Digital Impressions for Fabrication of Definitive "All-on-Four" Restorations

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Purpose: *The aim of this study was to assess the accuracy of digital impressions for "all-on-four" implant rehabilitation.*

Materials and Methods: *Patients edentulous in one or both jaws were randomly selected for this study. Complete arch immediately loaded prostheses supported by 4 implants (2 axial and 2 tilted) were placed. Five hours after implant placement, screw-retained full-arch temporary prostheses were positioned. After 4 months, a digital scan body was used to finalize definitive prosthesis. Radiographic assessments were obtained immediately after surgery and at each follow-up visit. Bone level measurements were reported at 6 and 12 months, and bone loss between upright and tilted implants was compared.*

Results: *Fourteen definitive cast metal frameworks prosthesis were delivered to the patients. No implant dropout occurred. All prosthesis were screwed onto the dental implants, and x-ray examinations revealed a bar-implant connection accuracy. The implant survival rate was 100% for all positioned implants. No statistically significant differences (*$P > 0.05$*) in crestal bone loss between tilted and upright implants were detected.*

Conclusions: *Digital impression creates an accurate physical model significantly improving efficiencies for the dental team and streamlining the workflow. (Implant Dent 2015;24:125–129)*

Key Words: digital impression, all-on-four, tilted implants

The basis for prosthetic work in implant dentistry remains an intraoral impression that is subsequently poured in dental stone. This traditional workflow has proven itself in clinical practice, although impression materials are prone to dimensional changes because of on-going chemical reactions,[1] and stone will show expansion because of secondary reactions while setting.[2] As the impression procedure is at the origin of the workflow, potential errors introduced in this phase will reverberate in the rest of the workflow. The misfit of framework will generate stress on the implants, which may have a biological effect on the bone-implant interface.[3,4] Also prosthetic complications as screw loosening or fracture may be related to ill-fitting framework fit.[5]

Although none of the techniques has proven to be a gold standard, digital implant impressions constitute a major role in the development of the full digital workflow for fixed implant prosthetic restorations.[6]

With a digital impression system, the data from the intraoral scanner can be electronically transmitted to the manufacturer for the fabrication of a definitive prosthetic restoration.[7,8] Implants, however, will only show a range of motion of 3 to 5 μm in axial direction and 10 to 50 μm in lateral direction after osseointegration due to compression of the bone.[9] An intraoral scanner could overcome some of the errors associated with traditional impression taking[10] and cast production,[11] as digital output data can be fed directly into a digital workflow.

In the literature, there are clinical reports about digital impression technique in implant dentistry, but most of them reported to fabricate a customized anatomic abutment and zirconia restoration.[12–15] Consequently, the aim of this study was to assess the accuracy of digital impressions for "all-on-four" implant rehabilitation.

MATERIALS AND METHODS

This clinical study was performed in the Department of Dentistry, San Raffaele Hospital, Milan, Italy. From November 2011 to June 2012, 14 patients, 8 women and 6 men with a mean age of 56.3 years (range, 43–80 years) were randomly selected for this study. The following inclusion criteria were adopted: all patients were in good health, patients had to be edentulous (in 1 or

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both jaws) or had a few hopeless teeth, and severe atrophy of the mandible or maxilla in posterior regions. Exclusion criteria were the absence of any active infection or severe inflammation in the areas intended for implant placement, presence of chronic systemic disease, smoking more than 15 cigarettes, bruxism habits, and poor oral hygiene.

The diagnosis was made clinically and radiographically (preoperative panoramic radiograph and computer tomography scan) (Fig. 1). All patients gave their written informed consent for immediate implant loading and digital impression procedure.

Surgical Procedure

One hour before surgery, the patients received 2 g amoxicillin (Zimox; Pfizer Italia, Latina, Italy) and 1 g twice a day for a week after surgical procedure. Surgery was performed under local anesthesia (optocain 20 mg/mL with adrenalin 1:80.000; Astra, Milan, Italy).

In edentulous mandibule, incisions were made on top of the alveolar crest, from the first molar on one side to the first molar on the contralateral side with bilateral releasing incisions. Subperiosteal dissection on the lingual and vestibular surfaces was carried out, and mental foramina were sited. The most posterior implants were placed close to the anterior wall of the mental loop and were tilted distally about 30 to 35 degrees relative to the occlusal plane. The posterior implants, which were 4.5 mm in diameter and 15 or 13 mm in length, typically emerged at the second premolar position. Anterior implants were either 4.5 or 3.8 mm in diameter and 13 mm in length (Winsix; BioSAFin, Ancona, Italy) (Table 1). After placement of the posterior implants bilaterally, additional implants were placed in the anterior space (Fig. 1, B). When necessary, bone shaping was performed with a round bur to level the bone crest, and to achieve crestal positioning in the posterior arches, bone recontouring was performed distal to the angled implants.

In edentulous maxillary patients, incisions were made on the alveolar crest from the first molar on one side to the first molar on the contralateral side with bilateral releasing incisions. Subperiosteal dissection was carried out. The most posterior implant was placed close to and parallel with the anterior sinus wall. Thus, this implant was tilted distally approximately 30 to 35 degrees. The lower corner of the implant neck was positioned at bone level.

Then, the placement of implants in the anterior part of the maxilla was performed, and the implant neck was positioned at bone level. The posterior implants were 4.5 mm in diameter and 15 or 13 mm in length, and the anterior implants were either 4.5 or 3.8 mm in diameter and 13 mm in length (Winsix; BioSAFin) (Table 1).

The implant in immediate function had a final insertion torque of at least 40 N·cm. Underpreparation was performed in soft bone to obtain high primary stability. In 3 patients, anterior implants were immediately positioned in postextraction sockets. In fresh sockets, granulation tissue was removed. Angulated abutments (Extreme Abutment, EA Winsix; BiosSAFin) for anterior implants were set at 17 degrees and those for posterior implants at 30 degrees to compensate for the lack of parallelism between implants. These abutment angulations were chosen so that the prosthetic screw access holes were in an occlusal or lingual location. Flap adaptation and suturing were performed in the usual manner with 4-0 nonresorbable suture.

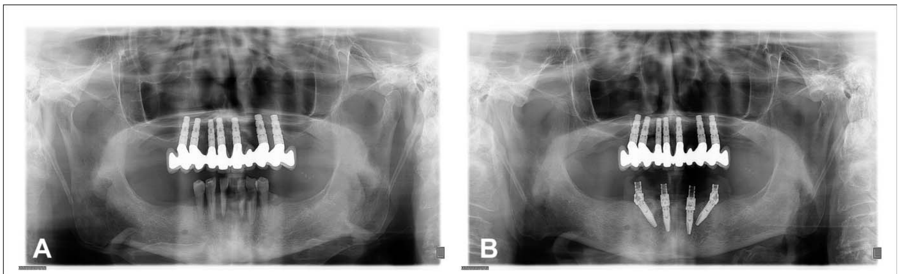

Fig. 1. Maxillary edentulous ridge (**A**); panoramic radiograph after implant placement (**B**).

Prosthetic Protocol

The vertical dimension was established and corrected using facial reference marks recorded before surgery. Immediately after implant placement, traditional impression materials (Permadyne; ESPE, Seefeld, Germany) were used to take the impressions, the implant analogs were attached to the impression copings, and a stone model was created with the analogs representing the positioning of the implant in the model. Five hours after implant placement, screw-retained full-arch temporary prosthesis by only all-acrylic resin frameworks were positioned. After 4 months, a digital scan body was used to finalize definitive prosthesis (Fig. 2). The scan body replaced the traditional impression coping and allowed the implant fixture to be captured with an intraoral digital scanning device.

The intraoral scanner used in the study was Lava COS (3M Espe, St. Paul, MN) with software version 2.1. The Lava COS uses active wavefront sampling[15] to obtain a 3D model of the dentition. The Lava COS is a 3D video system that captures 20 3D frames per second, which are registered real time. After the scanning procedure, a postprocessing cycle is necessary to recalculate the registration and compensate for potential errors, resulting in a high-resolution model that is uploaded to 3M. Before scanning with the Lava COS, teeth need to be dusted with Lava Powder (3M Espe), a titanium oxide powder. The latter has to do with the technology the scanner uses.

Scannable impression copings were secure to the implants with the corresponding screwdriver. The dust particles on implant abutments were used for registration of the 3D patches obtained during scanning. High-accuracy scanning protocol for scanning consists of a calibration with the aforementioned calibration block followed by a slow zigzag scanning of the dentition. After the scan, the calibration with the calibration block is performed for a second time. The calibration measurements are used to calculate and compensate for errors that have occurred during scanning.

Table 1. Implant Diameters and Lengths for Maxilla and Mandible (Maxilla, n = Implant = 24; Mandible, n = Implant = 32)

Maxilla (n = 24)	Diameter (mm)	Length 13 (mm)	Length 15 (mm)
Upright (n = 12)	4.5	8	0
	3.8	4	0
Tilted (n = 12)	4.5	4	4
	3.8	2	2
Mandible (n = 32)	**Diameter (mm)**	**Length 13 (mm)**	**Length 15 (mm)**
Upright (n = 16)	4.5	6	0
	3.8	10	0
Tilted (n = 16)	4.5	2	4
	3.8	8	2

Then the opposing arch was sprayed and scanned in similar fashion, followed by a scan of the buccal aspect of the patient's dentition in maximum intercuspation.

All the scans of the scanner were uploaded to the laboratory and returned after postprocessing. The virtual images were evaluated for accuracy of detail and correct occlusal relationship. Once the virtual model is created with the dental implant in position, virtual digital creation of framework and restorations can be designed through the computer-aided design (CAD) software.

The monolithic model, which includes a removable die of a replica of the CAD/computer-aided manufacturing prosthetic manufacture, was used by the laboratory to fabricate the restoration. As the definitive frameworks are being milled titanium (Fig. 2), the rapid prototype model is simultaneously sent to the dental laboratory for use in fabricating the definitive restoration. Fourteen definitive prostheses were made by acrylic resin masticatory surfaces and metal frameworks for increased strength and rigidity (Fig. 1). All prostheses were positioned and screwed onto dental implants. The Sheffield 1-screw test[16] was carried out to check the precision of bar.

The marginal fit of frameworks screwed onto the implants was checked by radiographic evaluation (Fig. 2). Articulating paper (Bausch Articulating Paper, Nashua, NH) was used to check the occlusion and adjust it, if necessary. Static occlusion consisted of central contacts established on all masticatory units. Dynamic occlusion included canine/premolar guidance, regardless of the opposite arch settings. Screw access holes were covered with provisional resin (Fermit; Ivoclar Vivadent, Bolzano, Italy). All patients followed a soft diet (avoiding bread and meat) for 2 months.

Follow-up

Follow-up visits were performed by a dental hygienist at 3, 6, and 12 months after implant insertion. Success criteria for implant survival were the presence of implant stability, the absence of radiolucent zone around the implants, no mucosal suppuration, and no pain.

Restoration success was defined as the absence of fractures of the acrylic resin superstructure, even if one or more implants supporting the restoration have been removed. Implant survival was defined as the absence of implant mobility, swelling, or pain in the surgical site at the time of examination.

Implant success was defined as implant survival with marginal bone loss of less than 1.5 mm after 1 year of loading and no more than 0.2 mm of

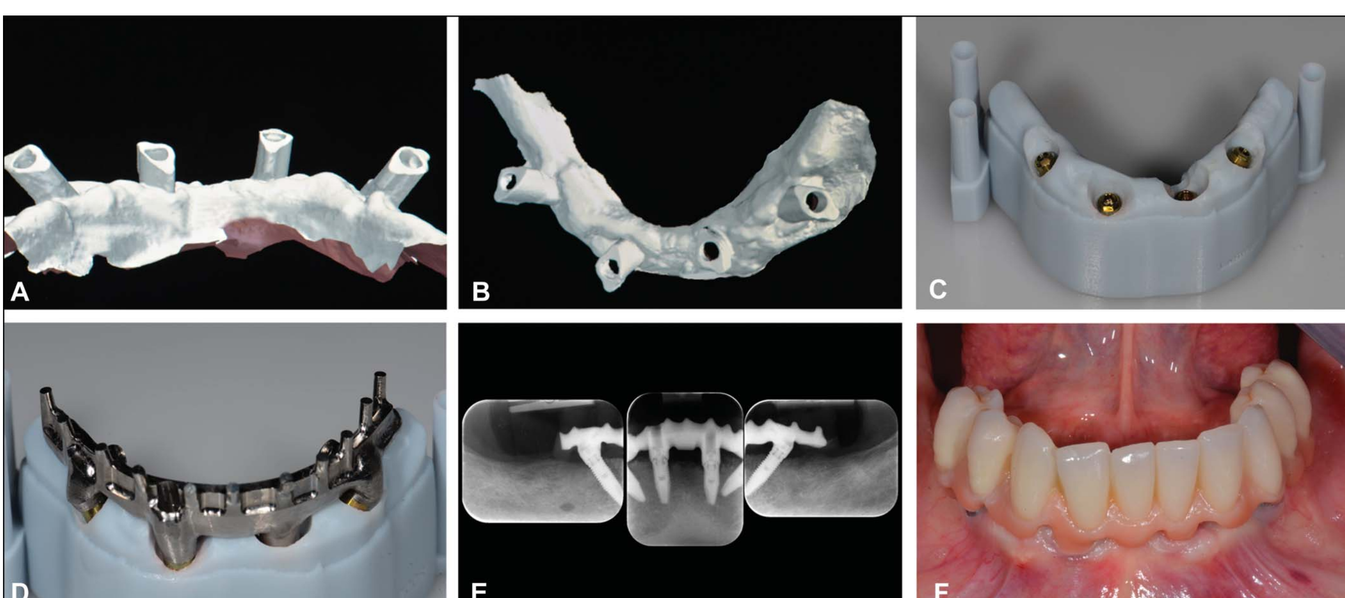

Fig. 2. Scan bodies fit into the dental implant fixture. Image of virtual framework (**A** and **B**); occlusal view of the stereolithographic model (**C**); framework screwed on the stereolithographic model (**D**); radiographic evaluation of the marginal fit of frameworks screwed onto the implants (**E**); and final restoration (**F**).

Table 2. Crestal Bone Loss Values (Mean ± SD) for Maxillary and Mandibular Tilted and Upright Implants (Maxilla n = Implant = 24; Mandible n = Implant = 32)

	Upright		Tilted	
Bone Loss	Maxilla (n = 24)	Mandible (n = 40)	Maxilla (n = 24)	Mandible (n = 40)
6 mo (mm)	1.05 ± 0.29	0.88 ± 0.46	1.04 ± 0.39	1.06 ± 0.56
12 mo (mm)	1.07 ± 0.99	1.02 ± 0.72	1.07 ± 0.81	1.10 ± 0.89

loss between each follow-up appointment after the first year of function.

Radiographic Examination

Radiographic assessments were made using panoramic radiographs obtained immediately after surgery and at each follow-up visit (Fig. 1). The correct assessment of marginal fit of frameworks screwed onto the implants was checked by radiographic evaluation (Fig. 2). Bone level measurements were performed on the mesial and distal aspect of each implant, using the implant-abutment junction as a reference point. To adjust for dimensional distortion and enlargement on the radiographs, the actual sizes of the implants were compared with the measured implant dimensions on the radiograph.[4,17] A radiologist twice measured the changes in marginal bone height over time: he marked the reference points and measured lines on the screen interactively; the numeric value of measurements was reported by software (CDR; Schick Technologies, Long Island City, NY). The implant height (a known dimension) was used for calibration. The radiographic measurements were compared with the values obtained immediately after surgery.

Statistical Analysis

A dedicated software (SPSS 11.5.0; SPSS, Chicago, IL) was used for all statistical analyses. Bone level measurements were reported as mean ± SDs at 6 and 12 months. Bone loss around the upright and tilted implants was compared by means of the Student *t* test at a significance level of $P = 0.05$.

RESULTS

Fourteen patients were treated with immediately temporary loaded 14 complete-arch prostheses (6 maxillary and 8 mandibular region) supported by 4 implants (in total 56 implants). After 4 months, 14 definitive cast metal framework prostheses were delivered to the patients. No implant dropout occurred. All prostheses were screwed onto the dental implants, and x-ray examinations revealed a bar-implant connection accuracy (Fig. 2). The implant survival rate was 100% for all positioned implants. None of the 14 fixed prostheses were lost during the observation period, representing a prosthetic survival rate of 100%. No occlusal screw loosening was observed.

At the 12-month evaluation, periimplant crestal bone loss averaged 1.07 ± 0.99 mm for upright maxillary implants and 1.07 ± 0.81 mm for tilted maxillary implants (Table 2). In the mandible, a mean periimplant crestal bone loss of 1.02 ± 0.72 mm for upright implants and 1.10 ± 0.89 mm for tilted implants were found (Table 2). No statistically significant differences ($P > 0.05$) in crestal bone loss between tilted and upright implants was detected at 6- and 12-month follow-up evaluation in either jaws.

DISCUSSION

All final prosthesis screwed onto the dental implants revealed a very accurate bar-implant connection. The scan bodies fit precisely into the dental implant fixture in the mouth to allow for accurate capture the position of the implant fixture, just as a traditional implant impression coping does.[17] The scan body has a precise geometrical shape on the surface to allow for optical capture of the fixture. Once the scan body image is captured and registered, the CAD software through alignment algorithms can accurately position the implant into the virtual model. Additionally, new developments for digital impression processing allow for the digital creation of a physical dental model with a removable repositionable implant analog so the laboratory technician can use the digital model in a traditional fashion for restoration fabrication.

As reported in this clinical study, Lava COS had low variation in its measurements with a few angular errors and positive values.[15] In a vitro study, Ender and Mehl[18] have compared the Lava COS to the cast of an Impregum impression. In their study, the accuracy was defined by the terms "trueness": the deviation of the model about the true size of the object and "precision": the fluctuation of the different measurements. The trueness of the Lava COS was better than an Impregum impression.

The video system, as LAVA COS with a frame rate of 20 images per second, may lead to an accurate surface registration. The Lava COS uses powder particles as markers as an extra tool for the computer to join the different pieces of the 3D model. As registration errors, however minute, will always occur in registration procedures,[19] one expects an additive effect of these errors over the length of the arch. When comparing intraoral scanners in full-arch impression procedures, it would be interesting to involve the influence of the length of the span to assess the expected additive effect of the registration errors that may occur.

In the study of Ender and Mehl,[18] an increase in the deviations between the models in certain areas were noted, but these can be explained by the registration procedure. The algorithm most likely tried to register the surfaces in such a way that the overall mean deviation between the surfaces is the smallest and this may conceal an increase in deviations between the surfaces and makes interpretation of deviations difficult. A best fit algorithm on basis only of the area where the scanning was started may have shown a possible increase in deviations in their study.

Once the scan body is scanned and the structured data are captured, software is then used to process each data point to create a geometrical virtual 3-dimensional model. The CAD software applications have created the virtual geometric 3-dimensional model, computer-aided manufacturing techniques use various printing, and milling machines to create an exact replica of the virtual model in a physical form.

Conclusions

This study advocates the use of the intraoral scanner, which virtually creates an accurate physical model that significantly improves efficiencies for the dental team and streamlines the workflow. This improved workflow should provide benefits to the dentist, the laboratory technician, and to the patient. Additional clinical studies are necessary to assess the efficiency of digital impression procedure.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

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