

Innovative Approach to Computer-Guided Surgery and Fixed Provisionalization Assisted by Screw-Retained Transitional Implants

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Purpose: The objectives of this case series are to describe a novel clinical approach to treat completely edentulous patients and determine its viability. Computer-guided implant planning was used to create a screw-retained surgical template (ST) supported by transitional implants and a fixed screw-retained provisional prosthesis supported by the transitional implants at the time of definitive implant placement. **Materials and Methods:** Five patients with at least one edentulous arch were treated. After the diagnostic tooth setup was performed, a duplicate with radiopaque acrylic resin was fabricated to serve as a surgical template (ST) for the placement of screw-form transitional implants and a radiographic guide (RG). Four transitional implants were strategically placed through the guide where they would not interfere with the future definitive implants. The transitional implants were used to support the RG during computed tomographic scanning. Subsequently, the RG was converted into a second ST based on three-dimensional virtual planning. Eight implants were placed by the computer-guided system, and an immediate prefabricated fixed provisional was connected to the transitional implants. **Results:** All the implants included in the study achieved primary stability and osseointegrated successfully. For 4 months, the transitional implants served successfully as abutments for the provisional prosthesis. **Conclusion:** This innovative clinical approach overcomes the limitations of a mucosa/bone-supported ST by offering fixed, reproducible support for the RG and ST by means of transitional implants. The delivery of a prefabricated screw-retained provisional on transitional implants allows for passive healing and minimum chairside adjustments. INT J ORAL MAXILLOFAC IMPLANTS 2015;30:403–410. doi: 10.11607/jomi.3817

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Fixed implant rehabilitation of completely edentulous patients is a clinical challenge. Compared to the mandible, the edentulous maxilla presents a more complex situation, such as a challenging resorption pattern, increasing the functional and esthetic demands for a fixed reconstruction. Therefore, the eventual outcome of treatment is greatly influenced by careful planning to address esthetic and functional demands in accordance with prosthetically driven implant placement.^{1–3}

Advancements in three-dimensional (3D) imaging technology have helped to overcome these challenges by allowing better visualization of the soft and hard tissues. This improvement facilitates implant treatment planning related to anatomical and prosthetic conditions, leading to a more predictable outcome.^{4,5} Currently, 3D planning software programs are available to transfer the information from a digital 3D planning environment to the intraoperative surgical field by means of computer aided or guided surgery.^{6–8}



Fig 1a Try-in of diagnostic functional wax-up.



Fig 1b Duplication of the validated diagnostic tooth setup with radiopaque material.

Computer-aided technology has shown significant improvements in accuracy in comparison to conventional implant placement.^{9–11} The evidence suggests that computer-guided implant placement may be sufficiently accurate to justify its use when proper safety margins are respected.^{12,13}

Two different computer-derived manufacturing processes are available to fabricate surgical templates (STs) that correspond to the preoperative virtual planning and allow implant placement precisely in the planned positions. Stereolithographic (SLA) templates are based on a combination of computer-aided design/computer-assisted manufacture technology and rapid-prototyping (3D printing) technology for fabrication.^{14–17} Precise virtual implant placement planning in 3D planning software programs is based on the computed tomography (CT) scans of a patient's bony anatomy and a radiographic guide (RG) containing the tooth or teeth to be replaced. The SLA template is produced by additive manufacturing (3D printing) based on the virtually planned information and incorporates precise drill sleeves for implants. The lack of accuracy and reproducible seating in the oral cavity of SLA templates are often reported as main causes of inaccuracies of such guided systems.^{10,17} Alternatively, cone beam CT (CBCT)-derived laboratory-based surgical templates are fabricated on a dental stone model that incorporates radiopaque resin acrylic teeth, which later serves as an RG. Here, accurate fit of the template is first confirmed intraorally before exposing the patient to CBCT. After the implant virtual planning, the RG is converted directly into an ST following a series of laboratory procedures.^{18–20} This direct conversion of the radiographic guide into an ST is a great advantage because an accurate and reproducible fit is confirmed during CBCT acquisition and guided implant placement.

In contrast to a partially edentulous situation, in the edentulous arch, reproducible seating and stability of the ST remain major limitations because of the

lack of rigid areas or teeth to serve as vertical stops for the ST. Horizontal side pins have been used in an attempt to improve stability of the soft/hard tissue-supported templates. However, deviations from planned to achieved implant position continue to be reported.^{17,21} Furthermore, the decision to use such an ST in the edentulous arch often implies the use of a flapless approach. This results in significant surgical limitations, such as a lack of keratinized peri-implant mucosa caused by the punched access and a challenging approach to bone grafting with soft tissue-supported templates.^{13,15}

Several approaches have been described in the literature to convert the seating of the ST from a soft and depressible surface, such as the oral mucosa, to a hard and stable seating. This has been achieved via vertical surgical fixation screws,²² transitional implants in the retromolar area,²³ and presurgical prosthetically strategic placement of three or more narrow-diameter implants (transitional implants).^{14,24} In addition, horizontal fixation screws have been added to mucosa-supported templates to increase retention.¹⁵

The postoperative provisionalization of a fully edentulous patient remains as a critical phase in implant treatment. Well-documented immediate implant loading protocols can solve this problem, but this technique may only be indicated in the absence of limiting factors, such as poor primary stability, bone grafting procedures, reduced implant size, and low implant insertion torque.^{25–27}

In this context, the purpose of this clinical case series is to: (1) describe a novel protocol for guided implant placement in fully edentulous patients using transitional implants to support a screw-retained ST and a provisional prosthesis; and (2) determine whether the proposed technique is compatible with predictable implant placement and osseointegration of the definitive implants, while transitional implants are used to support the ST and provisional prostheses.



Fig 2a Placement of four mini-implants.



Fig 2b Mini-implant placement at the sites of the maxillary lateral incisors and first premolars.



Fig 2c Connection of screw-retained titanium copings to the transitional implants and widening of the perforations on the RG in the mini-implant positions to facilitate intraoral pickup with clear acrylic resin.

MATERIALS AND METHODS

Patient Selection

This study was approved by the institutional review board committee of the Harvard Medical School (CHS no. M22413-102). From January 2012 to April 2013, five patients with six edentulous arches presented at the oral implantology clinic at the Division of Regenerative and Implant Sciences, Harvard School of Dental Medicine. The common chief complaints were unstable removable prostheses or failing fixed prosthodontics. All patients were sufficiently healthy to receive dental implants. After clinical and radiographic examinations, five edentulous maxillae and one edentulous mandible were treatment planned. The maxillary implant-prosthodontic design included eight implants supporting 4 three-unit fixed partial dentures and, in the mandible, six implants supporting 3 fixed partial dentures.

Diagnostic Planning

A diagnostic wax-up was performed to establish appropriate function and esthetics and serve as an ST for the computer-guided surgery (Fig 1a). The prosthetic acrylic resin teeth were adjusted and arranged without waxing the labial or buccal flanges to establish the appropriate emergence profiles and evaluate the necessary soft and hard tissue replacement. The palatal and lingual aspects were designed with the same method used to record a complete denture base to ensure proper support and retention for prosthetic teeth. The diagnostic wax-up was evaluated clinically to assess occlusion, relationships between teeth and the alveolar ridge, occlusal plane, phonetics, and esthetic parameters during the try-in stage.

Subsequently, the diagnostic wax-up was duplicated in 30% radiopaque acrylic resin (Scanocryl, Effect Dental Products) for teeth, 10% radiopaque acrylic resin for the soft tissue, and a radiolucent transparent acrylic resin (ALIKE, GC America) for the palatal

aspect (Fig 1b). The duplicate would serve as an ST for placement of transitional implants and later as an RG for CBCT scans.

Transitional Implant Placement

After comprehensive clinical and radiographic examinations, four transitional implants were placed in an anteroposterior quadrilateral distribution. The locations for the transitional implants were selected to avoid the planned locations for the definitive implants. Perforations were made on the duplicate of the wax-up so that it could serve as an ST for transitional implant placement. After local anesthesia was induced (2% lidocaine hydrochloride with 1:100,000 epinephrine, Henry Schein), four transitional implants (2.2 × 7 mm, Anew, Dentatus) were placed in a flapless technique and sufficiently parallel to have a common path of draw in the designated positions (Figs 2a and 2b). Screw-retained titanium copings (SR-49, Dentatus) were then connected to the transitional implants (Fig 2c). The ST perforations were widened to prevent interference with the titanium copings; thus, the ST was seated exclusively by mucosal support at the palatal/lingual aspect, and occlusion was confirmed. Then, the surrounding soft tissue was protected with rubber dam. While the ST was held securely in place manually, the coronal portions of screw-retained titanium copings were bonded and connected to the ST with clear acrylic resin (ALIKE, GC America). The ST/titanium coping complex was unscrewed, and the remaining spaces between the titanium copings and the ST were filled in with clear acrylic resin to secure these connections. Customized protection caps (SR-68, Dentatus) were placed onto the transitional implants, and the intaglio surface of patients' provisional complete denture was relieved to avoid any contacts between the transitional implants and the prosthesis.



Fig 3a Master cast with mini-implant analogs in place.



Fig 3b Occlusal view of the RG with the addition of the fiduciary markers for CBCT.



Fig 3c Occlusal view of the RG in position and secured to the transitional implants.

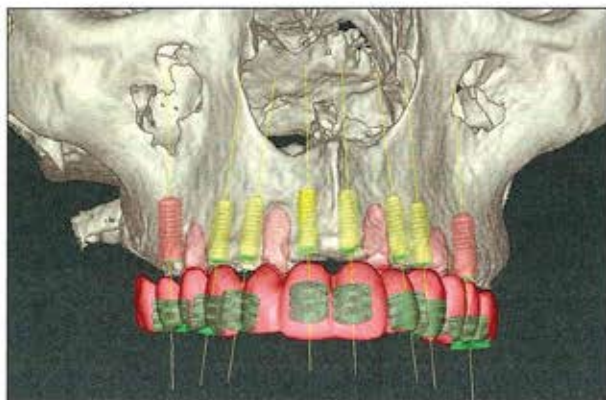


Fig 4 Facial view of the 3D plan for the definitive implants. The radiographic tooth setup secured to the four transitional implants is shown in red. The definitive implants are shown in yellow for 3.3-mm-diameter implants and red for 4.1-mm-diameter implants. Yellow orientation lines indicate the implants' planned axes. Guided sleeves are represented in green.

Laboratory Procedures and Virtual Implant Planning

In the laboratory, transitional implant analogs (SR-83, Dentatus) were connected to the titanium copings in the ST/titanium coping complex and retrofitted to the master cast. The areas of transitional implants in the master cast were relieved to incorporate the transitional implant analogs into the model without interference. The seating and stability of the screw-retained complex on the master model were verified and retrofitted by securing the analogs with type IV stone (Pattern Resin LS, GC America) and creating an emergence profile using a gingival mask (GI-Mask, Coltene/Whaledent) (Fig 3a). Then, the master cast was mounted to the opposing cast on the articulator in a predetermined vertical dimension of occlusion and centric occlusion relation during the diagnostic wax-up stage.

The screw-retained ST/titanium coping complex was then converted into an RG for CBCT scanning by attaching three fiduciary markers (Templix, Straumann) to the screw-retained complex according to the manufacturer's protocol (Figs 3b and 3c). Thus, the

converted RG was able to be securely seated and connected onto the transitional implants in the same position during the CT recordings and guided surgery.

The converted RG was connected to the transitional implants without interference from the soft tissues. The RG was solely supported by the transitional implants. The patient underwent CBCT scanning (i-CAT, Imaging Sciences). The digital data were transferred into a 3D planning software program (coDiagnostiX, Straumann), in which the jaws were evaluated by multiple cross-sectional and 3D images. Eight implants (Straumann) were virtually planned and placed in the positions of the central incisors, canines, first premolars, and first molars, in consideration of bone, soft tissue, planned definitive prosthesis, and underlying anatomical structures (Fig 4). The definitive maxillary restoration was planned as four segmented three-unit fixed partial dentures supported by eight implants. The virtual plan, then, served as a blueprint for the fabrication of surgical guides that allowed exact implant placement.

The screw-retained RG was then converted into a screw-retained ST by inserting 5-mm- or 2.8-mm-diameter guided sleeves (Straumann) in the virtually planned implant positions following the manufacturer's protocol (Fig 5a). In preparation for provisionalization on the day of implant placement, a screw-retained fixed resin provisional prosthesis supported by the four transitional implants was fabricated on the master cast using screw-retained titanium copings (SR-49, Dentatus) (Fig 5b). Its fit and occlusion were verified on the master cast and mounted to the opposing cast, which was an accurate reproduction of the patient's intraoral situation.

Guided Implant Placement and Provisionalization

All patients were treated under local anesthesia (lidocaine hydrochloride 2% with epinephrine 1:100,000, Henry Schein). Buccal and palatal mucoperiosteal flaps were designed and elevated in the areas that needed bone grafts. When flapless implant placement was feasible, the ST was connected to the transitional implants without interference from the soft tissues, and

Fig 5a Occlusal view of the ST containing the guided sleeves and the mini-implant copings.



Fig 5b View of the laboratory-fabricated maxillary provisional.



Fig 6 The ST has been secured to the mini-implants and the definitive implants placed through the guided sleeves.



Fig 7a Immediate postsurgical facial view of a screw-retained provisional.

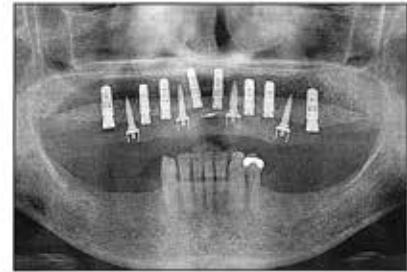


Fig 7b Immediate postsurgical panoramic radiograph with the provisional prosthesis supported by four transitional implants.



Fig 8a Occlusal view after removal of the four transitional implants.

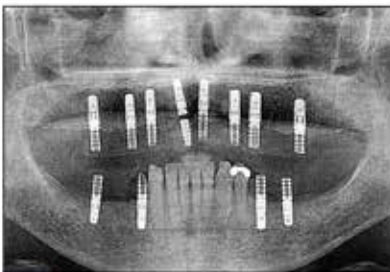


Fig 8b Panoramic radiograph of screw-retained provisional supported by the definitive implants.

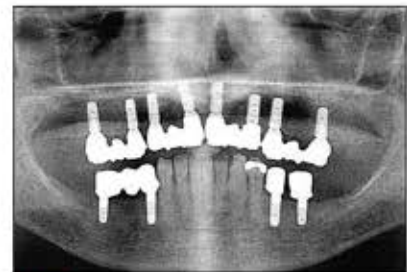


Fig 9 Panoramic radiograph with the definitive prostheses on the day of delivery.

a soft tissue punch was used precisely through the sleeve. The seating and stability of the ST were confirmed, so that it was solely supported by the transitional implants in the same position as the RG during CBCT scanning. The drilling sequence was followed by surgical placement, guided by the planning software. Based on the virtual plan, in which sleeve diameter and positions were selected, the correct combination of drill handles and guided instruments (Straumann) was used to prepare each implant bed. A double irrigation system was used. The implants were placed through the guided sleeve in the ST. All implants were placed and achieved primary stability after guided osteotomy based on the preoperative virtual plan (Fig 6). After removal of the ST, guided bone regeneration was performed with Bio-Oss (Geistlich Pharma North America) and Bio-Gide (Geistlich Pharma North America) around the implants as needed from the preoperative virtual plan. Primary closure was achieved and the areas were sutured with 5-0 Gore-Tex (W. L. Gore & Associates).

The laboratory-made screw-retained fixed resin provisional was connected to the four transitional implants and torqued into place manually (Fig 7a). After minor occlusal adjustments and relief of any soft tissue contacts, marginal adaptation of the titanium copings to the transitional implants was verified with a panoramic radiograph (Fig 7b).

The patient was seen after 2 weeks. During the follow-up visit, the screw-retained resin provisional was removed from the transitional implants so that sutures could be removed and soft tissue healing evaluated. The patients were able to function with the fixed resin provisionals with satisfactory esthetics and comfort. After a 4-month healing period, all the transitional implants were removed, and the fixed resin provisional prosthesis was connected to the definitive implants (Figs 8a and 8b). The patient received a definitive prosthesis that was based on the intended implant prosthodontic design (Fig 9).

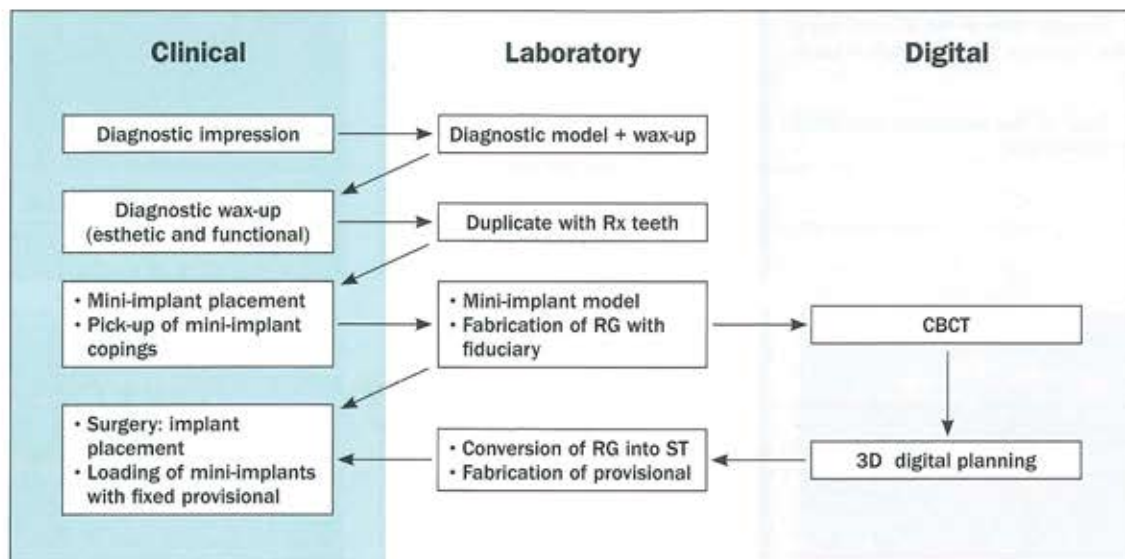


Fig 10 Overall workflow of the protocol.

RESULTS

The overall workflow of the protocol used in this study is summarized in Fig 10. The protocol was divided into clinical, laboratory, and digital preparation phases, which are illustrated in Figs 1 to 9.

Forty-five implants were placed in six edentulous arches in five patients (Table 1). All the osteotomies were performed through the sleeves fixed in the guided ST, and the depths and positions of the osteotomies were controlled by the guiding sleeves and guided surgical instruments based on the preoperative virtual planning. Flapless guided implant placement was performed for 26% of the implants placed, and 22.2% of the implants required simultaneous bone grafting. Patients reported no postoperative pain or discomfort.

At 2 weeks after placement, one of the patients reported minor pain and mobility around one of the maxillary right anterior transitional implants; the mini-implant was removed. Periapical radiographs and clinical examination showed no significant bone loss patterns around the failed transitional implant. Even with the loss of the transitional implant, the ST was stable on the other transitional implants and remained in the same reproducible position as for the CBCT scan. An additional transitional implant was inserted to replace the lost transitional implant in the same position but more palatally to achieve primary stability. Then, the titanium coping of the new transitional implant was successfully incorporated into the ST, and all the transitional implants were loaded after the placement

of the definitive implants with a fixed resin provisional prosthesis. The loading of fixed provisional prostheses onto the transitional implants required only minor occlusal adjustments without any misfits, which were verified on a panoramic radiograph. At 4 months after loading, the transitional implants successfully served as abutments for a provisional prosthesis, resulting in a 95.7% success rate for the mini-implants. The transitional implants were removed by reverse torquing, and the fixed provisional prostheses were transferred and connected to the definitive implants.

DISCUSSION

To achieve satisfactory functional and esthetic outcomes when treating edentulous patients with dental implants, the placement of dental implants requires precise assessment of all surgical sites and the prospective prosthetic restoration.¹⁸ Advancements in CBCT scanning, coupled with computer-assisted treatment planning, allow for prosthetically driven implant placement via guided surgery and provide a high degree of restorative predictability and confidence in improving the clinical outcome. It has been demonstrated that the use of a computer-guided system minimizes the risks that are involved in conventional implant surgery, and its accuracy in the planning and placement of dental implants justify its use, especially in treating maxillary edentulous patients.^{12,13,17} However, the challenges associated with computer-guided

Table 1 Summary of Patient and Implant Data

Patient no.	Patient data			Implant and surgical data				Mini-implant survival
	Age (y)	Sex	Arch	Types and dimensions	No.	Flapless	GBR	
1	57	F	Max	BL, 3.3 × 10 mm	6	0	2	100%
				BL 4.1 × 10 mm	2	2	0	
2	64	F	Max	BL, 3.3 × 10 mm	8	0	2	100%
3	62	F	Max	BL, 3.3 × 10 mm	2	0	0	100%
				BL, 3.3 × 12 mm	6	0	2	
4	45	M	Max	ST/RN, 3.3 × 10 mm	6	0	2	75%*
				ST/RN, 4.8 × 10 mm	2	2	0	
5	68	M	Max	BL, 3.3 × 10 mm	6	6	0	100%
				BL, 4.1 × 10 mm	2	2	0	
			Mand	BL, 3.3 × 10 mm	4	0	2	
				ST/WN, 4.8 × 10 mm	1	0	0	
					45	12 (26%)	10 (22%)	95.75%

BL = Bone Level (Straumann); ST/RN = Soft tissue level, regular neck implant; ST/WN = Soft tissue level, wide neck implant.

*One mini-implant was lost 2 weeks after placement.

systems remain. For example, because of the significant lack of bony structure, any need for bone grafting will add complexity to the use of soft tissue-supported templates. The risk for transfer error from CT acquisition, to the software planning stage, to the surgical field caused by angular transformation and unstable seating of the ST is still substantial.^{9,17-19,28}

The present approach resulted in accurate transfer of the 3D planning to the surgical field in treating edentulous maxillary arches; the transitional implants supported the RG and its further direct conversion into an ST. The seating of the RG and ST was reproducible and consistent without interference from the soft tissue during CT scan acquisition and at the time of surgery. This minimized the inaccuracies involved with seating and movement of a mucosa-supported ST.^{10,17} Furthermore, the support of the ST with the transitional implants was stable enough to eliminate the use of horizontal side pins during surgery. It also allowed a combination of flap and flapless implant placement, even when bone grafting was required, without compromising its seating during surgery; this would have been challenging with a mucosa-supported ST.

Previous authors have attempted to use transitional implants to stabilize an ST and/or fixed provisionals.^{14,22,23} Maintenance of a stable position of an ST through the support of transitional implants helps surgeons to locate the prosthetically driven implant positions, thereby enhancing predictable implant placement with precision. It has also been demonstrated that prosthetic design and prosthetic screw emergence were greatly improved with fixed STs. Two

transitional implants were placed on the same day of definitive implant placement to stabilize the ST; however, this did not serve as a guide for the implants.²³ In a clinical study by Tahmaseb et al,²⁴ three transitional implants were placed in a tripod-like configuration to stabilize a guided ST and serve as a digital reference. The approach demonstrated a high level of precision with the use of transitional implants; however, they were not loaded to support the provisional. To provide a fixed provisional, immediate loading of definitive implants is required, and this involves sophisticated and time-consuming procedures. In the current study, the transitional implants supported not only the ST but also the fixed provisional, which was fabricated from a master cast representing the accurate positions of the transitional implants and the intraoral situation. Loading of a screw-retained provisional on the transitional implants had the advantages of efficient delivery of the prosthesis with minimum chairside adjustments, avoiding the complications of immediate loading procedures, and minimizing the risks of failure in grafted areas and with definitive implants postoperatively.

One of the transitional implants in a patient was mobile and thus retrieved during the preparation stage. Another transitional implant was placed in a more palatal position and reconnected to the RG. During the 4-month healing period, the transitional implants successfully supported a provisional.

Further studies should investigate the accuracy of this novel approach and compare it to that of mucosa-supported ST and long-term data with transitional implants as interim abutments for a provisional.

CONCLUSIONS

The fixed and reproducible seating of the radiographic guide/surgical template supported by transitional implants overcomes the limitations of mucosa/bone-supported surgical templates. It proved to be a reproducible and predictable method in the present patient series. Additionally, the delivery of a screw-retained provisional supported by transitional implants on the day of surgery allows for minimal chairside adjustments and passive soft tissue healing.

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