A Novel Computer Algorithm for 3D Printing a Nose Prosthetic: A Pilot Study

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ABSTRACT

Objectives: To describe a novel computer algorithm that can be used to create a three-dimensional (3D) model of a nose.

Methods: A computer algorithm utilizing a 3D animation software, Blender (Blender Foundation, Inc, USA), and Adobe Photoshop CS6 (Adobe Systems, Inc, USA) was developed to create a 3D model of a nose. Photographs of five subjects were processed with the computer algorithm to create a virtual 3D model of each nose. The model was then printed using a desktop 3D printer. Attending physicians, residents, and medical students completed a survey, and were asked to rate the similarity between the subjects' photographs and their 3D printed nose on a Likert-type scale [0- completely different to 10- identical].

Results: Thirty-six survey respondents evaluated four views for each of the five modeled noses. The mean score for the overall similarity between the photographs and the 3D models was 8.41 +/- 1.27. The mean scores for each nasal comparison ranged from 7.97 to 8.62. 97.8 % of respondents were able to match the correct 3D nose to the corresponding subjects' photographs. All clinicians surveyed indicated that they would consider utilizing this tool to create a temporary prosthesis rather than referring to a prosthodontist.

Conclusion: This computer algorithm can be utilized to model and 3D print a human nose. The 3D printed models closely depict the actual images of each subject's nose, and can potentially be used to create a temporary prosthesis to fill external nasal defects.

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INTRODUCTION

- Nasal defects caused after trauma or Mohs surgery involving the nose can be very detrimental. Reconstruction surgery using skin and cartilage grafts often requires multi-step operations. Nasal prosthetics used in rehabilitation require referral to a third-party provider, and can be very costly.
- Three-dimensional (3D) printing techniques have been developed to use Computer Tomography (CT) scans and 3D modeling software to create anatomically accurate models. The cost of these software and equipment remains a limitation for widespread use.
- We introduce a computer algorithm that utilizes 2D pictures of a patient and two software packages that are affordable and commercially available to create a model of a nose.
- *Hypothesis:* This algorithm can produce a 3D printout of a nose that is very similar to the actual images of the patients.

METHODS AND MATERIALS

Image Acquisition

- Five volunteers were recruited for this pilot study and agreed to have their picture taken. Four images of each subject were taken in Front, Basal, Right, and Left views.

Computer-based Algorithm (Figure 1)

- The four images were scaled to real life size in Adobe Photoshop CS6 (Adobe Systems Inc, San Jose, CA).
- The four calibrated images were uploaded into a free animation software, Blender (Blender Foundation Inc, USA).
- The first outline of the nose is drawn by adding vertices in *Wireframe* mode using all four views.
- The fine editing of the nose contour and shadows is done under the *Subdivision Surface* modifier.

3D Printing

The model is printed with High Impact Polystyrene using a Lulzbot Taz 5 Desktop 3D printer.

Cross-sectional Survey (Figure 2)

A survey comparing the 3D model printouts to the four images of each of the 5 cases was produced.

A Likert-type scale rating system of 0-10 was utilized. *(0 = completely different; 5 = somewhat similar; 10 = identical).*

For each case, participants were asked to:

- Match the appropriate nose model to the corresponding images.
- Rate the similarity of the 3D model to each image in 4 views.

We also Assessed:

- The algorithm's capacity for clinical utility.
- Attending physician's willingness to try the software for modeling prosthetics.

Statistical Analysis (Figure 3)

Data from the surveys were collected, and mean values of the ratings for each model and each view were calculated. Analysis of Variance (ANOVA) was done to assess statistical significance of mean score comparisons. Statistical comparisons were performed using the R Statistical System (www.r-project.org, v3.2). A P value < 0.05 was considered significant. Where appropriate, multiple comparisons were performed using the Tukey test.

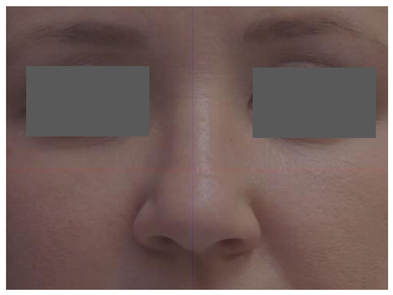
RESULTS

Twenty images were displayed for a total of five cases, and compared to five 3D nose models corresponding to each of the cases.

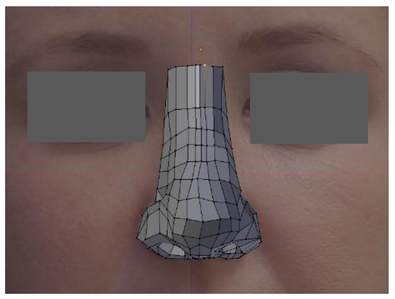
The survey was administered to n = 36 respondents including surgeons (n = 7), residents (n = 14), and medical students (n = 15).

The mean (± SD) score for the overall similarity between the models and the pictures among all 36 respondents was 8.42 ± 1.34. The mean score breakdown according to training level for overall similarity was 7.71 ± 1.09 for Attending Physicians, 8.54 ± 1.01 for Residents, and 8.56 ± 0.74 for Medical Students. Over 85% of the scores were a grade of 8 and above.

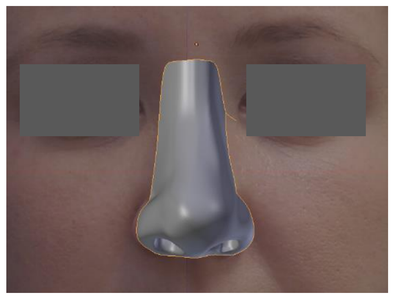
- All 7 (100%) of Attending Physicians responded that they would use this tool instead of referral to a prosthodontist.
- Approximately 98% of respondents were able to correctly match the subject photograph to the equivalent 3D nose printout.



***Step 1*: Image imported into Blender**



***Step 2*: *Wireframe* outline of nose created using Blender**



***Step 3:* Fine editing of nose contour by Subdivision Surface modifier**

***Step 4:* 3D model printed using a Lulzbot Taz 5 Desktop 3D printer**

Figure 1. Steps of the computer-based algorithm

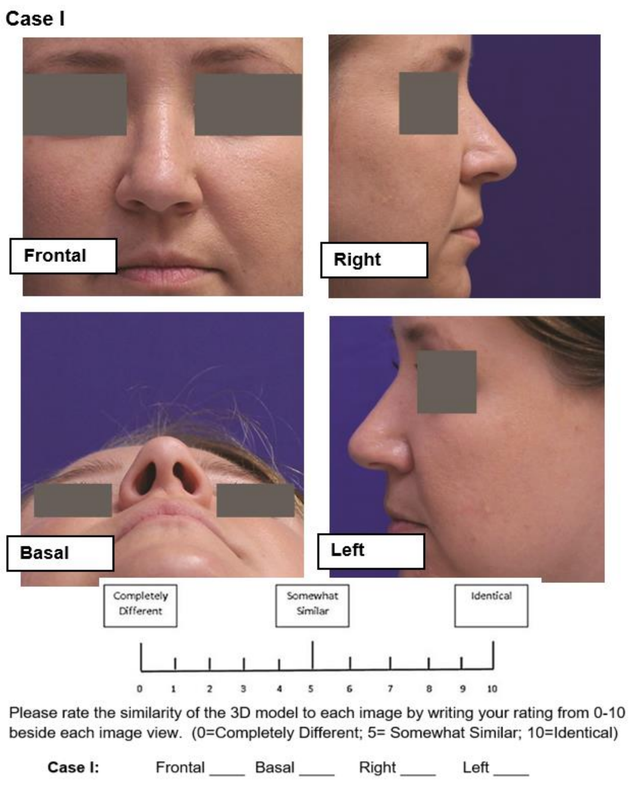


Figure 2. Example of survey question

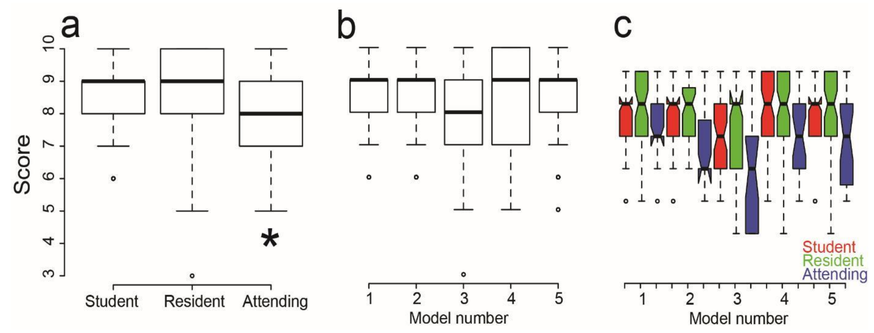


Figure 3. Results from statistical comparisons using box-plots. (a) Comparison of scores (y-axis) assigned by skill level (x-axis). Analysis of variance (ANOVA) demonstrated a statistically significant difference with the attending group (asterisk) showing the lowest scores (mean ± SD, 7.71 ± 1.09 ; F = 31.6, P < 0.001) compared to the two other groups. (b) Comparison of scores by 3-D model did not show a significant difference (F = 1.5, P = 0.22). (c) Similar comparison of score (x-axis) with model grouped by skill level of assessment (F = 2.23, P = 0.13). The colors as shown in the legend indicate the skill level. In each comparison, the boxplot indicates the 25th-75th interquartile range within the box centered around the median and spread of data by the *whiskers*. Circles indicate outliers.

DISCUSSION

- The results of this pilot study show that our computer algorithm can create 3D models of noses that are very similar in appearance to the actual images of subjects.
- Mean scores for all training levels were similar. Attending physicians had a lower mean score, as expected given their years of experience making them more critical in their scoring. Score ratings for all 5 models were very promising.
- Our algorithm uses inexpensive software that has a reasonable learning curve. The printing cost around US $20 per model, while a prosthetic made by an anaplastologist can range in cost from US $10,000 to US $15,000 per device, and may take up to 10 weeks to complete.[1]
- Similar 3D modeling techniques rely on expensive modeling software and require CT scans.[2] Our algorithm provides a solution that does not expose the patient to unnecessary radiation and can allow for more customization. This also makes it useful as an inexpensive teaching tool for residents.
- A limitation of the study is the small sample size and the learning curve for the resident or surgeon compared to CT based modeling software that create models based on nasal anatomy. A larger study can be conducted with real-time training of residents to assess the feasibility of using this technique in practice.

CONCLUSIONS

- This algorithm can be utilized as a clinical tool to print a 3D depiction of a nose. The 3D printouts are similar to the images of the subject's nose.
- The applications of this algorithm include the potential for use as temporary prosthetics to fill nasal defects and for use in surgical planning.
- The results of this pilot study are very promising, but further investigation using a larger sample size is needed before we can proceed to using this model in clinical practice.

REFERENCES

1. Jeffery MC (University of NMC). American Association of Maxillofacial Prosthetics.
2. He Y, Xue G, Fu J. Fabrication of low cost soft tissue prostheses with the desktop 3D printer. 2014:1-7.