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DENTAL TECHNIQUE

Prosthetic articulator-based implant rehabilitation virtual patient: A technique bridging implant surgery and reconstructive dentistry

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ABSTRACT

This technique report describes a fully digital workflow to create a prosthetic articulator-based implant rehabilitation (PAIR) virtual patient for complete-arch or complete-mouth implant rehabilitation. This workflow uses a custom gothic arch tracer during the cone beam computed tomography (CBCT) scan and a 3-dimensional virtual facebow when superimposing data. The PAIR virtual patient possesses reliable centric relation and vertical dimension of occlusion and is compatible with virtual articulators. Computer-aided implant planning and a digital prosthetic design can be seamlessly integrated by using this virtual patient. (J Prosthet Dent 2023;130:8-13)

Coordinating the surgical phase and restorative phase is essential for complete-arch or complete-mouth implant-supported prostheses.[1,2] For this treatment, the implant surgery should be planned in a prosthetically driven way[3]; meanwhile, to establish a restorative plan with proper esthetics and occlusion, smile analysis, facebow records, and articulators are necessary.[4,5] Integrating this information correctly and transiting from implant surgery to prosthetic restoration seamlessly are challenging.[6]

In recent years, virtual patient technology has brought a new solution for implant-supported prostheses.[7,8] Created by superimposing various images from an actual patient, the virtual patient presents face, teeth, intraoral soft tissue, and bone structures in a 3D simulation at the same time. Thus, a thorough treatment plan can be made even when the patient is absent.[9,10] The use of virtual patients for implant-supported prostheses has been increasingly reported, helping design the prostheses based on the existing dentition,[11] planning the position of the implants according to face-oriented prosthetic design,[12] facilitating immediate loading,[13] and achieving a predictable facial profile.[14]

However, previously reported virtual patient workflows have been limited to assembling the data of hard and soft tissues. When patients initially have altered occlusion, how to obtain the optimal centric relation (CR), vertical dimension of occlusion (VDO), and facebow record and how to integrate all information into a virtual patient remain unsolved questions.

An articulator-based virtual patient could be the answer to unifying the CR, VDO, and facebow record for clinical situations that need both extensive surgical and restorative operations.[15] The aim of this technical report was to describe a fully digital workflow to create a prosthetic articulator-based implant rehabilitation (PAIR) virtual patient.

TECHNIQUE

Figure 1 shows the general workflow of the PAIR virtual patient.

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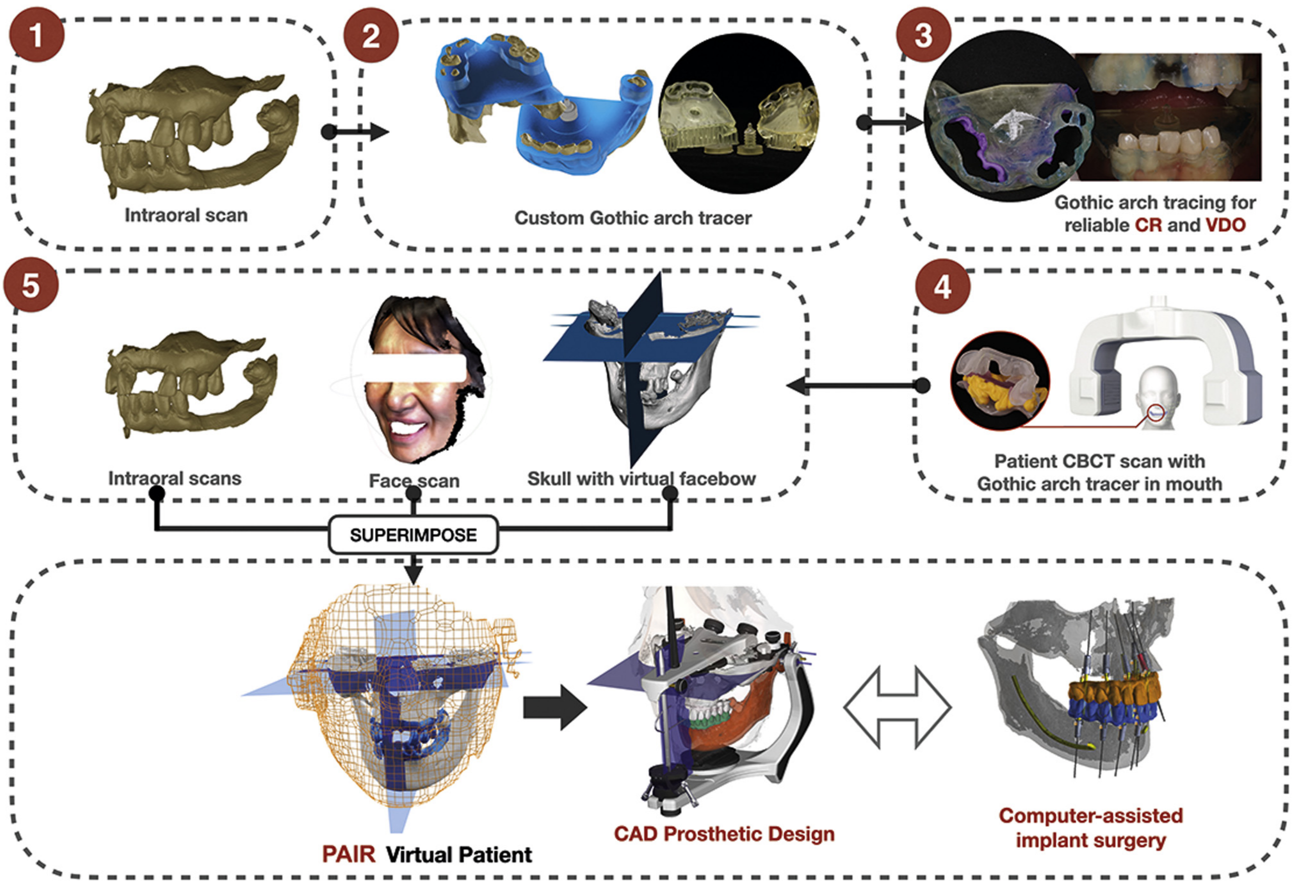

Figure 1. Digital workflow of PAIR virtual patient. CBCT, cone beam computed tomography; PAIR, prosthetic articulator-based implant rehabilitation.

1. During the first clinical visit, obtain scans of the maxillary and the mandible arches with an intraoral scanner (TRIOS 3; 3Shape A/S). Make occlusal scans in a proximal CR and VDO to align the digital casts.
2. Export the intraoral scans into standard tessellation language (STL) files. Use the occlusal device module in a dental computer-aided design (CAD) software program (exocad; exocad GmbH) to design a tooth-supported template on each arch scan. These templates will act as the base of the gothic arch tracer (Fig. 2A).
3. Import the templates, jaw scans, and an existing STL file (Supplementary File 1 available online) of the gothic arch tracer parts into an open-source 3D software program (Blender, v2.83; The Blender Foundation). Combine the maxillary and mandibular gothic arch tracer parts with the maxillary and mandibular tooth-supported templates, creating a tooth-supported gothic arch tracer. Fabricate the custom gothic arch tracer (Fig. 2B) by using a 3D printer (SprintRay Pro 95; SprintRay) with surgical guide resin (SprintRay Surgical guide 2; SprintRay).
4. During the second visit, collect all the data needed for the PAIR virtual patient. Assemble the gothic arch tracer and place it intraorally (Fig. 3A). If needed, reline the appliance with a polyvinyl siloxane material (Blu-Bite Fast Set Complete Package; Henry Schein, Inc) to increase stability. Evaluate the appropriate VDO and adjust the height of the tracing screw to match it.
5. Ask the patient to perform lateral and anterior mandibular movements and then remove the appliance. An arrow-shaped trace should be shown on the maxillary appliance (Fig. 3B). Align the center of the central pin receiver to the tracing's arrow point. Attach the receiver to the maxillary plate by using a light-polymerizing resin (Triad Gel; Dentsply Sirona) (Fig. 3C). Reinsert the appliance. Ask the patient to occlude to the position where the tracing screw's tip is located at the center of the central pin receiver. The patient's arches are now in the correct CR and VDO.
6. With the appliance inserted, make a CBCT scan (field of view: 10×14 cm). The scan should include the maxilla, mandible, infraorbital point, and

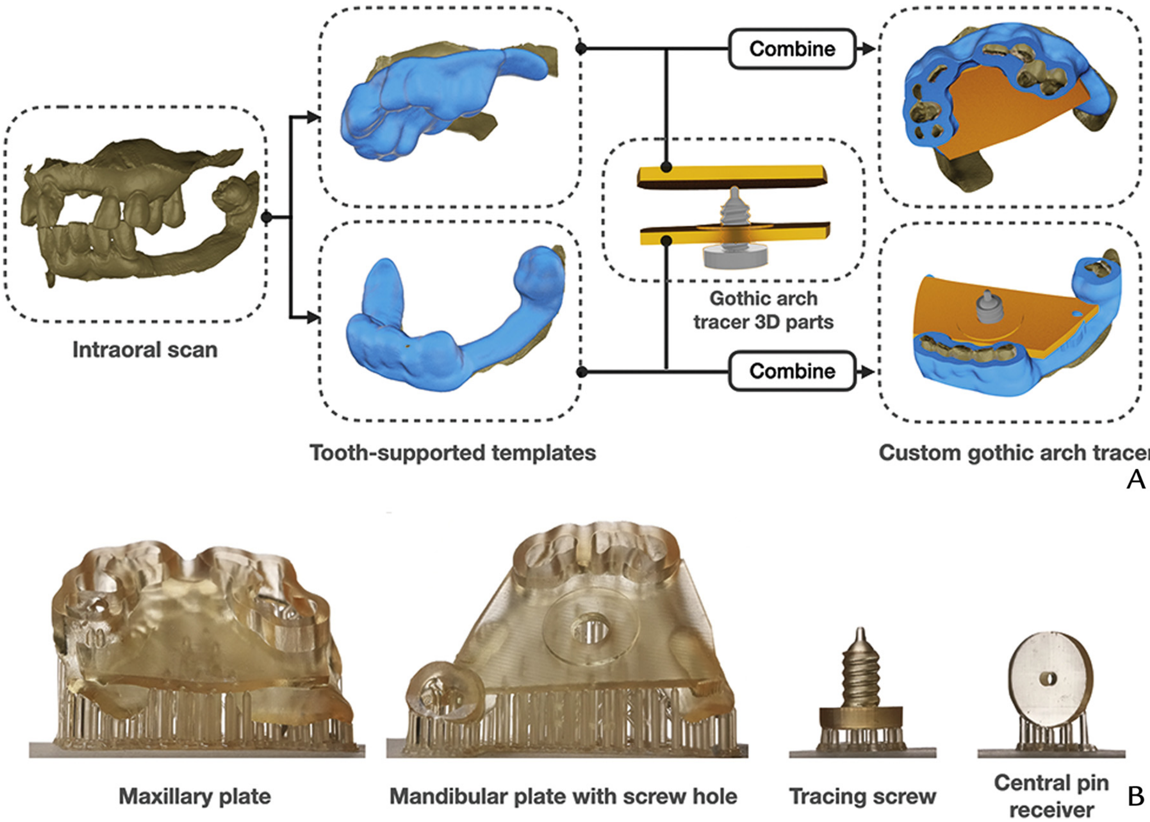

Figure 2. A, Custom gothic arch tracer designed based on intraoral scans from first visit. B, Three dimensionally printed custom gothic arch tracer.

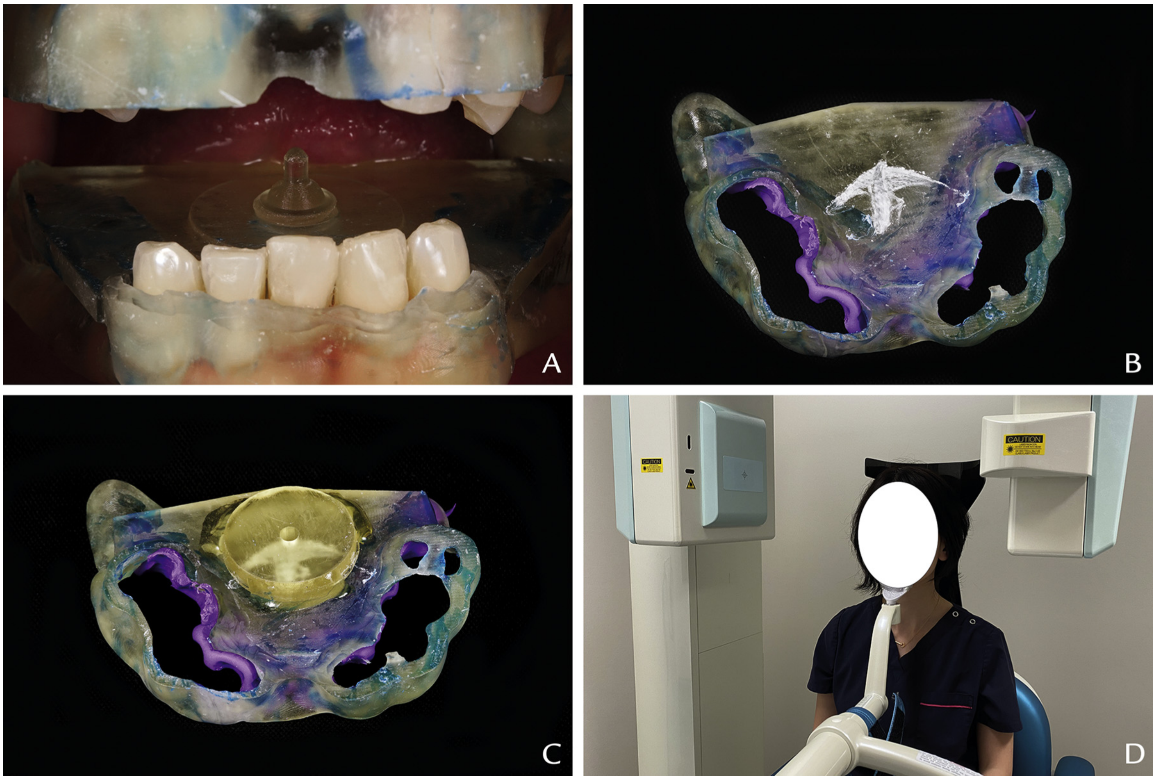

Figure 3. A, Tracer fitted in mouth. B, Gothic arch tracing. C, Center of centric pin receiver aligned to arrow point. D, CBCT scan with tracer inside of patient's mouth. CBCT, cone beam computed tomography.

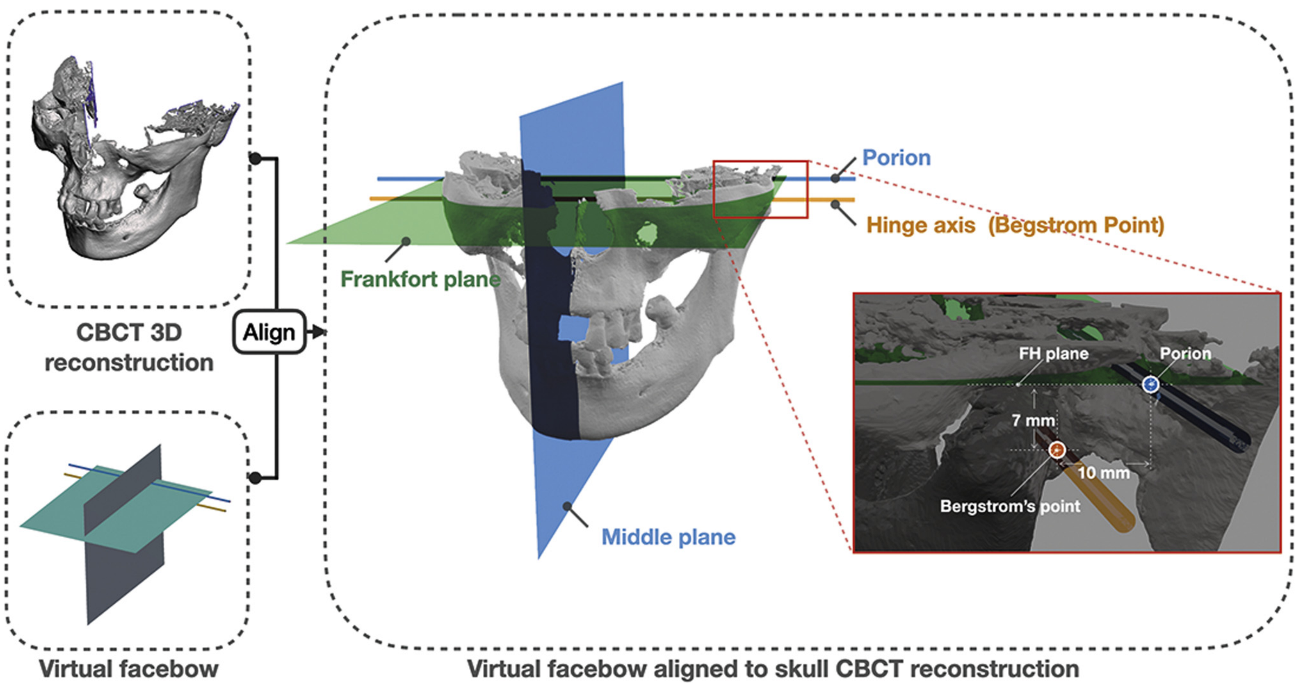

Figure 4. Three dimensional virtual facebow consisted of middle plane, Frankfort plane, shaft representing Porion, shaft representing mandibular transverse axis; virtual facebow aligned to 3D skull reconstruction from CBCT scan. CBCT, cone beam computed tomography.

external acoustic meatus area. Export the CBCT images as digital imaging and communications in medicine (DICOM) files.

7. Make face scans with a smartphone (iPhone 11 Pro; Apple Inc) with a 3D scan application (Hege 3D scanner; from Apple App Store, developer: Marek Simonik).[15] Export the scans as polygon file format (PLY) files.
8. Open the CBCT images with an implant planning software program (BlueSkyPlan v4.70; Blue Sky Bio LLC). Create a 3D bone model as well as a face model from the CBCT images and export them as STL files.
9. Import the CBCT bone model, face model, and a 3D facebow (Supplementary File 2 available online) into the open-source 3D software program (Blender, v2.83). The 3D facebow comprises a middle plane, Frankfort plane, a Prion shaft, and a hinge axis shaft. Align the facebow to the skull by matching the planes and external ear canal (Fig. 4). The hinge axis shaft will be at the Bergstrom point, which is an average hinge axis point.[16]
10. Import the face scans and intraoral scans into the open-source 3D software program (Blender, v2.83). Align the face scans to the CBCT face model. Match the intraoral scans to the teeth in the CBCT bone model. At this point, the PAIR virtual patient is created (Fig. 5).

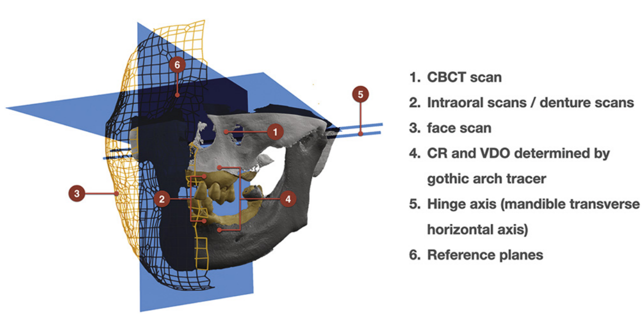

Figure 5. Prosthetic articulator-based implant rehabilitation virtual patient consisted of CBCT, face scan, and intraoral scan. CBCT, cone beam computed tomography; CR, centric relation; VDO, vertical dimension of occlusion.

DISCUSSION

This report described a workflow for creating a PAIR virtual patient. Different from previous dental virtual patient techniques, this protocol included gothic arch tracing when making the CBCT scan and a 3D virtual facebow when assembling the data. Therefore, the CR, VDO, and hinge axis, which are essential for prosthetic rehabilitations, are incorporated into this simulation. Because all the 3D objects were aligned to the CBCT 3D reconstruction, the PAIR virtual patient shared the same 3D coordinates as the CBCT image. When being imported into the CAD software program, it could be

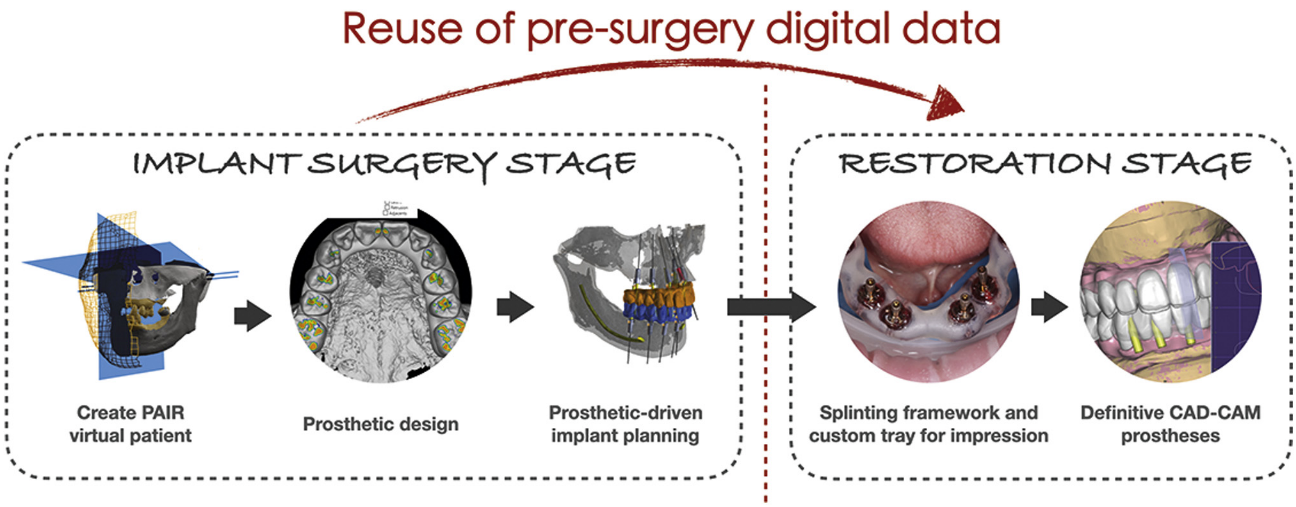

Figure 6. Presurgical planning contained data of facebow records, esthetic information, interarch relationship, and planned implant position. CAD-CAM, computer-aided design and computer-aided manufacture; PAIR, prosthetic articulator-based implant rehabilitation.

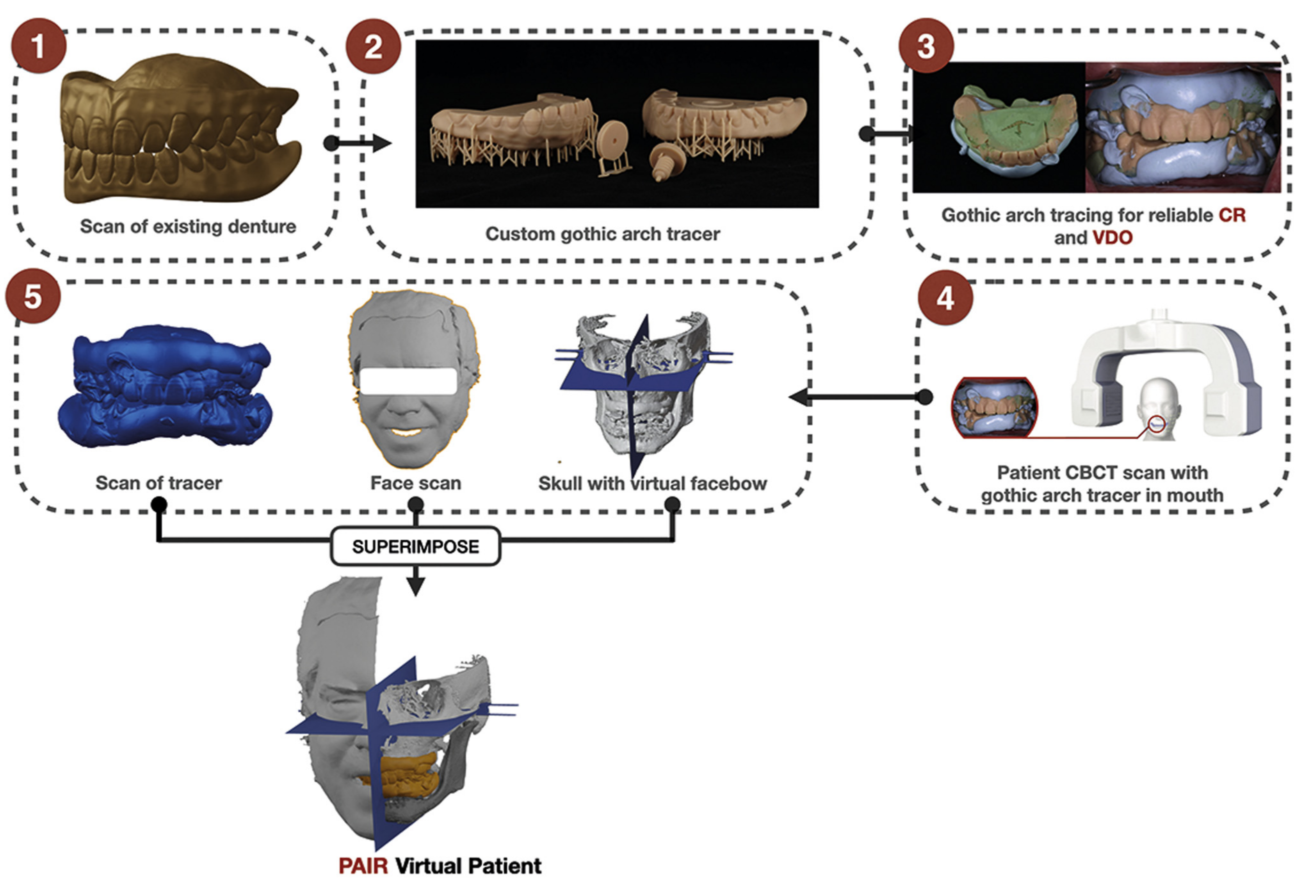

Figure 7. PAIR virtual patient workflow for edentulous patient. Different from partially edentulous workflow, existing dentures scanned and converted into 3D-printed gothic arch tracer. Scan of tracer used to create virtual patient instead of intraoral scans. CR, centric relation; PAIR, prosthetic articulator-based implant rehabilitation; VDO, vertical dimension of occlusion.

aligned to a virtual articulator by matching the virtual facebow. Thus, a prosthetic design could be made based on all these virtual simulations. The 3D files of designed prostheses can be directly reimported to the implant planning software program, guiding a prosthetically driven ridge-reduction protocol and implant positioning.[17] This workflow can be adopted for implant-supported prostheses of edentulous patients (Fig. 6). For these patients, the gothic arch tracer is made from denture scans and is relined with a radiopaque polyvinyl siloxane material (Blu-Bite Fast Set Complete Package) before making a CBCT scan.[18] When creating the virtual patient, scans of the tracer are used instead of an intraoral scan.

In addition to presurgical implant planning, a PAIR virtual patient could also facilitate the postsurgical restorative phase (Fig. 7). Given that this virtual patient already contains face scan and articulator-related information, it can be reused in the restorative phase, eliminating the need to make a facebow record, or remounting on the articulator after the implant surgery. For the definitive complete-arch implant impression, a splinted framework is needed to ensure accuracy.[19] Presurgical implant planning data are required to fabricate the splinted framework and the custom tray for the definitive impression, even before implant placement.[20] Therefore, the reuse of the presurgical PAIR virtual patient during the prosthetic phase should increase clinical efficiency. Possible factors influencing the accuracy of this virtual simulation include the acquisition of scan data, superimposing procedure, as well as virtual articulator configurations.

Limitations of this technique include the need for a CBCT scan. Therefore, this workflow should be limited to patients who need restorations supported by multiple implants. CBCT images in the current workflow play important roles, including bridging the face scan and intraoral scan together, providing face reference planes, and indicating the hinge axis. For a prosthetic treatment without CBCT images, a virtual facebow fork must be used to align the intraoral scans to the face scan.[21] In addition, the horizontal axis point must be determined from anatomic landmarks in the face scan. Therefore, future reports are needed to illustrate the workflow without CBCT images. Furthermore, the present workflow requires a knowledge of operating a 3D software program. In future, a single-step approach combining all these computerized work steps would help implement this technique as a routine clinical protocol.

CONCLUSIONS

The present workflow created a PAIR virtual patient with reliable CR and VDO and compatible with virtual articulators. This technique helps the bridging of implant surgical and restorative phases, enhancing the clinical procedures and increasing treatment predictability for patients who need complex implant-supported prostheses.

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