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Digital Workflow for Full-Arch Immediate Implant Placement Using a Stackable Surgical Guide Fabricated Using SLM Technology

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Keywords
Bone reduction; computer-guided implant surgery; digital workflows; full-arch fixed implant-supported prostheses; full-arch immediate loading; immediate interim fixed complete arch prostheses.

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Accepted April 29, 2021

doi: 10.1111/jopr.13375

Abstract

The failing dentition of partially edentulous individuals may be used as an initial reference for stackable restrictive surgical guides during full-arch immediate implant placement. The stackable guide option derived from a digital workflow increases the predictability of the performance of bone reduction, immediate implant placement, and immediate loading of provisional implant-supported fixed dental prostheses. The present paper aims to report a practical approach to design and produce a metal framework with occlusal rests to facilitate the use of a tooth-supported surgical guide when full-arch immediate implant placement is indicated in patients with failing dentition.

Surgical guides are easily adaptable to various clinical scenarios when they are tooth-supported. Natural dentition and existing fixed dental prostheses (FDPs) provide support and stability to the guide during implant insertion. The intraoral optimal fit of tooth-supported guides is a crucial component for designing (computer-aided design [CAD]) and fabricating guides (computer-aiding manufacturing [CAM]). However, scanning and manufacturing errors may introduce inaccuracies to the planned implant position.

In severe periodontally compromised dentition cases, natural teeth mobility precludes obtaining an acceptable passive fit of surgical guides. Direct splinting of the mobile teeth before data

Figure 1 Periodontal splint in the palatal aspect of mobile teeth in maxillary anterior and maxillary right sextants.

collection could avoid instability of surgical guides during implant placement.[1] A strategy to reduce the deviation between the virtual planning and the actual position of the inserted implants is to support the guides selectively by specific points (small surfaces) instead of broad surfaces.[2]

Although resin surgical guides are more easily adapted to the arches when minimal misfits are present when compared with metal guides, the stability that the latter offers is superior to the former.[2,3] Additionally, the thinner struts of a lattice-type metal framework for surgical guides provide more visibility and operative space when compared to resin guides.[3] Thus, instead of photopolymerizing resin, a cobalt-chromium alloy (Co-Cr) framework could minimize the contact with the teeth surface and provide multi-angle observation of the adaptation.[3]

This clinical report describes the digital workflow involved in the fabrication of a strut-based lattice structure specifically designed for failing dentition when immediate full-arch rehabilitation is planned.

Clinical report

A healthy nonsmoker 50-year-old female patient with failing maxillary dentition who was diagnosed as having stage IV, grade C periodontal disease according to the 2017 World Workshop classification,[4,5] was treatment planned to receive an implant-supported fixed complete denture (ISFCD) with immediate implant placement. Therefore, bone reduction (to create prosthetic space and hide the prosthetic–soft tissue transition line) and immediate placement and loading were planned simultaneously. Digital planning was performed as follows.

A periodontal splint was created on the lingual aspect of the mobile teeth; isolated teeth remained unsplinted (Fig 1). Both arches were scanned, and maxillomandibular records were obtained with an intraoral scanner (TRIOS, 3Shape; Copenhagen, Denmark). A cone-beam computed tomography (CBCT) scan of the patient (NewTom VGi, Quantitative Radiology; Verona, Italy) was taken to obtain a digital imaging and communications in medicine (DICOM) file.

Both the DICOM and standard tessellation language (STL) datasets were imported and superimposed into an implant planning software program (6D Dental Planning Software, 6D Dental Tech Co., Hangzhou, China) to design the surgical guide. A tooth-supported template was created in the dental planning software (Fig 2A). The designs were exported in STL format as file A. All the dental implants planned were Straumann BLT (Institut Straumann AG; Basel, Switzerland) size 4.1 mm × 10 mm for sites #16 and 26, and 3.3 mm × 12 mm for sites #12, 14, 22, and 24.

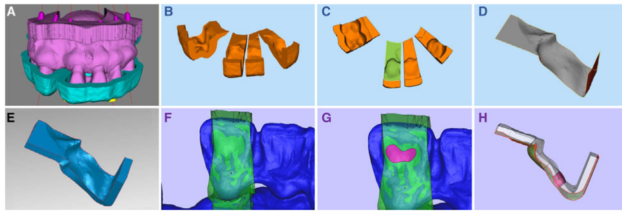

Figure 2 Digital workflow for designing the tooth-supported metallic framework surgical guide (Generation of files A, B, C, and D).

Design of occlusal rests

File A was transferred into the STL editor software Materialise Magics v20.03 (Materialise Co.; Leuven, Belgium). This software facilitates data preparation; however, it is not capable of creating 3D models. The gingival area was eliminated from the buccal side. The proximal area was subtracted from the tooth-supported surgical guide in the supporting teeth (Fig 2B). One of the supporting teeth was selected, the intaglio surface was extracted (Fig 2C), and it was exported in STL format as file B. File B was transferred into 3D reverse engineering software for producing and examining digital models of physical objects (Geomagic Studio 2012 software, 3D Systems; Morrisville, NC) (Fig 2D). In brief, this software provides workflows for creating manufacturing-ready 3D models. To create file C, a 1.5-mm thickness of B was created by duplicating and offsetting a mesh in one direction, resulting in a polygon object with volume (Fig 2E). The intraoral scanning (IOS) data were transferred into Materialise Magics (Fig 2F). One spot was extracted on four to six supporting teeth from the shared intaglio surface of file C with IOS (Fig 2G). For instance, an attrition facet with an area of about 4 mm^2 was considered applicable. To create file D, the remaining area was removed except for the spot with the shared surface (Fig 2H). File C was transferred into Materialise Magics, and the cameo surface was extracted as file E (Fig 3A). File E was transferred into Geomagic Studio. To generate file F, a mesh was duplicated and offset in a reverse direction of file E, resulting in a 1.2-mm-thick polygonal object (Fig 3B). File D and file F were merged into Materialise Magics software to create file G (Fig 3C). The fitness of the contact spot with the tooth surface was evaluated (Fig 3D).

Design of the supporting structure in Geomagic Studio

A framework with a width of 1.5 mm was generated to connect all the occlusal rests (Fig 4A). The bottom surface matched the top surface of the anchor guide (Fig 4B). An STL file format from the CAD surgical guide was joined with the STL files of the stackable surgical guides (Fig 4C) for selective laser melting (SLM) (laser power 200 W, scanning speed 600−675

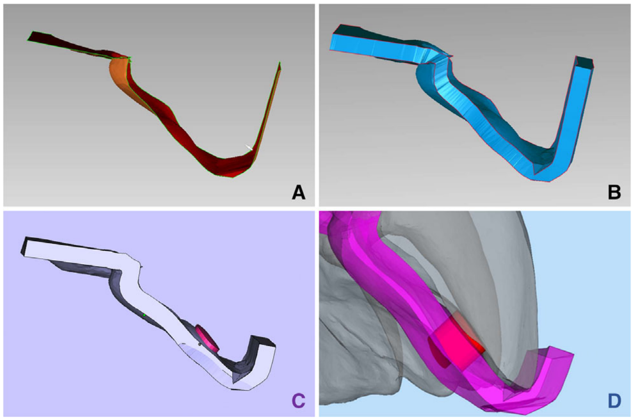

Figure 3 Design of the tooth contacts with the intaglio surface of the rests of the surgical guide (creation of files E, F, and G).

mm/s, scanning spot 30 μm using Sisma Additive Manufacturing, SISMA S.p.A.; Vicenza, Italy). Co-Cr alloy powder (DPR M-01Materials; DPR Materials, Beijing, China) was used to fabricate the surgical guide framework.

Placement of Co-Cr alloy surgical guide

The fit of the occlusal rests must be assessed intraorally before surgery. Starting with a crevicular incision, a mucoperiosteal flap was raised, the tooth-supported guide was inserted (Fig 5A), the fixation guide was anchored and bone reduction followed to obtain a minimum of 15mm height of prosthetic space for a monolithic zirconia ISFCD (bone reduction ranged between 2 and 4 mm depending on the site) (Figs 5B, 5C), the implant guide was fitted according to the assembly pins (Fig 5D), and the implant-guided surgery was continued (Fig 5E). Next, the screw-retained abutments were inserted (Fig 5F), the milled multilayered polymethylmethacrylate (PMMA) teeth component (PREMIOtemp, Primotec; Norwalk, CT) of the provisional maxillary ISFCD was joined to the abutments (Fig 5G), and the maxillary arch was restored with the finalized provisional ISFCD (Fig 5H). The final prosthesis is planned to be a screw-retained ISFCD made of milled monolithic zirconia.

In the present technical report, the angular, global, depth, buccolingual, and mesiodistal deviations between the virtually planned and actual implant positions were measured (Fig 6A, 6B; Table S1).

Discussion

Tooth-supported surgical guides offer a unique feature by reproducing landmarks given by the teeth for consistent support, stability, and retention.[6] The superior accuracy of implants placed through tooth-supported guides has been proven in bench-top, cadaver, and clinical studies[7–10] However, there is little information about the error that could be introduced from guided surgery aided by tooth-supported surgical guides. Nevertheless, the authors inductively assume that these inaccuracies are potentially attributed to a misfit of supported surgical guides and that the adaptation of guides could be more complex in clinical scenarios with severely periodontally compromised or failing dentition, especially when tooth micro-movement occurs.

This report described a digital workflow of immediate implant placement for ISFCD, which included a periodontal splint and an open guide with occlusal rests providing more visibility than the commonly used surgical guides. These particular features aimed to stabilize the supporting teeth and improve the guide adaptation. As shown in the literature, surgical guides that rest selectively on specific points (small surfaces) instead of larger areas (broad surfaces) present better stability[11] and lower adaptation errors compared to guides that rest indiscriminately on the entire surface of the supporting teeth.[12–14] The accuracy of this single case (Fig 6A, 6B; Table S1) was within the range that has been reported for tooth-borne surgical guides with nonmobile dentition.[9,10]

Fracture of surgical guides rarely occurs, but it causes severe intraoperative complications during surgery when it happens. From this perspective, metal frameworks offer higher strength and more operative space, in addition to the ability to do multi-angle observation, facilitating deviation identification. Although lost-wax casting, milling, and printing produce Co-Cr restorations with similar laboratory costs, in vitro studies have proved that SLM exhibits better microstructures and mechanical properties than those fabricated with milling or conventional casting.[15–19]

To utilize the described technique successfully, several considerations should be contemplated:

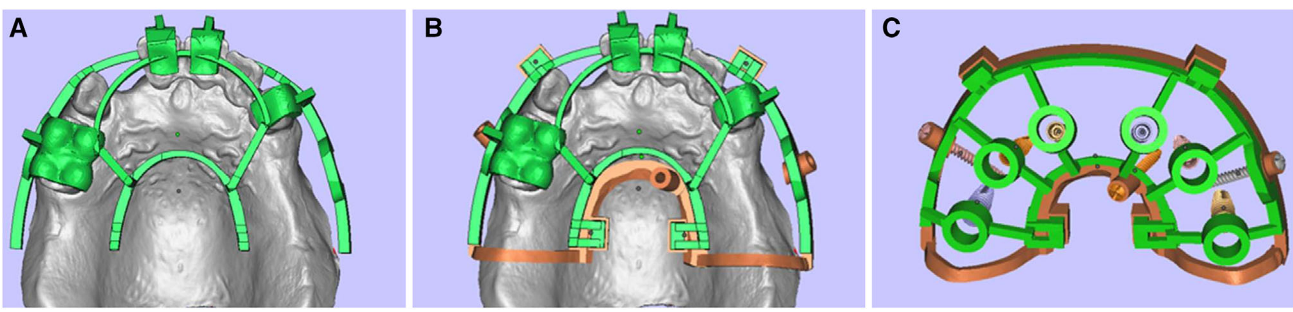

Figure 4 Stackable guide design, tooth-supported framework on anchor guide.

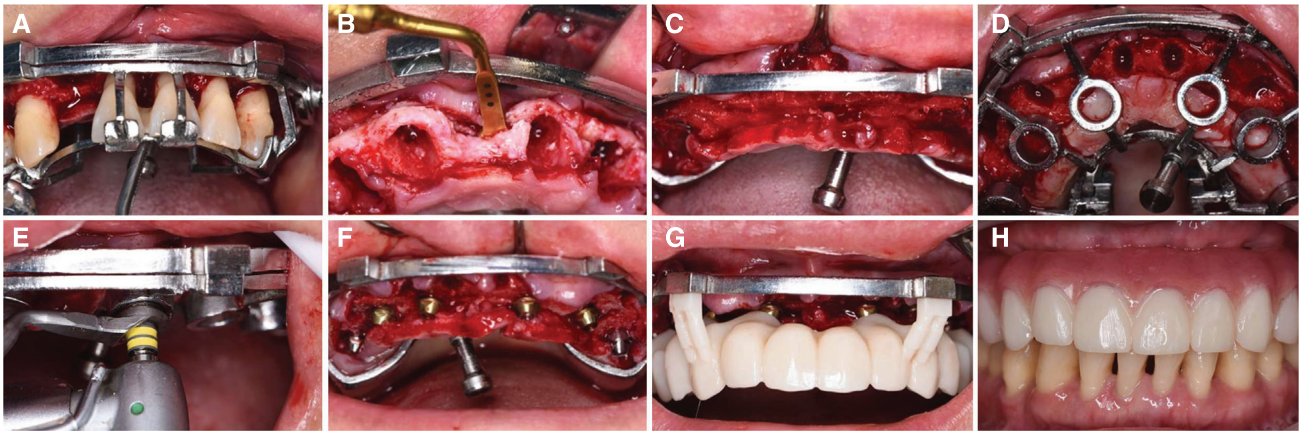

Figure 5 Surgical implant stage and provisional maxillary complete implant-supported fixed dental prostheses delivery. A, Tooth-supported guide with anchor guide. B, Bone reduction. C, Anchor guide by itself. D, Implant guide on anchor guide. E, Osteotomy/implant drilling. F, Prosthetic abutments. G, Poly(methylmethacrylate) dentition placed with anchor guide. H, Provisional prosthesis in the oral cavity.

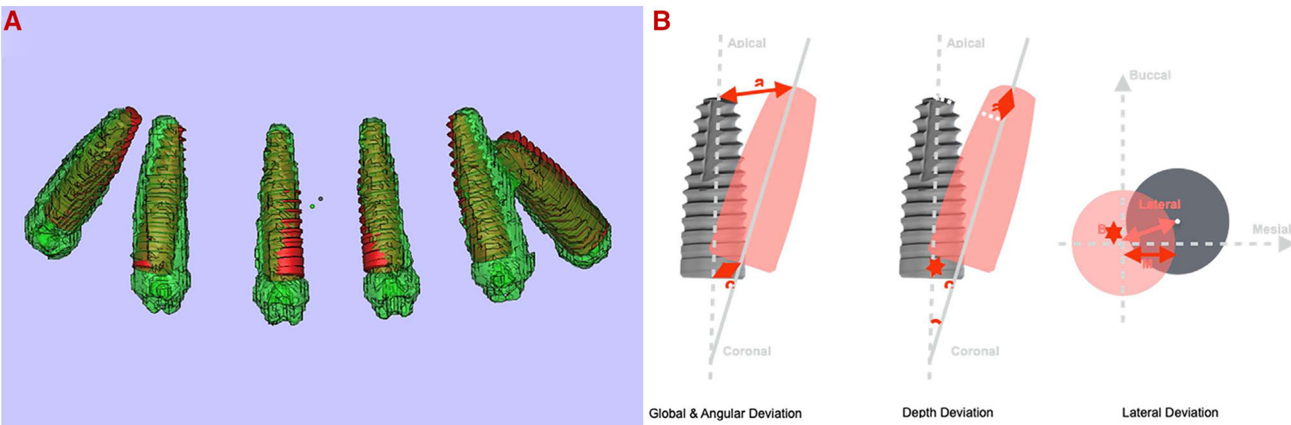

Figure 6 Postoperative evaluation. A, Postoperative implant position superimposed onto the preoperatively planned position using Geomagic Studio. B, Measurement of deviation between planned and placed implants.

1. Disease control measures should be implemented, including scaling and root planing, oral hygiene instruction, and smoking cessation. Re-evaluation after disease elimination or reduction provides more accurate data about the periodontal status of the remaining teeth, including the degree of mobility. It is important to note that hopeless teeth without infection in cases where ISFCD is planned should not be extracted, as these can support surgical guides.
2. A minimum of three teeth with anteroposterior (A-P) spread up to four units are needed to prevent the framework from tilting.
3. If a conventional impression were taken, it would result in tooth displacement. Consequently, IOS is recommended, as it is a useful tool for reproducing the severely mobile and/or misaligned dentition positions without displacement.[20]
4. The fit should be checked on a printed model with high surface quality before surgery to exclude errors in the fabrication process.[21]

The overall treatment planning, including periodontal, surgical,[22] and prosthodontic therapy,[23–25] in addition to quality control throughout the manufacturing process,[26] contributes to the success of the treatment. The patient was satisfied with the titanium-reinforced PMMA provisional full-arch ISFDP due to improved function and aesthetics (Fig 5H). Further research is expected to evaluate the repeatability and the accuracy of this clinical technique in multicenter studies.

As per the clinical procedure's limitations, the cost of producing an SLM Co-Cr appliance is still higher than milling Co-Cr, and printing or milling a resin one. It is expected that the cost of SLM will gradually decrease.

Conclusions

This article introduced and described a step-by-step digital workflow of a clinical technique to design and manufacture a metal framework with occlusal rests to facilitate tooth-supported surgical guides for full-arch immediate implant placement when the remaining supporting failing dentition are mobile. The similarities between the obtained and planned implant positions of our single case were encouraging. Investigations may further validate the benefits of this strategy.

Acknowledgements

The last author (K.I.A.) expresses his sincere gratitude to The American Academy of Esthetic Dentistry (AAED) and The American Academy of Implant Dentistry Foundation (AAIDF) for their financial support.

Funding

This study was supported by a grant from the Foundation of Peking University School and Hospital of Stomatology (KUSSNT-19B11), Peking University Health Science Center Youth Science and Technology Innovation Cultivation Fund (BMU2021PYB017).

Conflict of interest statement

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Calculated differences between planned and placed implants in terms of global, angular, depth, and lateral deviations