

DENTAL TECHNIQUE

Digital database for nasal prosthesis design with a 3D morphable face model approach

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Various computer-aided design (CAD) techniques have been used to aid facial prosthesis design, including free-form sculpting,^{1,2} templates of presurgical anatomy,³ scans of volunteers,⁴ and mirroring contralateral features.⁵⁻¹⁰ CAD can benefit clinicians by simplifying processes, reducing dependence on artistic skills, enhancing reproducibility, and improving process efficiency.^{4,8,10} Patients may benefit from reviewing different design options, inputting during real-time adjustments, reduced clinical sculpting time, and the potential to store successful designs.^{4,8,10,11} CAD approaches require an understanding of maxillofacial prosthetic and anatomic principles,^{4,8,12} as well as access to suitable software programs, training, and techniques.^{10,11,13}

Nasal prostheses can be challenging to design because of the unpaired nature of the facial feature, which can preclude the use of mirroring techniques.^{12,14}

ABSTRACT

Designing nasal prostheses can be challenging because of the unpaired nature of the facial feature, especially in patients lacking preoperative information. Various nose model databases have been developed as a helpful starting point for the computer-aided design of nasal prostheses, but these do not appear to be readily accessible. Therefore, an open-access digital database of nose models has been generated based on a 3-dimensional (3D) morphable face model approach. This article describes the generation of the database, highlights steps for designing a nasal prosthesis, and points readers to the database for future clinical application and research. (*J Prosthet Dent* 2023;■:■-■)

Furthermore, information about the previous anatomy may be unavailable or may have been distorted, limiting the benefit of preoperative scans.^{12,14} In these scenarios, a preexisting systematically organized digital library of varying nose shapes or proportions could provide a rapid and straightforward way of trialing multiple options as a starting point for prosthesis design.^{12,14}

Various libraries of facial features have been created based on the scans of volunteers or anatomic casts.^{11,12,14} In the authors' experience, these databases are not readily accessible⁹ because of missing links or because data have been incorporated in software programs,

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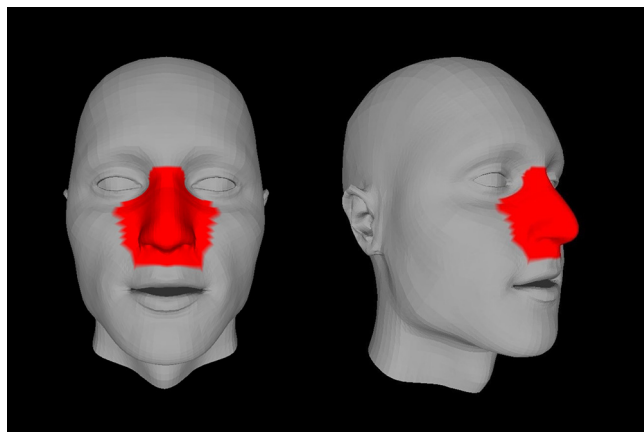


Figure 1. Three-dimensional morphable face model with red indicating region cropped from each randomly generated face. Reviewing cropped region may aid positioning of nose model.

which may now be obsolete. Creating new databases of raw scans can have limitations, as identifying and scanning new volunteers can be resource-intensive, raw scans can be difficult to manipulate, and sharing personal data has important ethical considerations.¹⁵ An alternative approach could involve using statistical shape models to generate a database of simple, well-behaved meshes that contain no personal information.

The 3-dimensional morphable face models (3DMFMs) are generative models for face shape and appearance which allow 3D facial reconstruction from 2D and 3D images.¹⁵⁻¹⁸ 3DMFMs can model shape deformations, identify shape differences in shape families, and sample shape variation.^{15,16} The Leeds face model (University of Leeds) was generated based on the facial scans (DI3D; Dimensional Imaging Ltd) of over 100 volunteers of varying ages, sexes, and ethnicities. The model uses 219 dimensions that describe an instance of a face. When all numbers are set to 0, the mean face is produced. Each number is scaled as the standard deviation of that dimension, with a value of 1 representing 1 standard deviation from the norm.

To create a nose model database with sufficient facial variation, random numbers were generated for the 219 dimensions at up to both 1 and 2 standard deviations to create a sample of 200 randomly generated faces.^{15,16} The area of interest was marked on the Leeds face model (Fig. 1) to indicate the planned outline of the nose models with extension beyond the nasal region to facilitate blending. The randomly generated faces were cropped, and the 200 resultant noses were manually screened to remove implausible or noticeably similar examples.¹⁶ The final 44 noses were summarized in a database guide with thumbnail images and written descriptions of bridge profile, tip projection, nose length-to-width ratio, and key measurements (nose length, nasal bridge length, and nose width) (Fig. 2). The open-access

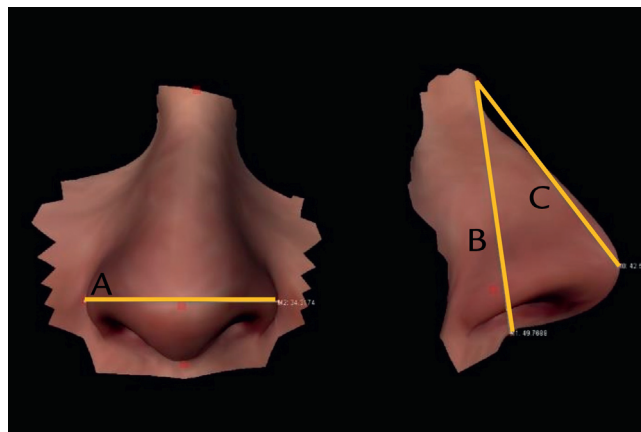


Figure 2. Measurements obtained by measuring distance between key vertices on all nose models. A, Nose width. B, Nose length. C, Nasal bridge length.

database of nose models was made available for research and clinical use.¹⁹

The following technical steps outline the process for designing a nasal prosthesis with the database of nose models generated by using a 3DMFM approach. A facial scan of a volunteer has been used as an example, and their nose removed to mimic a nasal defect. The volunteer provided facial photographs to imitate preoperative images to aid CAD. The reader can review the figures to compare the facial prosthesis design to the original facial scan to consider the suitability of this approach.

TECHNIQUE

1. Collect all required data. Make a facial scan with an appropriate facial scanner, such as a handheld structured light scanner (Artec Space Spider; Artec 3D). Process the data, and export the facial mesh (Figs. 3 and 4). Source clinical or patient photographs showing the preoperative nose shape.
2. Review the database guide to select appropriate nose model(s) to trial. Select nose shape by comparing preoperative information to thumbnail images and written descriptions. Consider the nose model measurements and remember that nose models can be resized. In patients with limited preoperative information, use neoclassical canons or geometric rules to support nose model selection but account for ethnic variation and patient's preference.²⁰⁻²²
3. Import the facial mesh and nose model(s) into the operator's preferred CAD software program (such as Geomagic Freeform; Oqton). Orient the facial mesh so that it is approximately aligned with the nose models (Fig. 5).
4. Review the nose model(s) and select the most appropriate one based on the operator's expertise,

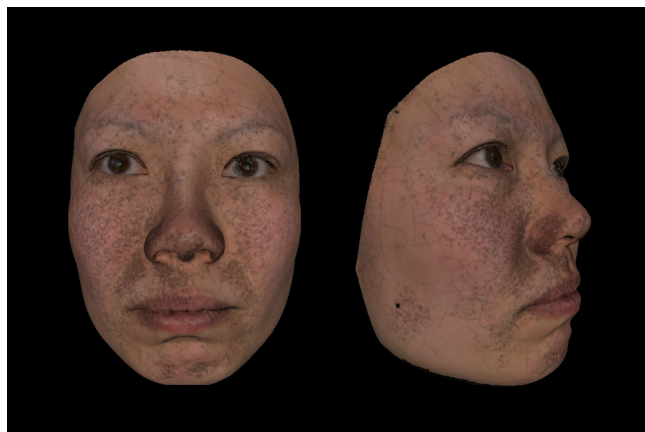


Figure 3. Scan of volunteer with optical scanner (Artec Space Spider; Artec 3D) showing unedited facial features.

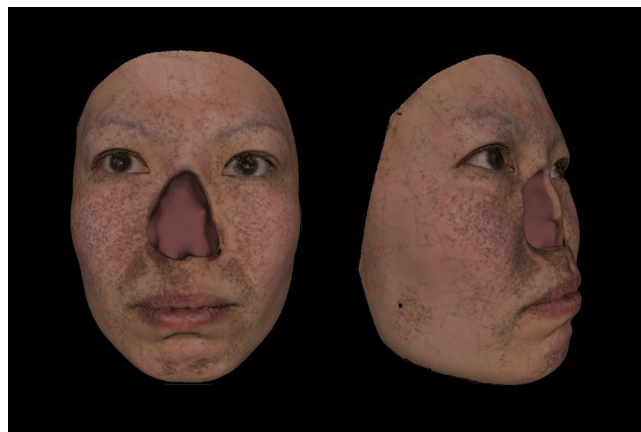


Figure 4. Facial part removed to mimic full nasal defect for reconstruction.

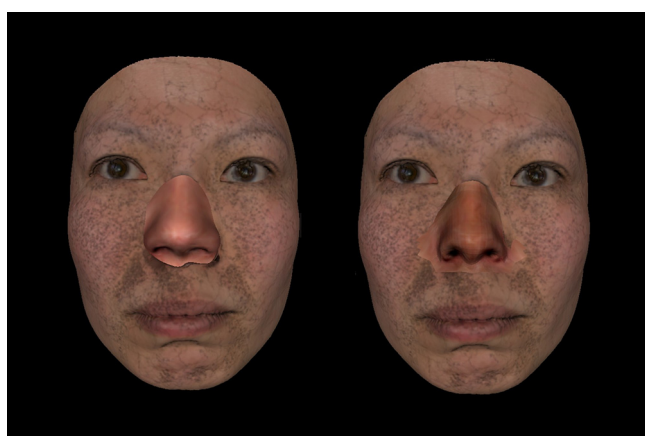


Figure 5. Facial mesh aligned with nose models with open-source software program for editing meshes (MeshLab; <https://www.meshlab.net/>). Two examples of nose models trialed from database.

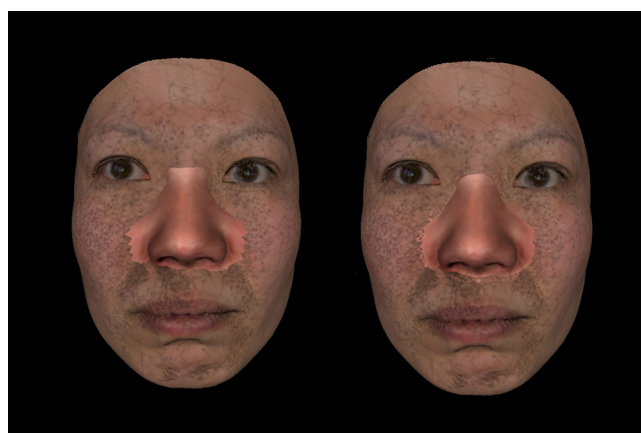


Figure 6. Preferred nose model aligned and blended to facial mesh with computer-aided design sculpting tools (Meshmixer; Autodesk Inc).

patient's wishes, and any available preoperative photographs.

5. Resize or rescale the selected nose model as required and fine-align to the facial mesh. To guide positioning of the nose model, review [Figure 1](#) which illustrates the region that has been cropped from the randomly generated faces. The addition of a midsagittal reference plane may help identify the correct rotational positioning of the nose model.
6. Blend the margins of the nose model to the facial mesh with the CAD software program (Geomagic Freeform; Oqton) and sculpting tools ([Fig. 6](#)). Thicken the fit surface of the nose model to the desired thickness to ensure structural integrity of the silicone material and adapt to the facial mesh.
7. Modify the design to incorporate any retentive components and adjust the nasal features (such as the nasal contours or nostrils) to the needs of the patient ([Fig. 7](#)).

8. Once completed, use the CAD file to produce a 3D printed replica or negative mold according to the operator's preferred digital workflow and 3D printing materials (such as Model V2 Resin; Formlabs).

DISCUSSION

The digital nose model database may support operators with an understanding of prosthetic principles and general CAD techniques to design nasal profile dressings and intermediate or definitive nasal prostheses. While no absolute contraindications exist for using this database, other CAD techniques may be more appropriate in specific clinical contexts. Preoperative scans may be better suited to situations where a patient's nasal anatomy is not distorted and facial scanning can be coordinated before surgery.³ With combined midfacial defects, the database could be used in conjunction with other techniques (such as mirroring) but could be more

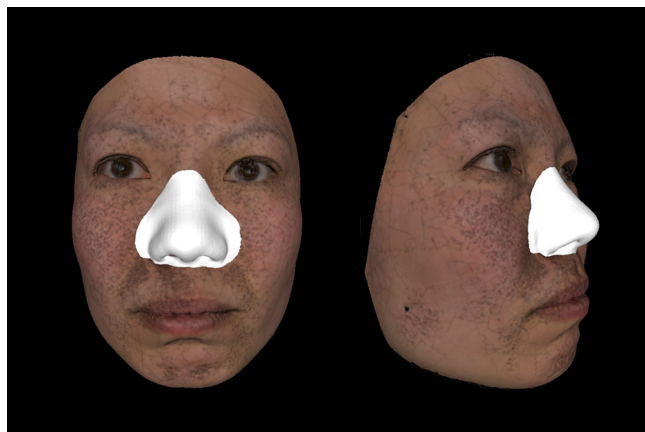


Figure 7. Additional features added and fit surface of nose model thickened into printable computer-aided design file with custom software program.

complex because of disruption of key landmarks and lines of symmetry.¹³

Although an explicitly defined method for nose model selection is lacking, this database can be used with standard prosthetic principles, neoclassical canons, and geometric rules.^{20–22} These should be interpreted with caution and modified to account for interethnic variation and differences in patients' preference.^{20–22} As all nose models have a standardized orientation, operators can rapidly trial multiple options to identify a sensible starting point for CAD. The polygon file format will be compatible with a variety of software programs, and the straightforward, well-behaved meshes will be ideal for resizing and manipulating with CAD tools. The nose models will be less detailed than raw meshes, and additional features (such as folds and creases) may need to be added.

While the Leeds face model has been created based on the scans of over 100 volunteers of varying ages, sexes, and ethnicities, the sample may be insufficient to create a truly representative model that fully explains the shape variations of nasal features.^{15,18} The low prevalence of some features within the database (such as concave bridges) may be attributed to fewer instances within the sample population and consequently a lower probability of being generated. The 3DMFM dimensions were varied at up to 2 standard deviations to generate a variety of nose models including less commonly encountered shapes. The number of nose models was then reduced to balance shape variety with clinical usability. The database could be refined as training set sizes are increased or demographically specific 3DMFMs are produced.¹⁸

Further improvements could be implemented to semiautomate key CAD steps. Software programs could be developed to automatically select, align, and rescale

nose models based on the selection of facial landmarks. Vertices corresponding to the nostrils could be deleted programmatically. Augmented reality programs could aid nose model selection and facilitate greater patient input.²³ Finally, 3DMFMs could design facial prostheses in a semiautomated and statistically meaningful way based on the characteristics of the patient's surrounding facial features.¹⁷ Further research is underway to assess the accuracy and repeatability of using 3DMFMs to aid facial prosthesis design in laboratory and clinical settings.

SUMMARY

The generation of a user-friendly, open-access digital database of nose models based on a 3DMFM approach is described. The CAD technique offers a sensible starting point for facial prosthesis design and may be useful where preoperative information is limited. Research is ongoing to assess the use of 3DMFMs in aiding facial prosthesis design.

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