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DENTAL TECHNIQUE

Creating three-dimensional virtual patients by superimposing intraoral and facial digital scans guided with an aligner system: A dental technique

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ABSTRACT

A technique for creating 3-dimensional virtual patients (3DVPs) by superimposing intraoral and facial digital scans guided with a novel aligner system is described. This aligner system supports design modifications to adapt to different facial scanning methods (FSMs) and reduce the impact of FSMs on the accuracy of 3DVPs. Two different designs of the aligner system are described: one for use with less-accurate FSMs and another for use with more-accurate FSMs. These virtual designs are available for download and use. (J Prosthet Dent 2022;■:■-■)

Various aligner systems have been developed to guide the superimposition of intraoral and facial digital scans to create 3-dimensional virtual patients (3DVPs). They have been used for different clinical purposes, including obtaining virtual facebow records or performing facially driven digital diagnostic waxing procedures.[1-11] Intraoral digital scans are acquired by using intraoral scanners (IOSs), whereas facial digital scans can be acquired by using various facial scanning methods (FSMs). Although most aligner systems can be used to superimpose intraoral digital scans with facial digital scans acquired with any FSM, the accuracy of a 3DVP is greatly influenced by which FSM is used, being more accurate when using more accurate FSMs.[12,13]

Most accurate FSMs, such as stationary facial scanners or professional handheld scanners, however, may be unsuitable for many dental clinics, principally because of their high cost.[14,15] Therefore, alternative FSMs have been proposed, with mobile device-compatible 3D sensor cameras attracting the most interest, principally because of their low cost and ease of use.[15-19] However, improving the accuracy of 3DVPs created with facial digital scans acquired by using these FSMs is important and can be achieved by intervening in the design of the aligners.[20,21]

For a 3DVP to be accurate, the regions of the aligners involved in the superimpositions should be extensive and contain sufficient shape details because superimpositions are performed by using best-fit algorithms. To avoid superimposition errors, all methods used to scan these regions of the aligners should be able to capture shape details.[22] In general, FSMs have less ability to capture shape details than IOSs and laboratory scanners, and less-accurate FSMs have even less ability than more accurate ones.[18,19,22]

This article describes a technique for creating 3DVPs by superimposing intraoral and facial digital scans guided by a novel aligner system that supports design modifications to adapt to different FSMs in order to reduce the impact of FSMs on the accuracy of 3DVPs. Two designs

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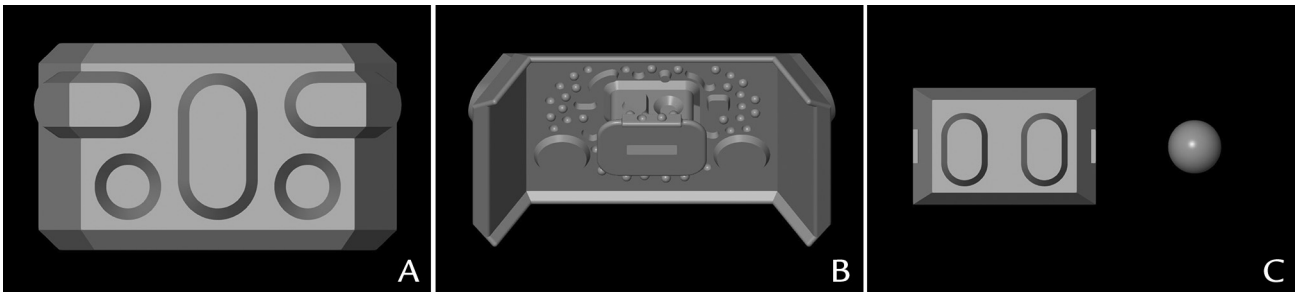

Figure 1. Virtual designs of aligners for less-accurate facial scanning methods. A, Frontal view of virtual design of buccal aligner. B, Posterior view of virtual design of buccal aligner. C, Virtual designs of forehead aligners.

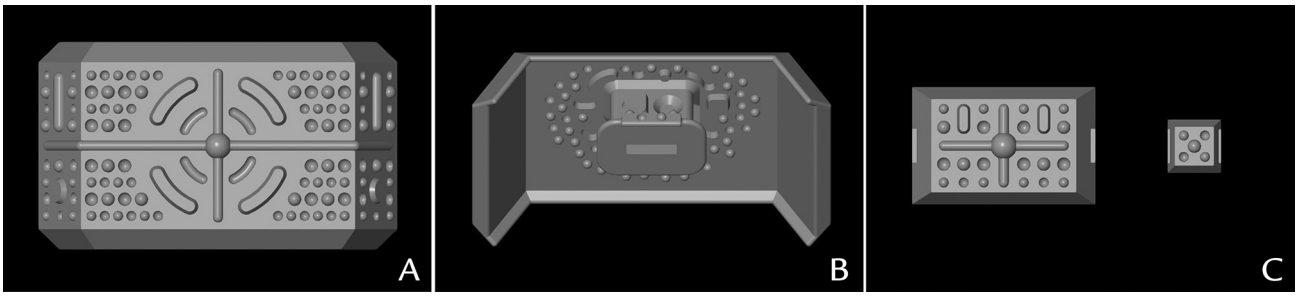

Figure 2. Virtual designs of aligners for more-accurate facial scanning methods. A, Frontal view of virtual design of buccal aligner. B, Posterior view of virtual design of buccal aligner. C, Virtual designs of forehead aligners.

of the aligner system are described: one for use with less-accurate FSMs (Fig. 1), such as some mobile device-compatible 3D sensor cameras, composed of aligners with fewer shape details in regions that are scanned by using FSMs (Fig. 1A, 1C) (Supplemental File 1, available online), and another for use with more-accurate FSMs (Fig. 2), such as some professional handheld scanners composed of aligners with more shape details in the regions that are scanned by using FSMs (Fig. 2A, 2C) (Supplemental File 2, available online). As the technique is the same with both designs of the aligner system, the use of only 1 is described.

TECHNIQUE

1. Manufacture the virtual designs of the aligners—1 copy of the virtual design of the buccal aligner (Supplemental File 1A, available online), 1 copy of the virtual design of the central forehead aligner (Supplemental File 1B, available online), and 2 copies of the virtual design of the lateral forehead aligner (Supplemental File 1C, available online)—in an opaque material that meets biocompatibility requirements[23,24] (VisiJet M2R-WT; 3D Systems, Inc) with an additive manufacturing (AM) machine (ProJet MJP 2500 Plus; 3D Systems, Inc) according to the manufacturer's protocol (Fig. 3).
2. Manufacture the virtual design of the tray of the buccal aligner (Supplemental File 3, available online) in a material that meets biocompatibility requirements[23,24] (Surgical Guide Resin; Formlabs, Inc) with an AM machine (Form 3B; Formlabs, Inc) according to the manufacturer's protocol (Fig. 4).
3. Assemble the buccal aligner and its tray by inserting the tip of the tray into the hole of the buccal aligner (press them together until they are firmly attached) (Fig. 5).
4. Acquire the patient's maxillary, mandibular, and occlusal digital scans by using an IOS (TRIOS 3; 3Shape A/S) as per the manufacturer's protocol (Fig. 6).
5. Acquire the patient's facial digital scans by using an FSM such as a smartphone with an integrated 3D sensor camera (iPhone 12 Pro; Apple, Inc) controlled with a mobile application (Heges 3D Scanner; Marek Simonik) as per the manufacturer's protocol (Fig. 7). First, acquire a reference facial digital scan with the additively manufactured aligners placed on the corresponding areas of the patient's face (Fig. 7A): the forehead aligners on the forehead area (the central one in the center and the lateral ones on the sides close to the temporal line of the frontal bone), fixed to the head by a headband (Elastic tape; William Prym Holding GmbH), and the buccal aligner over the buccal area, fixed to the maxillary arch with high- and low-viscosity polyvinyl siloxane impression material (VPS Hydro; Henry Schein, Inc) loaded onto its tray. Place the forehead

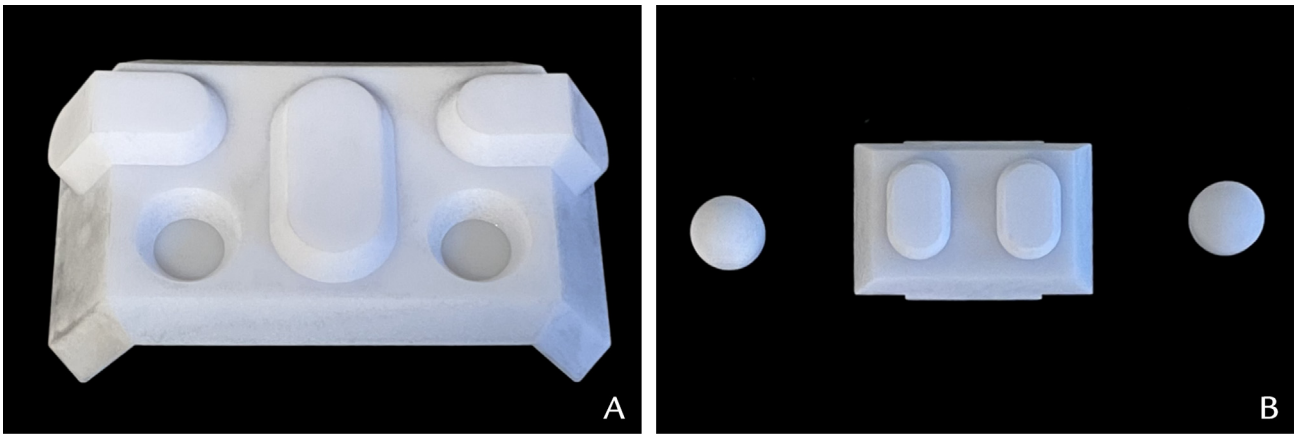

Figure 3. Additively manufactured aligners. A, Additively manufactured buccal aligner. B, Additively manufactured forehead aligners.

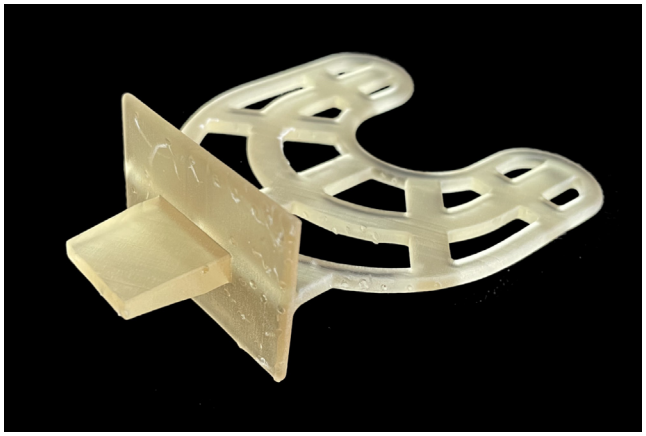

Figure 4. Additively manufactured tray of buccal aligner.

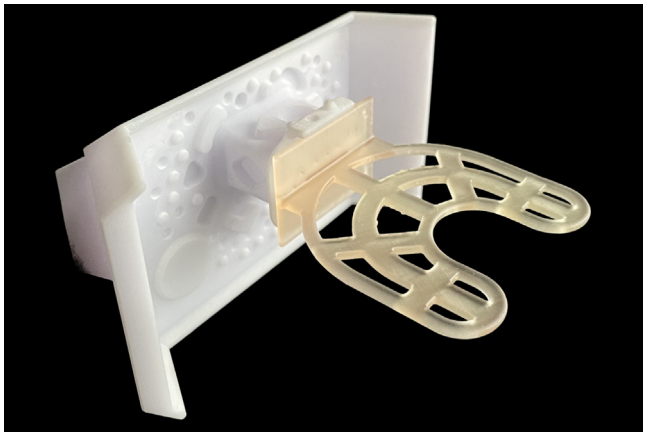

Figure 5. Additively manufactured buccal aligner and its tray assembled.

aligners first and, before placing the buccal aligner, instruct patients to avoid moving their eyebrows until all facial digital scans have been acquired. Check that the forehead aligners do not move in the absence of eyebrow movement (otherwise, correct their placement). After acquiring the reference facial digital scan, obtain at least 1 definitive facial digital scan with the buccal aligner removed (carefully, without separating it from its tray) and the forehead aligners in place in a specific facial expression such as at rest (Fig. 7B).

6. Acquire the digital scan of the back of the buccal aligner with the IOS (Fig. 8).
7. Superimpose intraoral and facial digital scans to create a 3DVP (Fig. 9). For that, import all previous digital scans to a dental computer-aided design software program (exocad; exocad GmbH) and perform the following steps: first, superimpose the digital scan of the back of the buccal aligner with the maxillary digital scan (Fig. 9A); second, superimpose the virtual design of the buccal aligner with the digital scan of the back of the buccal aligner

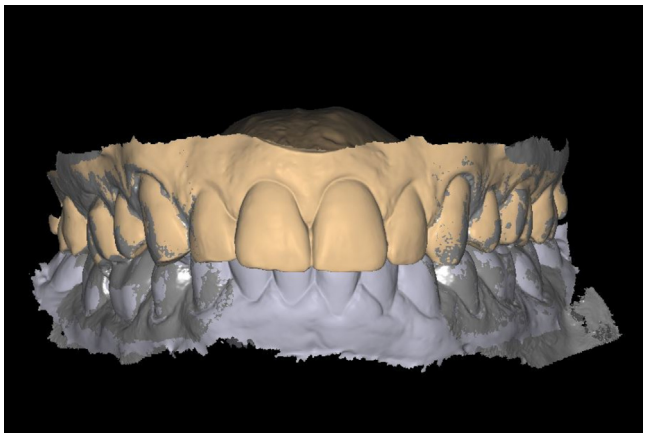

Figure 6. Intraoral digital scans.

(Fig. 9B); third, superimpose the reference facial digital scan with the virtual design of the buccal aligner (Fig. 9C); fourth, superimpose the definitive facial digital scan with the reference facial digital scan (Fig. 9D); and, finally, if necessary, superimpose the

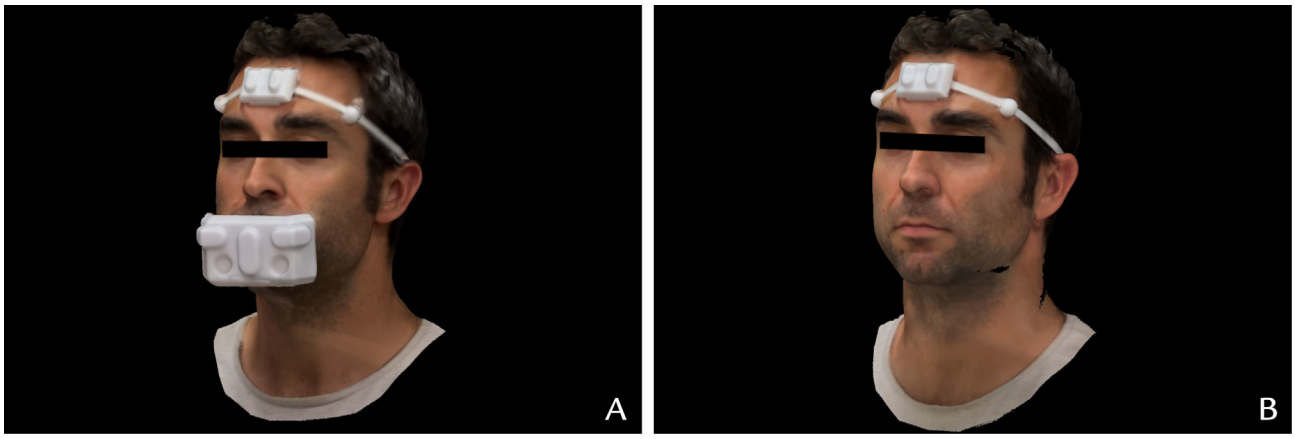

Figure 7. Facial digital scans. A, Reference facial digital scan. B, Definitive facial digital scan at rest.

mandibular and occlusal digital scans with the maxillary digital scan. Perform all superimpositions by using a best-fit algorithm after selecting the regions of the digital scans to be superimposed (Fig. 9).

DISCUSSION

A technique to create 3DVPs by superimposing intraoral and facial digital scans guided with a novel aligner system is described. The aligner system is composed of 4 reusable aligners: 3 forehead aligners and 1 buccal aligner, with a removable and disposable tray (a removable and disposable tray is used to enable the use of both standard and custom trays without the need to remanufacture the buccal aligner as was required with most previously developed aligners of this type). The aligners, as well as the tray of the buccal aligner, can be additively manufactured, taking into account that they should meet or exceed the biocompatibility requirements established for medical devices in contact with intact skin surfaces and, in the case of the buccal aligner and its tray, also with intact mucosal membrane surfaces, the duration of contact being long term for aligners and limited for the tray of the buccal aligner.[23,24] The aligners should be sterilized before reuse by following the instructions of the manufacturer of the material used to manufacture them.

An innovation of the aligner system is that it supports design modifications to adapt to different FSMs in order to reduce the impact of FSMs on the accuracy of 3DVPs. Almost all previously developed aligner systems propose a single design for all FSMs[1-11] without taking into account that not all FSMs have the same ability to capture shape details and that not capturing shape details of the aligner regions involved in the superimpositions may lead to errors that affect the accuracy of the resulting 3DVPs.[22] That is why 2 different aligner system designs are described: one for use with more-accurate FSMs with a greater ability to capture shape details and another for use with less-accurate FSMs with less ability to capture shape details (this design should only be used with FSMs that cannot capture the shape details of the first design). The buccal aligner is a further innovation of the aligner system. The regions involved in the superimpositions are notably more extensive than those of most previously developed aligners of this type,[1-11] which favors the accuracy of the superimpositions, and therefore that of the resulting 3DVPs. Even so, there is no need for a laboratory scanner to obtain its digital scan after acquiring the reference facial digital scan because only the digital scan of its back is necessary (Fig. 8); this can be obtained by using an IOS. In addition, the regions of the buccal aligner that are scanned by using FSMs (Figs. 1A, 2A) do not coincide with those scanned by using IOSs (Figs. 1B, 2B), which enables the independent adaptation of the shape details of those regions. Thus, the difference between the 2 described aligner system designs is only in the shape details of the aligner regions that are scanned by using FSMs (Figs. 1A, 1C, 2A, 2C), whereas the shape details of the regions scanned by using IOSs are similar (Figs. 1B, 2B) as all IOSs have a similar ability to capture shape details.

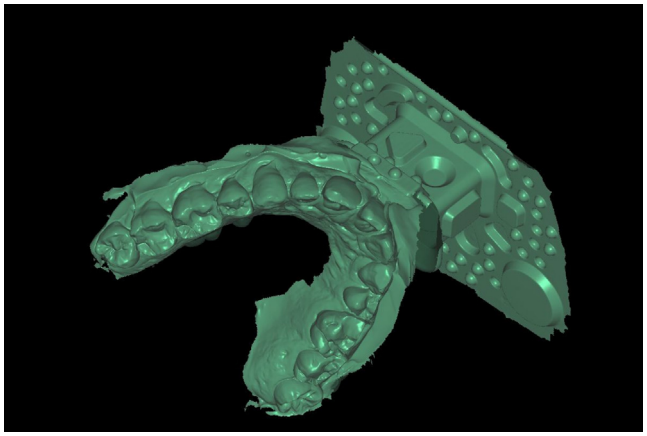

Figure 8. Digital scan of back of buccal aligner.

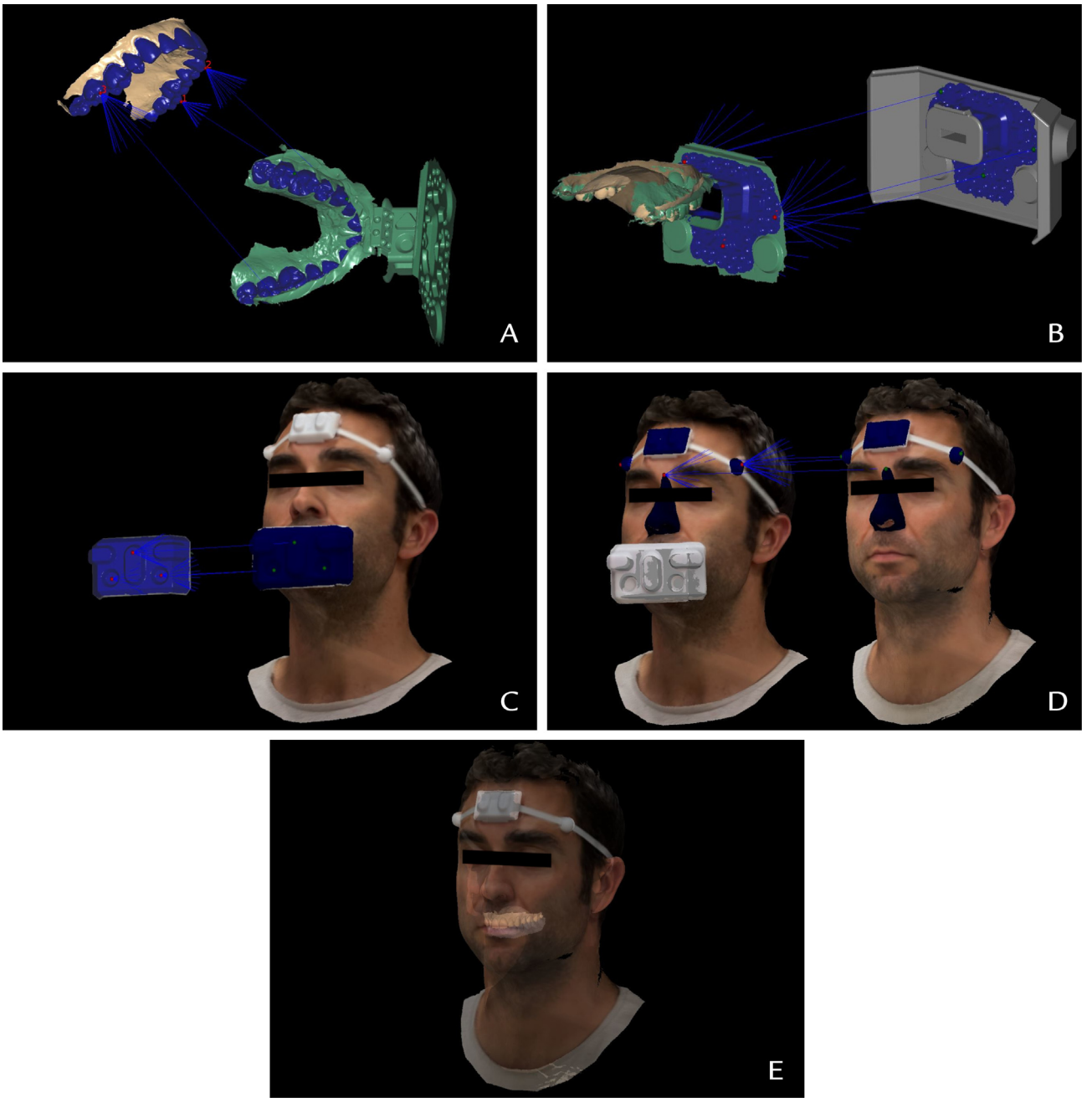

Figure 9. Superimposition of intraoral and facial digital scans. A, Superimposition of digital scan of back of buccal aligner with maxillary digital scan. B, Superimposition of virtual design of buccal aligner with digital scan of back of buccal aligner. C, Superimposition of reference facial digital scan with virtual design of buccal aligner. D, Superimposition of definitive facial digital scan with reference facial digital scan. E, Three-dimensional virtual patient created by superimposing intraoral and facial digital scans. *Blue* indicates regions selected for superimposition with best-fit algorithm.

Limitations of the novel aligner system include that its buccal aligner should be manufactured accurately, as its virtual design is involved in the superimpositions (Fig. 9B, 9C), and therefore, manufacturing errors may lead to superimposition errors that affect the accuracy of the resulting 3DVPs. However, if this is not possible, it could be manufactured less accurately, and its digital scan acquired with a laboratory scanner could substitute the virtual design in the superimpositions. To avoid the need for an AM machine with high accuracy or the presence of a laboratory scanner in the clinic, reusable buccal aligners could be manufactured externally, and the disposable trays and reusable forehead aligners could be manufactured in-house on a more accessible AM machine.

Virtual designs of the novel aligner system can be downloaded and used by the dental community. However, studies are needed to assess the accuracy of

3DVPs created with this technique, to optimize the aligner system, and to develop new designs for different FSMs.

SUMMARY

A technique for creating 3DVPs by superimposing intraoral and facial digital scans guided with a novel aligner system is described. The aligner system supports design modifications to adapt to different FSMs in order to reduce the impact of FSMs on the accuracy of 3DVPs. Two designs of the aligner system are described: one for use with less-accurate FSMs and another for use with more-accurate FSMs. Their virtual designs are available for download and use.

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