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A Full-Digital Technique to Mount a Maxillary Arch Scan on a Virtual Articulator

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Abstract

Mounting casts accurately on an articulator is a prerequisite for the treatment planning/execution of complex dental cases that require occlusal rehabilitation. A full digital approach to transfer the position of maxillary dentition to a virtual articulator, by using intraoral scans and cone beam computed tomography (CBCT) files is presented. This technique offers reduced chairside time and the flexibility of choosing the orientation plane. It can be used in orthognathic surgeries, complex interdisciplinary treatments requiring a CBCT scan with a large field of view, or treatments that already have the head CT or CBCT scans from previous diagnosis/treatment.

The articulator, an instrument simulating the position and movement of jaws, has been used as an essential tool in diagnosis, planning, and laboratory procedures in dental treatment. Recently, with the advancement of technology, this dental tool is shifting from a mechanical device to its digital alternative, the virtual articulator.[1,2] Embedded in computer software, the virtual articulator provides a series of advantages: full analysis of static/dynamic jaw movements and occlusion; detailed visualization of tooth contacts and virtual treatment design; and ability to be integrated with other digital workflows in dentistry such as digital smile design, computer-assisted implant planning, and digital maxillofacial surgery planning.[3,4]

So far, virtual articulators in most dental computer-aided design and manufacturing (CAD/CAM) systems (such as CEREC, 3Shape, and Exocad) share the same structures and working principles of traditional mechanical articulators. To reproduce the individual jaw movement as accurately as possible, some information, including the spatial relationship between maxillary arch and skull, must be recorded from the patient and transferred to the articulator.[5-8] In the conventional approach, the use of the facebow transfer and physically mounting the cast are mandatory. For programming a virtual articulator, several techniques have been proposed.[9-13]

In the technique introduced by Gartner and Kordass, following the conventional approach, the mounted articulator and casts were scanned by an optical scanner and then converted into a virtual articulator.[9] At present, this modality has been adopted by most dental CAD/CAM systems; however, it is not a full digital workflow and shows several disadvantages. First, the traditional facebow and articulator mounting procedure is still needed, requiring additional treatment time. Second, this approach cannot avoid the inaccuracies, such as the expansion of the plaster and the deformation of the bite-registration material, derived from conventional mounting procedures.[3] Recently, full digital approaches have been introduced. Solaberrieta et al used a “virtual facebow” to align the intraoral scan to the 3D face scan, and then oriented the digital maxillary model to a virtual articulator by matching the face landmarks.[10] Other techniques, sharing a similar idea, also rely on the face scan.[11-13] However, the face scanner and software are not readily available in most dental clinics and labs, making this approach hard to implement.

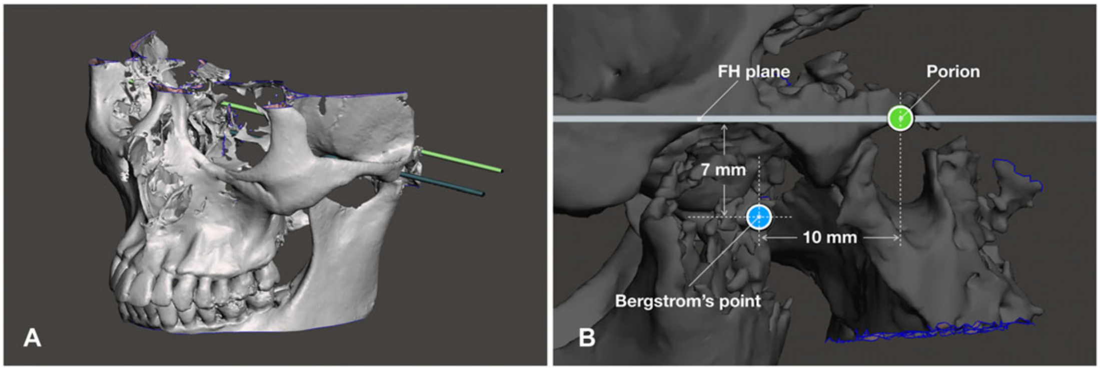

Figure 1 3D reconstructed skull with shafts passing through rotation center of condyles (blue) and upper margins of external acoustic meatus (green).

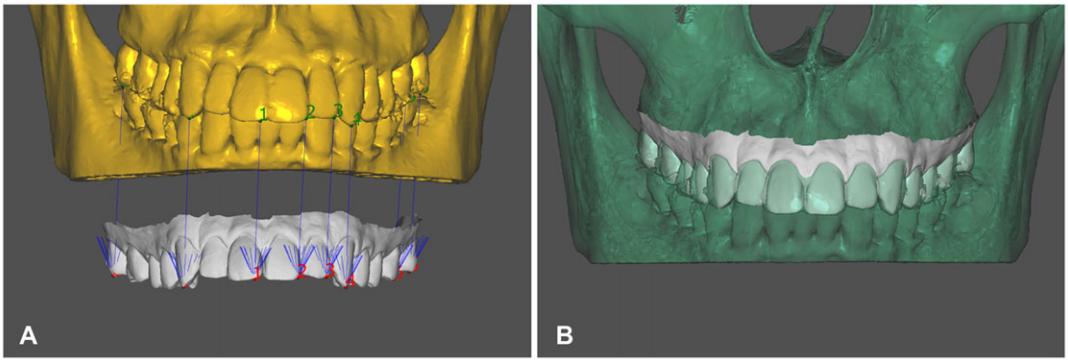

Figure 2 Registration of skull and optical scan of maxillary arch.

The aim of the present article was to introduce a full digital technique for relating the maxillary model to the virtual articulator, using devices readily available in the dental clinic (CBCT machine and intraoral scanner) and is compatible with present dental CAD/CAM systems.

Technique

1. Perform a CBCT scan. The field of view (FOV) should involve the maxilla, infraorbital point, and external acoustic meatus. Export the data into digital imaging and communications in medicine (DICOM) files.
2. Scan maxillary/mandibular arches and register their occlusal relationship using an optical intraoral scanner (TRIOS; 3Shape, Copenhagen, Denmark). Export the scans as standard triangle language (STL) files.
3. Convert the DICOM files into a 3D model and export data into STL format using Blue Sky Plan (V4.1.0; Blue Sky Bio, Grayslake, IL). This step can also be done by other software such as 3D Slice, an open source software.
4. Import the 3D skull model into an STL file editing software (Meshmixer; Autodesk, San Rafael, CA). Build 2 cylinders in Meshmixer. Transform them into long shafts by setting their diameter to 2 mm and length to 200 mm. Align one shaft to the upper margin of each ear canal. Register another to Bergstrom's point (10 mm anterior to the center of external auditory meatus and 7 mm below the Frankfort horizontal plane), indicating the arbitrary hinge axis of the mandible (Fig 1).[14] These shafts are used to align the skull model to the virtual articulator.
5. Export the skull model with shafts into STL format.
6. Load the edited skull model and optical scans into a dental CAD software (Exocad; exocad GmbH, Darmstadt, Germany). Superimpose the maxillary arch to the skull (Fig 2).
7. Align the hinge axis of the skull with the joint axis of the virtual articulator, making the reference plane (Frankfort horizontal plane was used in the present demonstration) parallel to the upper arm of the articulator (Fig 3).
8. Load the mandibular arch and align it to the maxilla according to the occlusion scan in maximum intercuspation (Fig 4).

Discussion

The present article describes a full digital approach to articulate a maxillary arch scan on a virtual articulator. This technique only relies on readily available devices in the dental clinic (CBCT machine and intraoral scanner) and is compatible with present dental CAD/CAM systems.

In the clinic, the position of maxilla and hinge axis is mostly transferred using an arbitrary facebow, a device located on a patient's head by two posterior reference points around the temporomandibular joint and a third anterior reference point on

Figure 3 Registration of skull and virtual articulator. Horizontal reference plane is parallel to upper arm of articulator, and hinge axis of skull is superimposed with joint axis of articulator.

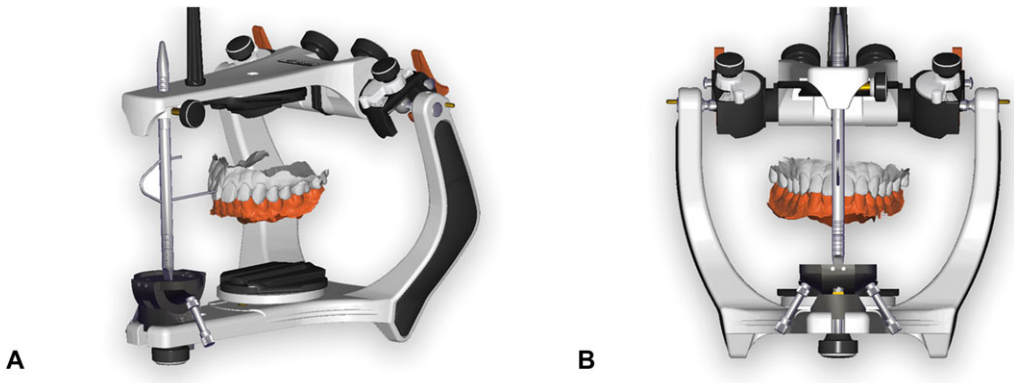

Figure 4 Mounted virtual articulator. (A) Side view. (B) Front view.

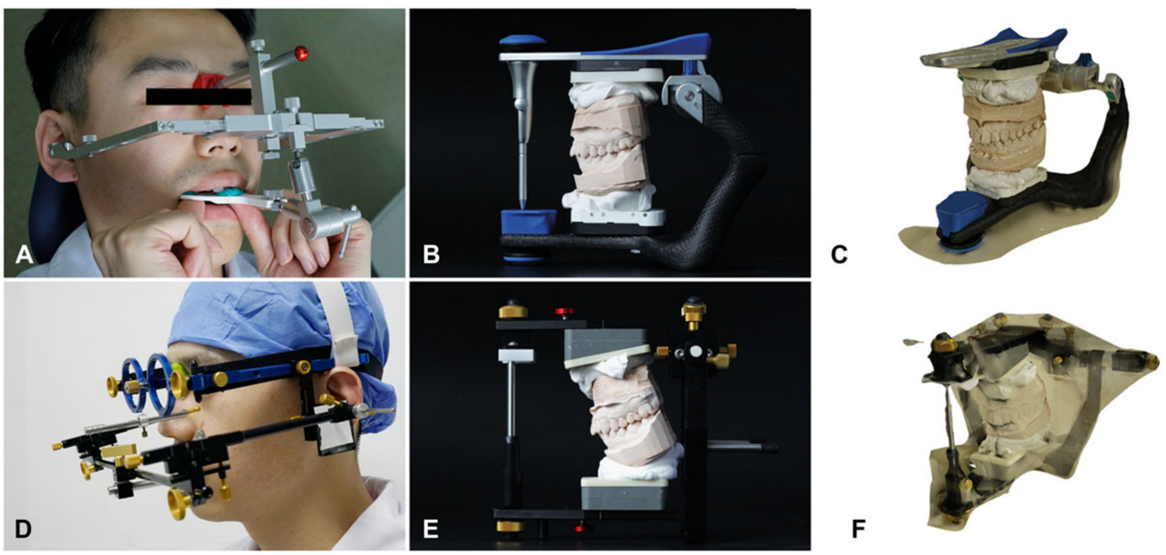

Figure 5 Mounting of 2 physical articulators. (A) Arbitrary facebow record. (B) Mounted articulator from arbitrary facebow. (C) Scan of articulator. (D) Kinematic facebow record. (E) Mounted articulator from kinematic facebow. (F) Scan of articulator.

the face. The 3D reconstruction from CBCT images can provide these reference points as well as the maxillary arch position, thus making it feasible to function as a facebow. At the same time, it can avoid some inaccuracy rising from the assembling of mechanical facebow components and the deformation of wax or plaster materials. Moreover, the 3D images can provide varied anterior reference points, such as nasion, orbitale, and Guichet point. In this demonstration, the Frankfort plane was used because the virtual articulator type was Bio-art A7 Plus, which used orbitale as the third point of reference. In practice, the choice of reference plane should be based on the articulator system in the CAD software and the clinic's needs.[15]

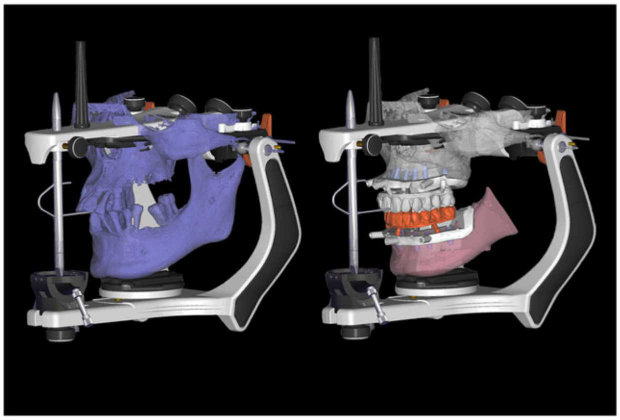

Figure 6 Application of present technique in guided full mouth immediate implant placement and rehabilitation.

To locate the rotation center of the mandible, Bergstrom's point was selected. It is an average hinge axis point that can be determined by the spherical insert of the external ear canal and Frankfort plane,[15] which could be found on the 3D model constructed from CBCT.

To assess the accuracy of the present technique, 2 physical facebow records, including an average facebow (Artex; Amann Girrbach, Charlotte, NC) record and a kinematic facebow (CADIAX; Gamma Dental, Klosterneuburg, Austria) record, were performed on the same subject and compared to the present virtual technique. Once mounted, these 2 physical articulators were optically scanned (ReCapTM Photo; Autodesk). By superimposing the maxillary dentition, the hinge axis deviations of the present technique and the arbitrary facebow transfer were calculated using the kinematic approach as a gold standard (Fig 5). The present technique showed a 0.44° angular deviation, 3.78-mm-left condylar deviation, and 4.23-mm-right condylar deviation, while the arbitrary facebow transfer demonstrated a 0.53° angular deviation, 5.94-mm-left condylar deviation, and 6.20-mm-right condylar deviation.

The limitation of this method could be the need for a CBCT with a FOV containing the maxilla and external ear canals. Keeping with the ALARA principle (radiation exposure to the patient should be as low as reasonably achievable), it is not justifiable to apply this technique in simple prosthodontic or orthodontic cases.[16,17] The indication of the present technique could be orthognathic surgeries, complex interdisciplinary (i.e., orthodontic, prosthetic, implant, and TMJ) cases that need a CBCT scan with a large FOV, or patients who already have the head 3D radiograph from previous diagnosis/treatment (Fig 6).[18-20]

Additional studies are needed to assess the accuracy and reliability of this technique. Furthermore, the present workflow does require knowledge of operating 3D software programs such as Meshmixer, Blue Sky Plan, and Exocad.

Summary

The present article introduced a full digital approach to articulating a scan of the maxillary arch on a virtual articulator, using only a CBCT and intraoral scanner. In addition to a reduced chairside time, this technique also presents the flexibility of choosing orientation planes.

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