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DENTAL TECHNIQUE

Reverse impression technique: A fully digital protocol for the fabrication of the definitive fixed prosthesis for completely edentulous patients

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ABSTRACT

In complete arch implant rehabilitation, one of the greatest difficulties still encountered in the digital workflow is the deviation of the implant position during intraoral scanner (IOS) data acquisition. As a result, the passivity of a definitive prosthesis fabricated using IOS data might be compromised. Thus, an implant position verification method is essential, either digitally or conventionally executed. A fully digital protocol for the fabrication of the definitive fixed prosthesis for completely edentulous patients, without the interference of any conventional step within the digital process, is presented. For the verification of the captured position of the scan-bodies, novel scan analogs were connected to the interim prosthesis extraorally and scanned. The virtual superimposition of the interim prosthesis intraorally with the same prosthesis extraorally served as a verification device for the position of the implants. (J Prosthet Dent 2023;■:■-■)

Conventional protocols for complete arch fixed implant-supported prostheses have been successfully used for decades, but the recent evolution of digital technology and intraoral scanners (IOSs) has simplified the procedure, reduced treatment time, and increased accuracy.[1-3] However, technology presents its own limitations. Interimplant distance, clinician experience, scanning path strategy, calibration of the IOS, surface characteristics, presence of blood or saliva, and ambient light may all affect the accuracy of IOS data acquisition.[4-8] This initial IOS discrepancy may adversely affect the passivity of the prosthesis.[9]

At present, 2 of the most commonly used digital methods for implant recording are intraoral scanning and photogrammetry.[9] Although IOSs can record the implant position, 3-dimensional (3D) deviations have been reported, and verification methods are still needed.[4,9] Photogrammetry may accurately capture the implant position but does not capture the surrounding anatomic structures, and an additional soft tissue digital scan or conventional impression is necessary.[10-12] The digital scan must include information on the soft tissues, adjacent tooth position and anatomy, as well as prosthetic parameters such as the vertical dimension and intermaxillary relationship.

Different conventional verification methods have been described, including a splinted open tray impression, a verification device for the definitive cast, and a computer-aided design and computer-aided manufacturing (CAD-CAM) prosthesis.[13-15] Therefore, the need for a fully digital workflow that does not entail complex conventional verification methods or high-cost digital devices is required. The use of the existing interim prosthesis seems to be a logical alternative for verifying the implant position digitally, as has been done for many years in the conventional way, by taking

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Figure 1. Clinical evaluation of 3D-printed dentures for esthetic and functional analysis. 3D, 3-dimensional.

advantage of the interim prosthesis to fabricate the definitive cast and obtain the exact position of the implants.

The purpose of this technique article was to provide a fully digital protocol for the fabrication of the definitive fixed prosthesis for completely edentulous patients.

TECHNIQUE

1. Fabricate and deliver a removable denture, conventionally or digitally, for the evaluation of all the parameters, esthetic and functional, if the existing one is not correct (Fig. 1). Scan the denture, digitally modify the intaglio surface by removing the buccal flange and palatal extension, and provide a flat intaglio surface. Make perforations digitally according to the emergence of the virtual abutments of the implant planification and fabricate the interim prosthesis (polymethyl methacrylate multiblank; anaxdent).

2. Place the implants fully guided by following the planification and using a surgical guide (Surgical Guide Resin; Formlabs). Connect screw-retained titanium interim abutments to each implant, widen the perforations of the prosthesis, if needed, and protect the surrounding soft tissue with dental dam (nic tone rubber dam; Expert Tech Solutions). Connect the prosthesis to the coronal part of the titanium abutments after transepithelial placement with a polymethyl methacrylate-based material (SR Ivocron; Ivoclar AG) if immediate loading is possible. If not immediately loaded, this step may be accomplished after osseointegration depending on the surgery (Figs. 2 and 3). To position the prosthesis accurately over the interim abutments, use a guide that has been designed and fabricated for this purpose. The fixation pins of the referred guide and the surgical guide share the same position, and the design restricts movement of the prosthesis. Design the repositioning guide of the prosthesis in the same open-source software program (Meshmixer; Autodesk, Inc) used to design the surgical guide. Then, 3D print the guide (Form 2; Formlabs) with a surgical resin (Surgical Guide Resin; Formlabs), postprocess, and sterilize for 30 minutes at 120 °C according to the manufacturer's guidelines. The borders of the guide should start from the level of the fixation pins (2 subnasal and 2 in the tuberosity area) over the crestal bone and should surround the whole structure of the prosthesis with which it is in contact via small extensions of the proper guide. The structure of the guide should not interfere with the path of insertion of the prosthesis over the interim abutments.

3. After the osseointegration phase, make an intraoral digital scan (TRIOS 3; 3Shape A/S) of the external surface of the interim prosthesis, of the antagonists, and of the occlusion. Recording the intermaxillary relationship of the interim restoration is essential to stabilize all the prosthetic parameters during the subsequent steps of the workflow. After removing the interim prosthesis and screwing the scan abutments over the transepithelial abutments, perform the definitive scan intraorally (Fig. 4).

4. Clean and air dry the interim prosthesis and screw the scan analogs (Scananalog; Dynamic Abutment Solutions) over the interim abutments. Obtain an additional extraoral scan of the prosthesis starting from the occlusal surface that can be more easily recognized by the IOS software program. After the acquisition of the external part of the prosthesis, capture the intaglio surface with the scan analogs (Fig. 5).

5. Remove the scan analogs from the interim prosthesis and replace it intraorally over the transepithelial abutments after removing the intraoral scan abutments.

6. In a CAD design software program (DentalCAD 3.0 Galway; exocad GmbH), superimpose the standard tessellation language (STL) files of the interim prosthesis intraorally and extraorally. From the scan analog, the software program can insert the scan abutment on top of it.

7. The dental laboratory technician takes as a reference the position of the implants obtained from the prosthesis and begins the design of the definitive prosthesis (DentalCAD 3.0 Galway; exocad GmbH).

8. After the design of the prosthesis, evaluate the passivity of the prosthesis with a resin prototype and the esthetic and functional parameters (Fig. 6).

9. If passivity is confirmed with the resin prototype, the dental laboratory technician can proceed with the fabrication of the definitive prosthesis.

10. At the next clinical appointment, remove the interim prosthesis and deliver the definitive prosthesis. Confirm the passivity with radiographs, tighten the prosthesis according to the manufacturer's recommendation, and seal the access holes with Teflon (Teflodent Nastro; Henry Schein) and composite resin (Micerium ENA HRi; Micerium S.p.A.) (Figs. 7 and 8).

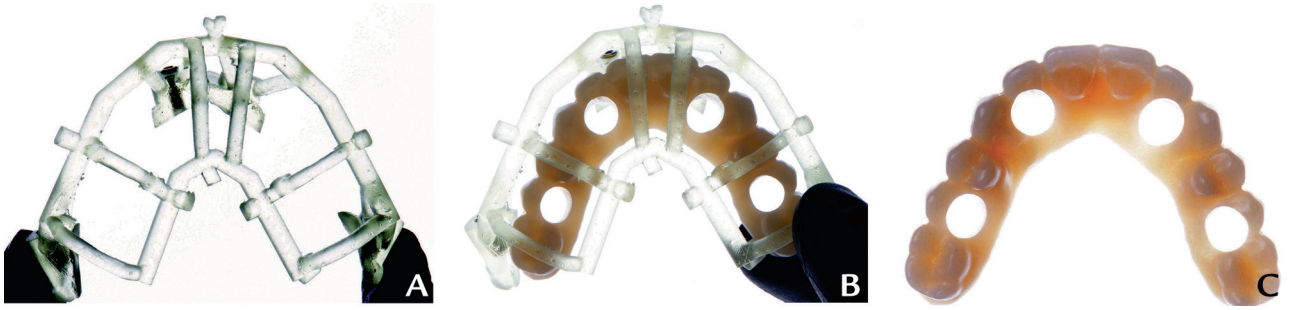

Figure 2. A, Guide to position interim prosthesis. B, Interim prosthesis placed inside guide. C, Interim prosthesis (milled duplicate of diagnostic dentures designed without flange) with access holes depending on implant plan.

Figure 3. Interim prosthesis after pickup of implants extraorally.

DISCUSSION

A step-by-step, fully digital protocol for the fabrication of a complete arch implant-supported prosthesis is described. Its novelty is that the verification method for the prosthesis passivity is fully digital and that no additional devices are required. This protocol can be used for patients where the interim prosthesis is fabricated intraorally by connecting the implant connection with the prosthesis. The technique is similar to the conventional method, where the interim prosthesis is removed from the patient's mouth and implant analogs are screwed from the intaglio surface of the prosthesis. A definitive cast is fabricated by pouring these analogs.[16] However, this conventional method is time-consuming, with errors that include the expansion of gypsum and also the possibility of movement of the implant analog during the procedure.

In complete arch implant rehabilitation, after the implant placement, a pick-up of the prosthesis is typically performed, accompanied by the relevant guide.[17] As a result, the prosthesis itself can be used to verify the implant position, as the implants were captured intraorally, ensuring passivity. Thus, an additional pick up verification device is not needed, as the multiunit prostheses are tightened at the correct torque with no loosening.

The present protocol is straightforward, provided analogs are available from the implant company. There is no need to fabricate a CAD-CAM device or a template with surfaces to perform a pickup,[18] a process that requires additional laboratory and clinical time. An advantage is that extraoral scanning is more straightforward and potentially more accurate than intraoral scanning, where ambient light and intraoral conditions can affect accuracy.[4,7] The missing link has been the availability of analogs that could be scanned. These scan analogs are made from a polymeric material that facilitates the scanning process.

Another advantage is the straightforward superimposition with the best fit algorithm in the CAD software program. This minimizes errors for cross mounting digitally because the 2 STL files, one of the prosthesis intraorally and the other extraorally, are identical.[19] This superimposition of the 2 virtual casts entails a precise correlation of the implant position, the vertical dimension of occlusion, and the position of the teeth,

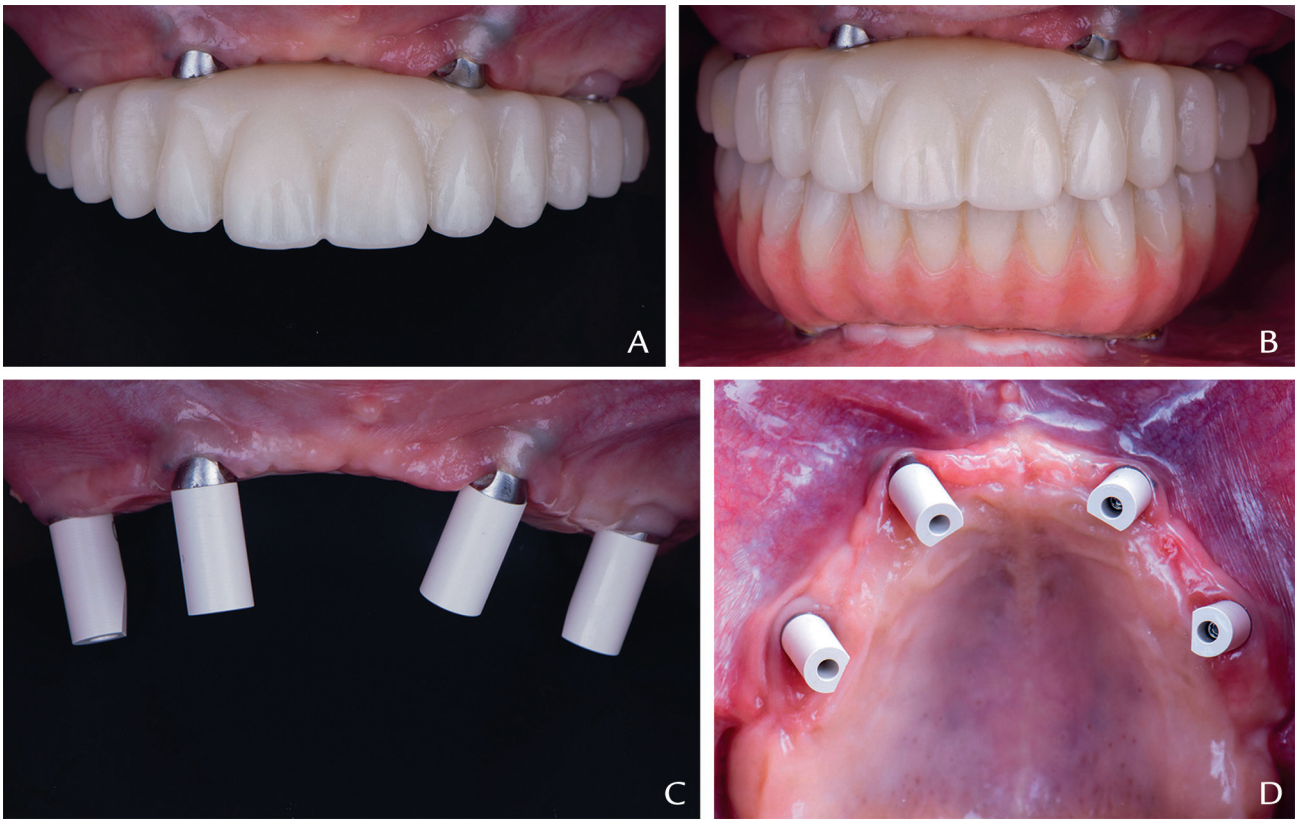

Figure 4. Steps of intraoral scanning workflow. A, Interim prosthesis for acquisition of external surface, placed intraorally. B, Occlusion with definitive mandibular prosthesis after scanning mandibular arch as separate step. C, D, Scan abutments placed intraorally in frontal and in occlusal view.

Figure 5. Interim prosthesis extraorally with scan analogs screwed to interim abutments and ready to be captured with intraoral scanner.

Figure 6. Resin prototype screwed intraorally before fabrication of definitive prosthesis to evaluate passivity of prosthesis over multiunit abutments.

making the design of the definitive prosthesis more predictable.

Limitations of this digital protocol include the lack of clinical studies and the flat morphology of the intaglio surface of the prosthesis, possibly leading to the inaccurate stitching of images, with a possible error on the definitive surface and consequently of the implant position. If misfit occurs because of the inaccuracy of the digital scan, the prototype should be sectioned and reconnected intraorally.

The present protocol uses an IOS system to scan the prosthesis with the scan analogs. This procedure could decrease accuracy, as the overall quality of the digitalized data depends on the specific system used and scanning completely edentulous patients has limitations.[1,20] The use of

Figure 7. Definitive prosthesis (monolithic, milled, stained zirconia) screwed intraorally with torque of 15 Ncm.

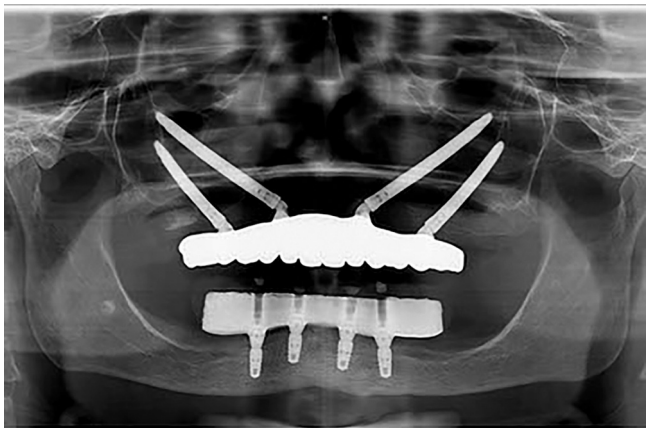

Figure 8. Postoperative panoramic radiograph.

an extraoral optical scanner may therefore show higher precision and eliminate any distortion from the IOS system.[21]

SUMMARY

The present article presents a step-by-step, digital workflow for complete arch fixed implant-supported prostheses. This protocol verifies the 3D implant position without the interference of an analog step, simplifying the prosthetic procedure for both clinician and dental laboratory technician.

REFERENCES

1. Papaspyridakos P, Vazouras K, Chen YW, et al. Digital vs conventional implant impressions: a systematic review and meta-analysis. *J Prosthodont*. 2020;29:660–678.
2. Tohme H, Lawand G, Chmielewska M, Makhzoume J. Comparison between stereophotogrammetric, digital, and conventional impression techniques in implant-supported fixed complete arch prostheses: an in vitro study. *J Prosthet Dent*. 2023;129:354–362.
3. Peñarrocha-Diago M, Balaguer-Martí JC, Peñarrocha-Oltra D, Balaguer-Martínez JF, Peñarrocha-Diago M, Agustín-Panadero R. A combined digital and stereophotogrammetric technique for rehabilitation with immediate loading of complete-arch, implant-supported prostheses: a randomized controlled pilot clinical trial. *J Prosthet Dent*. 2017;118:596–603.
4. Gómez-Polo M, Ortega R, Sallorenzo A, et al. Influence of the surface humidity, implant angulation, and interimplant distance on the accuracy and scanning time of complete-arch implant scans. *Dent J (Basel)*. 2022;127:104307.
5. Mizumoto RM, Yilmaz B, McGlumphy Jr EA, Seidt J, Johnston WM. Accuracy of different digital scanning techniques and scan bodies for complete-arch implant-supported prostheses. *J Prosthet Dent*. 2020;123:96–104.
6. Di Fiore A, Meneghello R, Graiff L, et al. Full arch digital scanning systems performances for implant-supported fixed dental prostheses: a comparative study of 8 intraoral scanners. *J Prosthodont Res*. 2019;63:396–403.
7. Wesemann C, Kienbaum H, Thun M, Spies BC, Beuer F, Bumann A. Does ambient light affect the accuracy and scanning time of intraoral scans? *J Prosthet Dent*. 2021;125:924–931.
8. Li H, Lyu P, Wang Y, Sun Y. Influence of object translucency on the scanning accuracy of a powder-free intraoral scanner: a laboratory study. *J Prosthet Dent*. 2017;117:93–101.
9. Revilla-León M, Att W, Özcan M, Rubenstein J. Comparison of conventional, photogrammetry, and intraoral scanning accuracy of complete-arch implant impression procedures evaluated with a coordinate measuring machine. *J Prosthet Dent*. 2021;125:470–478.
10. Amin S, Weber HP, Finkelman M, El Rafie K, Kudara Y, Papaspyridakos P. Digital vs. conventional full-arch implant impressions: a comparative study. *Clin Oral Implants Res*. 2017;28:1360–1367.
11. Hussein MO. Photogrammetry technology in implant dentistry: a systematic review. *J Prosthet Dent*. 2021. https://doi.org/10.1016/j.prosdent.2021.09.015 [Epub ahead of print.].
12. Sallorenzo A, Gómez-Polo M. Comparative study of the accuracy of an implant intraoral scanner and that of a conventional intraoral scanner for complete-arch fixed dental prostheses. *J Prosthet Dent*. 2021;128:1009–1016.
13. Jorge E, Funkenbusch PD, Ercoli C, Moss ME, Graser GN, Tallents RH. Verification jig for implant-supported prostheses: a comparison of standard impressions with verification jigs made of different materials. *J Prosthet Dent*. 2002;88:329–336.
14. Su FY, Tsai JC, Morton D, Lin WS. Use of intraoral scan for implant-supported dental prosthesis to design and fabricate a CAD-CAM verification device: a dental technique. *J Prosthet Dent*. 2021;125:204–207.
15. 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*. 2022;128:858–863.
16. Balshi TJ, Wolfinger GJ, Alfano SG, Cacovean JN, Balshi SF. Fabricating an accurate implant master cast: a technique report. *J Prosthodont*. 2015;24:654–660.
17. Papaspyridakos P, De Souza A, Bathija A, Kang K, Chochlidakis K. Complete digital workflow for mandibular full-arch implant rehabilitation in 3 appointments. *J Prosthodont*. 2021;30:548–552.
18. 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;124:423–427.
19. Revilla-León M, Sicilia E, Agustín-Panadero R, Gómez-Polo M, Kois JC. Clinical evaluation of the effects of cutting off, overlapping, and rescanning procedures on intraoral scanning accuracy. *J Prosthet Dent*. 5 January 2022. https://doi.org/10.1016/j.prosdent.2021.10.017 [Epub ahead of print.]
20. Lyu M, Di P, Lin Y, Jiang X. Accuracy of impressions for multiple implants: a comparative study of digital and conventional techniques. *J Prosthet Dent*. 2022;128:1017–1023.
21. Lee SJ, Kim SW, Lee JJ, Cheong CW. Comparison of intraoral and extraoral digital scanners: evaluation of surface topography and precision. *Dent J (Basel)*. 2020;8:52.

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