Digital fixed complete-arch rehabilitation: From virtual articulator mounting to clinical delivery

Article *in* Journal of Prosthetic Dentistry · December 2020

DOI: 10.1016/j.prosdent.2020.08.049

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CLINICAL REPORT

Digital fixed complete-arch rehabilitation: From virtual articulator mounting to clinical delivery

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ABSTRACT

The virtual articulator is a tool that reproduces the relationship between the jaws in a virtual environment. The purpose of this clinical report was to describe a completely digital protocol starting from the virtual articulator mounting to developing static and dynamic occlusion in a complex prosthetic rehabilitation. (J Prosthet Dent 2020;■:■-■)

For complex oral rehabilitations, an accurate maxillomandibular relationship and harmony with mandibular movements are key factors in the successful planning and delivery of treatment.[1] The mechanical articulator has been used in prosthodontics[2] because it can simulate the condylar position and the movement of the jaws. With the advance of technology, virtual articulators are becoming important tools in digital dentistry.[3] Virtual articulators can be completely adjustable or mathematically simulated.[4-6] Their challenges include the difficulty in transferring the masticatory movements that depend on the patient's muscles, which have to be adjusted by computerized axiography.[7]

Various methods for mounting physical casts on virtual articulator systems have been described[8-12]; however, it is now possible to perform a virtual mounting in maximal intercuspal position (MIP) for virtual waxing and subsequent computer-aided design and computer-aided manufacturing (CAD-CAM) processing.

The purpose of this clinical report was to describe a protocol for virtual mounting as per the technique described by Lepidi et al[12] and to show how to develop static and dynamic occlusion and simulate mandibular movements in a completely digital workflow.

CLINICAL REPORT

A 37-year-old woman with a history of unsuccessful orthodontic therapy and a maxillary left lateral incisor restored with a crown presented with the complaint of not being satisfied with her smile. A skeletal class III malocclusion was diagnosed (Fig. 1A, 1B). The proposed treatment plan comprised an interdisciplinary approach including orthodontics, orthognathic surgery, and prosthetic treatment. The orthodontics and orthognathic surgery provided a skeletal class I relationship, but with maxillary diastemas (Fig. 1C-E). The prosthetic therapy was carried out in the following phases: trial restoration, virtual mounting and diagnostic waxing on a virtual patient, and provision of the definitive restorations.

A diagnostic waxing was developed as per the design from the Digital Smile Design system (Smile Creator; exocad GmbH),[13] a waxing cast was fabricated by 3D printing, and a silicone index was produced from it. The first trial restoration was made intraorally with an interim composite resin (Luxatemp Fluorescence; DMG) and was used as the interim prosthesis during the entire planning phase (Figs. 1F, 2).

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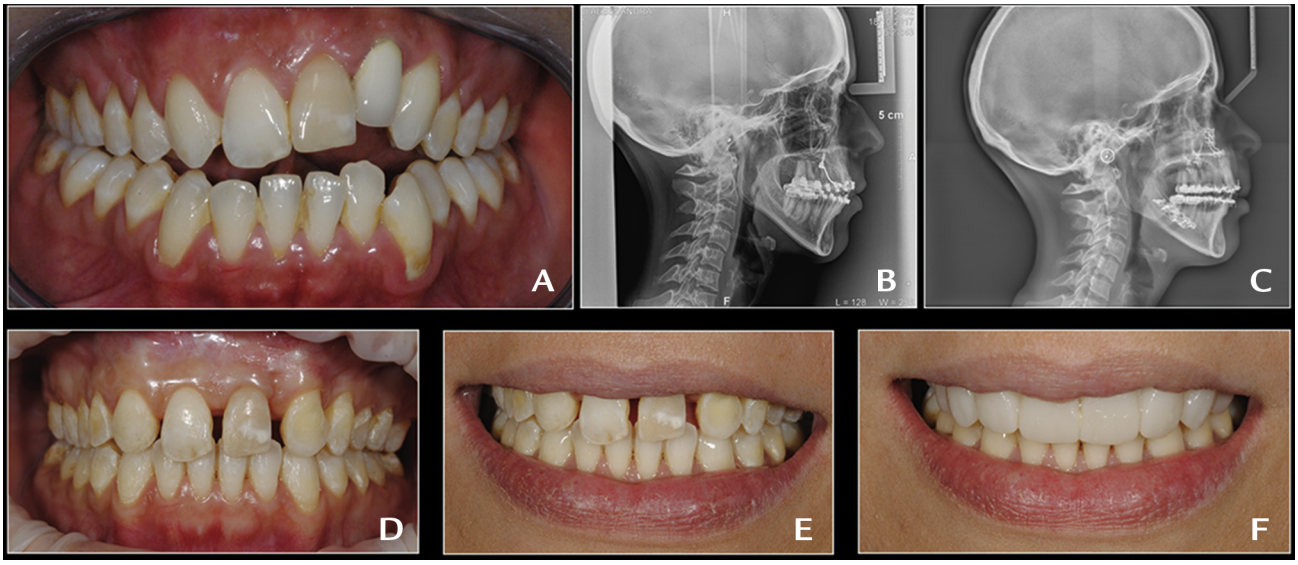

Figure 1. A, Initial intraoral presentation. B, Cephalometric radiograph before orthognathic surgery. C, Cephalometric radiograph after orthognathic surgery. D, Intraoral view after orthodontic treatment. E, Smile before first trial restoration. F, Smile with first trial restoration.

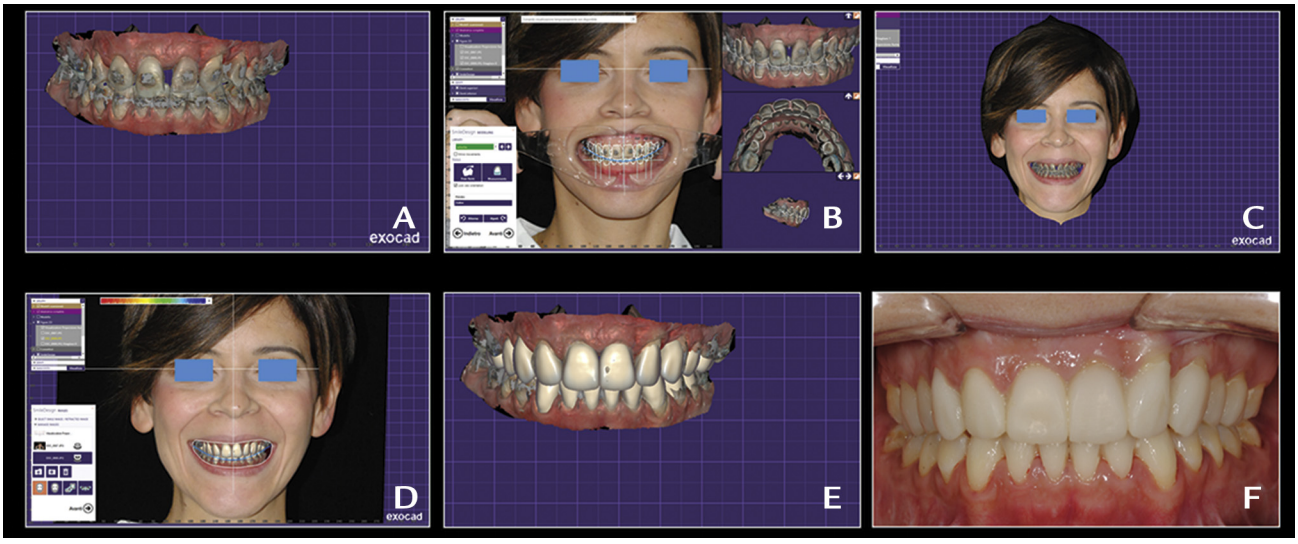

Figure 2. Digital workflow procedure according to digital smile design. A, STL file from intraoral scan after orthodontic treatment. Brackets still in place. B, Procedure to evaluate golden proportion of teeth. C, After matching between STL file by intraoral scanner and 2D photograph of smile. D, Result of digital smile design. E, Esthetic digital waxing. F, Intraoral view, esthetic trial restoration in situ. STL, standard tessellation language.

A cone beam computed tomography (CBCT) scan of her was made 6 months after orthognathic surgery with the direct trial restorations in place. The CBCT scan included the maxilla, infraorbital point, and external acoustic meatus. This scan was used as a virtual facebow to mount the intraoral scans onto the virtual articulator with the following steps.[12] A 3D model of the skull was generated from the CBCT images by using a dental CAD software program (Exocad; exocad GmbH). This model was imported into a standard tessellation language (STL) file–editing software program (Meshmixer; Autodesk). A 3D rod was aligned to the upper margin of each ear canal, and another rod was aligned to the Bergstrom point[12] (10 mm anterior to the center of external auditory meatus and 7 mm inferior to the Frankfort horizontal plane), indicating the transverse horizontal axis of the mandible. The skull cast together with the rod was imported into Exocad. A maxillary scan made by using an intraoral scanner (CS 3600; Carestream) was superimposed to the skull cast by superimposing the teeth (Fig. 3A). By registering the references on the skull, the scans were mounted on the virtual articulator (Fig. 3B, 3C). The mandibular cast was registered to the maxillary cast with an interocclusal optical record in MIP (Fig. 3D).

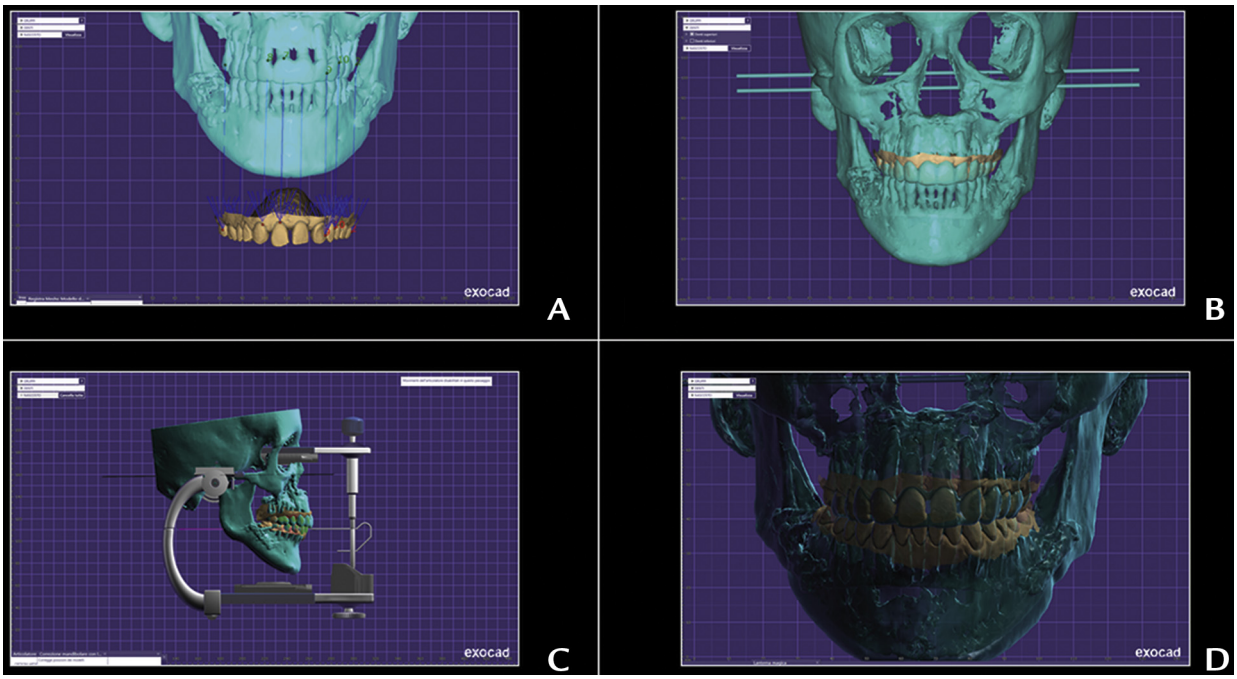

Figure 3. 3D skull reconstruction from CBCT images made with a facebow in place. A, Superimposition procedure of maxillary arch to skull. B, 3D reconstructed skull with shafts passing through Bergstrom points (10 mm anterior to center of external auditory meatus and 7 mm below Frankfurt horizontal plane) and upper margin of each ear canal. C, Alignment transverse horizontal axis of skull with joint axis of virtual articulator: shafts used to align skull model to virtual articulator Type A. D, Intraoral scans oriented on skull so virtual mounting obtained. CBCT, cone beam computed tomography; 3D, 3-dimensional.

The virtual articulator parameters used in the present treatment were Bennett angle of 10 degrees; lateral side shift of 0.5 mm; and sagittal condylar inclination of 35 degrees. The simulation of the movements started from a reference position of the jaws in occlusion passing through a condylar axis at the rest position. A digital waxing (Fig. 4) was designed with an increased occlusal vertical dimension (OVD) of 0.9 mm in the posterior region (Fig. 5). The occlusal contacts in protrusion and lateral excursion were verified during the diagnostic waxing phase. The second trial restorations were made from autopolymerizing composite resin (LuxaCrown; DMG) to test the function and adaption to the new OVD.[2]

The tooth preparations were minimally invasive. For the posterior teeth, the preparations were limited to buccal and interproximal surfaces between the second premolars and first molars. Preparation of the occlusal surfaces of the posterior teeth was not necessary because of the increased OVD. For the anterior teeth, the preparations included the axial surfaces of the central incisors and the facial and mesial surfaces of the canines (Fig. 6). Subsequently, both arches were scanned with the intraoral scanner with the patient in MIP. The definitive restorations were designed and fabricated by CAD-CAM (Fig. 5). The occlusal scheme was mutually protected articulation. Eight lithium disilicate maxillary veneers and 2 crowns (IPS e.max Ceram; Ivoclar Vivadent AG) were adhesively bonded with a resin cement (Variolink Esthetic Cement; Ivoclar Vivadent AG). The occlusion was compared with the diagnostic waxing by evaluating the occlusal contacts with 2 thicknesses of articulating paper (Bausch Articulating Papers Blue and Red; Bausch) (Fig. 6). She was recalled 6 months later and the occlusion reevaluated (Figs. 7-9).[14]

DISCUSSION

A fully digital prosthetic protocol is presented that used a virtual articulator in the diagnostic waxing phase of the occlusion, starting from MIP. Virtual articulators have been developed for CAD-CAM processing,[4] including those using an electronic system for recording mandibular movements such as the Jaw Motion Analyzer[5,6] (JMA^{+}nalyser; Zebris Medical GmbH) and mechanically simulated virtual articulators that record and reproduce the mandibular movements for dynamic occlusion, as well as occlusal contacts in a static position.

This novel digital approach enabled tooth-supported restorations starting from a virtual waxing that had developed optimal static and dynamic occlusion. Nevertheless, the accuracy needs to be verified with a clinical study.

In this clinical report, the virtual mechanically simulated articulator was used because it is straightforward to use, and the static occlusion in MIP can be designed with

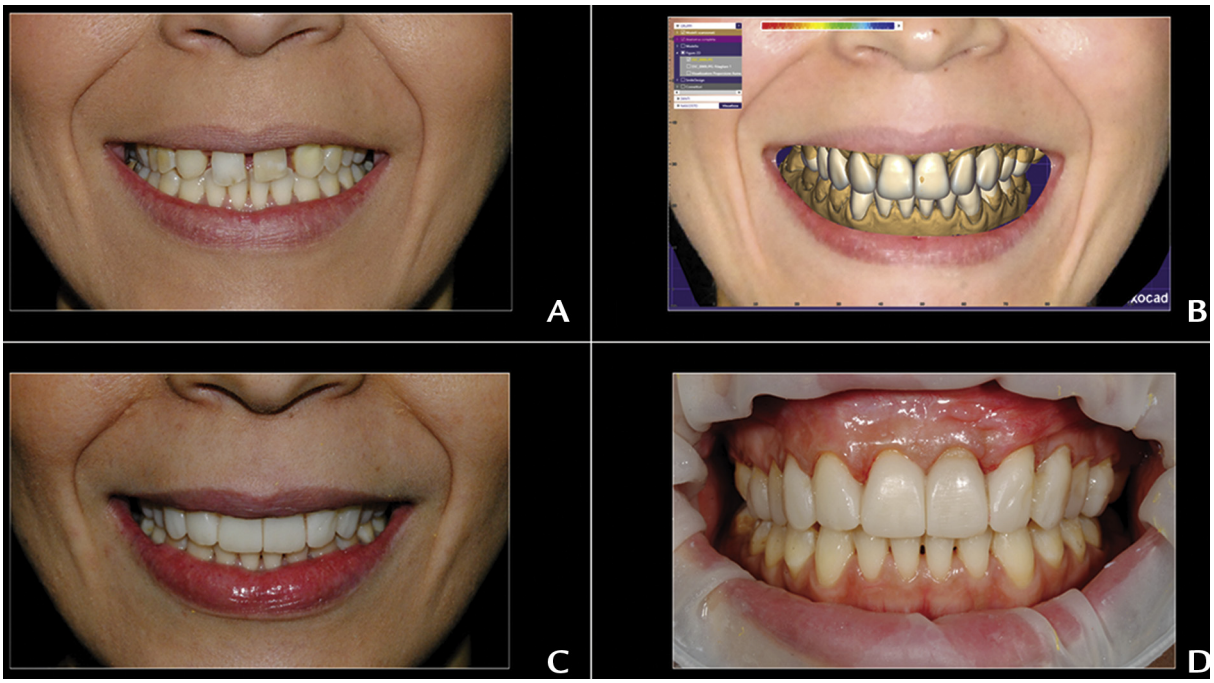

Figure 4. Main steps of second waxing and trial restoration after mounting in virtual articulator to reproduce correct alignment of maxillary arch. A, Initial smile. B, Virtual waxing. C, Smile with trial restoration. D, Intraoral photograph of second trial restoration with esthetic and functional criteria.

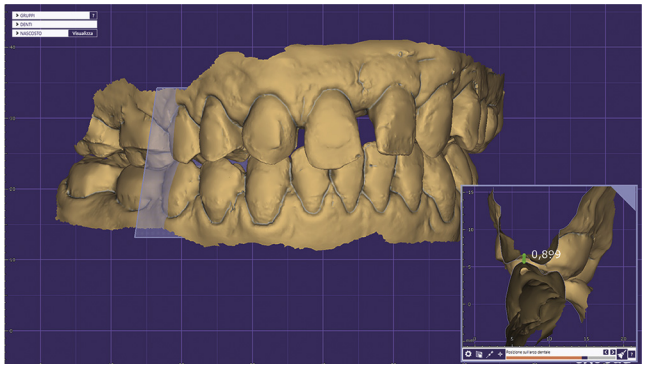

Figure 5. Occlusal vertical dimension increased by 0.9 mm at premolar region.

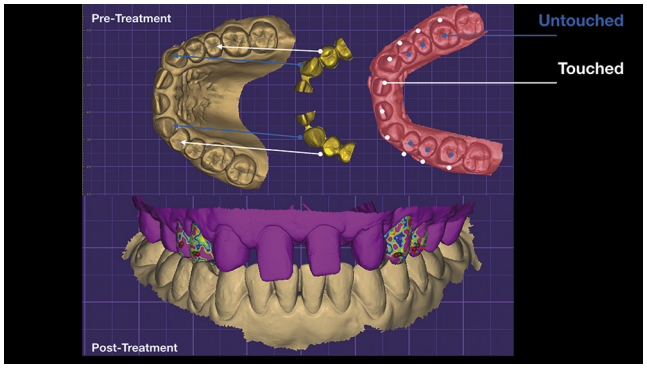

Figure 6. Interocclusal record of maxillary and mandibular arches in maximal intercuspal position.

the correct morphology without interfering in the mandibular movements. As shown, the virtual mounting of the jaws in a virtual articulator can generate an animation of mandibular movements around a first intercondylar transverse horizontal axis in the initial rest position that allows a virtual simulation of mandibular movements and dynamic occlusion. To reduce inaccuracies during the direct acquisition of the arches by intraoral scanner, some tips have been adopted: scanning occlusal tooth surfaces with as few acquisitions as possible to have less overlapping is more suitable for alignments.[15-18]

She was satisfied with the outcome. The occlusal contacts of the definitive restorations were consistent with those simulated in the virtual articulator. Laboratory and clinical time for occlusal adjustments were shortened, although studies are encouraged. This proposed digital workflow for fixed complete-arch rehabilitation with a virtual articulator possesses advantages in the phase of treatment planning and for the establishment of a harmonious occlusion from the virtual space to the actual patient. However, a CBCT scan with a large field of view was needed, which increased the radiation exposure.

Figure 7. Virtual mounting and evaluation of movements versus clinical evaluation.

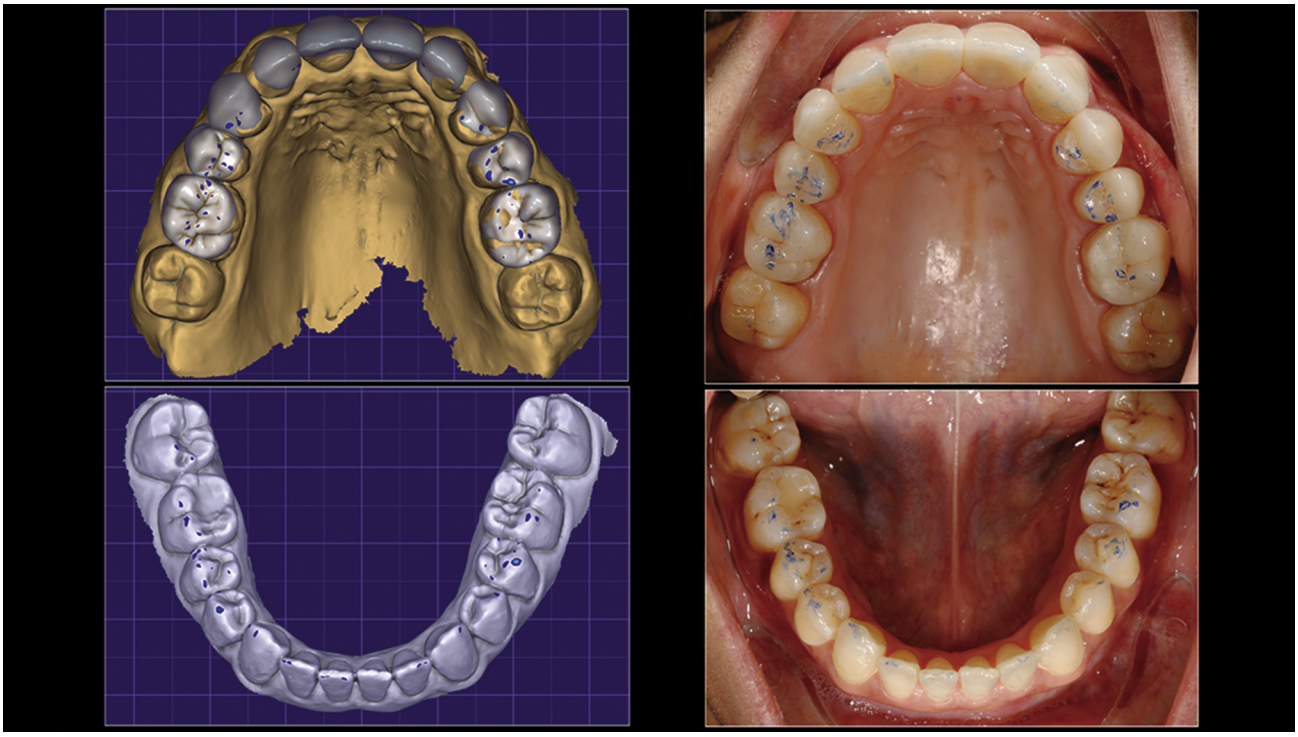

Figure 8. Occlusal contacts of digital design and definitive restorations.

Figure 9. Occlusal views at 6-month recall. Left: contact points in static occlusion. Right: contact points in static and dynamic occlusion.

SUMMARY

This clinical report demonstrated a completely digital workflow for fixed complete-arch rehabilitation. The application of a virtual facebow transfer and virtual articulator enabled a simulation of jaw movements and occlusal contacts in a virtual environment. As a result, comprehensive rehabilitation planning was performed in a straightforward way, and predictable clinical outcomes were achieved.

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Acknowledgments
The authors thank Aldo Grammatica and Domenico Faretra for their great support in the writing and critical revising of this article.

https://doi.org/10.1016/j.prosdent.2020.08.049