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DENTAL TECHNIQUE

A fully digital workflow for prosthetically driven alveolar augmentation with intraoral bone block and implant rehabilitation in an atrophic anterior maxilla

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ABSTRACT

A fully digital workflow for prosthetically driven alveolar augmentation and implant rehabilitation in the esthetic zone was planned and executed by using a bone harvest guide, trim guide, graft guide, and implant guide. A controllable procedure and predictable results can be realized by adopting this digital workflow. (J Prosthet Dent 2023;130:668-73)

Tooth loss is often accompanied by a bone defect, and bone augmentation is usually necessary, especially in the anterior maxilla.[1] Because of the osteogenic, osteoinductive, and osteoconductive properties of autogenous bone graft (ABG), its use has been recommended for the management of Benic and Hämmerle Class 4 and Class 5 bone defects.[2,3]

The use of digital technology for prosthetically driven dental implantation and tissue defect reconstruction has been an exciting advance in implant dentistry.[1,4] However, unlike Ti-mesh,[5] which is straightforward to shape, augmentation with ABG with a digital workflow remains challenging. Augmentation with ABG involves 3 processes: bone harvesting, trimming, and placement. Osman and Atef[6] and De Stavola et al[7] have reported the use of osteotomy guides to control the volume of the bone retrieved and reduce complications during ABG harvesting. However, a 1-piece design containing both the tooth locating and osteotomy components is vulnerable to seating tract limitations and can lead to unstable seating of the guide and prevent its precise positioning. Furthermore, the authors are unaware of reports on digital bone block trimming and the digital fabrication of graft guides.

The present article introduces a step-by-step, fully digital workflow for the precise, controllable, and predictable planning and execution of prosthetically driven alveolar augmentation with ABG and implant rehabilitation in the esthetic zone.

TECHNIQUE

The technique is described for a 25-year-old man who sought replacement of his missing maxillary left canine with an implant-supported restoration (Fig. 1). The region had severe alveolar atrophy, and the defect was categorized as Class 4 according to Benic and Hämmerle.[2] The procedure received approval from the ethics committee, and the patient provided informed consent.

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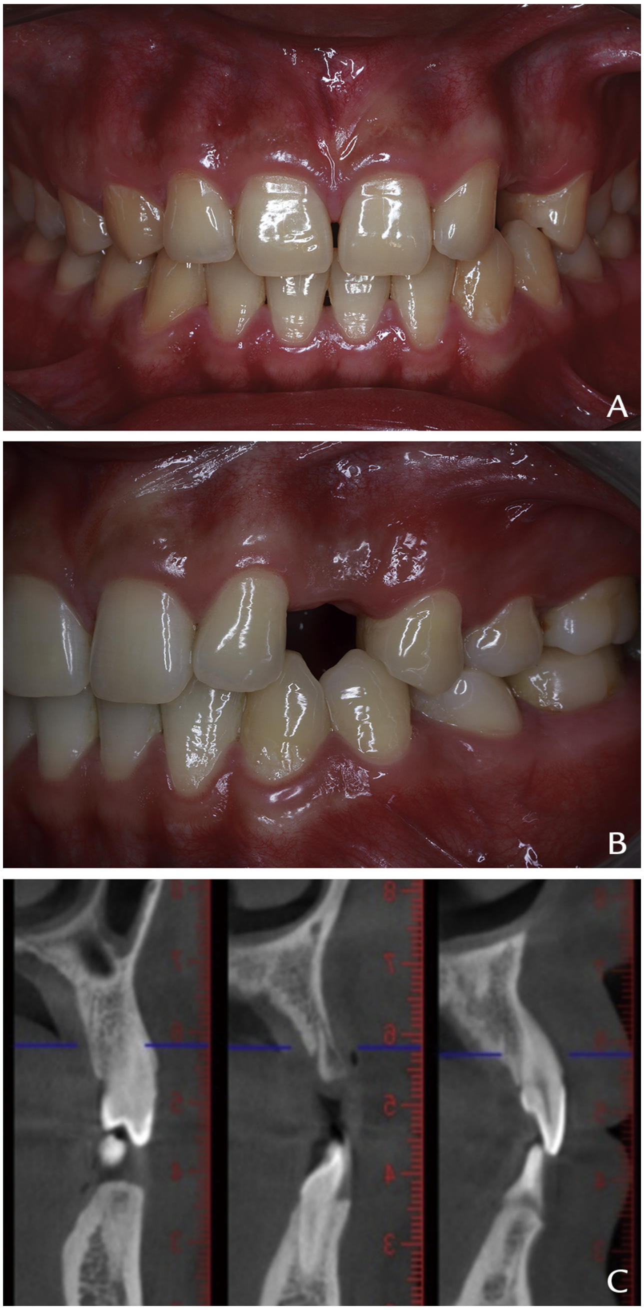

Figure 1. Pretreatment examination. A, Frontal view. B, Lateral view. C, Severe horizontal bone defect revealed on cone beam computed tomography.

The specific process is as follows:

1. Scan the mounted diagnostic casts (LS 3 Scanner; KaVo), and import the data into a dental software program (Dental System; 3Shape A/S) to design the definitive prosthesis. Import the Digital Imaging and Communications in Medicine (DICOM) data from the cone beam computed tomography (CBCT) scan into a 3-dimensional medical image processing software program (Mimics Medical 20.0; Materialise) to reconstruct the jaw and transfer it into a standard tessellation language (STL) format. Combine the dentition with the definitive prosthesis, and superimpose them onto the jaw in a reverse engineering software program (Geomagic Studio 2015; 3D Systems) by using the corresponding tooth surface features for registration. Next, position the definitive implant as instructed by the designed prosthesis (Fig. 2A, 2B). Design the target bone graft to achieve 2-mm buccal bone thickness and bone contour reconstruction at the specified implant site (Fig. 2C, 2D).
2. Position the graft fixation screw, and choose several adjacent teeth to act as a shell to generate the graft guide (Fig. 3A). Map out the safe donor area 3 mm away from critical anatomic structures. Move the joint target graft and the graft fixation screw to a safe area and position them such that the graft's outer contour is approximately the same as that of the safe area and ensure that sufficient bone volume can be obtained (Fig. 3B). Draw 4 bounded osteotomy planes based on the target graft, taking the thickness loss of the osteotomy instruments into account. Based on the 4 osteotomy planes, generate a frame that fits the jaw surface and drill 2 screw holes in it to complete the osteotomy template design (Fig. 3C). Generate several drilling rings in the same direction as the required entry paths of the graft fixation screw and template retaining screws. Design a shell that fits the adjacent tooth surfaces, and connect it to the drilling rings to generate a tooth-supported shell (Fig. 3D). The osteotomy template and tooth-supported shell will then form the harvest guide.
3. Position the virtual cut bone block at the recipient site (Fig. 3E). Evaluate the position and amount of the block fitting surface that needs to be trimmed by using Boolean operators and generate the trim guide (Fig. 3F). All designs are constructed in 3D image–based engineering and reverse engineering software programs (Mimics Medical 20.0 and Geomagic Studio 2015) to process 3-dimensional medical images and generate the guide, respectively. Print the osteotomy template with a cobalt-chromium alloy by using a 3D printer (Mlab; Concept Laser) to ensure strength. Print the other guides with photopolymer resin by using a 3D printer (Objet500 Connex3; Stratasys).
4. Conduct a preoperative clinical evaluation of the tooth-supported shell and graft guide, and ensure that they are fully seated (Fig. 4A, 4B). Make an incision based on the range of the shell drilling rings at the donor site, and drill holes in the bone through the drilling rings by using a No. 701 dental fissure bur (Fig. 4C). Next, detach the shell and position the

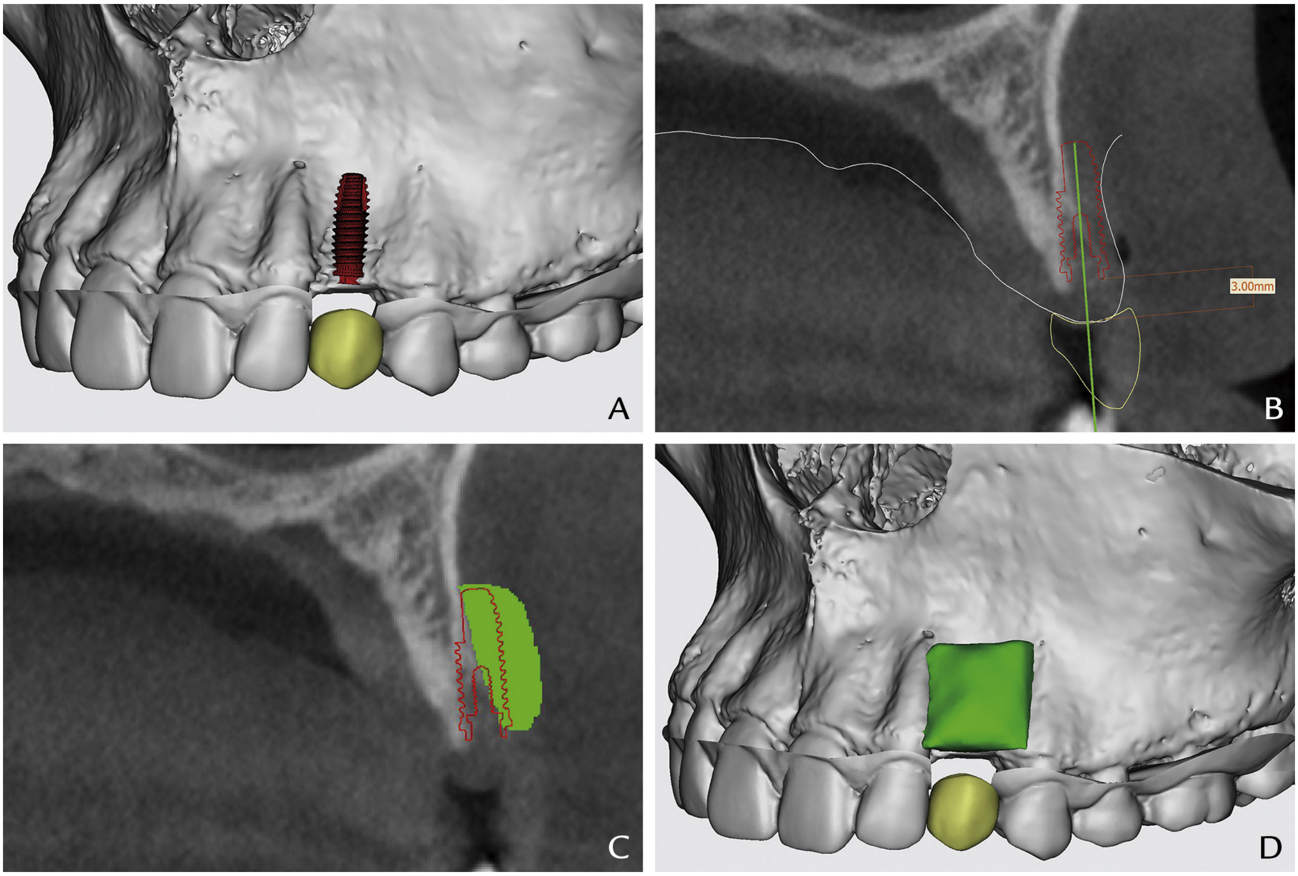

Figure 2. Design of definitive prosthesis, implant, and graft. A, Dentition scan model superimposed onto 3-dimensional reconstructed maxilla. Definitive prosthesis (*yellow*) and definitive implant (*red*) planned. B, Planned prosthesis (*yellow*) and implant (*red*) on cone beam computed tomography. C, Virtual plan of bone block graft (*green*). D, Virtual plan of bone block graft (*green*).

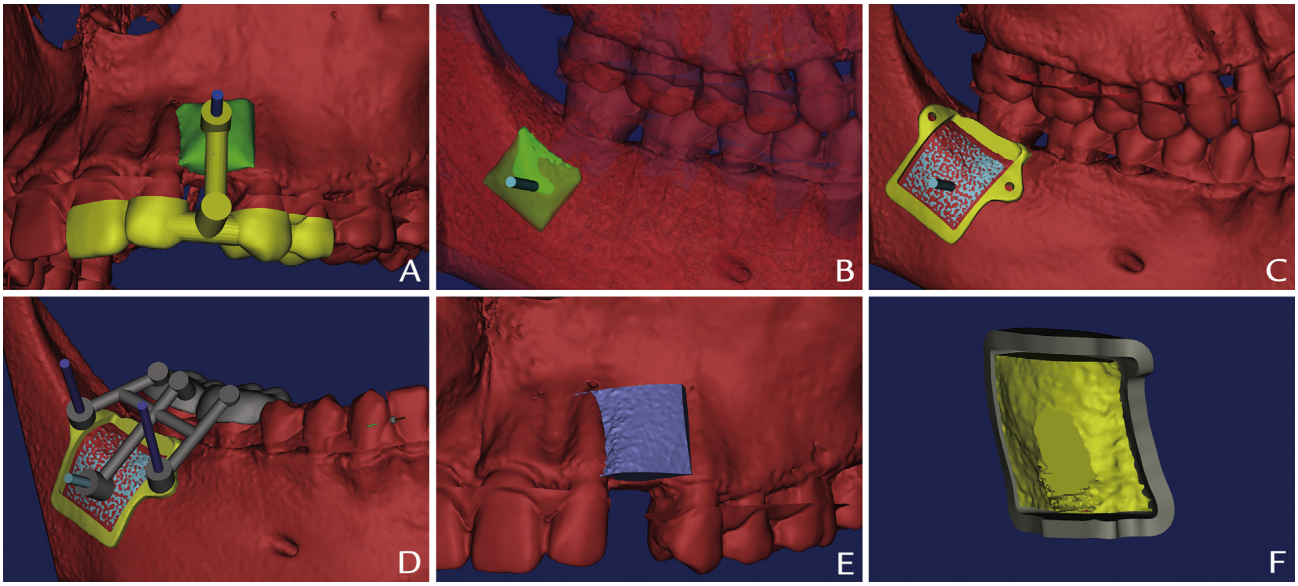

Figure 3. Design of bone harvesting guide, trim guide, and graft guide. A, Designed bone graft guide (*yellow*) and direction of graft fixation screw (*blue*). B, Target graft (*green*) and direction of graft fixation screw (*blue*) at donor site. C, Designed osteotomy template (*yellow*) with screw holes. D, Tooth-supported shell (*gray*). Blue and purple cylinders indicate direction of graft fixation and template retaining screws, respectively. E, Virtual cut bone block (*purple*) placed at corresponding location at recipient site. F, Designed bone trim guide (*gray*) and virtual trimmed block (*yellow*).

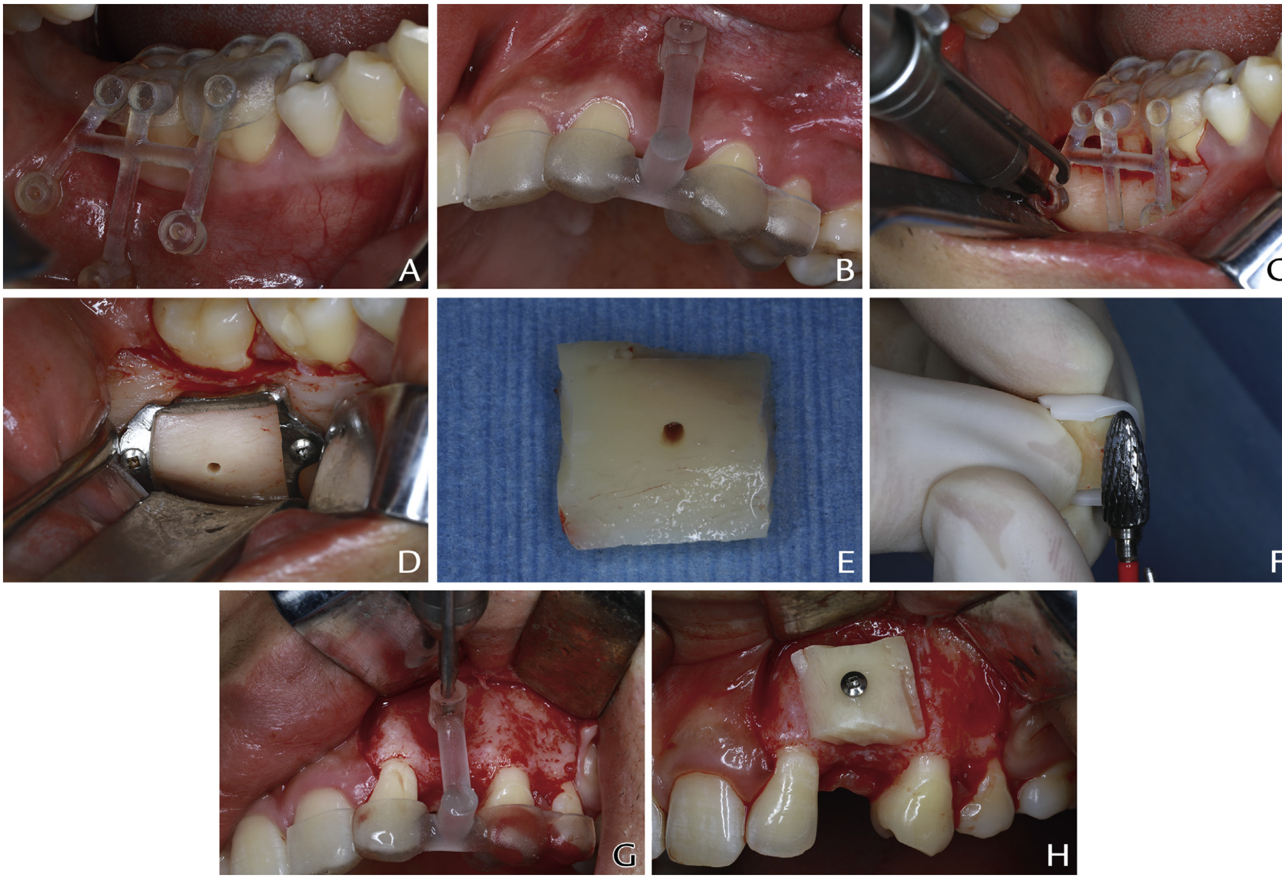

Figure 4. Bone graft surgery. A, Completed tooth-supported shell placed on corresponding teeth before surgery. B, Completed bone graft guide placed on corresponding teeth before surgery. C, With tooth-supported shell in place, holes drilled in jaw with guidance of drilling rings. D, Osteotomy template fixed with 2 screws according to predrilled holes. E, Harvested bone block. F, Trimming of harvested bone block placed in trim guide. G, Graft guide positioned to complete drilling process. H, Trimmed graft fixed to recipient site with screw.

osteotomy template by aligning its screw holes with the predrilled holes. Fix the template with screws, and ensure it closely fits the donor surface (Fig. 4D). Make osteotomy cuts by inserting the flat side of the piezoelectric device (Piezosurgery; Mectron Medical Technology) along the internal face of the template to the defined depth. Subsequently, remove the block with forceps and trim it with the trim guide (Fig. 4E, 4F). Expose the recipient site, and position the graft guide over the corresponding tooth to complete drilling (Fig. 4G). Use a screw to directly fix the trimmed graft to the recipient site along the completed holes on the graft and recipient site (Fig. 4H). Finally, suture the surgical site.

5. After 6 months, make a CBCT scan and reconstruct the healed jaw. Superimpose the initially designed implant onto the healed jaw. Following confirmation of sufficient bone around the planned implant site, make the implant guide based on the initially designed implant information. Remove the graft fixation screw by positioning it with the graft guide, and place the implant with the implant guide (Fig. 5A). After placing the scan body, obtain the position of the implant by using an intraoral scanner (TRIOS; 3Shape A/S). Superimpose the initially designed prosthesis onto the intraoral scan model, and adjust the emergence profile of the prosthesis into a shallow concave shape based on the soft tissue information in a dental software program (Dental System; 3Shape A/S). Finally, digitally mill the polymethyl methacrylate (PMMA) disk with a 5-axis milling machine to finish the screw-retained interim prosthesis (Fig. 5B).

DISCUSSION

The positioning and stabilization of a surgical guide are key factors in achieving high accuracy, and imprecise graft adaptation may affect graft integration, eventually leading to its loss.[8,9] Although ABG with staged implant placement has been the most reliable option for augmentation of severe atrophic alveolar bone,[1-3] its

Figure 5. Dental implant and restoration. A, Implant placed with implant guide. B, Screw-retained resin interim restoration being inserted.

limitations include difficulty in controlling bone block trimming and high technique sensitivity.[10]

To obtain a graft requiring minimal trimming for good contour, the graft design presented was prosthetically driven, and a site with a contour generally consistent with that of the target graft was identified as the harvest site. With this procedure, only the trim guide is needed to grind the intaglio fit surface of the graft, which simplifies the operative procedures, requires less surgical experience, and possibly reduces the block ischemia time. Hence, the graft can be directly fixed with the graft guide.

The bone harvesting guide was constructed with a split design, which may use more characteristic crown information, thereby enabling precise positioning and improved adaptation of the osteotomy template. A preoperative trial can be made of the tooth-positioning portion of the guide. Furthermore, the osteotomy guide is printed from metal and fixed with screws, thereby reducing the size of the surgical flap via the reduced guide volume, making the procedure more straightforward.[11]

Limitations of this technique include that it can only be implemented when the recipient site has a relatively regular shape and the donor site can provide sufficient bone volume. Furthermore, the design and production of the guide plates may increase planning time and cost.

For the present patient, the jaw was reconstructed immediately after ABG surgery from a CBCT scan and superimposed onto the preoperative jaw via unaltered

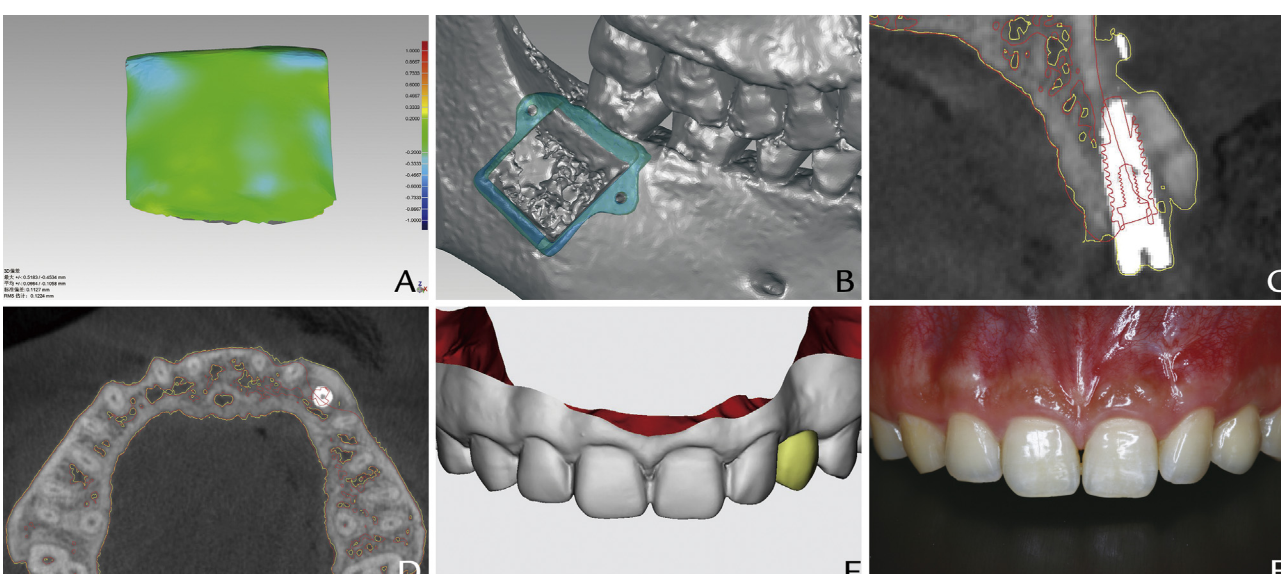

Figure 6. Evaluation and outcomes. A, Three-dimensional, color-coded mapping of differences between selected outer contours of planned and actual grafts. Different colors represent number of deviation ranges (green region represents deviation within ±0.2 mm). B, Designed osteotomy template is superimposed onto postoperative jaw. C, Postoperative cone beam computed tomography (*red*: preoperative jaw and initially designed implant; *yellow*: outline of maxilla 6 months after bone graft surgery). D, Cross-sectional view of postoperative cone beam computed tomography (*red*: preoperative jaw and initially designed implant; *yellow*: outline of maxilla 6 months after bone graft surgery). E, Original restoration design before bone graft surgery. F, Completed interim restoration, nearly identical to initial restoration design.

surface features for registration. The 2 models were subsequently trimmed, and only the outer contours of the planned and actual grafts were selected for further deviation analysis (Fig. 6A). The root mean square estimate (RMSE) was 0.12 mm. The graft-to-recipient site contact ratio was 81%. The maximum RMSE between the 4 actual and planned osteotomy planes was 0.61 mm (Fig. 6B). Following implant restoration, the preoperative jaw and the initially designed implant were superimposed onto the postoperative CBCT scan, and the result showed that the bone contour reconstruction and implant position were consistent with the initial design (Fig. 6C, 6D). Furthermore, the prosthesis nearly replicated the initial design (Fig. 6E, 6F). Overall patient satisfaction with esthetic evaluation by visual analog scale ratings was high for the prosthesis (94.1, 0-100) and soft tissue (93.3, 0-100). These results indicated that the digital workflow might enhance the contour and adaptation of the graft.

SUMMARY

The described technique provided a completely digital workflow for prosthetically driven intraoral bone block harvesting, trimming, grafting, and implant restoration in an atrophic anterior maxilla by using precise preoperative planning and completely controllable intraoperative guidance.

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