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Maxillary Full-Arch Immediately Loaded Implant-Supported Fixed Prosthesis Designed and Produced by Photogrammetry and Digital Printing: A Clinical Report

David Peñarrocha-Oltra, DDS, MSc, PhD,[1] Rubén Agustín-Panadero, DMD, PhD,[2] Guillermo Pradíes, DMD,[3] Sonia Gomar-Vercher, PhD,[4] & Miguel Peñarrocha-Diago, MD, DDS, PhD[1]

[1]Department of Oral Surgery and Implant Dentistry, Valencia University Medical and Dental School, Valencia, Spain
[2]Department of Stomatology, Valencia University Medical and Dental School, Valencia, Spain
[3]Department of Buccofacial Prostheses, Complutense University Dental School, Madrid, Spain
[4]Private Dental Practice, Valencia, Spain

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Correspondence
Miguel Peñarrocha-Diago, Clínicas Odontológicas, Gascó Oliag 1, 46021 Valencia, Spain.
E-mail: miguel.penarrocha@uv.es.

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Abstract

The present clinical report describes the use of a photogrammetry system (PICcamera) for obtaining impressions and designing and producing an immediately loaded CAD/CAM provisional fixed prosthesis delivered in the mouth within 24 hours after implant placement in the maxilla. The stereo camera was used to capture the implant positions, automatically taking 350 images in less than 2 minutes. This photogrammetry system takes 10 pictures per second with a margin of error of under 10 μm between two scan bodies, and identifies the spatial position of each implant without physical contact. The three-dimensional data for each implant are registered in vector format, together with all interrelated implant angles and distances. The information is stored in an STL file (PICfile). Information on soft tissues was obtained from an irreversible hydrocolloid impression that was poured in stone and scanned. An immediately loaded screw-retained fixed prosthesis was made from acetalic resin using CAD/CAM, and its passive fit was evaluated in the mouth using the Sheffield test and screw resistance test.

The conventional method of producing an implant-fixed prosthesis supported by multiple implants consists of taking impressions of implants and soft tissues with impression copings and impression materials and then producing the prosthesis using a master cast acquired from the impression.[1] More recently, intraoral scanners have been used for impression procedures in cases involving multiple implants for rehabilitating edentulous areas of a limited span.[1] However, the reliability of intraoral scanners remains questionable when they are used for the prosthetic rehabilitation of a complete arch.[1]

Photogrammetry is an option for direct and reliable recording of the position of intraoral implants. It registers the geometrical properties of three-dimensional (3D) objects and their interrelated spatial positions from photographic images. Photogrammetry was introduced in dentistry by Jemt and Lie in 1994 to analyze the distortion of implant frameworks.[2] The technique can also be used as a novel option for reliable, direct intraoral registration of the positions of multiple implants. So far, the technique has been used in laboratory studies to measure implant positions and to ensure the fit of prostheses, as well as for assessing framework deformations and mucosal recession.[3]

Jemt et al[4] described the use of photogrammetry for registering the positions of dental implants intraorally. They compared this technique with conventional impression taking, and concluded that photogrammetry constitutes a valid alternative. Since then, the technical advances have been considerable but have not been accompanied by developments in the application of photogrammetry to implant dentistry. In 2005, Ortrop et al demonstrated that under laboratory conditions, the 3D precision of implant center-point measurements with this technique averaged a 12 μm margin of error. Three-dimensional information can also be transferred to a computer for further analysis and verification.[5]

Photogrammetry has also been proposed as a technique for generating a 3D model of the patient's face and dental arch, for occlusion registration, and for treatment planning and documentation.[6] However, to date photogrammetry has not been proposed or even suggested as a technique for producing a complete arch implant-fixed prosthesis in combination with digital printing technology. This clinical report describes a photogrammetry (stereo camera) system used to record the positions of multiple dental implants for rehabilitating patients with implant-supported fixed prostheses.

Clinical report

A 60-year-old man reported to the Oral Surgery Unit of the University of Valencia (Valencia, Spain) requesting rehabilitation of the maxilla with an implant-supported complete-arch fixed prosthesis. He presented with a defective maxillary fixed partial denture, with the maxillary right lateral incisor, left central incisor, and left canine as abutments. All of the abutments presented caries secondary to inadequate marginal fit. The maxillary left second premolar was devitalized, and showed moderate periodontal involvement with grade II mobility, whereas the maxillary right second molar showed severe periodontal involvement with grade III mobility (Fig 1).

The treatment plan consisted of the extraction of all the maxillary teeth, with implant placement and immediate loading of a fixed prosthesis. First, impressions of the upper and lower arches were made in irreversible hydrocolloid impression material to obtain the soft tissues from the diagnostic casts before implant surgery (Fig 2). Diagnostic waxing was done to determine implant positions. Based on the diagnostic waxing study, an implant surgical guide was prepared, planning implant placements in the maxillary right first molar, right first and second premolar, right central incisor, left lateral incisor, left first premolar, and left first and second molar positions. The presence of enough residual alveolar bone height was confirmed by means of a panoramic radiograph and computerized axial tomography.

Eight implants were placed as planned (Mozo-Grau®, Valladolid, Spain; Fig 3A). During implant surgery the maxillary right second molar was maintained in order to facilitate spatial capture of the implant positions. To this effect, the stereo camera was used to register the prosthetic data. First, patient demographic and medical data were entered into the system. Then, the positions and the references of the implants (manufacturer, model, platform diameter, diameter and height of the healing abutments) and the code of each scan body were entered. The stereo camera was located 15 to 30 cm from the mouth of the patient at a maximum angle of 45° to the scan bodies. The camera took 50 to 60 3D photographs of each pair of PIC abutments (PICdental, Majadahonda, Spain). The PICcamera was mounted on a tripod to ensure stability, and the patient's head was moved into the correct position for capturing all the scan bodies. Data registered with the PICcamera for each abutment appeared onscreen. When the computer was registering data, a red bar appeared that turned green when the registration process was completed (Figs 3B–E). In this way, the photogrammetry device was used to identify the spatial position of each implant without physical contact. A total of 350 images were captured in less than 2 minutes to determine the relative position of each implant (angle and distance) in vector format. The final information was then stored in the system as an STL file (*PICfile*®; Fig 4A).

Photogrammetry does not register the patient's peri-implant soft tissues, only the vectorial relationship between the implant prosthetic platforms. Healing abutments were placed, and an irreversible hydrocolloid impression of the upper maxilla was made. The stone cast was scanned with an extraoral 3D scanner PICscan in open STL format to obtain soft tissue information. These data were then entered in the CAD software together with the PICfile.

The PICfile and the digitized cast were aligned using PICpro (PICdental), dental CAD software based on Exocad (Exocad GmbH, Darmstadt, Germany) with three-point registration, and subsequent enhancement using best-fit alignment. This process transferred the relative implant positions to the digital cast, including the shape of the soft tissues, which could then be used to determine the interfaces of the future prosthesis in relation to the patient's gingiva (Fig 4B).

The initial pretreatment diagnostic casts, including both upper and lower arches and their occlusion, were scanned in order to design and produce the interim prosthesis in proper occlusion (using CAD software). After surgery, STL files of the pretreatment diagnostic casts and the scanned implant master cast were superimposed. This was done using the palatine, retro-tuberosity areas and the remaining maxillary right second molars of the two images as references.

The fixed interim prosthesis was designed using Exocad in STL format (Figs 4C and D). A computer numeric-controlled milling machine with 5 degrees of freedom (Hermle C20; Maschinenfabrik Berthold Hermle AG, Gosheim, Germany) was used to produce the prosthesis in acetalic resin (TSM Acetal Dental; Pressing Dental Srl, Falciano, Republic of San Marino).

The interim fixed implant-supported prosthesis was evaluated in the patient's mouth. Passive fit between the framework and the implants was tested using the Sheffield test (one-screw test), the screw resistance test, and the digital pressure test. In addition, panoramic X-rays were taken. After the fit was confirmed, the prosthesis was screwed in place applying 25 Ncm torque (Figs 5A–C). The two operators noted no tension, misfit, or lack of adaptation at the time of screwing the framework in place.

The maxillary right second molar was then removed after fitting the interim prosthesis. The patient was advised to stay on a soft diet for the first 3 months and to avoid chewing movements that would generate excessive forces. He returned for checkups 1 week, 1 month, and 3 months after implant placement, and showed no biological or prosthetic complications (Figs 5D and 6A).

After 3 months, the final maxillary implant fixed prosthesis was produced and delivered. An STL file (PICfile®) obtained by photogrammetry on the day of implant surgery was used for producing the prosthesis. Only a new irreversible hydrocolloid impression for reproducing the current state of the soft tissue was required. Then, best-fit alignment (PICpro®) was performed using the soft tissue scan and the implant vectorial positions. With this new file, the model cast was then produced by stereolithography on which the final prosthesis was performed. To build the master model, the digital model was processed, providing the specific geometries of the implant connections, and then produced by stereolithography using a 3D printer (Objet 250® Eden; Stratasys, Rehovot, Israel). The model was processed in a manner that would allow for the addition of false gum at a later stage in the laboratory. The metal structure was reduced from the immediately loaded prosthesis shape and screw retained in the printed master model for finishing of the fixed prosthesis. Three months after placement of the fixed prosthesis, the definitive prosthesis was produced; the peri-implant mucosa and implant osseointegration were found to be normal (Figs 6B and C).

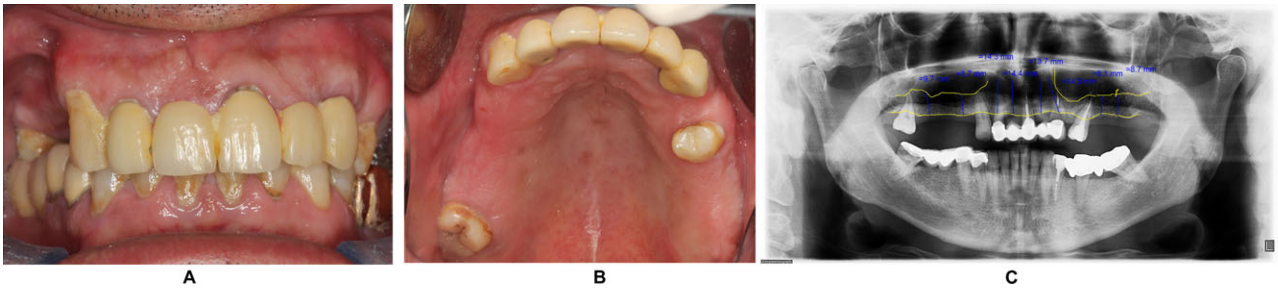


Figure 1 (A) Pretreatment frontal view of maximum intercuspation; (B) pretreatment occlusal view of the maxilla; and (C) pretreatment panoramic radiograph.

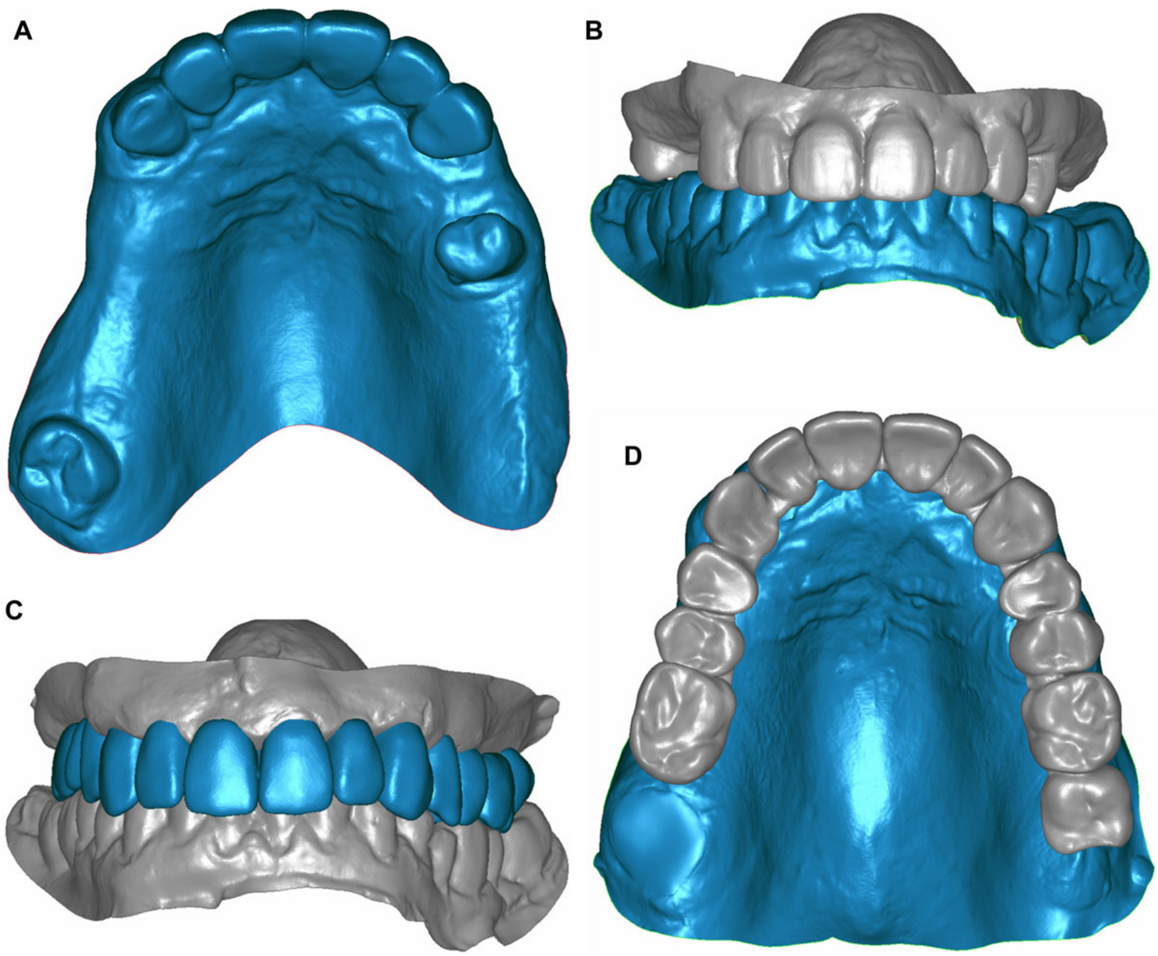
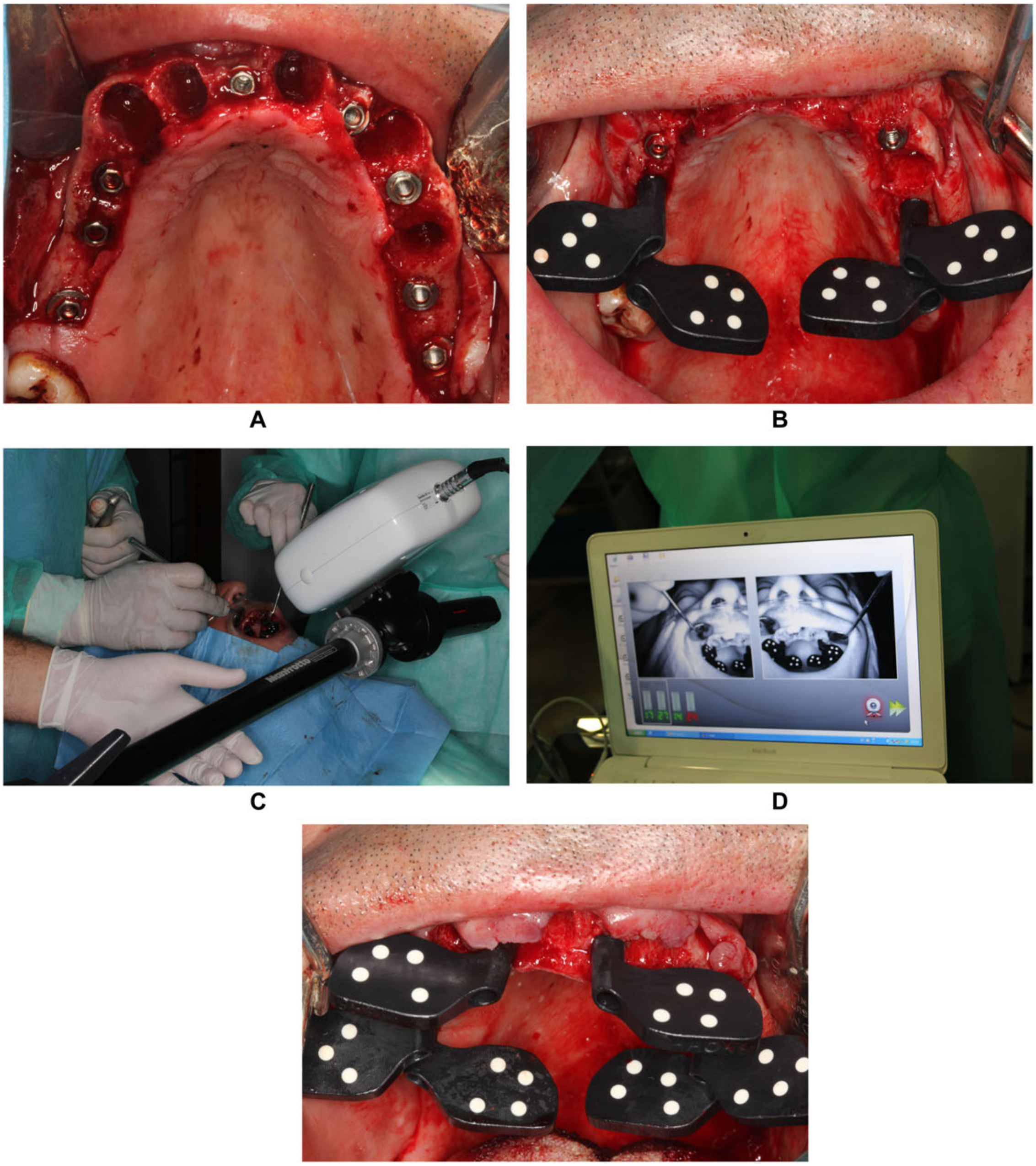


Figure 2 (A) Scanned image of the pretreatment occlusal view of the maxilla; (B) scanned image of the pretreatment frontal view of maximum intercuspation; (C) virtual image of the frontal view of the diagnostic wax-up; and (D) virtual image of the occlusal view of the diagnostic wax-up.



A B C D E

Figure 3 (A) Placement of 8 Mozo-GrauOsseus implants in the edentulous maxilla; (B) placement of PicAbutments on posterior implants; (C) intraoral scan performed with the stereo camera; (D) data processing with the stereo camera software; and (E) placement and image capture of PicAbutments® on anterior implants.

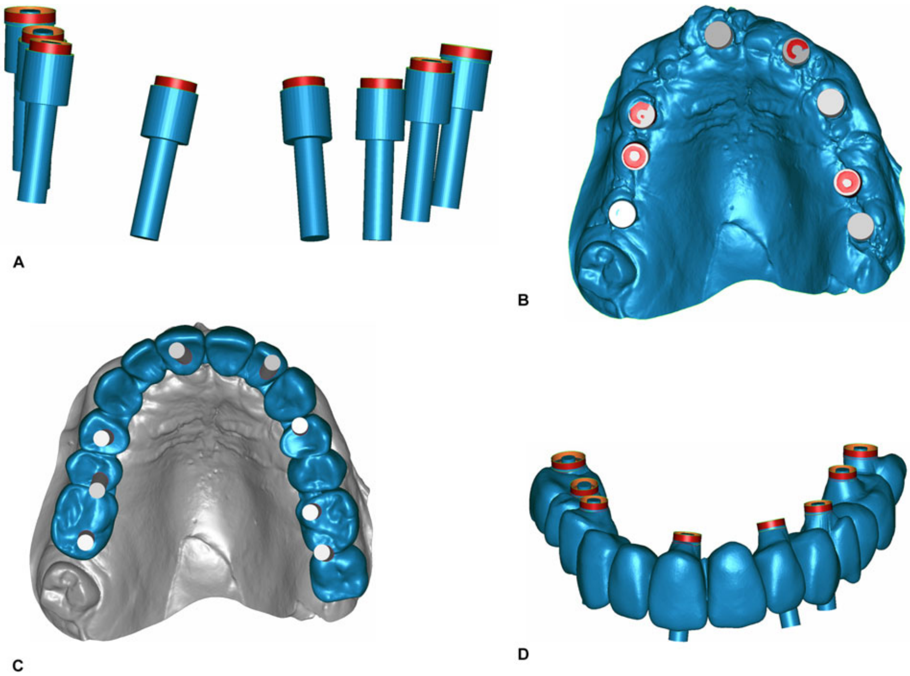


Figure 4 (A and B) Alignment by means of Best-fit of PICfile vector data and digitized plaster model; (C and D) virtual design of the prosthesis for immediate loading, showing the emergence profile.

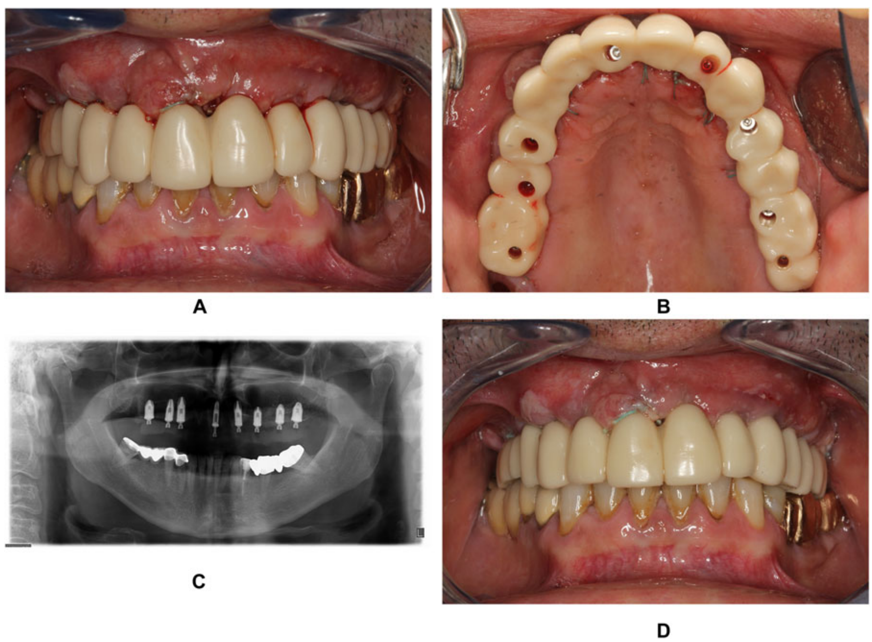


Figure 5 (A) Frontal view of the immediately loaded fixed interim prosthesis; (B) occlusal view of the immediately loaded fixed interim prosthesis; (C) panoramic radiograph of the immediately loaded fixed interim prosthesis; and (D) frontal view of the interim prosthesis 1 week after delivery.

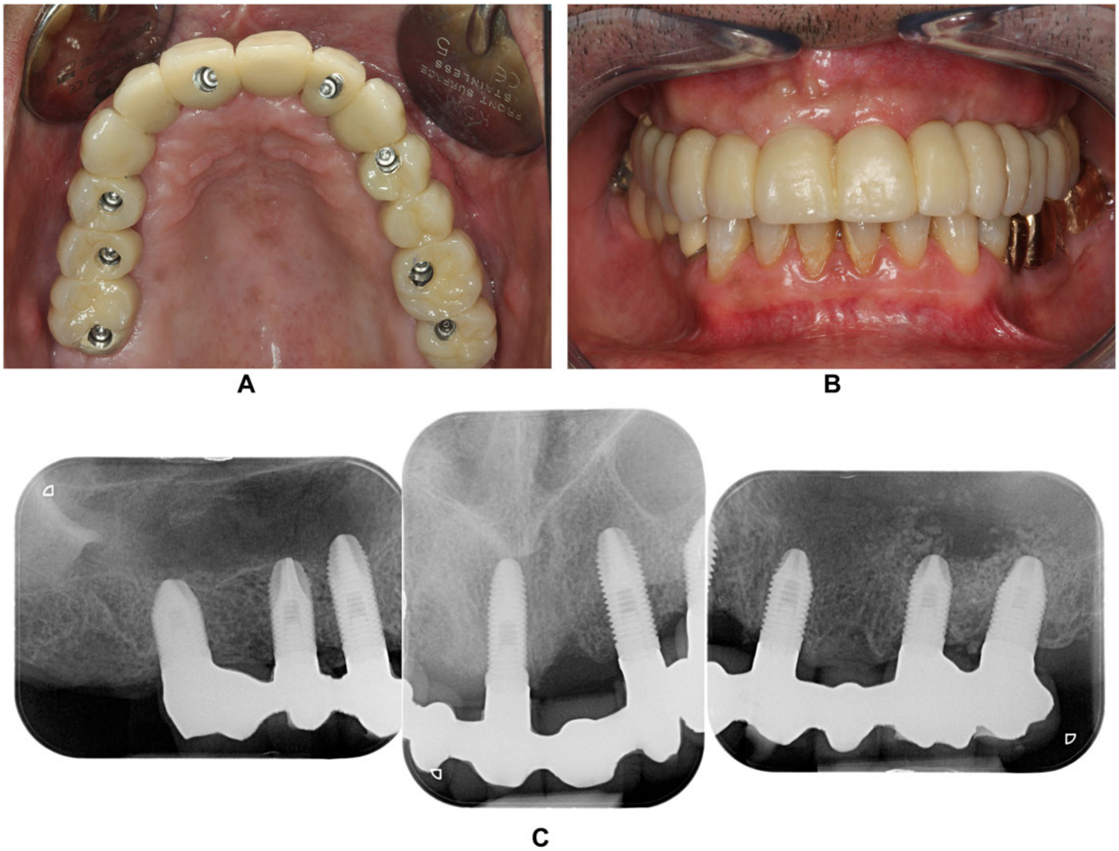


Figure 6 (A) Frontal view of the definitive maxillary fixed metal-ceramic prosthesis; (B) occlusal view of the definitive maxillary fixed metal-ceramic prosthesis; and (C) periapical radiographs of the completed definitive prosthesis.

Discussion

The literature has warranted immediate loading protocols. As long ago as 1997, Tarnow et al[3] described an immediate loading protocol for edentulous maxillae that aimed to stabilize intraosseous dental implants. The same author and several other investigators[3,7] have described the clinical factors to be considered when deciding whether to opt for immediate loading. Factors that allow immediate loading in the maxilla are: (1) primary stability of the implants; (2) adequate splinting of the implants; (3) interim prostheses that promote implant splinting and reduce the mechanical forces to which implants are subjected; and (4) prevention of restoration movement during the healing period.

Primary implant stability must be achieved for immediate loading. It is advisable for the implant insertion torque to be greater than 35 Ncm, with an implant stability quotient of over 60, as measured by resonance frequency (Osstell®, Gothenburg, Sweden).[8] This is only possible when the patient presents adequate bone quantity and quality. The implants (surface characteristics and dimensions) and clinical techniques should be selected to maximize and maintain bone-to-implant contact.[9]

In this report, the acetalic resin used as immediate loading prosthetic material was sufficiently resistant, as it offers a resistance of 123.5 ± 4.08 N (in response to thermocycling and cyclic loading), according to Arıkan et al.[10] This material is a semicrystalline polymer (75% to 85% crystalline) and has a number of additional advantages for applications of this kind, such as high abrasion resistance, a low friction coefficient, high thermal resistance, good electrical and dielectric properties, low water absorption, a lack of toxicity or allergenicity, and good esthetic effects.[10]

Intraoral photographic and video scanners share some of the advantages of photogrammetry. Scanners generate 3D images on the basis of a cloud of points that are able to reproduce surfaces. To join the points they use a so-called best-fit algorithm, which causes as many points as possible to coincide. Although practical evidence is limited, theoretically such successive joining of clouds of points could lead to the accumulation of error. For this reason, reliability decreases progressively with an increasing number of analyzed implants.[11,12] However, photogrammetry, in contrast to intraoral scanners, takes all measured data in each picture without matching needs, and generates director vectors of the exact positions of the implants in relation to each other. The information that makes it possible to calculate the positions of the implants is obtained without superimposing photos, which potentially ensures greater precision and a better prosthetic fit.

To digitize implants with intraoral scanners, it is still necessary to use the so-called scan bodies, which must have specific design, geometry, and reflection characteristics to obtain an accurate impression. Although they have been used in indirect scanning for years, there is practically no experience with their use in intraoral scanning. Commercial intraoral scan bodies for different implants are available, but no clinical studies other than clinical reports have been published. A recent study found conventional impression taking and white-light scanning of stone casts to yield a more accurate fit of an implant-supported prosthesis than scanning scan bodies intraorally.[13] In another study, a digitally coded healing abutment (Encode™; Biomet 3i, Palm Beach Gardens, FL) was proposed as an alternative solution to the direct and indirect implant scanning techniques.[2] With this system, an encoded abutment is screwed into the implant, an irreversible hydrocolloid impression is made, and the plaster print left by the abutment is directly scanned and digitally interpreted using a CAD/CAM system. To date, this technique has been tested in vivo for single implants and in vitro for up to six implants.[2] In summary, the technical features of the intraoral scanner system are undergoing rapid development; however, with the exception of experimental protocols,[14] intraoral scanning devices are currently not predictable in obtaining accurate impressions of more than three or four implants over the complete arch of the maxilla or mandible.[1]

Photogrammetry avoids the inconveniences of conventional impression techniques. There is no need for impression abutments, implant body analogs, trays, or impression materials. The PICcamera measures angles and distances between prosthetic attachments placed on the implants, allowing the patient total freedom of movement, and the presence of blood, saliva, or any other organic or inorganic residues does not affect measurement precision.[6] Avoiding the use of impression materials to register implant positions potentially reduces the possibility of error due to dimensional changes of the materials. In the opinion of the authors, the described technique also offers other advantages such as reduced chairside time, less economic costs over the long term, and greater patient comfort.

A limitation of this photogrammetric technology is the fact that it does not register the soft tissues. The PICfile only contains the information on position and angulation of the implants. This inconvenience is easily solved by scanning the patient cast, which provides the missing information. The two sets of data (PICfile and scanned cast) are aligned by best-fit, which allows virtual relation of the implants to the soft tissues. With implant positions determined by the stereo camera, and using an irreversible hydrocolloid impression of the soft tissues, the laboratory can produce multiple implant prosthetic structures using CAD/CAM, without the need for casting or milling procedures.[12]

Conclusions

Photogrammetry allows precise registry of the position and angulation of multiple implants in the three dimensions, converting all the clinically relevant information directly from the patient to a digital file, and eliminating the need for impression posts, implant analogs, trays, and impression materials. Further studies with control groups are needed to compare the accuracy of photogrammetry with the other available techniques for digitizing implant positions.

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