

3D Metal Printing - Additive Manufacturing Technologies for Frameworks of Implant-Borne Fixed Dental Prosthesis

Keywords

3D Printing
Additive Manufacturing Technologies
Castable Printed Pattern
Digital Dentistry
Direct Light Processing
Lithium Disilicate
Polymer Printed
Stereolithography

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ABSTRACT

An edentulous patient was rehabilitated with maxillary metal-ceramic and mandibular metal-resin implant-supported fixed dental prosthesis (FDP). Metal frameworks of the FDPs were fabricated using 3D additive manufacturing technologies utilizing selective laser melting (SLM) and electron beam melting (EBM) processes. Both SLM and EBM technologies were employed in combination with computer numerical control (CNC) post-machining at the implant interface. This report highlights the technical and clinical protocol for fabrication of FDPs using SLM and EBM additive technologies.

INTRODUCTION

The introduction of additive manufacturing (AM) technologies opened new possibilities in prosthetic dentistry for comprehensive rehabilitation of the patients.^{1,2} The American Society for Testing and Materials (ASTM) has defined AM as “a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies”.³ The ASTM international committee F42 on AM technologies has classified seven categories.⁴ Among all AM technologies, the powder bed fusion (PBF) technology is more commonly employed for 3D metal printing in dentistry. Typically, PBF technologies are based on selective laser sintering (SLS), selective laser melting (SLM) and electron beam melting (EBM).^{1,2} The main difference between the three PBF technologies is the route to reach the melting point of the metal.⁵⁻⁷ The SLS technology sinter the metal powder instead of fully melting the metal powder such as in the case of SLM and EBM technologies.⁶ The accuracy of AM technologies is dictated by grain size of the metal powder, layer thickness, building orientation, vacuum, presence of purified Ar/N₂ in the building chamber, beam scan-speed, beam size, energy density and scan spacing. Furthermore, other related parameters employed for scanning strategies such as orthogonal scans (x-y), repeated melting of each layer and heat treatment after building the structure significantly affect the final outcome.³⁻¹¹

Current knowledge dictates that mechanical properties of metals fabricated using AM procedures are similar to those that are milled and exceeds those that are manufactured through conventional casting routes.^{9,10,12-16} In order to achieve precise implant-framework interface and attain improved metal-ceramic bond strength, PBF technologies are combined with the computer numerical control (CNC) post-machining of the implant interface. In this regard, the SLM system was reported to exhibit metal-ceramic bond results exceeding the requirements of ISO 9691:1999(E) that is also comparable to conventional cast methods.¹⁶⁻¹⁹

Received: 10.06.2017

Accepted: 26.6.2017

doi: 10.1922/EJPRD_RevillaLeon05

In this clinical case report, technical and clinical protocols were described for fabrication of FDPs using SLM and EBM additive technologies used for the rehabilitation of an edentulous patient with implant-supported fixed dental prosthesis (FDP).

CLINICAL REPORT

A 68 year-old edentulous male patient with seven implants (Tissue Level RN Straumann Implant, Straumann, Basel, Switzerland) in the maxilla and six implants (4 Tissue Level RN and 2 NNC Straumann Implants, Straumann) in the mandible was referred to our clinic with the request of prosthetic rehabilitation (Figures 1a-c). The implants were placed more than nine months ago by a periodontologist in a private practice. The patient had an interim maxillary and mandibular complete denture (CD) and had two provisional implants with 2 mm diameter, 10 mm length (TempImplant, Straumann) in order to increase the retention of the interim mandibular CD. The patient expressed oral discomfort due to the mobility of the mandibular CD and was also not pleased with the appearance of the interim CDs.

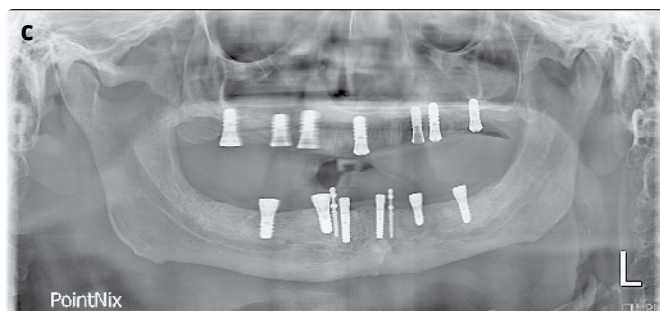


Figure 1 (a-c): Intraoral occlusal view of a) maxilla with seven implants, b) mandible with six implants and two provisional implants to increase the retention of interim mandibular complete denture, c) initial radiograph.

An extraoral and dento-facial analysis was performed in order to evaluate the lip support in close, rest positions and during smiling with and without the immediate CDs. Maxillary immediate CD was then duplicated without the buccal flange. Extraoral analysis indicated the need for some modification of the teeth position in the interim CDs.

After complete intraoral and radiographical analysis, in order to obtain master casts, impression copings were splinted in the maxilla and mandible and with an open custom-tray impressions were made (Impregum, 3M ESPE, St. Paul, USA).^{20,21} The impressions were then poured with Type IV plaster (Fuji Rock White, GC, Tokyo, Japan). Screw retained base plates (KFO acrylic resin, Bredent, Senden, Germany) with wax rims were prepared for the maxillary and mandibular arches. During this appointment, dento-facial and smile analysis along with phonetics were verified. Firstly, the try-in wax rim was used to determine the maxillary occlusal plane. Based on the patient's confirmation regarding the visibility of his teeth during rest position with a display of 1.5 mm, wax rim was adjusted. The level of maxillary occlusal plane was adjusted to the inter-pupillary line and the integration to the patient's face was confirmed. Once the lip support without a flange on the maxillary screw retained wax rim was acceptable, the incisal maxillary midline and lip line were marked. Then, the mandibular screw retained wax rim was adjusted until an interarch space of about 2 mm was reached at rest. Subsequently, the phonetics was evaluated letting patient pronounce the letters "f", "v" and "s" comfortably and clearly.

Maxillomandibular relationship was registered (Occlufast, Zhermack, Badia Polesine, Italy) while asking the patient to position the tip of his tongue on the back of his palate. Finally, a face bow was used to mount the casts on the semi-adjustable articulator (Panadent articulator, Panadent, Colton, CA, USA).

Screw retained teeth (Physiodens, VITA Zahn Fabrik, Bad Säckingen, Germany) without buccal flange set-up was tried-in. At this stage, the tooth display at rest was increased from 0 to 1.5 mm; the lip support was confirmed to be adequate supporting the upper lip. The phonetics was re-evaluated while analyzing the new teeth display, demonstrating no issues with the "f", "v" and "s" sounds. After group function was established and the teeth set-up was verified, screw-retained

(Metal temporary metallic abutments, Straumann) acrylic resin provisional restorations (Palapress Vario, Heraeus-Kulzer, Hanau, Germany) with cast metal frameworks (Viron 99, Bego, Bremen, Germany) were delivered (Figures 2a-b). Thereafter, the temporary implants were removed prior to the delivery of the provisional restorations at the same appointment. Next, the patient was provided with the hygiene instructions using superfloss and interproximal toothbrushes.

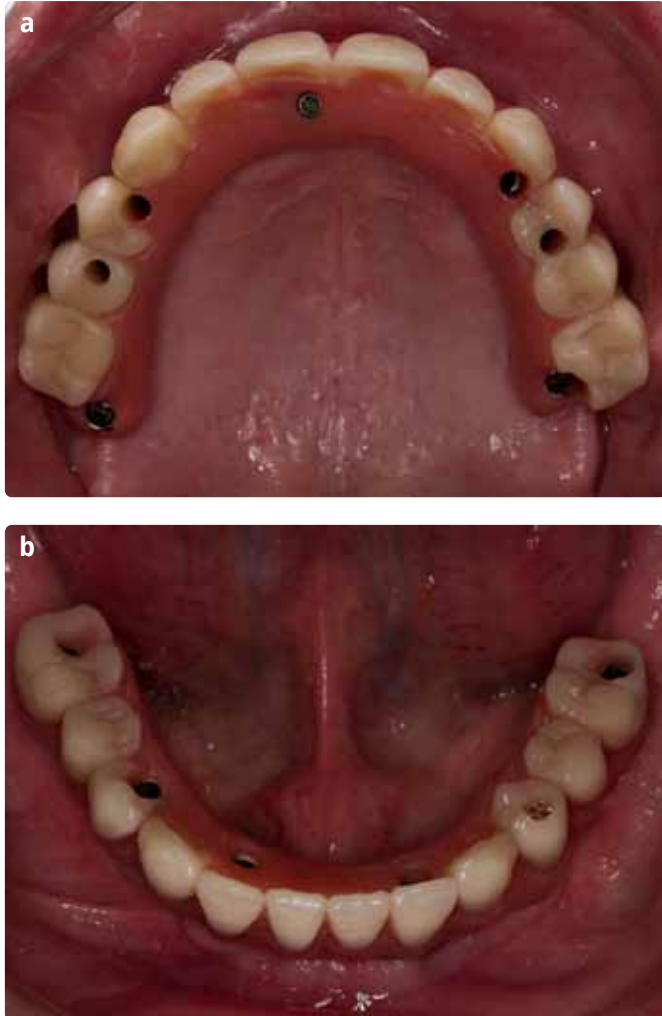
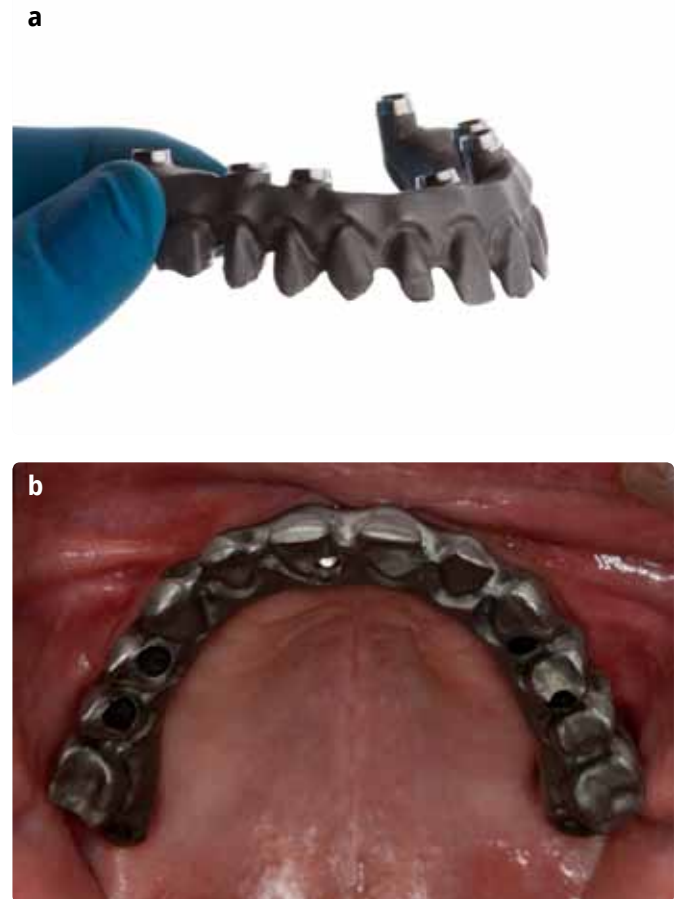


Figure 2 (a-b): Occlusal view of a) maxillary and b) mandibular screw-retained provisional restorations in the mouth.

Six months after delivery of the provisional restorations, function, phonetics and aesthetics of the screw-retained provisional restorations were re-evaluated that were observed intact with increased ability of cleansing. Provisional restorations were duplicated with non-reflective acrylic resin (Palapress Vario, Heraeus-Kulzer) and master casts were scanned (Renishaw DS10, Renishaw and Renishaw DS20, Medit, Gloucestershire, United Kingdom). The digital designs for the frameworks in the maxilla and mandible were made using the corresponding dental software (Exocad Dental CAD, Exocad GmbH, Darmstadt, Germany). Due to the slightly lack of parallelism between the implants, all frameworks were designed on the trans-occlusal abutments (RN SynOcta 1.5 screw-retained abutment, Straumann).

The STL files were used to fabricate the metal frameworks through AM technologies where the maxillary framework of the FDP was made of Cr-Co (SP2 Cr-Co Metal powder, Concept Laser, Lichtenfels, Germany) using SLM technology (Mlab SLM Printer, Concept Laser GmbH, Lichtenfels, Deutschland) and for the mandibular Ti framework (Ti6Al4V Metal Powder, Arcam AB, Mölndal, Sweden) was fabricated using EBM technology (Arcam Q2, Arcam AB).

During the try-in session, the fit of the frameworks on the implants were inspected through tactile sensation with the explorer, pericapical x-rays and one-screw test (Figures 3a-d).²² The maxillary framework was veneered with ceramic (Initial MC, GC, Leuven, Belgium) whole the mandibular with denture teeth (Physiodens, VITA Zahn Fabrik) and pink acrylic resin (Lucitone 199 Denture base resin, Denstply-Sirona, York, PA, USA). The occlusal adjustments were made where necessary and a group function was established.



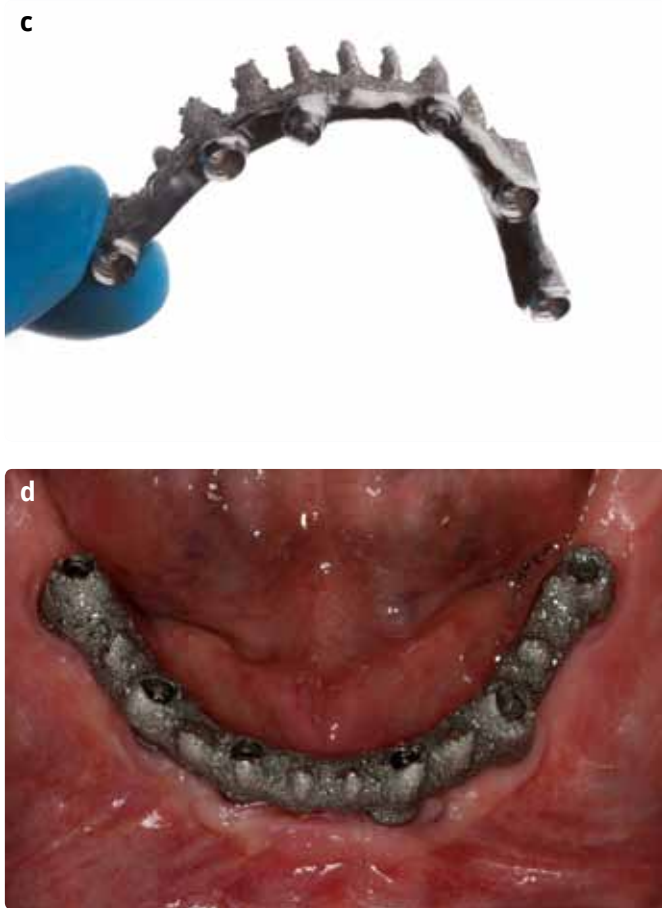


Figure 3 (a-d): SLM Cr-Co framework for the maxilla and b) occlusal view of framework during try-in, c) Ti mandibular framework fabricated using EBM technology, d) Ti mandibular framework in the mandible.

The FDPs were delivered to the patient along with a night guard (Figures 4a-c). Radiographic evaluation upon prosthesis delivery was repeated after 6 months (Figure 5). The patient was finally introduced to the annual maintenance protocol.



Figure 4 (a-c): Frontal view of the patient a) during smiling at baseline, b) after the delivery of maxillary and mandibular prostheses, c) during smiling.

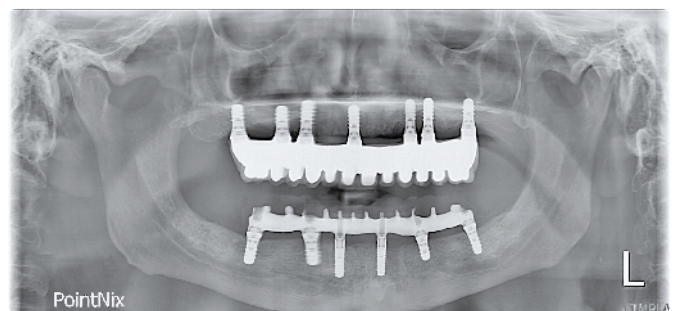


Figure 5: Final radiographic evaluation of the implant-borne FDP following delivery.

CONCLUSIONS

The additive manufacturing technologies used for metal frameworks are viable options to conventional casting methods for implant-borne FDPs that would eliminate arduous work of dental technicians.

ACKNOWLEDGEMENT

The authors acknowledge Dentware Ltd, Kristianstad, Sweden, for the fabrication of frameworks and the team members of Cimpla Dental Clinic, Madrid, Spain, for their assistance during the clinical work-flow.

DISCLOSURE

The authors declare that they have no conflict of interest.

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