and mandible were measured in the parallelometer and the optimal insertion direction was determined. Based on these findings, the designs for the two metal frameworks were sketched and the preparation plan for the abutment teeth was drafted *(Figure 2B)*.

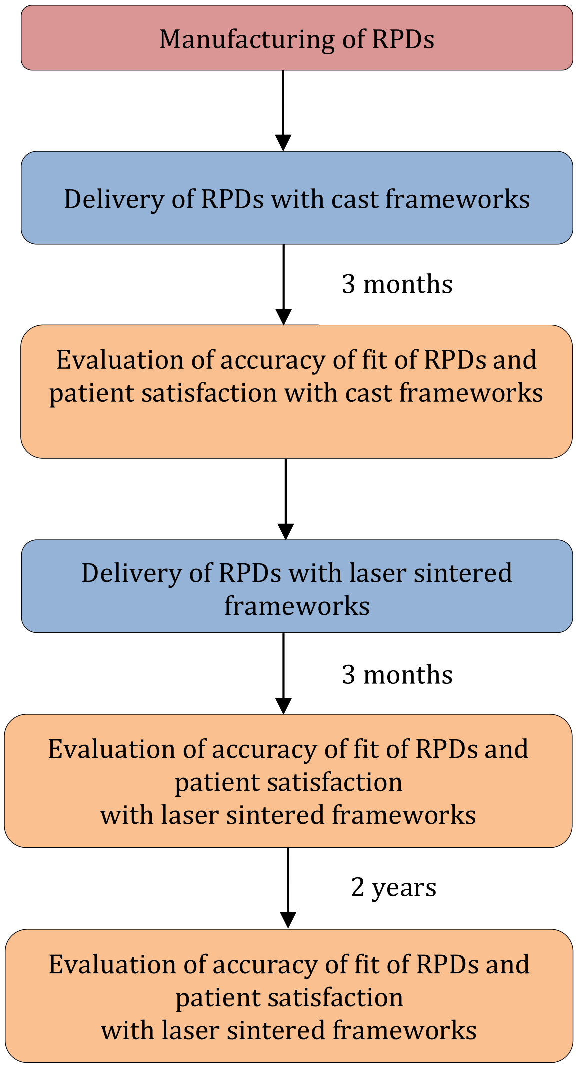

Figure 1: The fabrication steps of RPDs with metal frameworks manufactured using conventional and digital technologies.

To facilitate the preparation of the abutment teeth, the maxilla and mandible preparation splints were fabricated with marks of the insertion direction *(Figure 2C)*. After preparing the abutment teeth, the digital impressions of both jaws were made with the 3Shape TRIOS intraoral scanner and the conventional impressions using individual impression trays in occlusion using a polyether impression material (PermadyneTM, 3M ESPE) *(Figure 3A)*. Both types of RPDs were fabricated simultaneously by the same technician.

For the manufacturing of the RPD metal frameworks according to the lost wax casting technique, the polyether (Permadyne, 3M ESPE) impressions were poured using super-hard stone type 4 (Marmorock Saphir, Siladent Dr. Böhme & Schöps GmbH). The master casts were blocked out with wax and duplicated by using a silicone-based duplication material (rema Sil, Dentaurum) *(Figure 3B)*. The refractory casts were made using the phosphate-bonded investment material (Granisit Siladent Dr. Böhme & Schöps GmbH). The ready-made wax pattern materials were adapted on the refractory casts and invested in the same phosphate-bonded investment material

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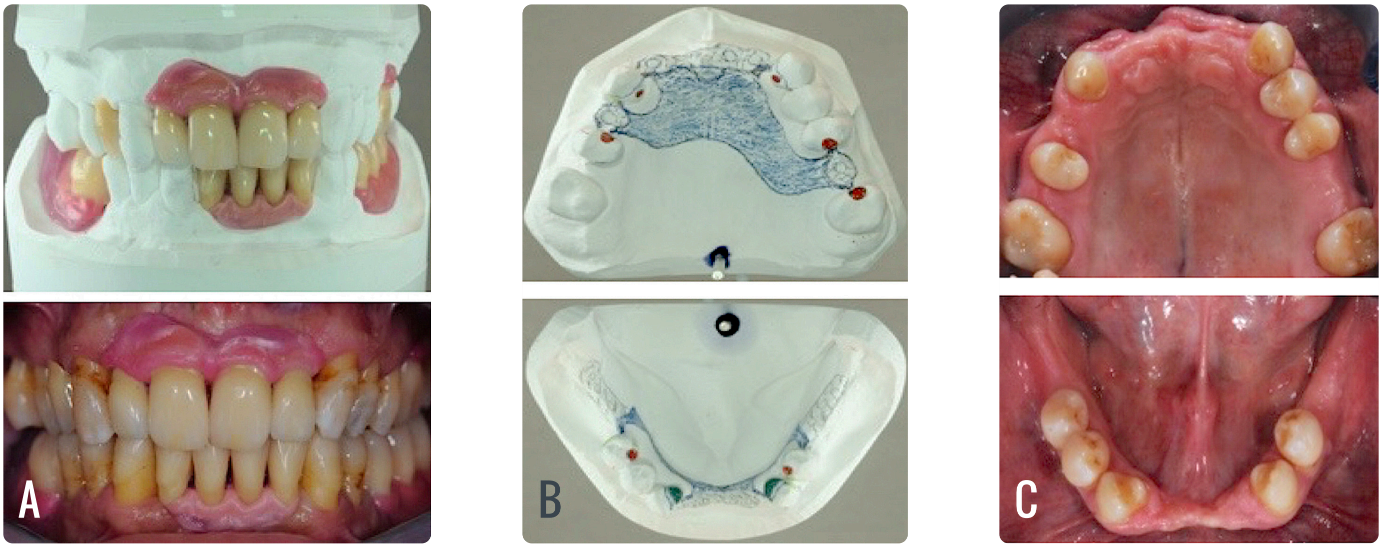

Figures 2A-C: Manufacturing steps of RPD metal frameworks: A) step 1: Try-in of Setup, B) step 2: Model analysis, C) step 3: Preparation of abutment teeth.

(Figure 3C). The RPD metal frameworks were casted using the centrifugal casting method with a high frequency casting machine (Degutron, Degussa) according to the manufacturers instructions *(Figure 3D*). Cr-Co-Mo alloy Type 5 (V-Alloy FG, DIN EN ISO 22674, Siladent) was used for casting of RPD metal frameworks. The cast RPD metal frameworks were air-borne particle abraded with 250 µm Al_2O_3 at a pressure of 3 bar. The finishing procedure of the RPD metal frameworks was carried out using carbide burs (Horico, Hopf, Ringleb & Co. GMBH & CIE). The description and sequence of the used instruments for this purpose are presented in the Table 1. Then, the RPD metal frameworks were further air-abraded with 125 Al_2O_3 at a pressure of 3 bar until matt surface was achieved. The tips of the retentive clasps were covered with a protective varnish and the RPD frameworks were processed in an electrolytic polishing unit (Eltropol 300; BEGO Bremer Goldschlägerei Wilh. Herbst GmbH & Co. KG) according to the manufacturers instructions. Finally, the frameworks were polished using the soft cut polishers (Soft Cuts PA; Shofu Inc), bristle brushes (Robinson; Buffalo Dental MFG. CO., Inc) and a polishing paste (Ti-Cor Polish, Ti-Hi Polish; Ticonium).

After the finishing and polishing of the metal frameworks, the setup transfer followed. After the final try-in *(Figure 3E*), the two removable partial dentures were completed and delivered to the patient *(Figure 3F*).

In the digital way of manufacturing metal frameworks, the digital scans *(Figure 4a*) in Standard Tessellation Language (STL) format were uploaded to the Silapart CAD / CAM software for digitally designing of the RPD frameworks. The digital RPD frameworks *(Figure 4b*) were exported as STL files to the direct metal laser sintering machine (ProX DMP 100; 3D System) of an external company for metal framework production. As a metal, Cr-Co-Mo alloy powder Type 5 (Sint-Tech, ST 2724G, NF EN ISO 22674, NF EN ISO 9693-1, SINT-TECH) was used with the following parameters: Power = 200 W, Wavelength = 1070 nm, layer thickness = 20 µm, and speed = 40 mm/s *(Figure 4b*). The RPD metal frameworks were delivered in the air-abraded *(Figure 4c*) condition (250 µm Al_2O_3, at a pressure of 3 bar) and had to be finished and polished in the dental laboratory similarly to the cast RPD metal frameworks. The set-up was manufactured with the aid of a silicone key so that the tooth set-up was almost identical to the RPDs with conventional cast frameworks. This step was followed by a complete try-in *(Figure 4d*), completion and delivery *(Figure 4e*) of the two RPDs. For the two sets of RPDs, appointments were made for the removal of pressure areas one day after delivery and remounting procedure of the symptom-free patient one week thereafter.

The patient was blinded to the clinical and conventional treatment protocols and randomly received the RPDs with the conventionally manufactured metal frameworks first. After 3 months, the accuracy of fit of the conventionally fabricated prostheses was analyzed using the replica method *(Figure 5, Tables 2 and 3*). Six elements of the RPDs were considered as areas of interest for the accuracy measurements, namely denture base, major connectors (palatal strap and lingual bar), minor connectors, rests as well as reciprocal arms and retentive clasps. At first the impression was taken with the respective RPDs using a silicone registration material (Fit Checker Advanced; GC Corp). An impression of the RPDs, including the silicone registration material was then made with an alginate impression material (Cavex Orthotrace Extra Fast Set). The alginate impressions were filled with silicone impression material (Vinylpolysiloxan Fitnis SH; Mono Kaniedenta) and the lower part of the silicone models was designed with silicone putty (Delta-SP 80 Softputty polyvinylsiloxan; Intertrading Dental AG). In order to assess the accuracy of fit of the maxilla and mandible RPDs, the replica models were cut in several places and the thickness of the silicone registration material in those areas was measured using the digital microscope (Keyence VHX-2000) at x200 magnification. All measurements were performed by one prosthodontic specialist with research experience calibrated using all used

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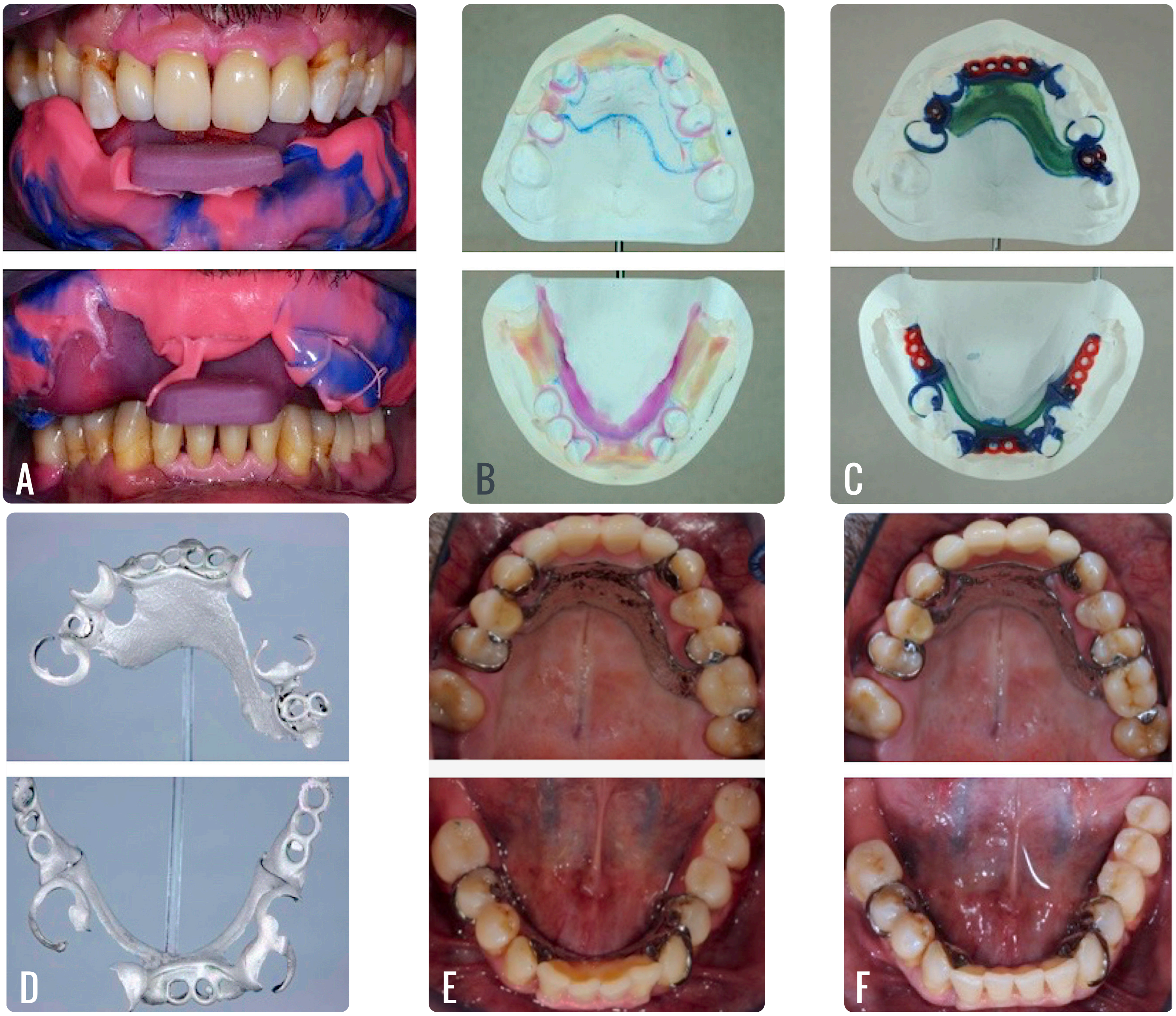

Figures 3A-F: Fabrication of RPD metal frameworks using conventional lost wax casting technique: A) step 4: conventional impressions of the maxilla and mandible, B) step 5: Master casts blocked out with wax, C) step 6: Refractory casts with wax pattern of RPD frameworks, D) step 7: Casted and sandblasted RPD frameworks, E) step 8, Try-in of RPD frameworks with setup, F) step 9 Delivery of RPDs.

Table 1. Instruments, sequence, shape, finishing areas and speed of application (rpm: rotation per minute) for finishing RPDs.

Finishing Instruments and Sequence	Shape	Finishing area	Speed (rpm)
Horico CARBIDE Black Coated Tungsten Carbide Cutter	S274 134 060 Helical Cross Cut Fine	Rests	15`000-20`000
Horico CARBIDE Black Coated Tungsten Carbide Cutter	S198 134 040 Helical Cross Cut Fine	Major and minor connectors, retentiv clasps, reciprocal arms	15`000-20`000
Horico CARBIDE Black Coated Tungsten Carbide Cutter	S198 140 016 Cross Cut Fine	Hard-to-access areas, light unevenness	15`000
Horico CARBIDE Tungsten Carbide Cutter	277 134 014 FSQ Helical Cross Cut Fine	Remove of casting pearls and sharp edges	15`000-20`000
Horico CARBIDE Tungsten Carbide Cutter	277 NEF 014 Cross Cut Fine	Adjustment to master model	20`000

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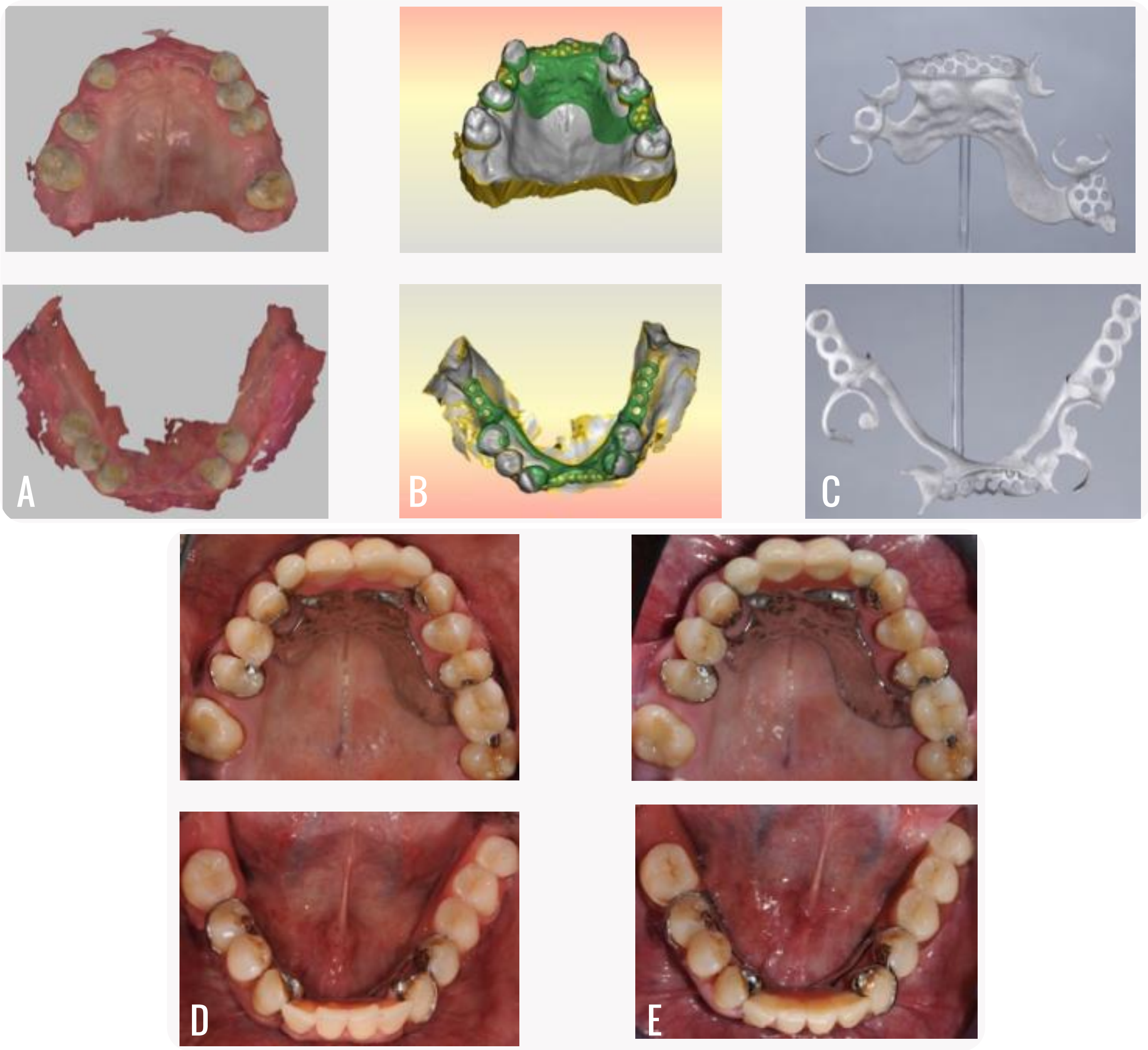

Figures 4A-E: Fabrication of RPD metal frameworks using direct metal laser sintering technology (DMLS) with ProX DMP 100 Machine from 3D Systems: A) step 4: Digital impressions of upper and low jaws, B) step 5: Master casts blocked out with wax, C) step 6: Refractory casts with wax pattern of RPD frameworks, D) step 7: Casted and sandblasted RPD frameworks, E) step 8, Try-in of RPD frameworks with setup, delivery of RPDs.

devices. Both digital and conventional workflows were measured similarly. In the maxilla, measurements were taken on 5 rests, 6 minor connectors, 2 reciprocal arms, 2 retentive clasps, 24 areas on the major connector and 5 areas of denture base. The denture base was measured at the points corresponding to the highest area of the alveolar ridge. There were three areas on the front and one area on each side. For all other components of the RPD, the measurements were made at one central and two peripheral locations *(Figure* 5). All measurements were repeated three times yielding to a total of 222 measurements *(Table 4*).

In the mandible, measurements were made on 4 rests, 4 minor connectors, 2 reciprocal arms, 2 retentive clasps, 15 areas on the major connector and 14 areas on the denture base. The lateral denture bases were measured at the lingual, buccal and the highest part of the alveolar ridge. In the area of the frontal denture base, measurements were made at the buccal areas and the highest part of the alveolar ridge while others were made at one central and two peripheral locations in all corresponding components of the RPD *(Figure 6*). All measurements were repeated three times yielding to a total of 195 measurements *(Table 5*).

The satisfaction of the patient with the aesthetics, retention, chewing ability, comfort as well as the general satisfaction was assessed with the numeric rating scale 0-10, where zero meant totally unsatisfied.

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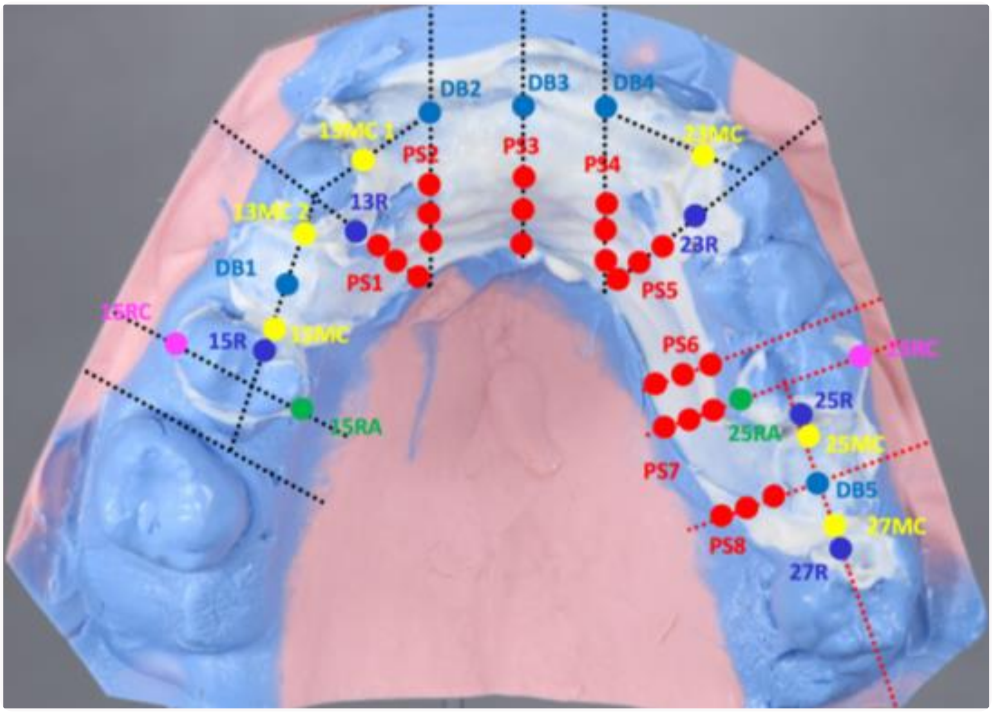

Figure 5: Replica model of the maxilla with section lines and measuring areas. 15R, 13R, 23R, 25R, 27R – rests; 15RA, 25RA – reciprocal arms; 15MC, 13MC1, 13MC2, 23MC, 25MC, 27MC – minor connectors; 15RC, 25RC – retentive clasps; PS1, PS2, PS3, PS4, PS5, PS6, PS7, PS8 – palatal strap; DB1, DB2, DB3, DB4, DB5 – denture base.

Table 2. Measurements on replica models of upper and low jaws.

	RPD Components	No. of RPD components	No. of areas	Measurements per area	No. of measurements
Maxilla	Rest	5	15	3	45
	Minor connector	6	18	3	54
	Major connector	1	24	3	72
	Reciprocal arm	2	6	3	18
	Retentive clasp	2	6	3	18
	Denture base	3	5	3	15
	Total				**222**
Mandible	Rest	4	12	3	36
	Minor connector	4	12	3	36
	Major connector	1	15	3	45
	Reciprocal arm	2	6	3	18
	Retentive clasp	2	6	3	18
	Denture base	3	14	3	42
	Total				**195**

After 3 months of wearing the conventionally manufactured removable partial dentures *(Figure 7a)*, the patient received the RPD DMLS technology produced metal frameworks *(Figure 7b)*.

The RPDs made with CAD / CAM technology were worn for 3 months. Thereafter, the same examinations as well as the evaluation of the patient's satisfaction were carried out similar to the conventional RPDs. The test results were compared with each other. Finally, the patient was allowed to choose the RPD he liked most.

The sequence of the treatments and examinations carried out is presented in Figure 1.

After 3 months of wearing the DMLS fabricated RPDs, the patient preferred them. Two years later, the fit accuracy of the chosen RPDs and patient satisfaction were re-evaluated in the same way *(Tables 4 and 5)*.

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Table 3. Accuracy fit measurements (μm) at different locations of C-LW and DMLS RPDs of maxilla and mandible jaw 3 months after delivery of the removable partial dentures.

RPDs	Fit accuracy measurements (μm)					
	Rest	Reciprocal arm	Minor connector	Retentive clasp	Major connector	Denture base
C-LW UJ						
MV	194	106	240	114	243	394
SD	113	38	144	61	147	229
Min	59	42	60	29	58	750
Max	421	164	489	172	512	115
DMLS UJ						
MV	244	49	201	15	413	279
SD	129	58	174	18	252	185
Min	63	0	25	0	68	112
Max	457	132	767	36	850	567
C-LW LJ						
MV	107	95	152	36	173	212
SD	93	47	154	46	251	243
Min	0	34	0	0	0	16
Max	285	157	453	113	824	859
DMLS LJ						
MV	184	40	198	41	124	220
SD	78	18	274	52	91	149
Min	62	23	25	0	0	0
Max	299	75	859	105	293	478

* Mean value (MV); Standard deviation (SD), and minimum (Min) and maximum (Max) values (μm). Conventional lost-wax and casting technique (C-LW), direct metal laser sintering (DMLS).

Table 4. Accuracy fit measurements (μm) at different locations of C-LW and DMLS RPDs of maxilla jaw (UJ) after 3 months and 2 years after delivery of the removable partial dentures.

RPDs	Fit accuracy measurements (μm)					
	Rest	Reciprocal arm	Minor connector	Retentive clasp	Major connector	Denture base
DMLS UJ						
MV	244	49	201	15	413	279
SD	129	58	174	18	252	185
Min	63	0	25	0	68	112
Max	457	132	767	36	850	567
DMLS UJ 2 y. later						
MV	148	18	211	20	457	442
SD	80	21	192	24	262	209
Min	56	0	0	0	90	141
Max	336	53	858	57	1146	787

Mean value (MV); Standard deviation (SD), and minimum (Min) and maximum (Max) values (μm). Conventional lost-wax and casting technique (C-LW), direct metal laser sintering (DMLS).

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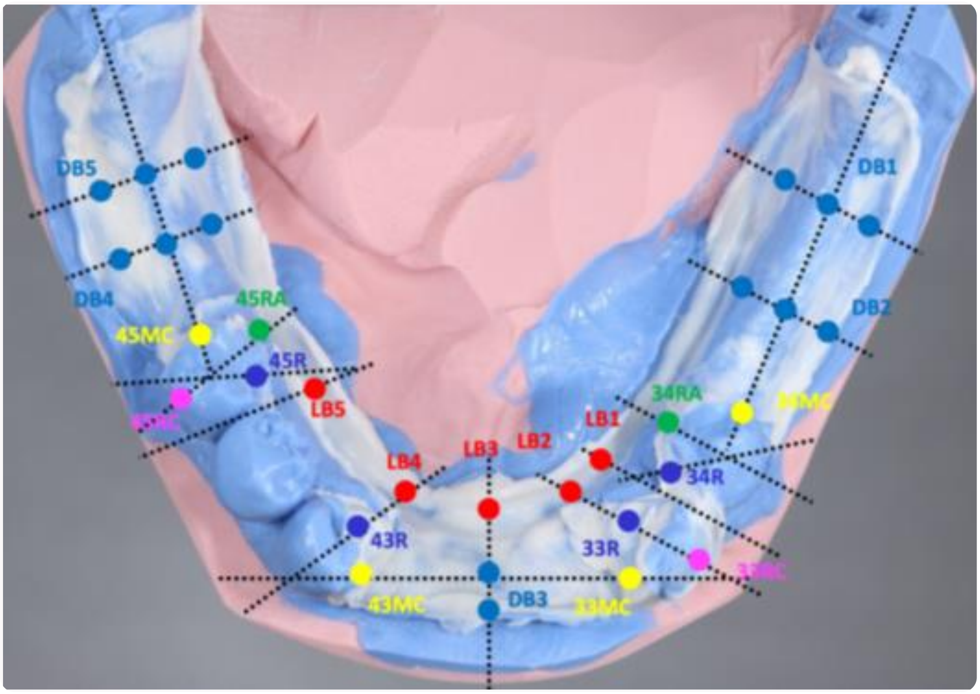

Figure 6: Replica model of the mandible with section lines and measuring areas. 34R, 33R, 43R, 45R – rests; 34RA, 45RA – reciprocal arms; 34MC, 33MC, 43MC, 45MC -minor connectors; 33RC, 45RC – retentive clasps; LB-1, LB-2, LB-3, LB-4, LB-5 – lingual bar; DB-1, DB-2, DB-3, DB-4, DB-5 – denture base.

Table 5. Accuracy fit measurements (μm) at different locations of C-LW and DMLS RPDs of mandible jaw (LJ) after 3 months and 2 years after delivery of the removable partial dentures.

RPDs	Fit accuracy measurements (μm)					
	Rest	Reciprocal arm	Minor connector	Retentive clasp	Major connector	Denture base
DMLS LJ						
MV	184	40	198	41	124	220
SD	78	18	274	52	91	149
Min	62	23	25	0	0	0
Max	299	75	859	105	293	478
DMLS LJ 2 y. later						
MV	228	74	587	45	176	356
SD	172	74	440	70	153	260
Min	0	0	114	0	0	0
Max	560	182	1390	157	518	957

*** Mean value (MV); Standard deviation (SD), and minimum (Min) and maximum (Max) values (μm). Conventional lost-wax and casting technique (C-LW), direct metal laser sintering (DMLS).**

RESULTS

The average gap between the intaglio surface of the maxillary RPD and the underlying abutment teeth was larger in the RPD with digitally fabricated framework and digital impression only in the areas of the rests and major connector compared to the RPD with conventional cast framework. In the other areas, the maxillary DLMS fabricated RPD showed better accuracy of fit. No gap values were noticed in the areas of the reciprocal arms and retentive clasps in the digital manufactured framework based on the lack of the silicone registration material and several small gaps with the minimum gap value of 25 μm in the areas of the minor connectors. The major connector of the conventionally manufactured framework showed on average a smaller gap with a maximum gap value of 512 μm compared to the digital framework with the maximum gap value of 850 μm.

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Figures 7A-B: Definitive maxilla and mandible RPDs. A) with cast frameworks; B) with DLMS frameworks.

The mandibular RPD with DLMS metal framework and digital impression showed only in the areas of reciprocal arm and major connector better fit accuracy in comparison to the RPD with conventionally cast metal framework. In contrast, the gap values in the areas of the retentive clasps in the two frameworks were comparable.

DISCUSSION

The elaboration and adaptation to the printed plastic model of the digitally manufactured metal frameworks took significantly less time compared to the conventionally manufactured metal frameworks. In contrast to the conventional manufacturing of the metal frameworks, digital design enables the dental technician to precise the blocking out of the digital models and the designing of the elements of the metal frameworks. On the other hand, due to the lack of routine for the dental technician, digital design was more time-consuming compared to the conventionally manufactured RPDs.

In the assessment using the numerical rating scale 1-10, the RPDs with digitally manufactured frameworks were rated better by the patient than the RPDs with conventional frameworks. The patient stated that he was very satisfied with all parameters. With the conventionally manufactured maxillary RPD, the patient was less satisfied (score 8) in terms of comfort compared to the conventionally manufactured mandibular partial prosthesis (score 9) in terms of comfort. The disturbing factors were the increased mobility of the prosthesis in the maxilla and the lingual bar in the mandible. The other parameters were rated by the patient with score 9 and there was no difference between the maxillary and mandibular prosthesis. Finally, the patient preferred the maxillary and mandibular RPDs, the metal frameworks of which were manufactured using digital technologies.

The greater satisfaction with the comfort and chewing ability can be explained by the measurements on the replica models. In the maxilla, despite the uneven distribution of the gaps with reciprocal arm and retentive clasps as well as with the minor connectors, there were many smaller gaps or even no gaps, which ensured a better retention, which was also clinically recorded. In addition, the digitally manufactured metal frameworks were a little more delicate than the conventionally produced ones, which could also contribute to better wearing comfort and better perceived aesthetics. The smaller gap below the major connector in the conventionally manufactured framework in the maxilla compared to the digital metal framework did not seem to disturb the patient. This could be explained on the one hand by the resilience of the mucosa in the palate and on the other hand by the limitations of the digital impressions of the edentulous areas.

Two years later, the fit accuracy of the mandibular RPD has deteriorated in all areas of the prosthesis. In the maxilla, on the other hand, the values of fit accuracy deteriorated in all areas with the exception of the rests and the reciprocal arms. These changes can have various causes, such as tooth movement, resorptions in the alveolar ridges, and distortion of the metal frameworks of the RPDs.

The patient satisfaction with the RPDs according to the numerical rating scale 1-10 has decreased from score 10 to 9 in relation to all parameters. The deterioration in patient satisfaction with the RPDs can be explained by the deterioration in the accuracy of fit of the prosthesis.

As part of the maintenance treatment, professional teeth cleaning was carried out, the dentures were cleaned in an ultrasonic bath and the retentive clasps were activated. One limitation of this clinical report is that the patient was not adapted to the use of a removable partial denture at the beginning. However, the patient was already adapted to the use of a RPD when he was experiencing the casted one. In addition, the changes of oral environment such as occlusion and alveolar ridge in the previous 3 months can also affect the fit and long-term effect of the new denture. Furthermore, it must be noted, that the conclusions of this study were deduced based on one patient. Therefore, upcoming clinical research should focus on this topic using crossover clinical trials.

CONCLUSIONS

The use of CAD / CAM technologies in manufacturing RPDs seems very promising and is comparable to the conventional manufacturing technique regarding accuracy and patient satisfaction. However, more clinical studies in this area are needed to evaluate all the benefits and challenges of implementation of the digital techniques in fabricating partial dental frameworks.

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DISCLOSURE

The authors declare that they have no conflict of interest.

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