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The Application of 3D Dense Face Alignment in Esthetic Rehabilitation

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Abstract

This article describes a technique for making an esthetic treatment plan by using a virtual face scan reconstructed from digital photographs through three-dimensional dense face alignment (3DDFA) and intraoral scans. Portrait photographs were captured with a digital camera and were reconstructed to a virtual 3D face scan by 3DDFA. After scaling the virtual face scan to the correct size, intraoral scans and virtual face scans were aligned to create a 3D view of the patient. A virtual diagnostic waxing was created accordingly. In select cases, this technique can provide 3D esthetic predictions when 3D face imaging devices are not available.

The concept of virtual smile design has been widely accepted in esthetic dentistry, and a variety of protocols have been introduced.[1–4] Compared with smile designs based on digital photographs, modern workflows integrating three-dimensional (3D) face scans and intraoral scans can provide better flexibility, efficiency, and visual perceptions.[5] However, specific 3D face imaging devices are needed when capturing face scans, which restricts the clinical application of 3D smile design.

3D dense face alignment (3DDFA) is a deep-learning based method which reconstructs a 3D face model from a single 2D face image input, and has been used for many face related tasks, e.g., recognition, animation, avatar retargeting, and image restoration.[6] Generally speaking, this method reconstructs 3D face models by morphing an average 3D face model to fit the landmarks recognized from the target 2D face image.[7] The generated 3D face model might be considered as a "virtual face scan" to replace the 3D face scan for 3D smile design, eliminating the requirement of 3D face imaging devices in selected cases.

In this technique, a workflow for integrating 3DDFA with 3D smile design is described. The 3D face model and the intraoral scan are combined to simulate the esthetic outcome in a direct and perceptive method.

Technique

A 25-year-old woman was referred to the clinic for her worn and discolored anterior teeth caused by fluorosis. To simulate the esthetic outcome of the treatment, a virtual diagnostic waxing was completed using the following protocol:

1. Make a full face frontal smile portrait of the patient by using a digital camera (EOS 80D; Canon Inc.) (Fig 1). Make another full face frontal portrait with a calibrated scale positioned beneath the orbits (Fig 2).
2. Download and install the open source 3DDFA program from online code repository: https://github.com/cleardusk/3DDFA_V2.
3. Reconstruct a 3D face model by importing Figure 1 to the 3DDFA program according to the provided instructions. Export the resulting 3D face model to Wavefront geometry definition format file (OBJ).
4. Measure the inter-lateral canthi distance $L_{physical}$ from Figure 2.
5. Import the 3D face model to 3D reverse engineering software program (Geomagic Studio 2014; 3D Systems). Measure the inter-lateral canthi distance of the 3D face model in its logical coordinate system $L_{logical}$ (Fig 3).

Figure 1 Full face frontal portrait of patient.

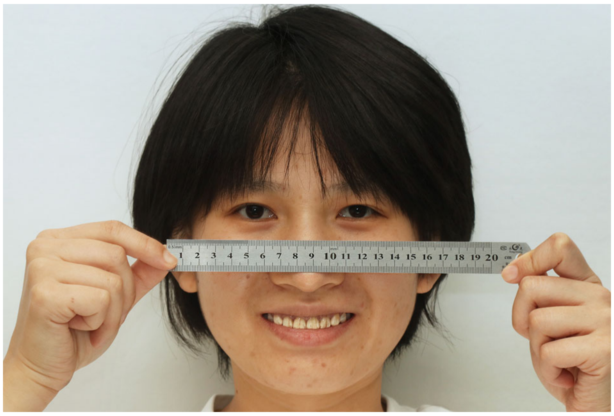

Figure 2 Full face frontal portrait with calibrated scale.

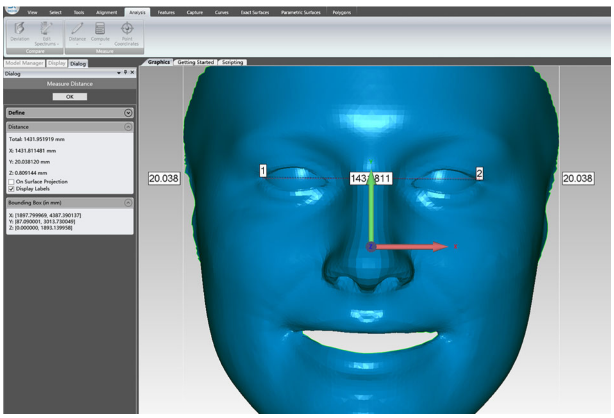

Figure 3 Measure inter-lateral canthi distance of reconstructed 3D face model.

6. Calculate the scale factor $S = L_{physical} \div L_{logical}$. Scale the reconstructed 3D face model with the scale factor S in Geomagic Studio 2014. Convert the scaled 3D face model to the polygon file format (PLY).
7. Make digital casts of patient's dentition and gingiva by using an intraoral scanner (TRIOS 3; 3Shape A/S). Import the digital casts, Figure 1, and the scaled 3D face

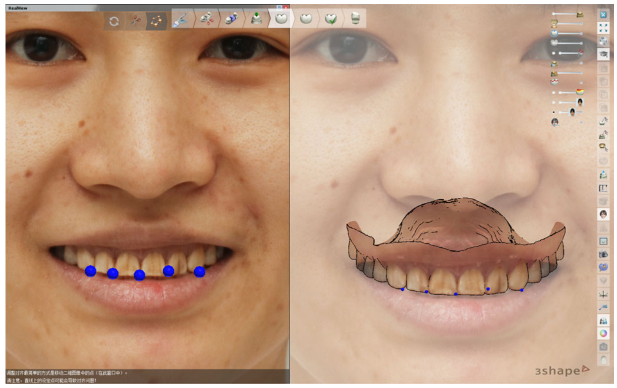

Figure 4 Aligned digital casts with portrait.

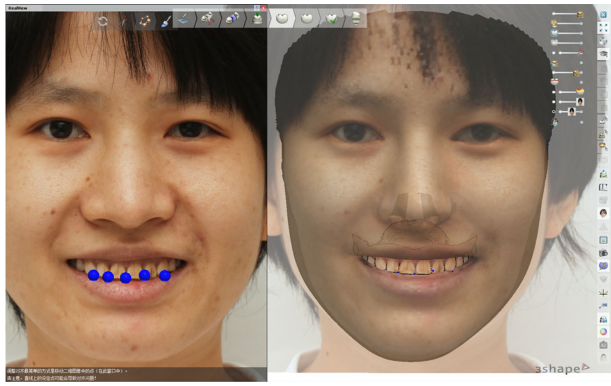

Figure 5 Aligned scaled 3D face model with portrait.

model to a dental design software program (Dental System 2020, 3Shape A/S) to create an order for virtual diagnostic waxing.
8. During the designing process, activate the "RealView" function in the toolbar. Align the digital casts with the portrait by placing at least four matching pairs of points on both of them (Fig 4).
9. Activate "Additional scans" function in the toolbar. Switch to "Align" mode and select the scaled 3D face model. Manually move and rotate the scaled 3D face model to align with the portrait by superimposing facial landmarks, e.g., pupils, apex nasi, labial commissures (Fig 5). If necessary, deactivate "RealView" function to move and rotate the face model from different views.
10. Finalize the align process and continue the designing process of the virtual diagnostic waxing (Fig 6).

Discussion

Several dental design software programs provide their own workflows for integrating 2D portrait images with 3D digital casts (e.g. "RealView" in 3Shape Dental System and "Smile Creator" in exocad DentalCAD), making it more intuitive to create virtual waxings. However, the view is often stuck to a single direction to prevent operators from observing from different angles, causing inconveniences to the practitioners and patients (see supplemental video). CEREC software (Dentsply

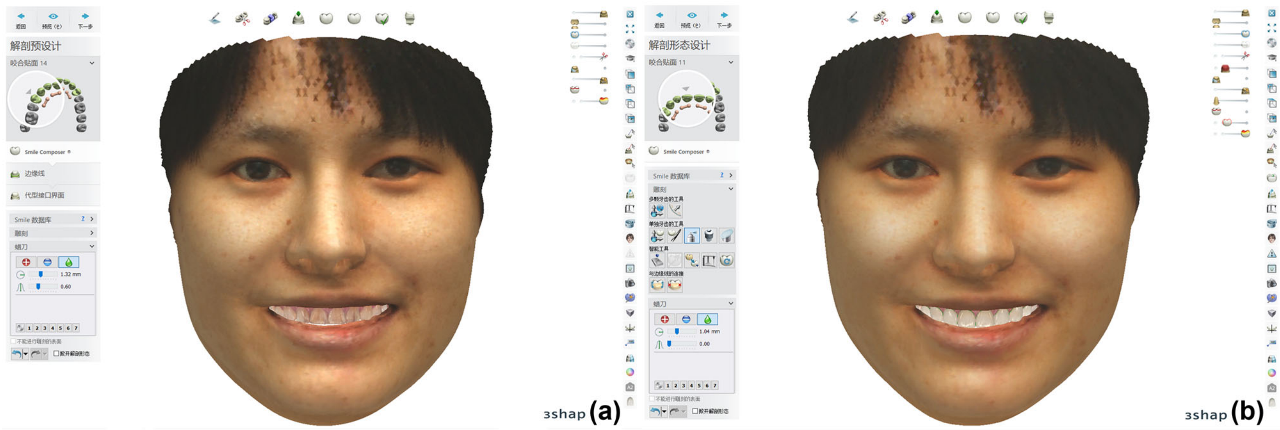

Figure 6 Aligned 3D face model and digital casts. A, Pretreatment view. B, Virtual smile design.

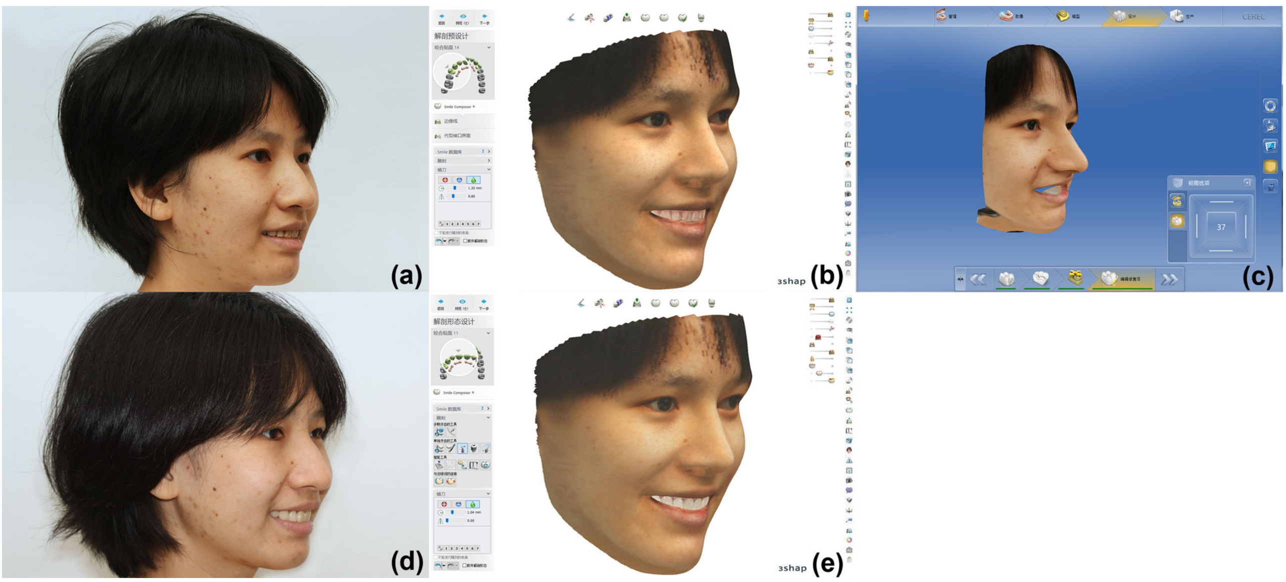

Figure 7 Real lateral profile of patient and simulated results. A, Patient's real lateral profile before treatment. B, Lateral view of reconstructed face model. C, Lateral view of avatar in CEREC Smile Design. D, Patient's lateral profile after treatment. E, Lateral view of virtual smile design.

Sirona) provides a workaround ("Smile Design" module) by projecting a 2D portrait image to a built-in 3D avatar. After scaling the avatar to the correct size and aligning the avatar with the digital casts, operators can fine tune the restoration designs with more freedom. A restriction of this module is that the avatar cannot be exported to open file formats. Moreover, the avatar seems to be rigid; it cannot be adapted to different facial profiles, which restricts its clinical application.

In the described technique, several advantages can be observed. It is a cost-effective method which uses conventional and versatile digital cameras rather than 3D face scanners. A single portrait cannot indicate 3DDFA to generate a face model with the correct size, so commercial software (Geomagic Studio) is used to scale the uncalibrated face model to fit the real size of the face (Steps 3, 4 and 5). It is also possible to achieve this goal with freeware, e.g., MeshLab, Meshmixer and Blender, to make this workflow more cost-effective. The 2D portrait image is reconstructed to a 3D face model to simulate a face scan, making it possible to move the viewpoint during the analyzing and designing process. The algorithm is open-source and the reconstructed face model is converted to open file formats. Operators can adapt this technique to their preferred dental software. Due to the characteristics of the algorithm, the profile of the 3D face model can be adapted automatically. The simulation of the esthetic outcome can be more realistic (Fig 7).

One of the concerns of this technique is the applicability. 3DDFA reconstructs face models by morphing an ideal average face model to fit 2D images, indicating that severe maxillofacial malformations, e.g., asymmetry, and malocclusion, are not suitable for this workflow. It is suggested that only selected cases with normal facial profiles are indicated for this technique.

Summary

A digital workflow for integrating 2D portrait images with 3D digital casts for esthetic dentistry is described. This technique is flexible and efficient, which should improve the simulation effect and predictability of the treatment outcome.

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Declarations of interest

None.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Video S1