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DENTAL TECHNIQUE

A 2-part facebow for CAD-CAM dentistry

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New materials with excellent mechanical and esthetic properties have been introduced for computer-aided design and computer-aided manufacturing (CAD-CAM) application.¹ The use of these dental materials with CAD-CAM requires the virtualization of dental patients.²

The equivalent of articulator-mounted maxillary and mandibular casts still applies in the digital workflow. Intraoral optical scanners can produce digital dental casts³ and register the maxillomandibular relationship.⁴

ABSTRACT

Converting the patient's clinical information into the virtual world is a prerequisite for the computer-aided design and computer-aided manufacturing (CAD-CAM) of dental restorations. This article describes a modified facebow which facilitates the radiation-free registration of the maxillary teeth to a 3-dimensional face image for transfer to a virtual articulator. This facebow can be easily fabricated with minimal materials and adjusted to fit different patients; its error in tooth registration was demonstrated to be less than 1 mm. (*J Prosthet Dent* 2016;■:■-■)

Articulators have been digitalized to simulate mandibular movement,⁵ and a virtual facebow has been proposed to transfer digitized maxillary teeth to the 3-dimensional (3D) extraoral image first and then to the virtual articulator.⁶ During the acquisition of the extraoral image, with proper lip and cheek retraction, the maxillary anterior teeth can be exposed so they can be used as reference markers for relating the teeth to the face.⁷ Cone beam computed tomography (CBCT), however, can capture teeth, face, and their relationship in a

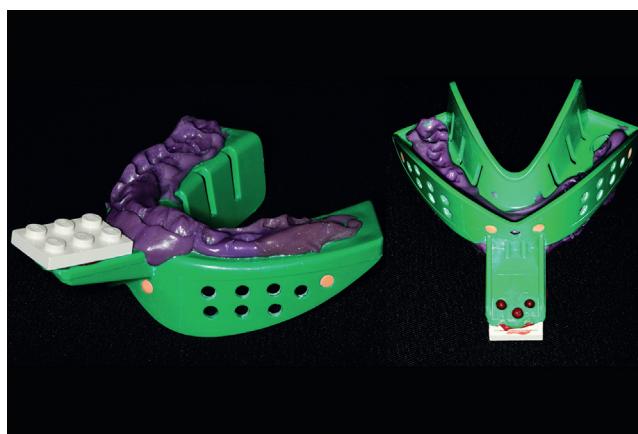


Figure 1. Occlusal wafer part of virtual facebow.



Figure 2. Facial part of virtual facebow.

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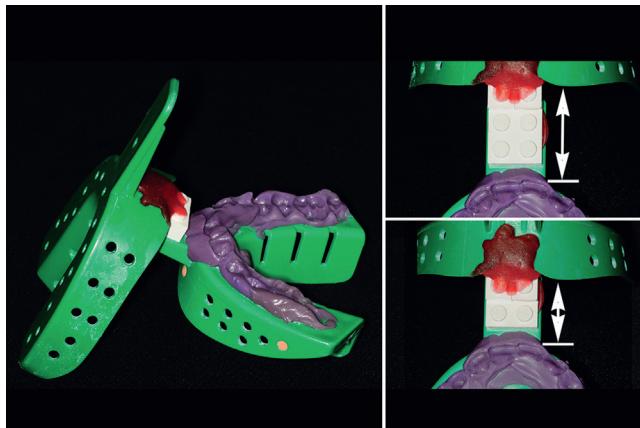


Figure 3. Assembled dual tray virtual facebow using Lego bricks.

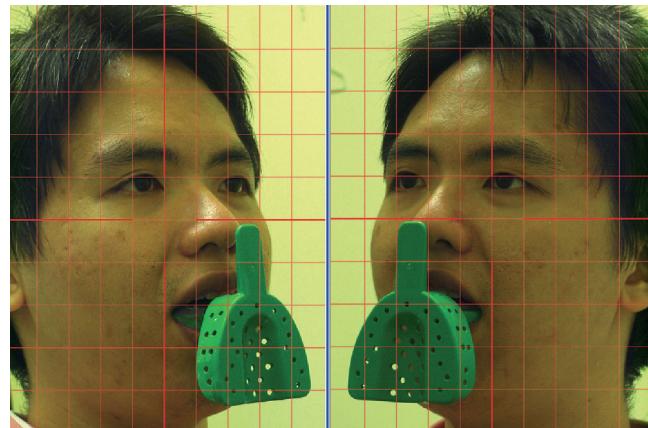
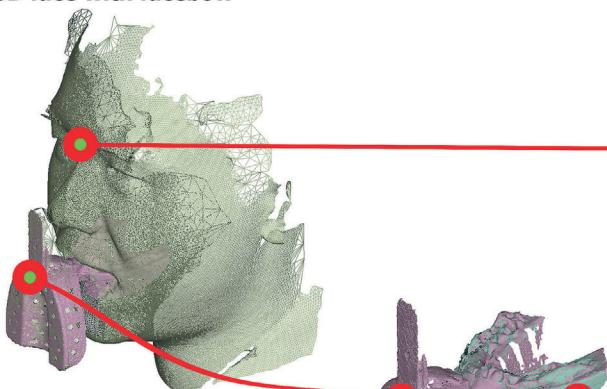
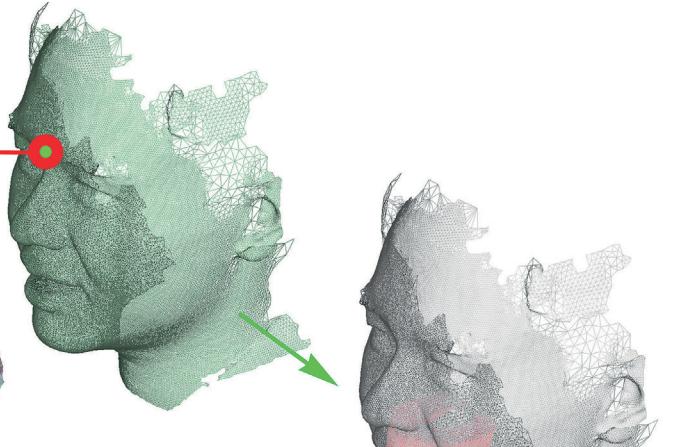


Figure 4. Dual tray virtual facebow in situ for stereophotogrammetry.

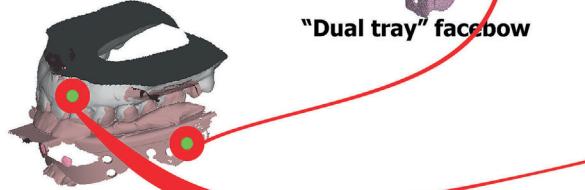
3D face with facebow



3D face in relaxation



"Dual tray" facebow



Maxillary teeth

Maxillary teeth with occlusal wafer of facebow



3D face in relaxation with maxillary teeth

Figure 5. Workflow of dual tray virtual facebow for mounting digital maxillary teeth to 3D face image.

single scan, although this increases radiation exposure that may not be justified in patients with limited restorative needs.⁸

This article proposes the use of a modified facebow for patient virtualization. Only a pair of disposable impression trays, 2 Lego (Lego Group) bricks, autopolymerizing acrylic resin, and occlusal registration materials is needed. All these materials are inexpensive and readily available and the fabrication is straightforward. Lego bricks are used to connect the 2 parts of the virtual facebow together. The Lego joint is stable and adjustable

and can be used in combination with different types and sizes of disposable trays.

TECHNIQUE

1. Select a mandibular disposable impression tray of an appropriate size (Coe Disposable Impression Tray; GC America). Inject occlusal registration material (Regisil 2X; Dentsply Intl) onto both the internal and external surfaces of the tray and ask the patient to occlude until it polymerizes. Drill a few



Figure 6. Full-face cone beam computed tomography scan with occlusal wafer.

Mfg Co). This forms the occlusal wafer of the facebow (Fig. 1).

2. Drill attachment holes in the central region of a maxillary impression tray and attach a Lego brick with autopolymerizing acrylic resin (GC Pattern Resin; GC America). This forms the facial part of the facebow (Fig. 2).
3. Assemble the 2 impression trays using the Lego bricks (Fig. 3). The distance from the maxillary anterior teeth to the facial part of the facebow is adjustable to accommodate anatomic variations among patients.
4. Make a 3D facial scan using a stereophotogrammetry device (3dMDface; 3dMD Inc) when the patient is in a relaxed position.

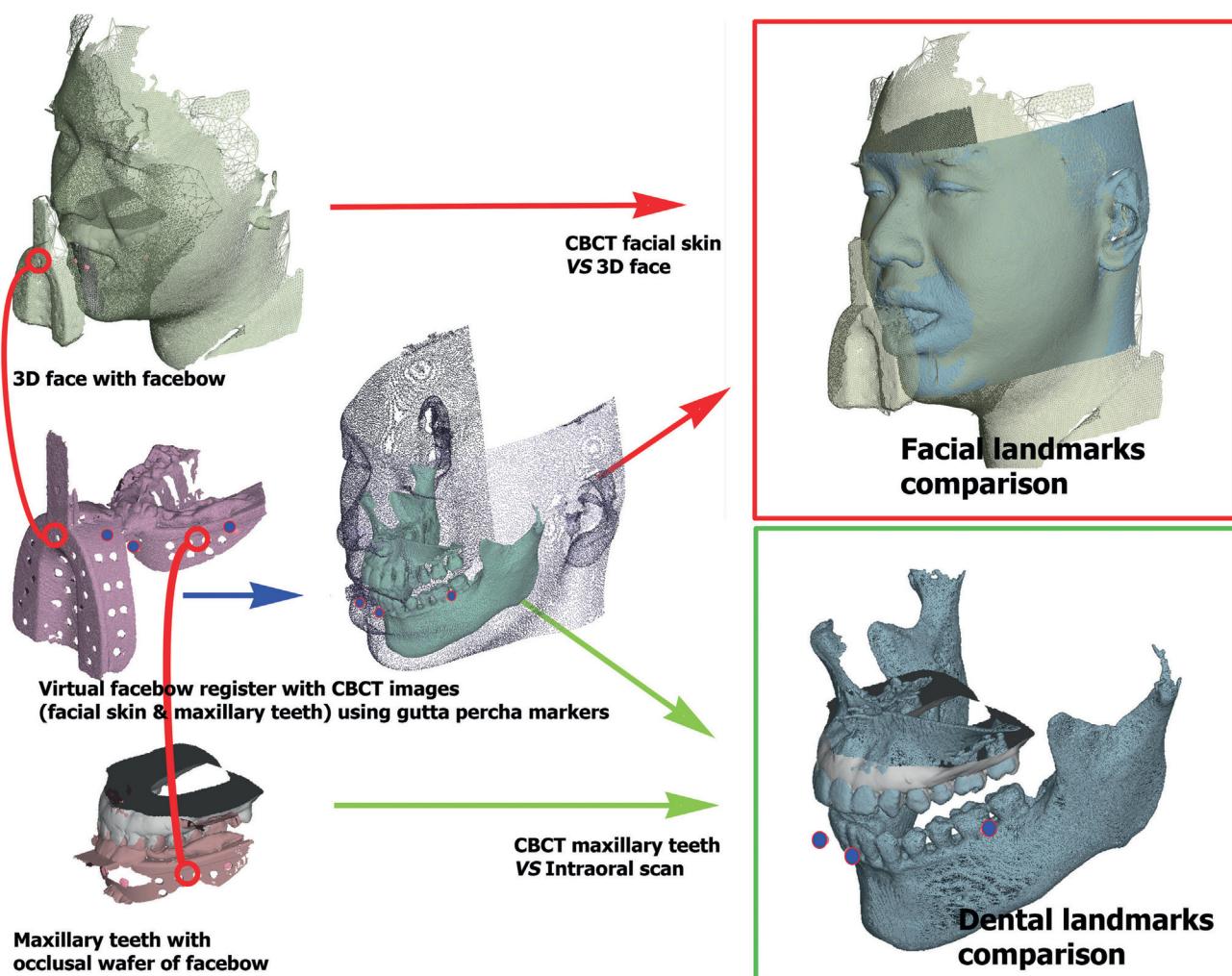


Figure 7. Comparison of facial and dental landmarks between virtual patient model and cone-beam computed tomography.

attachment holes (approximately 3 mm in diameter) at the tray handle and attach a Lego brick (product code: 3021; 23.8 mm × 15.8 mm plate) with autopolymerizing acrylic resin (Duralay; Reliance Dental

5. Make another 3D facial scan with the facebow in place (Fig. 4).
6. Scan the facebow using a hand-held laser scanner (Handyscan 3D; Creaform).

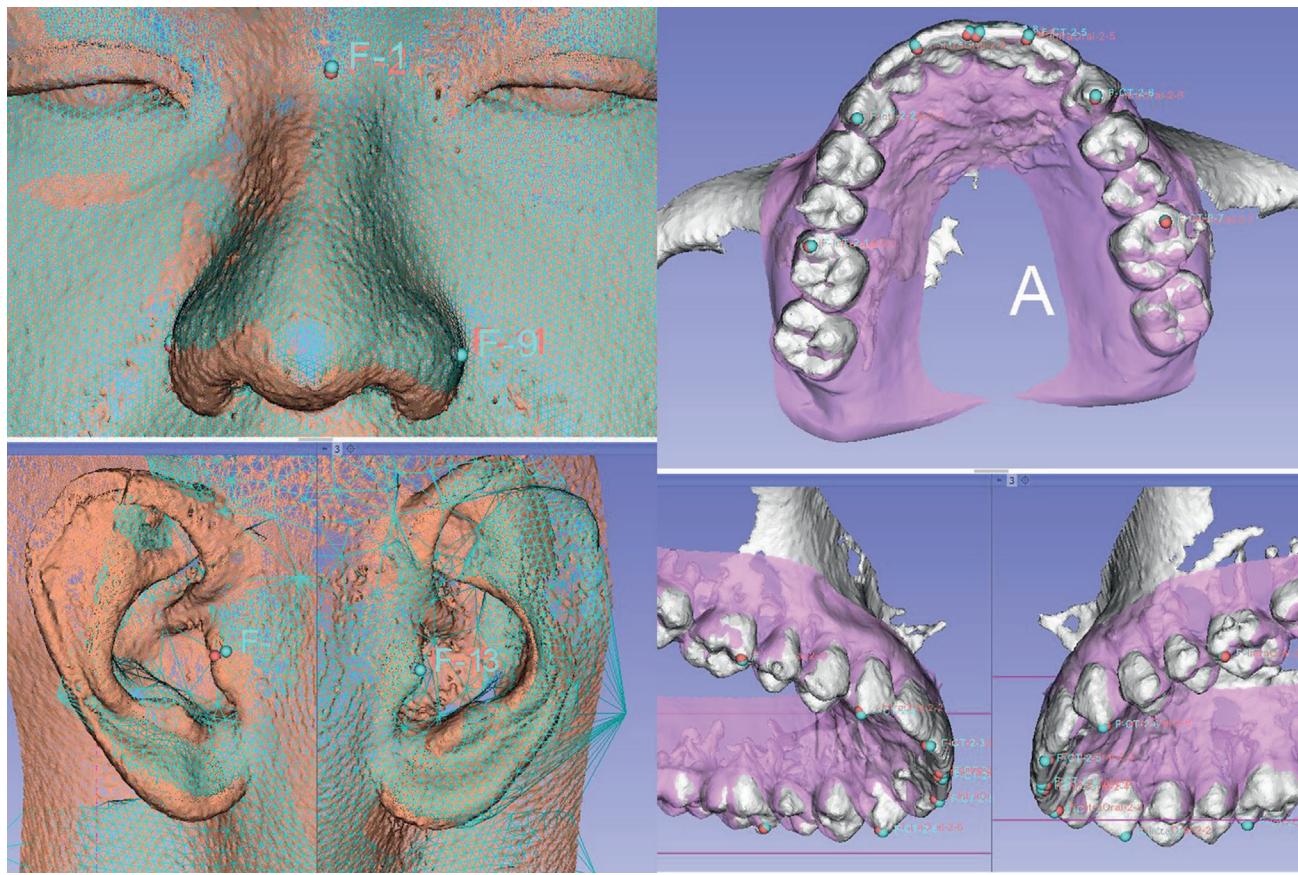


Figure 8. Error measurement with facial and dental landmarks comparison: red, landmarks from cone beam computed tomography; blue, landmarks from intraoral scan/stereophotogrammetry.

7. Scan maxillary and mandibular teeth and register their relationship with an intraoral scanner (True Definition; 3M ESPE).
8. Scan the buccal surface of the maxillary teeth and the rim and retention holes of the occlusal wafer in the patient's mouth with the intraoral scanner.
9. Import all the digital images into open source software (MeshLab v1.3.3; Visual Computing Lab of the ISTI-CNR) and align them using the Align filter (iterated closest point algorithm) (Fig. 5). With the virtual patient model formed, locate the reference horizontal plane on the face and transfer it to the virtual articulator where the teeth can then be mounted.⁶

DISCUSSION

This paper presents a 2-part virtual facebow for relating digital maxillary teeth to a 3D face image and virtual articulator. Transferring the position of maxillary teeth to the 3D face image is essential in patient virtualization as it determines the setting of the virtual articulator and hence the simulation of mandibular movements. The registration accuracy of teeth on the occlusal wafer has

been shown to improve by adding hexagon markers around the wafer.¹² Disposable impression trays are proposed because the rim and retention holes of the tray can facilitate the registration in a similar way to the hexagon markers. The technique is recommended for patients with maxillary teeth because the occlusal wafer will be more stable. However, the mandible is only for holding the occlusal wafer during intraoral scanning. For patients with an edentulous mandible, occlusal registration material could be applied on the wafer to record the alveolar ridge.

This virtual facebow also allows comparison of the resulting virtual patient model with that of the full-face CBCT scan. If verification is needed, 4 radiopaque markers such as gutta-percha (GP) can be inserted into the retention holes of the occlusal wafer, 2 in the center and 1 on each side of the rim (Figs. 1, 3). A full-face skull CBCT (field of view, $\varphi 20.0 \times 17.5$ cm; standard resolution, 0.4-mm voxel; 90 kV; 5 mA) can be made with the occlusal wafer in place (Planmeca ProMax 3D Mid; Planmeca) (Fig. 6). The facial skin, teeth, and radiographic markers can then be segmented in the CBCT by their respective Hounsfield unit thresholds, using image analysis software (3D Slicer⁹ version 4.3; Slicer

community). The facebow with the GP markers inserted is then scanned using the hand-held laser scanner, and the data imported into MeshLab with the full-face CBCT image model and virtual patient model aligned using a point-based algorithm with the GP markers as reference points (Fig. 7).

Five facial landmarks (nasion, right and left alars, and right and left tragiions)¹⁰ and 7 dental landmarks (proximal incisal edges of the maxillary central incisors; cusp tip of maxillary canines; and mesiobuccal cusp of the maxillary first molars)¹¹ are located in both the CBCT and the virtual patient models. The distances between the corresponding landmarks in the CBCT model and virtual patient model can then be measured by 3D Slicer software (Fig. 8). The preliminary data of the present article showed that the discrepancies at the maxillary incisors, canines, and first molars were 0.66 mm, 0.58 mm, and 0.26 mm, respectively. For the facial alignment, the mean distances of the nasion, alares, and tragiions between the full face CBCT model and virtual patient model were 0.83 mm, 0.77 mm, and 1.70 mm respectively (Fig. 8).

The observed discrepancy might be due to the different facial expressions made during CBCT and stereophotogrammetry (Figs. 4, 6). However, more well-designed scientific studies are needed to verify this observation. Distortion might be caused by the autopolymerizing resin attaching the Lego parts and plastic trays.¹³ In addition, the whole workflow, including multiple scans and software manipulation, does require considerable time.

SUMMARY

A novel and straightforward technique for fabricating a dual tray virtual facebow for mounting digital maxillary teeth to a 3D face image was presented.

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