Conventional Versus Digital Impressions for "All-on-Four" Restorations

Enrico Gherlone, MD, DMD, PhD[1]/Paolo Capparé, MD, MS[2]/Raffale Vinci, MD, DMD, MS[3]/
Francesco Ferrini, DDS[4]/Giorgio Gastaldi, MD, DMD[5]/Roberto Crespi, MD, MS[6]

Purpose: *This study aimed to evaluate the most accurate impression technique for "All on Four" restoration, comparing conventional (CIG) and digital impressions (DIG).* ***Materials and Methods:*** *Patients randomly selected for this study were required to be edentulous in at least one arch, presenting with severe posterior mandibular or maxillary atrophy. All patients underwent full-arch immediate-load rehabilitations, which were fixed to a total of four implants (two axial and two tilted). Following implant placement, patients were stratified into two groups. Conventional pick-up was carried out in the control group, and digital impressions were performed in the test group. Following prosthetic rehabilitation, patients underwent intraoral digital radiographs to check for the presence of voids at the bar–implant connection and to evaluate accuracy. Three-, 6-, and 12-month follow-up examinations were performed.* ***Results:*** *A total of 25 patients received immediately loaded "All-on-Four" prostheses (17 maxillary, 13 mandibular) supported by four implants (total 120 implants), of which five received both maxillary and mandibular prosthetic rehabilitation (three patients in CIG, two patients in DIG). No implant dropouts occurred, showing a survival rate of 100%. The digital impression procedure required significantly less time than the conventional procedure ($P < .001$).* ***Conclusion:*** *Results demonstrate that it is possible to develop computer-aided design/computer-assisted manufacturing (CAD/CAM) cobalt-chromium full-arch rehabilitations with satisfactory accuracy using digital impression techniques.* Int J Oral Maxillofac Implants 2016;31:324–330. doi: 10.11607/jomi.3900

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Dental stone intraoral impressions are still the preferred method in implant dentistry prostheses and have long been successful in clinical practice, despite the fact that dental stone is likely to undergo size variations resulting from ongoing chemical reactions[1] and because of secondary reactions while setting.[2] Because this impression procedure is the foundation of prosthetics, errors at this stage will affect the rest of the process. Any misfit of a framework may stress the implants, which could biologically affect the bone–implant interface.[3,4] Because of compression to the bone,[5] the range of motion of osseointegrated implants is 3 to 5 μm axially and 10 to 50 μm laterally. Incorrect framework fit may induce complications like screw loosening or fracture.[6]

No technique has proven ideal, but digital impressions may be considered pivotal in the elaboration of a fully digital approach for fixed implant prosthetic restorations.[7] An intraoral scanner[8,9] can reduce the margin of error caused by traditional impression taking[10] and cast production[11] methods because its digital models are instantly sent for the manufacturing of definitive prosthetic restorations. Many published studies have examined digital impression techniques in implant dentistry, but these have concerned a single customized anatomical abutment and zirconia restoration.[12–15]

The objective of this study was to compare conventional and digital impression accuracy in "All-on-Four" implant rehabilitation.

[1]Full Professor and Chairman, Department of Dentistry, Vita Salute University, IRCCS San Raffaele Hospital, Milan, Italy.
[2]Researcher, Department of Dentistry, Vita Salute University, IRCCS San Raffaele Hospital, Milan, Italy.
[3]Adjunct Professor, Oral Surgery Unit, Department of Dentistry, Vita Salute University, IRCCS San Raffaele Hospital, Milan, Italy.
[4]Adjunct Professor, Department of Dentistry, Vita Salute University, IRCCS San Raffaele Hospital, Milan, Italy.
[5]Associate Professor, Department of Dentistry, Vita Salute University, IRCCS San Raffaele Hospital, Milan, Italy.
[6]Adjunct Professor, Department of Dentistry, Vita Salute University, IRCCS San Raffaele Hospital, Milan, Italy.

Correspondence to: Dr Roberto Crespi, Department of Dentistry, Vita Salute University, San Raffaele Hospital, Via Olgettina N. 48, 20123 Milano, Italy.
Email: robcresp@libero.it

MATERIALS AND METHODS

From May 2012 to March 2013, a total of 25 patients—15 women and 10 men—were randomly assigned to the clinical study, carried out by the Department of Dentistry at San Raffaele Hospital, Milan, Italy. The mean age of these patients was 57.2 years, with a range between 43 and 70 years. All patients provided written informed consent for immediate implant loading and digital impression.

The following inclusion criteria were applied: good health, edentulous (in one or both arches) or with a few "hopeless" teeth. Patients were excluded from the study if they had active infection or severe inflammation in implant sites, suffering from any chronic systemic disease, smokers of >15 daily cigarettes, parafunctional habits, and poor cleanliness. After implant placement, the patients were stratified into control and test groups, from which conventional pick-up and digital impressions were taken, respectively. Clinical and radiographic diagnoses were made (preoperative panoramic radiograph and computed tomography [CT] scan; Fig 1).

Surgical Procedure

Patients were given 2 g amoxicillin (Zimox, Pfizer Italia) 1 hour before the procedure and 1 g two times daily for a period of 7 days following surgery. All patients underwent surgery under local anesthesia (optocain 20 mg/mL with adrenalin 1:80,000 [Astra]).

For patients with edentulous mandibulae, bilateral releasing incisions were made above the alveolar crest, starting from the first molar on one side, to the same point on the other.

A subperiosteal dissection on the lingual and vestibular surfaces was performed, and mental foramina were identified. The most posterior implants were positioned near the anterior wall of the mental loop and were distally tilted by approximately 30 to 35 degrees relative to the occlusal plane. The posterior implants, measuring 4.3 mm wide and 15.5 or 12 mm long, were placed at the second premolar position. Anterior implants were either 4.3 or 3.75 mm wide and 12 mm long (IDI Evolution; Table 1).

Additional implants were positioned in the anterior space after bilateral positioning of posterior implants.

As required, a round bur was used to shape the bone, particularly for leveling off the bone crest and for posterial arch crest positioning. Bone recontouring was completed distally to the tilted implants.

In edentulous maxillary patients, bilateral releasing incisions were made on the alveolar crest from the first molar on one side, to the same point on the contralateral side. A subperiosteal dissection was completed. The most posterior implant was placed near and parallel to the anterior sinus wall so that the implant could be tilted distally approximately 30 to 35 degrees. The lower corner of the implant neck was positioned at bone level.

Following this phase of the procedure, implants were placed in the anterior part of the maxilla, with the neck placed at bone level. The posterior implants measured 4.3 mm wide and 15.5 or 12 mm long, and the anterior implants were either 4.3 or 3.75 mm wide and 12 mm long (IDI Evolution; Table 1).

The implants identified for immediate function had a final insertion torque of at least 40 Ncm. High primary stability was obtained through the use of underpreparation in soft bone.

In three patients, anterior implants were immediately placed into postextraction sockets. In fresh sockets, granulation tissue was excised.

To compensate for reduced parallelism between implants, angled abutments (IDI Evolution) were positioned at 17 degrees for anterior implants and at 30 degrees for posterior implants. These angles were selected so as to guide the prosthetic screw access holes into an occlusal or lingual position. 4-0 nonresorbable sutures were required for flap adaptation and suturing.

Prosthetic Protocol

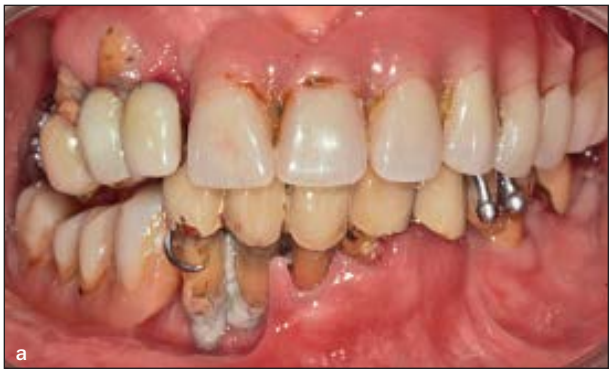
Facial reference marks recorded before surgery allowed the authors to establish and correct the vertical dimension. From the control group (conventional impression group, CIG), 15 "All-on-Four" prosthetic rehabilitations were made using traditional impression approaches (Permadyne, ESPE). Impression transfers were inserted into the fixture. After obtaining the impression, it was necessary to attach the implant analogs to the copings and then create a stone model to reproduce the exact position of the implant in the cast.

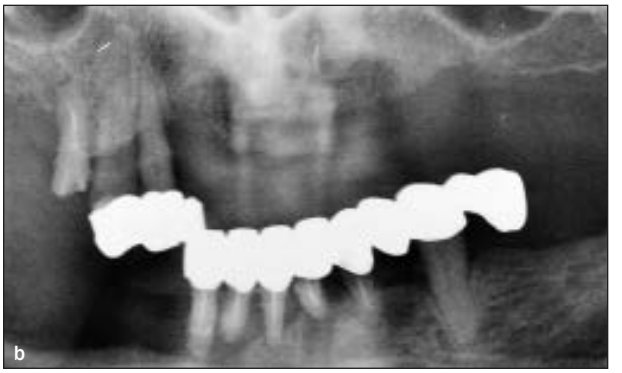
In the test group (digital impression group, DIG), a digital scanner was used to position 15 prostheses. The scan body replaces the traditional impression coping and allows an intraoral digital scanner to accurately capture the implant fixture (Fig 2).

In all cases, prostheses were delivered and placed within 24 hours from implant placement.

The intraoral scanner used in the study was a TRIOS (3Shape).

The TRIOS system works following the principles of confocal microscopy, including rapid scanning time. An illumination pattern provided by the light source causes light oscillation on the object. Pattern focus plane variation is achieved over various focus plane positions, as well as preserving the fixed space between the scanner and the object. Even when time-varying patterns are applied, single subscans can be achieved through the collection of two-dimensional (2D) images from different focal plane positions and at different moments within the pattern. At a single





Figs 1a and 1b Preoperative clinical and radiographic views of one patient.

Table 1 Dimensions of Implants Placed in the Study

	Implant diameter	Implant length	
		12 mm	15.5 mm
Maxillary implants (n = 68)			
Upright	4.3 mm	12	0
Upright	3.75 mm	22	0
Tilted	4.3 mm	2	10
Tilted	3.75 mm	4	18
Mandibular implants (n = 52)			
Upright	4.3 mm	6	0
Upright	3.75 mm	20	0
Tilted	4.3 mm	2	4
Tilted	3.75 mm	4	16

pixel position, the focal plane coincides with the scanning surface, allowing the pattern to be projected in focus and at high contrast onto the surface point, thereby generating wide variation in the pixel value over time. It is therefore possible to select the focusing plane settings accordingly so that each pixel will be in focus. The contrast information can then be converted according to the focal plane position into three-dimensional (3D) surface information on an individual-pixel basis. The 3D surface structure of the probed object is determined when the plane relating to the extremum in the correlation measure for each sensor in the camera's array is found. The variation created in the focal plane that is obtained by not moving the scanner relative to the object is a fundamental characteristic of the system. The focal plane should be periodically adjusted at a prespecified frequency, whereas the means of pattern generation, the camera, the optical system, and the object being scanned are fixed in relation to each other. Furthermore, as the time to 3D surface acquisition is short, there should be sufficient time to decrease any impact of movement from the probe to the scan abutments. This system has the property of telecentricity in the space of the object being scanned, and it is possible to move the focal plane and maintain telecentricity and magnification. Scannable impression copings (Fig 2) were screwed onto the implants.

A similar technique was applied to the opposing arch, following which the patient's dentition in maximum intercuspation was scanned from a buccal point of view, sent to the lab, and returned after processing (Figs 2b and 2c). The images were assessed for detail accuracy and correct occlusal relationships.

Computer-aided design (CAD) software can design a digital framework and restoration according to the model of the positioned implant (Figs 2d and 2e).

The laboratory uses this monolithic model, which comprises a removable die of a replica of the manufactured computer-aided design/computer-assisted manufacturing (CAD/CAM) prosthetic, to manufacture the restoration. As the final frameworks are milled in titanium (Figs 2f to 2h), the rapid prototype can be sent to the lab at the same time to be used for manufacturing the definitive restoration. In both groups, 30 definitive cobalt–chromium alloy prostheses were designed with acrylic resin masticatory surfaces and metal frameworks to ensure stronger and more rigid prostheses (Fig 1).

All prostheses were positioned and screwed to dental implants, and a Sheffield test was completed to verify the framework precision[16] (Figs 2i and 2j).

Outcomes of impression techniques were evaluated using the following clinical acceptance criteria: *(1)* accurate imprinting of implant areas; *(2)* no voids on the occlusal, buccal, and lingual sides; and *(3)* proper reproduction from the vestibule up to the mucogingival junction.[17] Impressions not meeting the criteria underwent retakes for conventional impressions or rescans/further scans.

Total treatment time and retakes/rescans required to meet acceptance criteria were evaluated to prove the efficacy of the two impression techniques. Treatment time (minutes/seconds) was represented by the

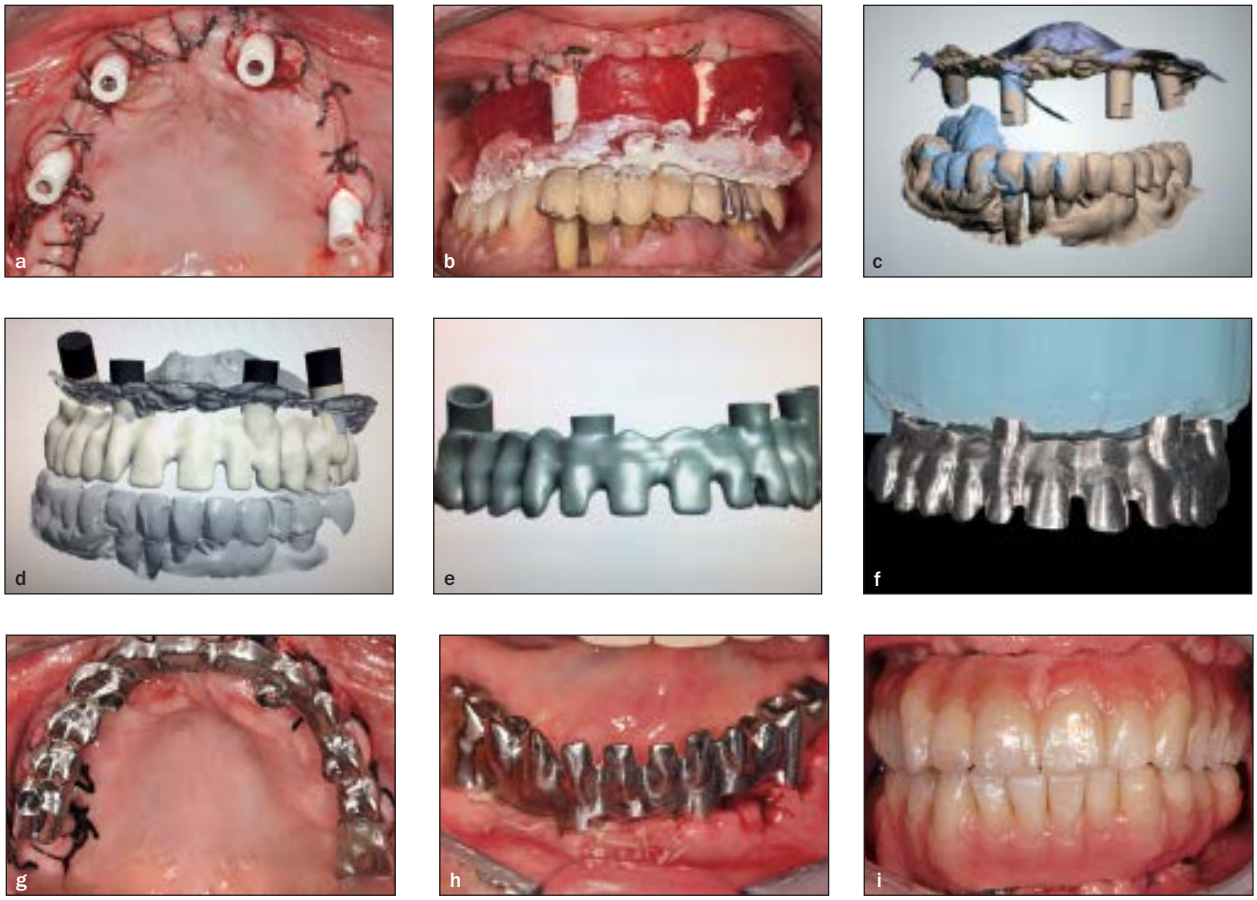


Fig 2a Scan bodies fit into the dental implant.

Fig 2b Registration of dentition in maximum intercuspation.

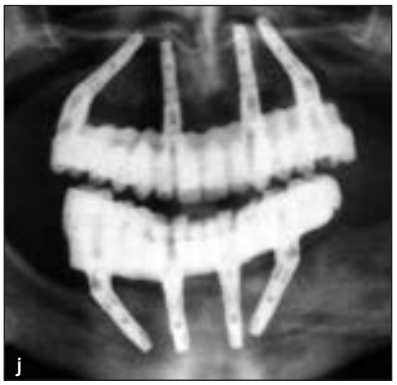
Figs 2c to 2e Images of virtual framework.

Fig 2f Framework screwed on the stereolithographic model.

Figs 2g and 2h Framework screwed on dental implants in both arches.

Fig 2i Definitive restorations.

Fig 2j Radiographic view.



time required to obtain an acceptable impression, in accordance with criteria (procedure time; Table 2). When necessary, impression retakes (conventional impressions) and rescans of missing areas (digital impressions) were registered as extra working time and additional events.

Articulating paper (Bausch Articulating Paper) was used to establish the presence of static occlusion, central contacts made on all masticatory units, or dynamic occlusion, including canine or premolar guidance, irrespective of the opposing arch settings. Occlusion was adjusted where necessary. Provisional resin (Fermit, Ivoclar Vivadent, Naturno) was used to fill in any screw access holes. Following this procedure, patients were required to follow a soft diet, consisting of no bread or meat, for a period of 2 months.

Follow-up

Patients were required to undergo dental hygiene follow-up at 3, 6, and 12 months post–implant placement. Successful implant survival was represented by the stability of implants and when no pain, mucosal suppuration, or radiolucent zones surrounding the implants were observed at follow-up.

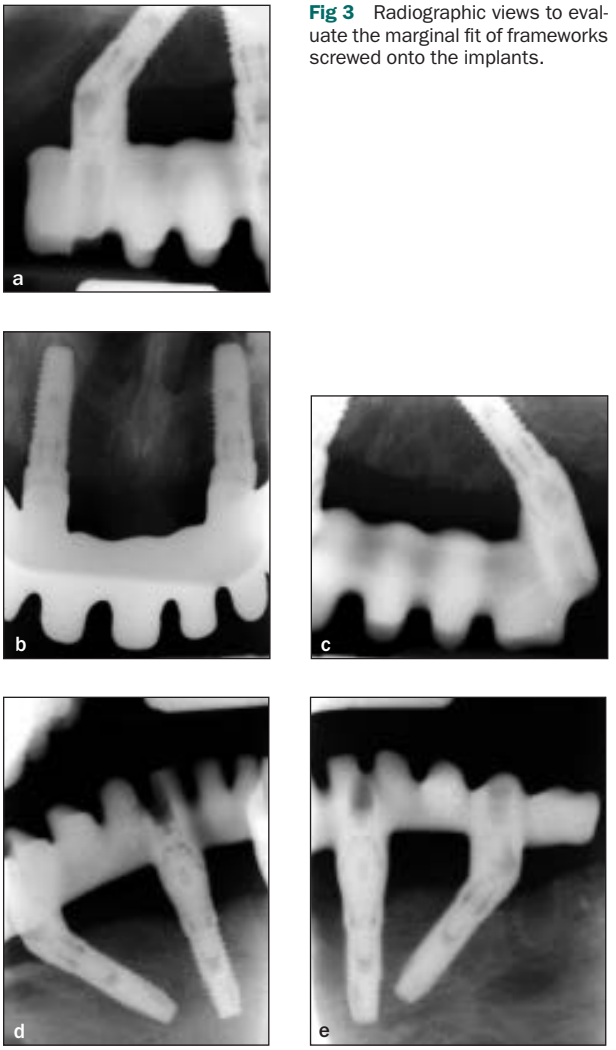


Fig 3 Radiographic views to evaluate the marginal fit of frameworks screwed onto the implants.

Successful restorations were defined if no acrylic resin superstructure fractures were observed, irrespective of the removal of one or more implant-supporting restorations.

Implant survival was defined by immobile implants and if the patient suffered no swelling or pain in the surgical area during follow-up.

Implant success was represented by implant survival plus marginal bone loss under 1.5 mm within 12 months after loading and the loss of 0.2 mm or less of bone between subsequent follow-up appointments.[18]

Radiography Examinations

Panoramic radiographs were taken straight after the surgical procedure and during each follow-up appointment (Fig 1). The main acceptance criteria adopted to assess the impression outcomes was the absence of voids at the bar–implant connection (Fig 3).

Intraoral digital radiographic exams (Schick CDR, Schick Technologies; Fig 3) were employed immediately after placement to verify the marginal fit precision of 30 definitive prosthetic frameworks fixed onto the implants in the two groups.

Furthermore, bone level was measured both mesially and distally for every implant, using the implant-abutment junction as a reference. The actual implant sizes and the implant dimensions shown on the radiography scan[4] were compared to adjust for size distortion and increases. The presence or voids at the bar-implant connection and any variation on marginal bone height over time were measured by a radiologist: CDR software (Schick Technologies) allows reference points and measured lines to be marked directly onto the touch screen, which are then automatically converted into numerical values of measurements.

The height of the implant (a known dimension) was utilized for calibration. Calculations were made as to the mesial, distal, and mean bone loss in the maxilla and mandible. Results are reported.

Statistical Analysis

The SPSS software (version 11.5.0; SPSS) was employed for the statistical analyses that were carried out. Bone level measurements are reported as means ± standard deviations at 6 and 12 months. The time needed for digital and conventional procedures was measured in seconds and is reported as means ± standard deviations. A comparison was made between bone loss around the upright and tilted implants within groups and between groups, using the Student *t* test, showing statistical significance at $P = .05$. To compare CIG and DIG in terms of treatment time and number of retakes/rescans, the Wilcoxon signed-rank test was used. *P* values at $< .05$ were considered statistically significant.

RESULTS

A total of 25 patients were treated with immediately loaded "All on Four" prostheses (17 maxillary, 13 mandibular region) supported by four implants (a total of 120 implants), and five patients underwent both maxilla and mandibular prosthetic rehabilitations (three in CIG, two in DIG).

In total, 30 definitive cobalt–chromium alloy prostheses were produced, using acrylic resin for the masticatory surfaces and metal frameworks to ensure stronger and more rigid prostheses.

No dental implant dropout was observed. The prostheses were all screwed onto dental implants, and to evaluate bar–implant connection accuracy, intraoral digital radiographs were performed to check for the presence of voids (Fig 2). Implant survival and prosthetic survival rates were observed at 100%, as 0% of the 30 fixed prostheses were lost upon observation.

Table 2 Analyzed Treatment Time Points

	Conventional	Digital
Procedure time	Placement/ removal of implant impression copings	Placement/ removal of scan body
	Assembly of impression coping and implant analog into the impression	Scan of scan body (maxilla and/or mandible)
	Implant impression taking (maxilla and/ or mandible)	Bite registration
Additional time	Retakes	Rescans

Table 4 Mean Crestal Bone Loss (in mm, ± SDs) for Tilted and Upright Implants of Both Groups

	Upright implants (n = 60)		Tilted implants (n = 60)	
Time	Conventional	Digital	Conventional	Digital
6 mo	1.11 ± 0.45	0.98 ± 0.57	1.01 ± 0.10	1.07 ± 0.76
12 mo	1.08 ± 0.77	1.13 ± 0.66	1.09 ± 0.32	1.06 ± 0.91

Table 3 Time Needed for Conventional and Digital Impression Procedures and Retakes/Rescans

Parameter	Conventional	Digital	*P* value
Procedure time (min:s)	18:23 ± 5:38	7:57 ± 3:08	< .001
Additional time (min:s)	5:49 ± 1:24	01:02 ± 0:48	< .001
No. of retakes/rescans	3	9	–

In the control group, one bar showed voids at the bar-implant connection, and implant impressions were immediately retaken. In the test group, all prostheses were fixed to the dental implants, and no void at the bar–implant connection was observed (Fig 3).

The analysis of procedure time revealed that the digital impression procedure took less time than the conventional procedure (Table 3), and the difference was statistically significant ($P < .001$). Digital impressions needed more rescans than conventional impressions needed retakes; however, the time for a rescan was far less than that for a retake (Table 3).

At the 12-month evaluation, in CIG, the peri-implant crestal bone loss showed an average of 1.08 ± 0.77 mm for upright implants and 1.09 ± 0.32 mm for tilted implants (Table 4). In DIG, a mean peri-implant crestal bone loss of 1.13 ± 0.66 mm for upright implants and 1.06 ± 0.91 mm for tilted implants was observed (Table 4). No statistically significant difference ($P > .05$) in crestal bone loss between tilted and upright implants was detected at the 6- or 12-month follow-up in either arch. Likewise, no statistically significant difference was found between CIG and DIG.

DISCUSSION

All definitive prostheses were fixed to the dental implants in "All on Four" rehabilitations, and all showed very accurate bar-implant connections from a radiographic point of view. Clinically and radiographically, there was no difference between the two groups of patients. However, this study showed greater efficacy when using digital impressions rather than conventional impressions, not only because the time undertaken for impression techniques was reduced, but also because of patient perception due to improved acceptance, reduced distortion of impression materials, and 3D previsualization.

Additionally, digital impressions completed the workflow by combining the use of intraoral scanning and the well-established CAD/CAM systems that are presently employed in implant dentistry. Thanks to its geometrical shape, scan bodies perfectly match the dental implant fixture in the mouth from a clinical point of view, which enables the implant fixture position to be captured accurately, similar to traditional impression coping techniques. After the image has been captured, CAD software employs alignment algorithms to recreate a virtual impression of the implant placement.

Additionally, because of leading edge developments in digital processing that facilitate the digital reproduction of a physical dental model with removable, repositionable implant analogs, the laboratory technician is able to readjust the digital model to comply with traditional techniques.

Lava COS, in a TRIOS clinical study, presented low measurement variations, with few angular faults and positive values.[15] In their in vitro study, Ender and Mehl[19] made a comparison between Lava COS and an Impregum impression case. Accuracy was represented by two different terms: "trueness" and "precision". The former refers to the discrepancy between the model and the actual object size, whereas the latter refers to the fluctuation in the various measurements. It was observed that the Lava COS was able to produce improved trueness compared with the Impregum impression.

A recent clinical study[15] analyzed the marginal fit of 20 zirconia crowns from digital intraoral impressions with active wavefront sampling and reported a 49-mm median marginal gap, whereas the control crowns created according to conventional impressions followed by the same CAD/CAM technology showed a median value of 71 mm.

Gherlone et al[20] conducted a 3-year retrospective study to evaluate the clinical performance of glass-ceramic/zirconia crowns fabricated using intraoral digital impressions. They observed that this approach enabled them to produce impressions with such a high level of accuracy that it could substitute for conventional impression techniques. Errors, however small, are highly likely to occur in all registration procedures,[21] and therefore, additional errors may be expected over the length of the arch. Some clinical studies in literature have examined the use of intraoral scanners in full-arch impression procedures. It is worth assessing whether registration errors are caused by the influence of the span in terms of the predicted additive effect. Increases in model differences in particular zones were commented on by Ender and Mehl,[19] and can be explained by the registration procedure. It is probable that the algorithm attempted to register the surfaces so as to achieve as small an overall mean deviation as possible among the surfaces, which may conceal any increase in deviation and render interpretation of deviations difficult. A best-fit algorithm based only on the scan starting area could have revealed possible deviation increases in that study.[22]

Following the scanning and recording of structured data, CAD software applications can then create a geometric virtual 3D model, and CAM techniques then employ several printing and milling machines to produce replica precise copy of the virtual model in a physical form.[22]

On the basis of this study, the authors advocate the use of an intraoral scanner in dental implant full-arch rehabilitations and digitally create an accurate dental impression, which greatly increases efficacy. This will also facilitate patient satisfaction and the previsualization of the work undertaken, reduce the likelihood of impression size variations, and allow for acceptable marginal fit values of the restorations.

CONCLUSIONS

This clinical study has demonstrated that it is possible to manufacture CAD/CAM cobalt-chromium full-arch restorations with satisfactory accuracy following a digital impression technique based on active wavefront sampling. However, more clinical studies are needed to further assess the efficacy of digital impression procedures.

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