THE JOURNAL OF PROSTHETIC DENTISTRY

DENTAL TECHNIQUE

A fully digital protocol to provide a fixed interim complete denture for immediate loading for a completely edentulous patient: A dental technique

José Espona, DDS, MSc,[a] Carla Vidal-Ponsoda, DDS,[b] Pau Quintana, DDS, MSc,[c] Víctor Henarejos-Domingo, DDS, MSc,[d,e] and Miguel Roig, MD, DMD, PhD[f]

ABSTRACT

Complete-arch immediate-loading implant-supported prostheses can represent a major challenge for the patient and the dental team. Obtaining stable references and an accurate occlusal record after implant placement to provide an interim prosthesis is a difficult task and can deviate from the initial treatment plan. The described technique presents a fully digital protocol to provide an immediate complete-arch implant-supported fixed interim prosthesis for edentulous patients by making postoperative cone beam computed tomography and intraoral digital scans that correlate with the previous plan. (J Prosthet Dent 2021;■:■-■)

When indicated, providing a complete-arch implant-supported fixed interim prosthesis for edentulous patients during the first week after implant placement, defined as immediate loading,[1-3] improves patient confidence, satisfaction, and overall quality of life during the treatment.[4-12] Conventional protocols have been based on the conversion of an existing removable complete denture or immediate denture into a fixed interim complete denture, as with the pickup technique described by Gallucci et al.[9,10,13] Such conversion is labor-intensive, technique-sensitive, time-consuming, and uncomfortable for the patient and the dental team, and the outcome can be unpredictable. Recently, digital protocols have been developed to simplify this procedure, reduce treatment time, and increase accuracy.[14-17]

Intraoral scanners (IOSs) can accurately record the implant position immediately after placement.[17-24] Nevertheless, the virtual definitive casts obtained are not error-free, and to ensure a correct passive fit of the dental prosthesis, correction or verification methods including analog verification devices, digitally scanned auxiliary devices, stereophotogrammetry, or cone beam computed tomography (CBCT) have been used.[25-32]

Immediately loading with a digital workflow requires a previous digital design of the interim prosthesis and virtual interocclusal records at the desired occlusal vertical dimension immediately after the surgery, ideally in centric relation (CR). Nevertheless, in completely edentulous patients, the lack of relevant references or fiducial marks such as teeth represents a major challenge to superimposing the different data sets. Combining the Digital Imaging and Communications in Medicine (DICOM) files from the CBCT scan with the standard tessellation language (STL) files from the IOS can be more complex than for partially edentulous patients.[33-36] The use of stable references allows the superimposition of the definitive intraoral scan to the previous intraoral scan and permits the dental laboratory technician to deliver an interim prosthesis with the previously planned occlusal vertical dimension, occlusal scheme, and esthetic parameters. Achieving accurate virtual interocclusal

[a]Associate Professor, Department of Restorative Dentistry, School of Dentistry, International University of Catalunya, Barcelona, Spain.
[b]Resident, Department of Restorative Dentistry, School of Dentistry, International University of Catalunya, Barcelona, Spain.
[c]Assistant Professor, Department of Restorative Dentistry, School of Dentistry, International University of Catalunya, Barcelona, Spain.
[d]Private practice, Barcelona, Spain.
[e]Associate Professor, Department of Restorative Dentistry, School of Dentistry, International University of Catalunya, Barcelona, Spain.
[f]Chairman and Professor, Department of Restorative Dentistry, School of Dentistry, International University of Catalunya, Barcelona, Spain.

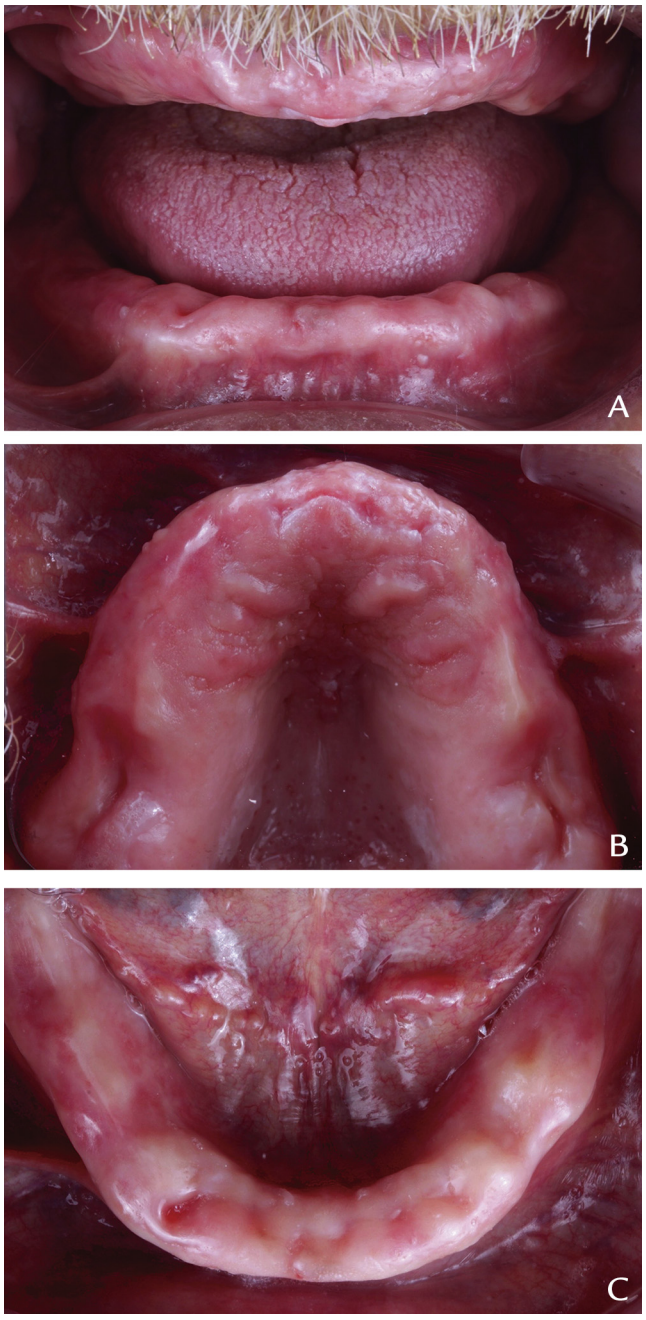

Figure 1. Intraoral images of initial situation. A, Frontal view. B, Maxillary edentulous arch. C, Mandibular edentulous arch.

records directly after surgery is almost impossible because of muscle fatigue and/or tightness.[37] As references can be lost during the surgical procedure, the placement of titanium pins into the edentulous arch on the day of the surgery in locations that are not altered during the implant placement has been described to obtain fixed intraoral landmarks.[37]

The purpose of this technique article was to describe a fully digital protocol to provide an immediately loaded fixed interim complete-arch prosthesis for completely edentulous patients, where obtaining stable references and an accurate occlusal registration after implant placement is a difficult task, by using various STL and DICOM files during different stages of the treatment, before and after implant placement.

Figure 2. A, Extraoral view of tooth arrangement evaluation. B, Tooth arrangement with flowable composite resin points as radiopaque markers.

TECHNIQUE

To illustrate the technique, a completely edentulous patient is presented for whom dental implants have been planned (Fig. 1). The sequence for the maxillary arch is presented.

1. Perform a tooth arrangement to evaluate all the parameters for a complete-arch implant-supported fixed prosthesis, fabricated either conventionally or digitally, depending on the clinician's preferences (Fig. 2A).

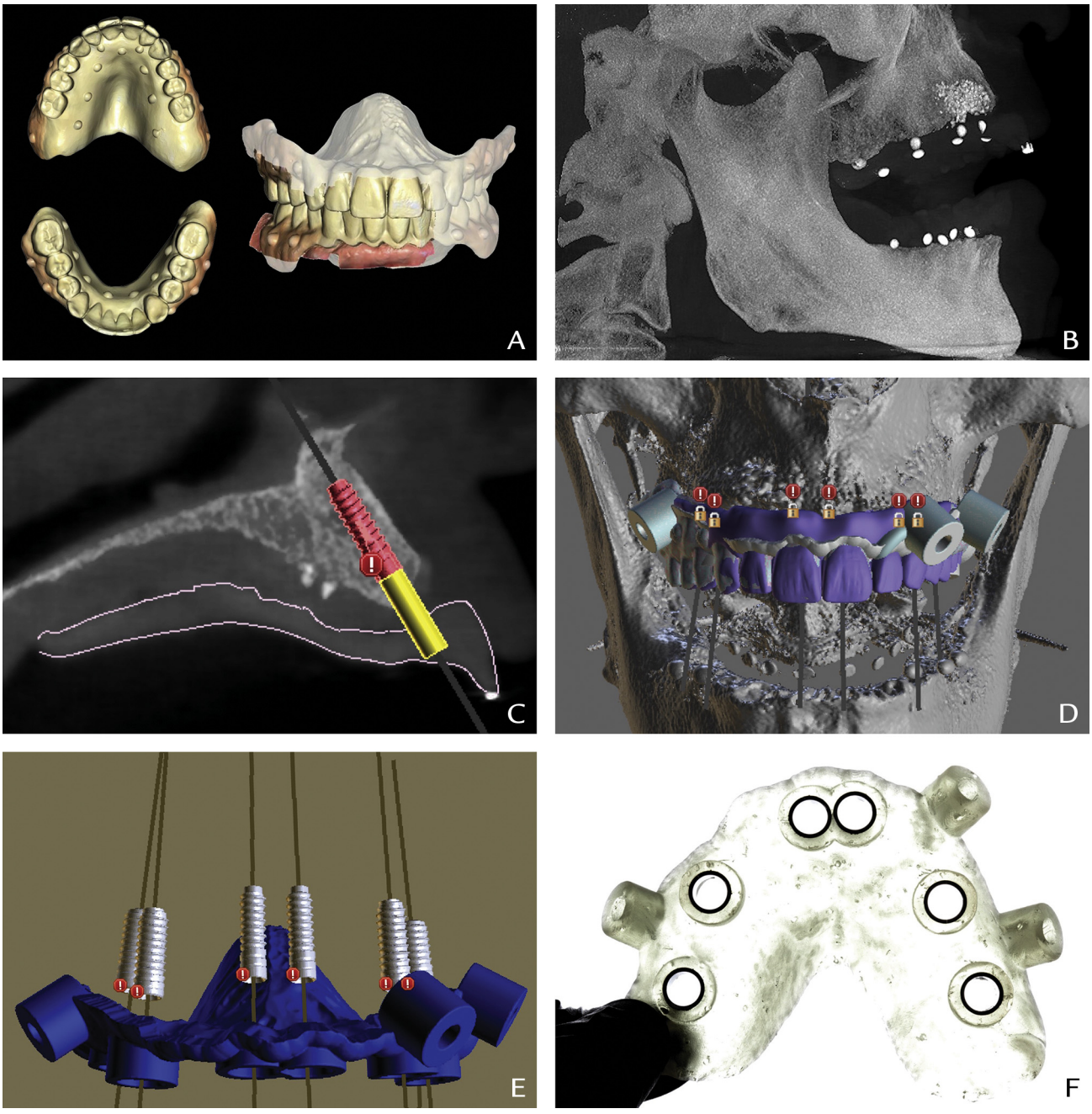

Figure 3. A, Digital scan of maxillary and mandibular tooth arrangement. B, CBCT scan with maxillary and mandibular tooth arrangement. C, Virtual implant treatment plan and superimposition of STLTA and CBCT1. D, E, Surgical guide design. F, Surgical guide. CBCT, cone beam computed tomography; STL, standard tessellation language.

2. Place a minimum of 7 interspersed flowable composite resin (Dyract flow; Dentsply Sirona) points as radiopaque markers on the maxillary tooth arrangement distributed on the buccal flange and the palatal aspect to ease the overlapping in the following steps (Fig. 2B).
3. Obtain a digital scan of the external, the intaglio, and the occlusion of the tooth arrangement by using an IOS (PrimeScan; Dentsply Sirona) and export the STL file as STLTA (Fig. 3A).
4. Make a CBCT (i-CAT FLX V17; i-CAT) scan with the tooth arrangement inserted in the mouth. Select a reconstruction volume size of at least 16 cm in height. Export as a DICOM file named CBCT1 (Fig. 3B).
5. Import and superimpose the files STLTA and CBCT1 into a free surgical implant planning

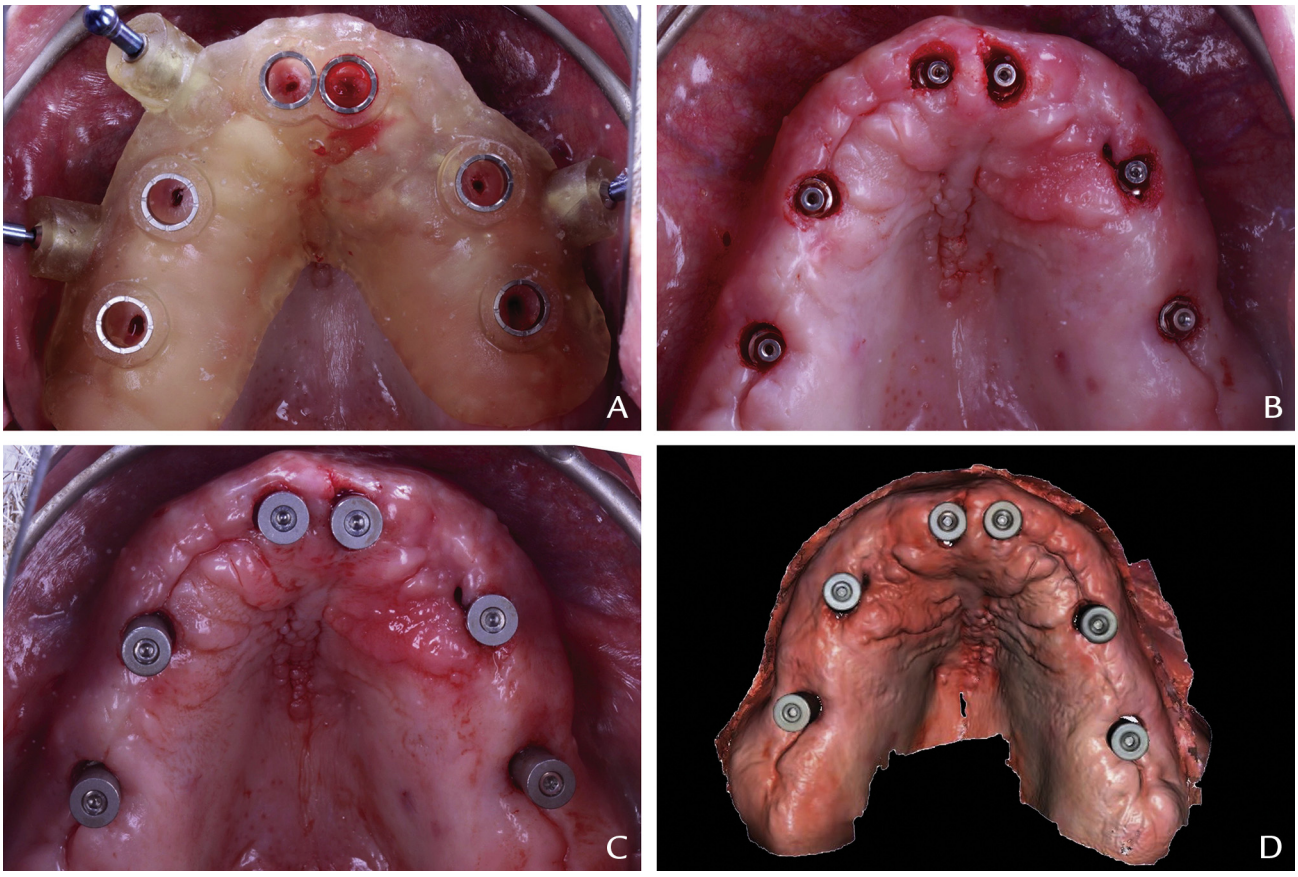

Figure 4. A, Guided surgery of maxillary arch with surgical guide fixed with anchor pins. B, Implants and transepithelial abutments placed. C, Metal scan bodies tightened to recommended torque. D, Postoperative intraoral digital scan (STLPOST). STL, standard tessellation language.

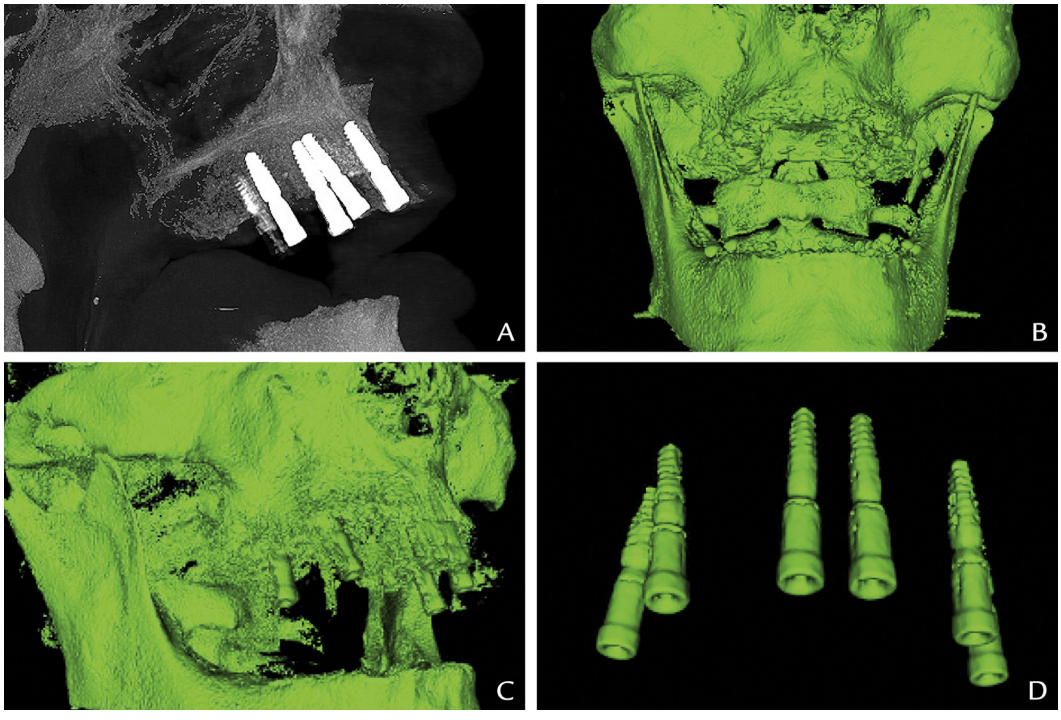

Figure 5. A, Postoperative CBCT scan with metal scan bodies (CBCT2). B, CBCT1 segmentation. C, D, CBCT2 segmentation. CBCT, cone beam computed tomography.

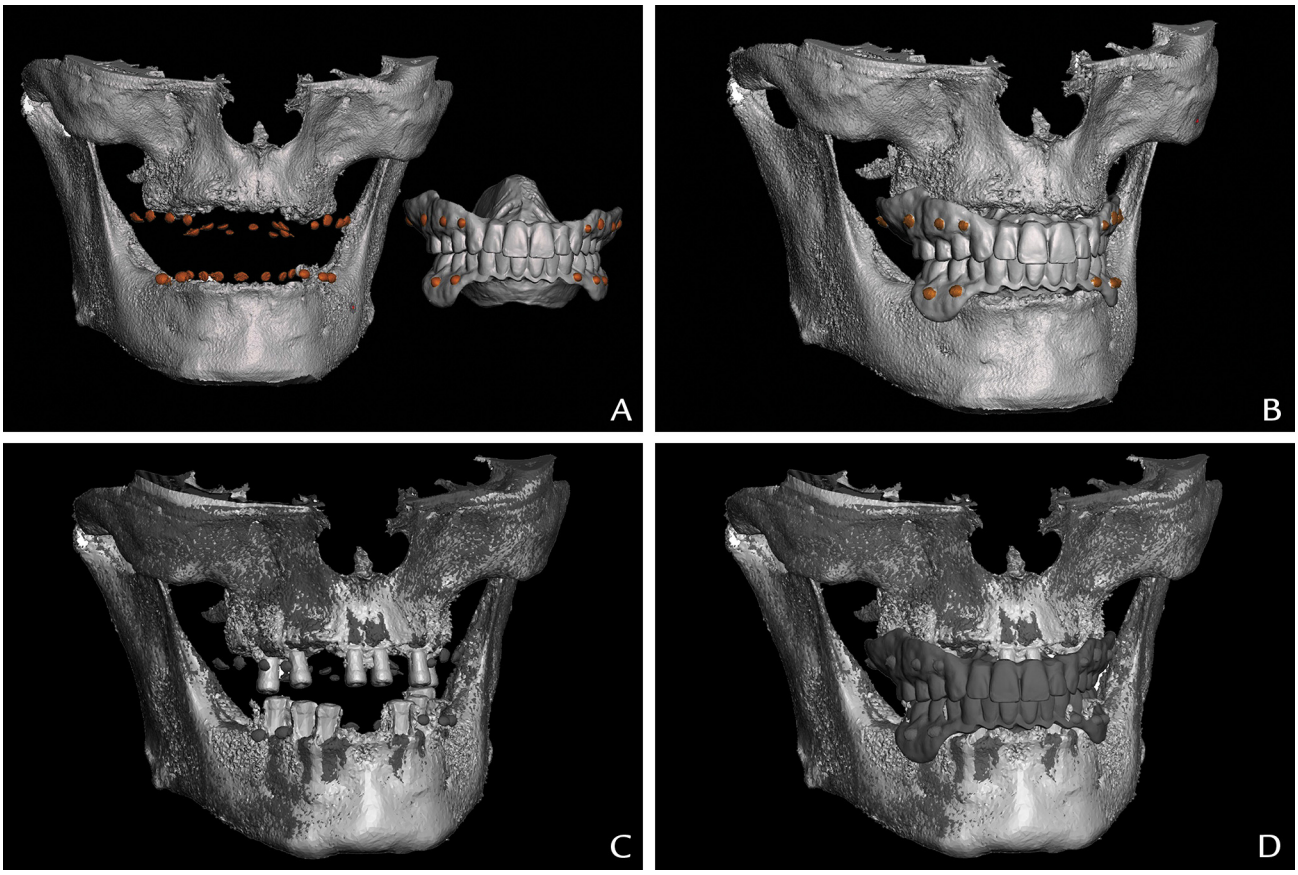

Figure 6. Alignment sequence. A, STLCBCT1 and STLTA with coincident areas, radiopaque markers, selected (highlighted). B, STLCBCT1 and STLTA aligned by using "align to target." C, STLCBCT1 and STLCBCT3 aligned by using stable and common anatomic landmarks as references, zygomatic bone or nasal spine. D, STLCBCT1, STLCBCT3, and STLTA aligned, correlating initial records with postoperative records. STL, standard tessellation language.

software program (Blue Sky Plan 4; Blue Sky Bio). Virtually plan the prosthetically driven implant placement (VEGA NV and VEGA RV; Klockner Implant System) (Fig. 3C). Virtually design the surgical guide and export it as an STL file for the subsequent fabrication named STLSG (Fig. 3D-F).

6. Place the dental implants by using the static implant surgical guide designed and following the drilling protocol recommended by the manufacturer (Fig. 4A). Screw the planned transepithelial abutments at the recommended torque (VEGA Permanent; Klockner Implant System) (Fig. 4B). If sufficient primary stability is achieved, attach the corresponding scan bodies (i-PV2 Scan-Abutment i-medlocate; Archimedes) (Fig. 4C), perform a postoperative intraoral digital scan (Prime Scan; Dentsply Sirona) (Fig. 4D), and export the STL file as STLPOST. The use of metal scan bodies is recommended to facilitate the overlapping of the data sets.
7. Place lip and cheek retractors (OptraGate; Ivoclar Vivadent AG) and the occlusal registration material (Occlufast Rock; Zhermack SpA) between the maxillary and mandibular arches to ensure a fixed maxillomandibular relationship and make a postoperative CBCT scan with the scan bodies inserted. Export as DICOM file CBCT2 (Fig. 5A). This maxillomandibular registration can be arbitrary. Remove the scan bodies, place healing caps over the transepithelial abutments, and schedule the delivery of the interim prosthesis in the patient within the next 24 to 48 hours.
8. Import the CBCT1 to a free and open-source software program (InVesalius 3.1; InVesalius 2007-2017) to convert the DICOM to an STL file, also known as segmentation. Manually select an adequate density of the CBCT1 file where only the bone and the radiopaque markers of the TA can be determined to be correctly segmented and save as STLCBCT1 (Fig. 5B). Perform the same process and values for the CBCT2 to obtain a single STL file where only the bone and scan bodies can be identified (STLCBCT2), and another exclusively for the scan bodies (STLCBCT2′) (Fig. 5C, 5D).

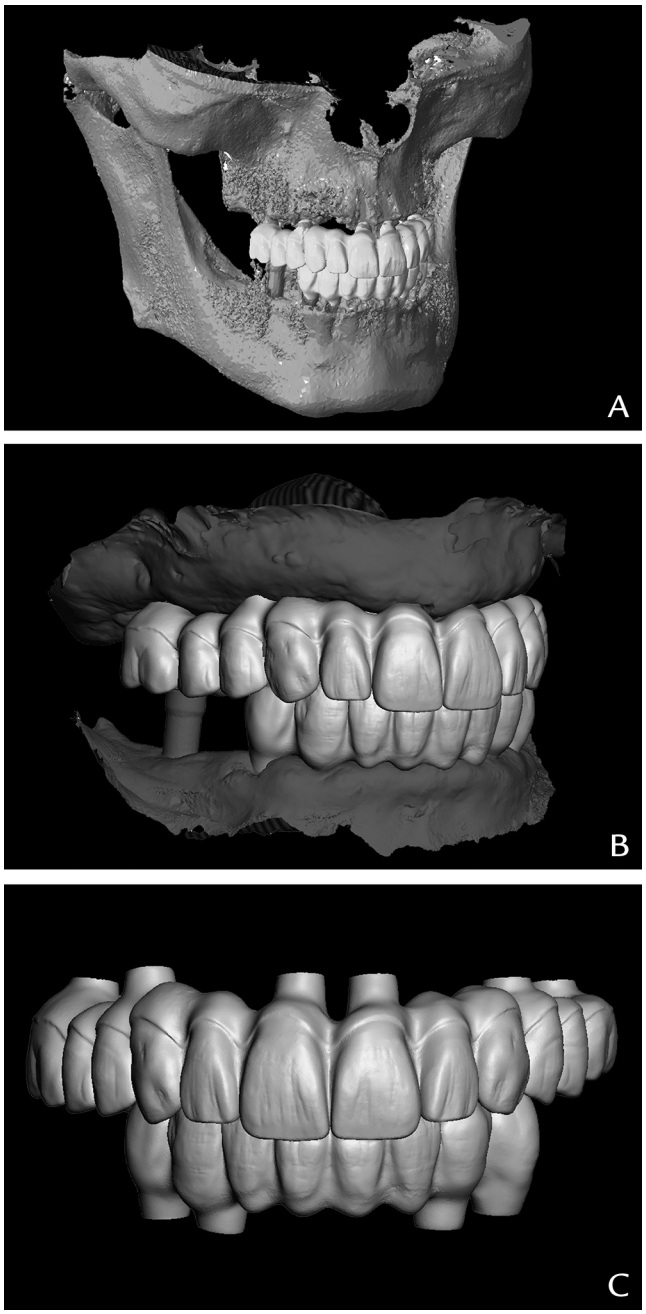

Figure 7. Tooth arrangement design adaptation. A, Tooth arrangement design adapted to STLCBCT3. B, Tooth arrangement design adapted to STLCORR. C, Definitive tooth arrangement design. STL, standard tessellation language.

9. Import the STLTA and STLCBCT1 files into a free computer-aided design (CAD) software program (Meshmixer 3.5; Autodesk Inc). Set as target the STLCBCT1 file and select with the brush the coincident areas between these different files as common points, which are the radiopaque markers, and align both files by using the tool "align to target" (Fig. 6A, 6B). At this point, the STLTA and the STLCBCT1 files have been correlated, which represent a link between the planned tooth position and the osseous structures.
10. Import also the STLCBCT2 and the STLCBCT2′ files to the Meshmixer program and combine them to obtain a unique file (STLCBCT3). Because they are in the same spatial orientation, no alignment is needed.
11. Set as target the STLCBCT1 file and align the STLCBCT3 by using stable and common anatomic landmarks such as the zygomatic bone or nasal spine as references (Fig. 6C). Now, the study CBCT and the postoperative CBCT, as STLs, are correlated with the STLTA file (Fig. 6D).
12. By using the Meshmixer program, correct the implant position of the STLPOST by placing as reference the STLCBCT2′ to improve the accuracy of the digital intraoral scan as described previously.[28,32,37] Once corrected, export the file as an independent STL named STLCORR.
13. Select as target the shape of the scan bodies from the STLCBCT3 and align it with the STLCORR file. At this point, all the different STL files described are aligned and correlated at the same 3D position by using the different stable references between them.
14. Adapt the shape of the initial tooth arrangement (STLTA) to the corrected postoperative intraoral digital scan (STLCORR) to obtain the definitive design of the complete-arch implant-supported fixed interim prosthesis (Fig. 7).
15. Mill the interim prosthesis from a colored polymethyl methacrylate (PMMA) disk (Multilayer PMMA Block A2; Huge Dental Material Co) by using a milling machine (DWX-52D; DGSHAPE Corp) and postprocess it.
16. At the next clinical appointment, remove the healing caps and tighten the complete-arch implant-supported fixed interim prosthesis at the manufacturer-recommended torque of 15 Ncm (Fig. 8). Evaluate the esthetics and the occlusal scheme and adjust if necessary.

DISCUSSION

The described digital workflow can help to deliver an immediate complete-arch implant-supported fixed interim prosthesis in edentulous patients in an efficient way. Transferring digitally the previously determined occlusal vertical dimension provides an immediate interim prosthesis with a well-controlled occlusion and

Figure 8. Delivery of complete-arch implant-supported fixed interim prosthesis. A, Frontal intraoral view. B, Occlusal intraoral view. C, Extraoral view at planned occlusal vertical dimension. D, Extraoral view, full smile.

excellent accuracy and optimizes the procedure by saving time and effort.

Some conventional and digital protocols require the intermaxillary relationship to be recorded intraorally and immediately after implant placement. In those situations, achieving the precise occlusal position is almost impossible. With the described technique, those records are made during the tooth arrangement visit and permit delivery of an interim prosthesis with replicated occlusal parameters. However, discrepancies between the initial planning and the definitive result may be from inaccuracies after CBCT segmentation and deviations during the surgery.

A drawback of the described technique is the need for the additional radiation dose with the postoperative CBCT scan. Costs and benefits of any additional radiation exposure should be carefully considered and analyzed according to the as low as reasonably available (ALARA) principle.[38] This postoperative CBCT has the double advantage of being correlated with the intraoral digital scan made immediately after the surgery and of improving the accuracy of the digital intraoral scan by correcting the implant position. Otherwise, with alternative workflows, those 2 objectives need to be achieved through 2 different methods.

This protocol requires that the dental laboratory technician be familiar with the different software programs and has the capacity to ensure the delivery of the interim prosthesis within 24 to 48 hours. Nevertheless, the chair time required is low, which means a greater comfort for the patient and the dental team.

SUMMARY

The described dental technique provides an alternative protocol for delivering an immediate complete-arch implant-supported fixed interim prosthesis in edentulous

patients by making a postoperative CBCT scan and intraoral digital scan just after implant placement to be correlated with the established treatment plan, optimizing at the same time the definitive design and manufacture. The passivity of the prosthesis made with the technique should be evaluated in a clinical study.

REFERENCES

1. Gallucci GO, Benic GI, Eckert SE, Papaspyridakos P, Schimmel M, Schrott A, et al. Consensus statements and clinical recommendations for implant loading protocols. Int J Oral Maxillofac Implants 2014;29(Suppl): 287-90.
2. Papaspyridakos P, Chen CJ, Chuang SK, Weber HP. Implant loading protocols for edentulous patients with fixed prostheses: a systematic review and meta-analysis. Int J Oral Maxillofac Implants 2014;29(Suppl): 256-70.
3. Peñarrocha-Oltra D, Covani U, Peñarrocha-Diago M, Peñarrocha-Diago M. Immediate loading with fixed full-arch prostheses in the maxilla: review of the literature. Med Oral Patol Oral Cir Bucal 2014;19:e512-7.
4. Penarrocha-Oltra D, Covani U, Penarrocha M, Penarrocha-Diago M. Immediate versus conventional loading with fixed full-arch prostheses in mandibles with failing dentition: a prospective controlled study. Int J Oral Maxillofac Implants 2015;30:427-34.
5. Grunder U. Immediate functional loading of immediate implants in edentulous arches: two-year results. Int J Periodontics Restorative Dent 2001;21: 545-51.
6. Kern JS, Kern T, Wolfart S, Heussen N. A systematic review and meta-analysis of removable and fixed implant-supported prostheses in edentulous jaws: post-loading implant loss. Clin Oral Implants Res 2016;27:174-95.
7. Goodacre C, Goodacre B. Fixed vs removable complete arch implant prostheses: a literature review of prosthodontic outcomes. Eur J Oral Implantol 2017;10(Suppl 1):13-34.
8. Huynh-Ba G, Oates TW, Williams MAH. Immediate loading vs. early/conventional loading of immediately placed implants in partially edentulous patients from the patients' perspective: a systematic review. Clin Oral Implants Res 2018;29(suppl 16):255-69.
9. Wittneben JG, Wismeijer D, Brägger U, Joda T, Abou-Ayash S. Patient-reported outcome measures focusing on aesthetics of implant- and tooth-supported fixed dental prostheses: a systematic review and meta-analysis. Clin Oral Implants Res 2018;29(Suppl 16):224-40.
10. Yao CJ, Cao C, Bornstein MM, Mattheos N. Patient-reported outcome measures of edentulous patients restored with implant-supported removable and fixed prostheses: a systematic review. Clin Oral Implants Res 2018;29(Suppl 16):241-54.
11. Feine J, Abou-Ayash S, Al Mardini M, de Santana RB, Bjelke-Holtermann T, Bornstein MM, et al. Group 3 ITI Consensus Report: patient-reported outcome measures associated with implant dentistry. Clin Oral Implants Res 2018;29(Suppl 16):270-5.
12. Suarez-Feito JM, Sicilia A, Angulo J, Banerji S, Cuesta I, Millar B. Clinical performance of provisional screw-retained metal-free acrylic restorations in an immediate loading implant protocol: a 242 consecutive patient's report. Clin Oral Impl Res 2010;21:1360-9.
13. Gallucci GO, Bernard JP, Bertosa M, Belser UC. Immediate loading with fixed screw-retained provisional restorations in edentulous jaws: the pickup technique. Int J Oral Maxillofac Implants 2004;19:524-33.
14. Lewis RC, Harris BT, Sarno R, Morton D, Llop DR, Lin WS. Maxillary and mandibular immediately loaded implant-supported interim complete fixed dental prostheses on immediately placed dental implants with a digital approach: a clinical report. J Prosthet Dent 2015;114:315-22.
15. Chao D, Crockett R, Wu B, Shah K. Digital workflow for predictable immediate loading in the mandible by using a shape memory dental implant abutment system: a clinical report. J Prosthet Dent 2020;123:1-5.
16. Joda T, Zarone F, Ferrari M. The complete digital workflow in fixed prosthodontics: a systematic review. BMC Oral Health 2017;17:124.
17. Li J, Sommer C, Wang HL, Lepidi L, Joda T, Mendonca G. Creating a virtual patient for completely edentulous computer-aided implant surgery: a dental technique. J Prosthet Dent 2021;125:564-8.
18. Albayrak B, Sukotio C, Wee AG, Korkmaz I-H, Bayindir F. Three-dimensional accuracy of conventional versus digital complete arch implant impressions. J Prosthodont 2021;30:163-70.
19. Papaspyrudakos P, Vazouras K, Chen YW, Kotina E, Natto Z, Kang K, et al. Digital vs conventional implant impressions: a systematic review and meta-analysis. J Prosthodont 2020;29:660-78.
20. Wulfman C, Naveau A, Rignon-Bret C. Digital scanning for complete-arch implant-supported restorations: a systematic review. J Prosthet Dent 2020;124:161-7.
21. Ahlholm P, Sipilä K, Vallittu P, Jakonen M, Kotiranta U. Digital versus conventional impressions in fixed prosthodontics: a review. J Prosthodont 2018;27:35-41.
22. Tan MY, Yee SHX, Wong KM, Tan YH, Tan KBC. Comparison of three-dimensional accuracy of digital and conventional implant impressions: effect of interimplant distance in an edentulous arch. Int J Oral Maxillofac Implants 2019;34:366-80.
23. Flugge TV, Att W, Metzger MC, Nelson K. Precision of dental implant digitization using intraoral scanners. Int J Prosthodont 2016;29:277-83.
24. Alikhasi M, Alsharbaty MHM, Moharrami M. Digital implant impression technique accuracy: a systematic review. Implant Dent 2017;26:929-35.
25. Roig E, Roig M, Garza LC, Costa S, Maia P, Espona J. Fit of complete-arch implant-supported prostheses produced from an intraoral scan by using an auxiliary device and from an elastomeric impression: a pilot clinical trial. J Prosthet Dent 17 February 2021. doi: https://doi.org/10.1016/j.prosdent.2020.10.024. [Epub ahead of print.].
26. Iturrate M, Eguiraun H, Solaberrieta E. Accuracy of digital impression for implant-supported complete-arch prosthesis, using an auxiliary geometry part-An in vitro study. Clin Oral Implants Res 2019;30:1250-8.
27. Blasi A, Henarejos-Domingo V, Madeira S, Blasi G, Roig M. Stone verification device for verifying the definitive cast of an implant-supported restoration: A dental technique. J Prosthet Dent 24 February 2021. doi: https://doi.org/10.1016/j.prosdent.2021.01.005 [Epub ahead of print.]. In press.
28. Gomez-Polo M, Ballesteros J, Perales-Padilla P, Perales-Pulido P, Gomez-Polo C, Ortega R. Guided implant scanning: a procedure for improving the accuracy of implant-supported complete-arch fixed dental prostheses. J Prosthet Dent 2020;124:135-9.
29. Iturrate M, Minguez R, Pradies G, Solaberrieta E. Obtaining reliable intraoral digital scans for an implant-supported complete-arch prosthesis: a dental technique. J Prosthet Dent 2019;121:237-41.
30. Penarrocha-Oltra D, Agustin-Panadero R, Bagan L, Gimenez B, Penarrocha M. Impression of multiple implants using photogrammetry: description of technique and case presentation. Med Oral Patol Oral Cir Bucal 2014;19:e366-71.
31. Pradies G, Ferreiroa A, Ozcan M, Gimenez B, Martinez-Rus F. Using stereophotogrammetric technology for obtaining intraoral digital impressions of implants. J Am Dent Assoc 2014;145:338-44.
32. Corominas-Delgado C, Espona J, Lorente-Gascon M, Real-Voltas F, Roig M, Costa-Palau S. Digital implant impressions by cone-beam computerized tomography: a pilot study. Clin Oral Implants Res 2016;27:1407-13.
33. Att W, Chen YW, Papaspyridakos P. Registration of patient-relevant references in edentulous jaws using intraoral scanners: simplification of the clinical procedure. Int J Esthet Dent 2019;14:394-404.
34. Griseto NT, Gallucci GO. Digital maxillomandibular relationship registration for an edentulous maxilla: a dental technique. J Prosthet Dent 2021;125: 858-61.
35. Moura GF, Siqueira R, Meirelles L, Mask B, Wang HL, Mendonça G. Denture scanning technique for computer-guided implant-supported restoration treatment of edentulous patients. J Prosthet Dent 2021;125:726-31.
36. Ahmed WM, Verhaeghe TV, McCullagh APG. Maxillary complete-arch implant-supported restoration: a digital scanning and maxillomandibular relationship workflow. J Prosthet Dent 2021;125:216-20.
37. Espona J, Roig E, Ali A, Roig M. Immediately loaded interim complete-arch implant-supported fixed dental prostheses fabricated with a completely digital workflow: a clinical technique. J Prosthet Dent 2020;124: 423-7.
38. Title 10, Section 20.1003. Code of Federal Regulations (10 CFR 20.1003). Washington: United States Nuclear Regulatory Commission; 2021.

Corresponding author:
Dr Víctor Henarejos-Domingo
Department of Restorative Dentistry
Facultad de Odontología, International University of Catalunya
Carrer Josep Trueta, s/n Hospital Universitari General de Catalunya
Sant Cugat del Vallès 08195
SPAIN
Email: victor.henarejos@uic.es

Acknowledgments
The authors thank the team of Dentalesthetic, especially Mr Pedro Perales-Pulido and Mr Pablo Rodríguez Martínez, and the Department of Restorative Dentistry of the International University of Catalunya for their daily support and help.

https://doi.org/10.1016/j.prosdent.2021.09.011