THE JOURNAL OF PROSTHETIC DENTISTRY

DENTAL TECHNIQUE

Esthetic treatment planning with digital animation of the smile dynamics: A technique to create a 4-dimensional virtual patient

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ABSTRACT

A method is presented for obtaining a virtual 4-dimensional patient that replicates the intended esthetic treatment. The process involves facial and intraoral scanning to acquire records and software manipulation to enable a virtual waxing of the smile. Once the digital design is complete, patient information can be merged to generate an animated video of the projected rehabilitation, displaying movement and smile dynamics. This strategy provides a noninvasive and reliable diagnostic tool for predicting clinical outcomes. (J Prosthet Dent 2020;■:■-■)

Technological devices for image acquisition offer efficiency,[1] accuracy, and a potential reproduction of the workflow, which are significant advantages for obtaining and analyzing patient records.[2-4] These appliances represent a novel and opportune approach to establish an individualized treatment plan.

Designing the smile for esthetic dentistry requires digitization and integrated data to develop a comprehensive diagnosis and a virtual simulation of the outcomes.[5,6] In the decision-making process, it is important to have a preview of clinical results before therapeutic procedures are performed because this enhances predictability[7,8] and improves communication among the dentist, dental laboratory technician, and patient.[9-11]

Initially, anatomic structures of the patient are converted into digital information that can be administered and exported.[12] Then, intraoral and extraoral scanning files can be merged by means of available knowledge and software programs.[13-15] This tactic involves computer-aided design and computer-aided manufacturing resources[16,17] to execute complex and multitask treatments.[18]

In this context, contemporary digital technologies make it possible to develop a complete virtual plan with facial references.[19-21] To capture a face scan, structured light technology[22,23] or laser scanning[24,25] can be applied. Furthermore, with stereophotogrammetry, a complete 3-dimensional (3D) facial record can be obtained instantaneously.[26] This technique uses multiple 2-dimensional (2D) images to develop a 3D cloud reconstruction. The method is radiation-free, generates suitable images, and straightforward, requires no extensive training.[27,28]

The available intraoral[29] and facial scanners capture data of the teeth, the gingiva, and the face.[30] Nevertheless, even with a 3D model, static images have limitations because they do not reproduce the animation of the smile.[31,32] As these devices do not capture movement, other tools are required to register facial and lip dynamics,[33] specifically by making a video.[34] But, it is expected that forthcoming developments will allow actual 3D facial recordings.

The virtual patient adresses this issue and consists of intraoral and facial scans[35] that can be merged with jaw and facial movements. If necessary, cone beam computed

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Figure 1. Pretreatment photographs. A, Smile at rest. B, Animated smile. C, Profile assessment of lips at rest. D, Lateral view of animated smile. E, 12 o'clock view.

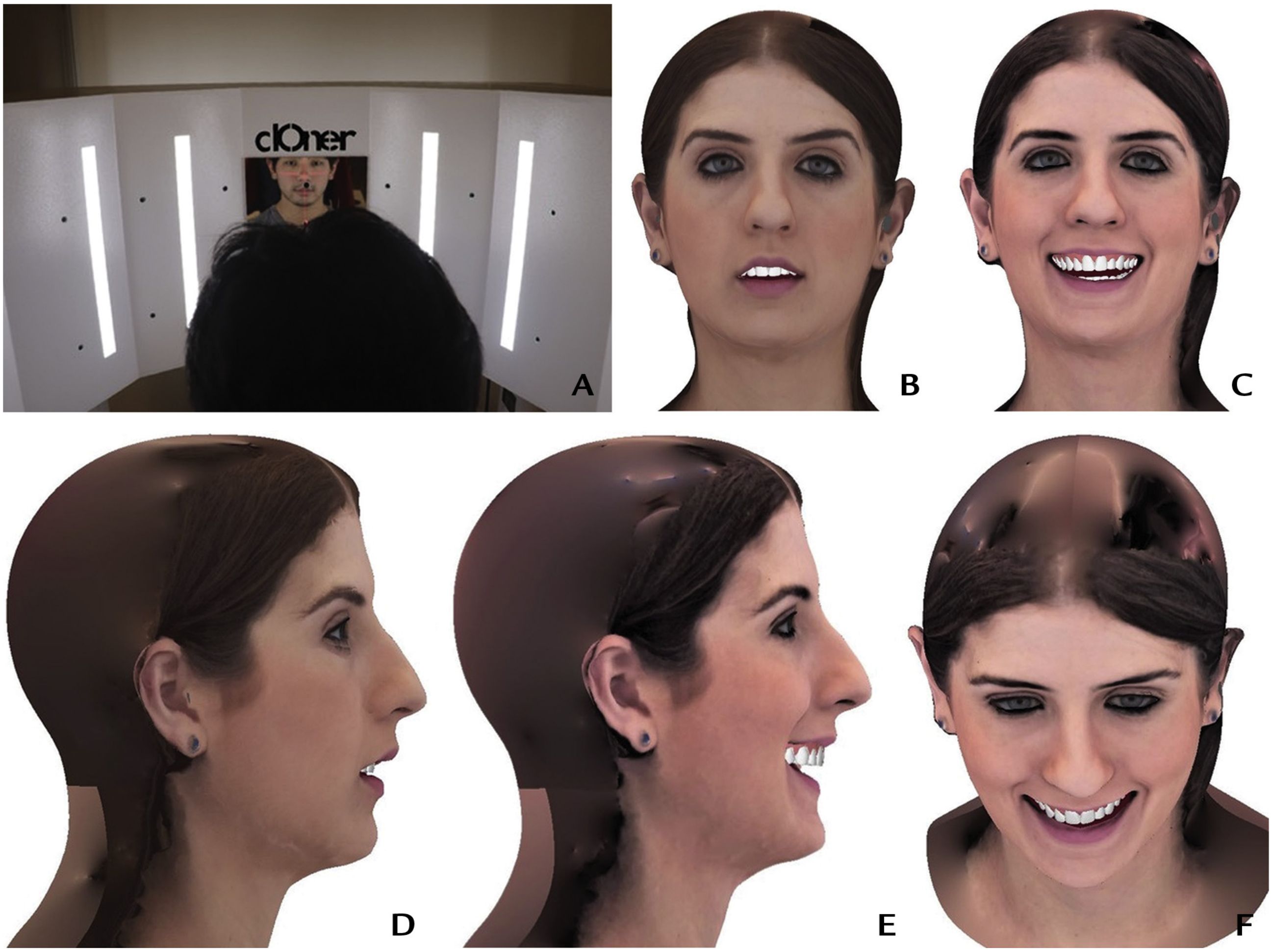

Figure 2. Facial scan obtained by postprocessing images in software program (3DF Zephyr; 3DFLOW). A, Stereophotogrammetry cabin (clOner; dOne 3D). B, Smile at rest. C, Animated smile. D, Lateral aspect of lips at rest. E, Profile outlook of animated smile. F, 12 o'clock view.

tomography images[36] can also be acquired. All these files can be overlapped and used together to create a 4-dimensional (4D) digital patient, allowing nonstatic and realistic treatment planning.[37,38]

The present article introduces a technique that combines facial imaging, intraoral scanning, digital planning software, and virtual animation of smile dynamics to reliably predict esthetic treatment.

TECHNIQUE

1. Initiate patient documentation. Make facial photographs in front, profile, and 12 o'clock views. Aim to capture the most spontaneous animated smile, especially in patients with a high smile line and/or with excessive gingival display (Fig. 1).
2. Record a video by using a mobile phone (iPhone; Apple Corp) to save the patient's dynamic movements from the rest position to the animated smile. Upload the video to a cloud storage system.
3. Acquire a precise facial scan in a stereophotogrammetry cabin (clOner; dOne 3D) equipped with 16 cameras (8 MP; 2.8 mm each) programmed to be synchronized and compose the image. Set the patient's head in a natural head position as per the linear references of the laser positioning structure. Capture photographs in a single command in less than 0.5 seconds. Perform the procedure in the following smile positions: at rest, half-open, and animated smile. Export the images by using the joint photographic group (JPG) format.
4. Import photographs into a photogrammetry and 3D modeling software program (3DF Zephyr; 3DFLOW). Apply the point georeferencing tactic to postprocess the data and transform the 2D images into a 3D colored mesh (Fig. 2). Save the record in object file (OBJ) format.
5. Scan the maxilla, mandible, and occlusal relations by using an intraoral scanner (TRIOS; 3Shape A/S). Extract the data in standard tessellation language (STL) file format (Fig. 3).

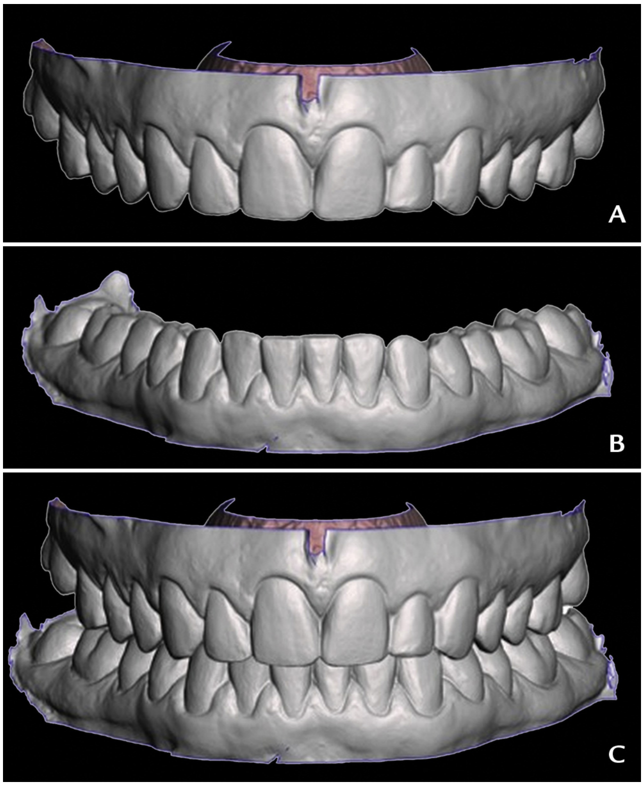

Figure 3. Intraoral scanner 3-dimensional casts. A, Virtual maxillary cast. B, Virtual mandibular cast. C, Occlusion record.

6. For complete patient digitization, transfer the 2D initial photographs, the intraoral scan, and facial scan to the digital smile design (DSD) app for iPad (Apple Corp). Merge the facial animated smile photograph with the intraoral and facial scans. Create an esthetic dental project by using the tools available in the DSD system. Choose the optimal layout of the teeth and define the new gingival contour, considering the facial references (Fig. 4).
7. Still using the DSD app software program, follow the 2D proposal to guide a complete 3D maxillary waxing. Verify the morphology and overall appearance of the planned smile from different angles, including front, profile, and 12 o'clock views, to achieve dentofacial harmony (Fig. 5). Save the data in a STL extension.
8. Use the references of the patient's initial video and operate an animation software (Maya; Autodesk) to develop the dynamic path of the smile from the rest position to the animated smile. Adopt the point correlation strategy to associate the 2D video with the 3D mesh of the intraoral and facial scans. Render data and generate a video of the smile project to create a 4D patient: a representation of 3 dimensions gathered with the patient in movement (Fig. 6, Supplemental Video 1, available online).
9. Analyze the video and adopt it as a prospective diagnostic tool to anticipate treatment outcomes. Demonstrate the animated preview to the patient and share data with the professional team. Obtain the patient's approval and, if necessary, apply changes to the project. Subsequently, use the 3D digital waxing file to make a resin cast of the maxilla (Standard Photopolymer Resin; FlashForge) with a 3D printer (FlashForge Hunter; FlashForge). Fabricate a silicone index with impression material (Silagum Putty and Honigum Light; DMG) from the printed cast. Finally, fill the index with bis-acryl resin shade A1 (Protemp 4; 3M ESPE) and produce trial restorations to clinically evaluate the smile planning (Fig. 7). The workflow of the technique is visually displayed in Figure 8.

DISCUSSION

The protocol presented in this article characterizes a method for treatment planning that incorporates the movements of smile dynamics. The visual perception is improved and clinical outcomes are adequately predicted.

In a conventional workflow, it is expected but not ensured that the planned smile will be precisely transferred to the definitive restorations.[9] Analog waxing from a 2D photograph of the patient may contain inaccuracies because the results depend mainly on the technician's impression and expertise.[31] The digital process overcome these concerns by combining imaging devices and new 3D reconstruction software.[4,8,36]

The smile design phase has been previously performed by using 2D digital images and has now developed into a 3D process. The intention is essentially the same, to develop a facially driven smile framework that will suggest the optimal 3D position of the teeth and gingiva of the maxillary arch. After data acquisition, the patient's digital files can be saved in a compatible format to be imported to the chosen technological system. Different software programs can be used to develop the new smile architecture, including Exocad (Align Technology),[17,21] 3Shape Smile Design (3Shape A/S),[29] and CEREC or CAD inLab (Dentsply Sirona).[30] These computer programs can be effectively applied for planning purposes.

The DSD app is also a file management system. DSD is a conceptual tool that analyzes the intraoral and extraoral linear references located on the 4 views of the patient's face: front, profile, 12 o'clock, and occlusal.[5,6,10,11,34] The video assessment is then used to confirm where these guidelines should be positioned. However, this examination is visual and subjective. The benefit of using 3D facial scans with movement is that the smile design can be checked, not only from the 4

Figure 4. Esthetic smile planning with DSD app. A, DSD software program and facial photograph of animated smile. B, Maxillary digital cast merged with 2D frontal photograph. C, Intraoral scan digital cast integrated with profile photograph. D, Facial scan imported into software program and superimposed on front view photograph. E, Merging intraoral and facial scans. F, Smile design guided by anatomic references. G, Before and after project simulation. DSD, digital smile design.

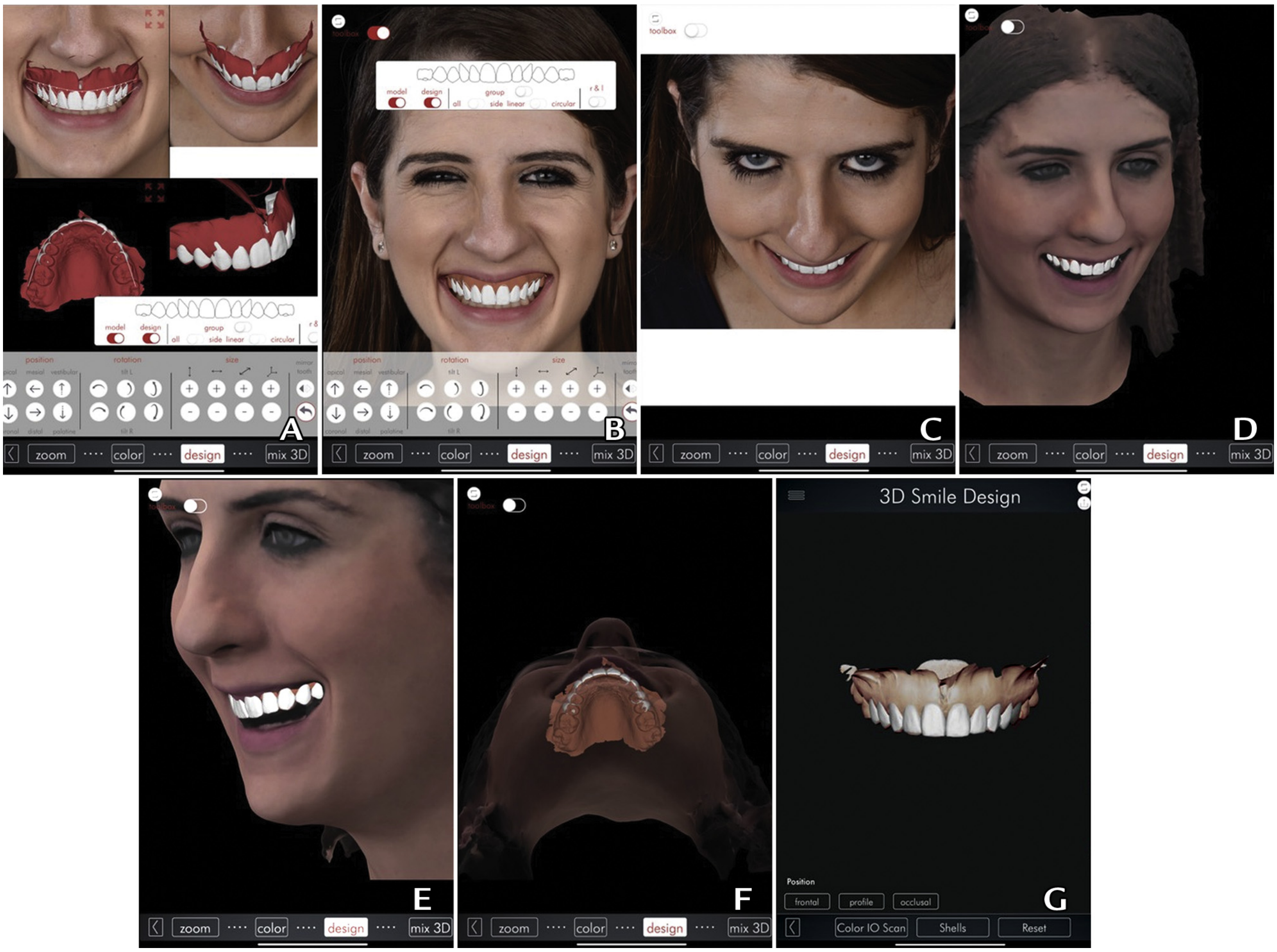

Figure 5. Computerized 3-dimensional waxing. A, 3D waxing cast presented at different angles to evaluate smile. B, Proposed design from frontal view. C, 12 o'clock view. D, 3D waxing incorporated into facial scan in anterior view. E, Smile design and facial scan in profile view. F, 3D waxing in inferior view. G, Definitive 3-dimensional smile design cast.

conventional perspectives but also in an infinite number of views; moreover, the project can be evaluated with actual facial movements (Supplemental Video 1, available online).

The merging of intraoral and facial scans[14,15,34] with computer manipulation allows complete digitization and the creation of a virtual patient.[19,20] Nevertheless, the common reference used to be a static smile position.[31,33] In the presented technique, an additional software program was used to convert the data into a realistic 4D patient, capable of showing the smile path. Hence, a complete periodontal and restorative simulation was conducted considering facial anatomy and lip movements.

The virtual plan was assessed in different positions and angles from a 3D perspective with lip dynamics, and the outcome of the additive trial restorations was a replica of the digital design. When it is not possible to provide trial restorations because of extruded teeth or abnormal tooth angulations, the opportunity to virtually preview the smile is another advantage of 4D simulation. Once the project is approved, the planning files can be used to mill and produce definitive restorations from the same digital library.

Limitations of the proposed strategy include the high equipment costs,[35] necessitating initial investments or the establishment of partnerships. In addition, dental professionals and technicians need training to understand and operate computer-aided design software.[1] The management of digital features is associated with an inherent learning curve, and scientific evidence should guide the educational progress.

The reported method points to a trend toward graphic simulation. A 4D patient has shown to be an accurate, realistic, and noninvasive diagnostic planning tool. Clinical studies are needed to validate its use in practice.

SUMMARY

The described technique introduces the integration of facial and intraoral scans with a smile design to create a

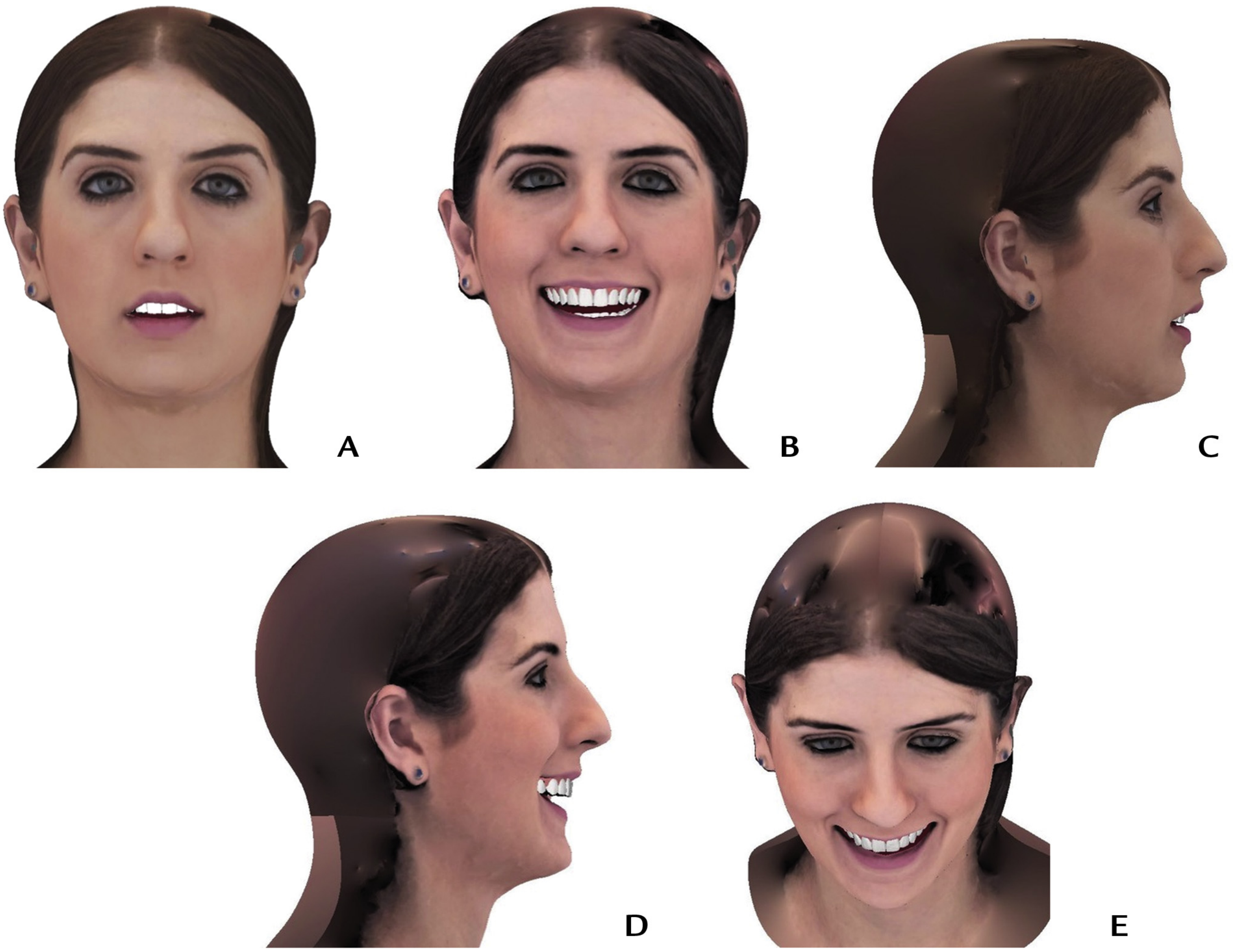

Figure 6. Video frames representing 4D virtual patient. 3D smile project incorporated into facial scan. A, Smile at rest. B, Animated smile. C, Lateral view of lips at rest. D, Profile appearance of animated smile. E, 12 o'clock view.

dynamic 4D patient. This protocol enables the development of a comprehensive digital planning that results in a final animated video of the smile path. The possibility of evaluating the smile in movement represents a promising diagnostic instrument to predict treatment outcomes.

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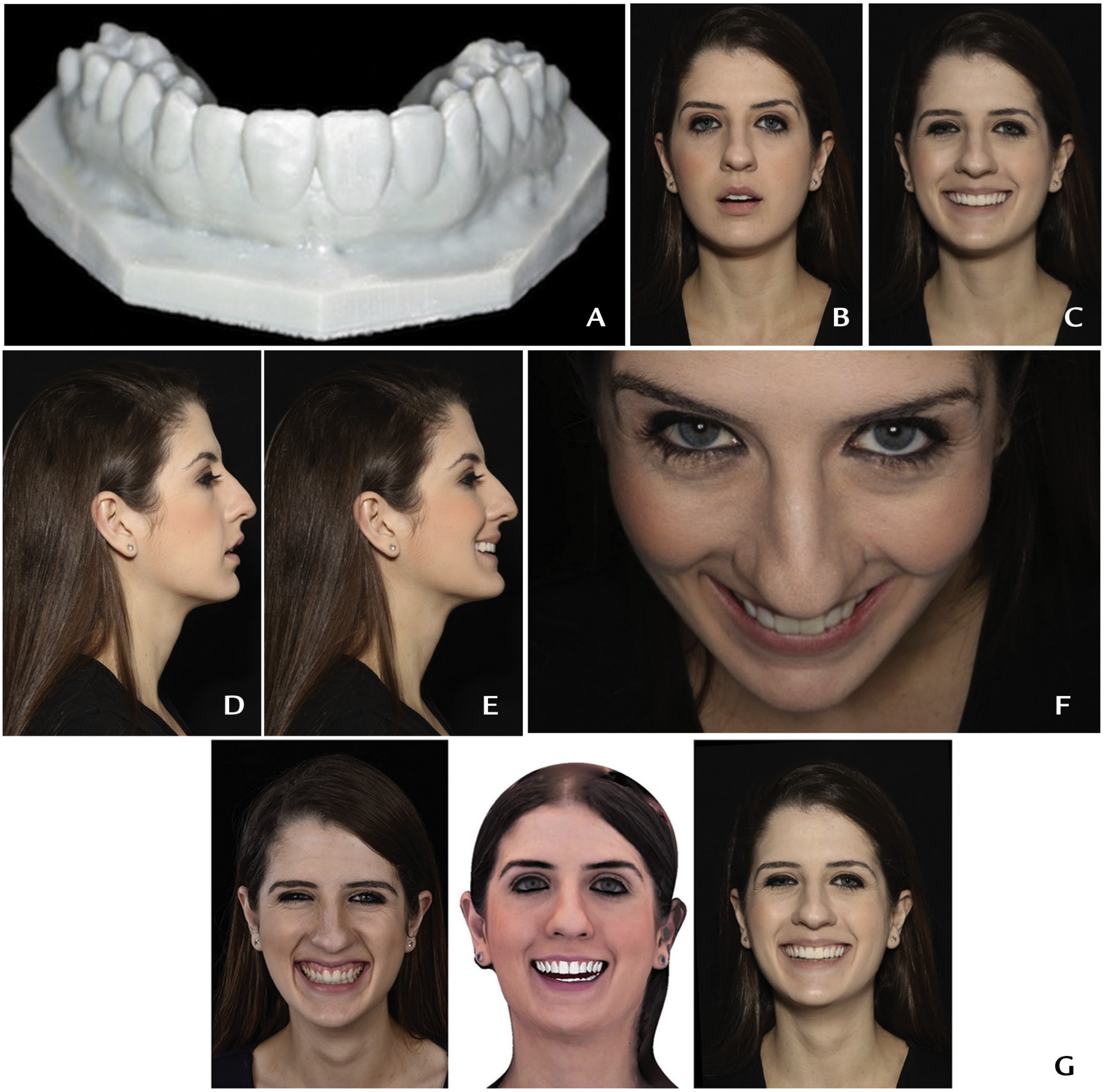

Figure 7. Result of technique. 3D printed cast and trial restorations. A, Maxillary cast. B, Smile at rest position. C, Animated smile. D, Profile aspect of lips at rest. E, Lateral assessment of animated smile. F, 12 o'clock view. G, Comparison between initial status, 4D virtual plan, and trial restorations.

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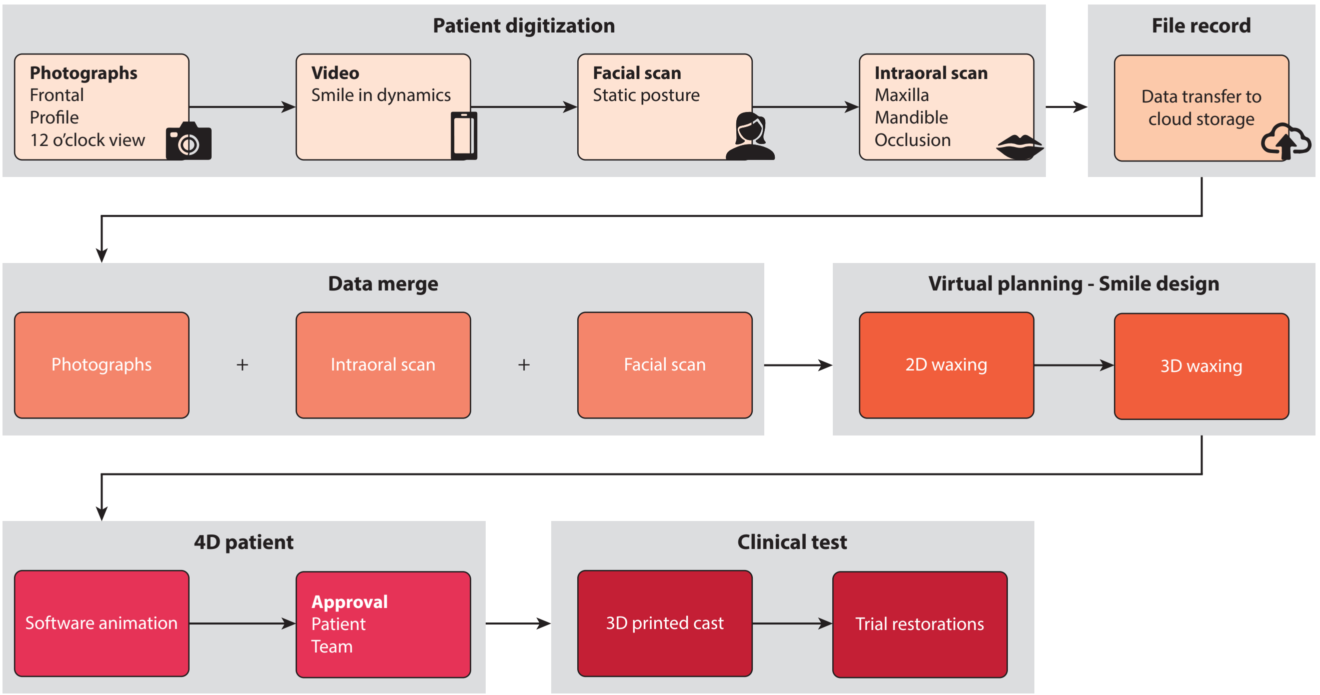

Figure 8. Four-dimensional patient workflow.

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https://doi.org/10.1016/j.prosdent.2020.10.015