

3D Separable 2-layered Elastic Models of the Face for Surgical Planning of Local Flaps

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Summary: Reconstruction with the use of local flaps always involves 3 dimensional movements. It is difficult to predict with 3D complex forms stereoscopic changes after local flap operations on the face. We have made 3-dimensional computer-assisted 2-layered elastic models of the face. The surface layer of the model can be detached from the inner layer. By observing the surface model after simulation surgery, it becomes possible to note the distortions caused by the flaps and to determine the tension of each stitch during suturing of the flap. For the simulation surgery, we used our model for a 73-year-old woman with basal cell carcinoma of the nose, selecting the best of several candidate flaps. The time of removal of the stitches could be delayed at the places with high tension. By using these separable 2-layered models of the face, we can choose the best reconstruction method. The actual operation can be performed smoothly, and the best time to remove the stitches can be determined. (*Plast Reconstr Surg Glob Open* 2018;6:e1857; doi: 10.1097/GOX.0000000000001857; Published online 9 July 2018.)

INTRODUCTION

The use of simulation surgery is a recent addition to plastic surgery, and local flap motility using the finite element method has been demonstrated by computer simulation.^{1,2} However, these simulations are performed on a flat surface. Three-dimensional facial flap motion of a complicated 3D form cannot be clearly demonstrated, so we must still rely on the actual experience of the surgeon.

We describe realistic 3-dimensional computer-assisted 2-layered elastic models of the face.³ The surface layer is made of polyurethane, and the inner layer of silicone. Using this model, residents and young doctors can understand 3-dimensional movements of several typical local flaps and experience realistic simulated surgery. The surface layer of these models adheres to the inner layer.

We have made another type of the model in which the surface layer can be detached from the inner layer. Detaching of the surface layer after simulated local flap surgery allows us to see it from various angles and recognize 3-dimensional distortion and flap tension simply and

visually. We would like to introduce this new model and describe its use in a patient.

MATERIALS AND METHODS

Construction of Separable 2-layered Elastic Models

The volume rendering is performed and stereolithographic data with external surface information are generated with a Digital Imaging and Communications in Medicine manager taken from a computed tomographic or magnetic resonance imaging scan. The mold data are calculated from the stereolithographic data. The method of making the mold and the 2-layered elastic models has been reported previously.³

First, the surface polyurethane is painted several times inside the 3D printed mold until the thickness reaches 1 mm. After hardening, polyurethane is removed from the mold. By repeating this process, a number of surface polyurethane layers can be made. Finally, silicone is poured on the polyurethane. After hardening, the silicone of the inner layer is removed from the polyurethane. The facial DICOM data of the corresponding author (K.U.) was used and can be used for various cases (Fig. 1).

Simulation Surgery

We applied this model for simulation surgery in a 73-year-old woman with basal cell carcinoma of nasal dorsum diagnosed by biopsy. A resident and young doctor planned reconstruction with several local flaps after resection of the tumor with 3mm margins⁴ (Fig. 2). A Limberg's flap from the left side, a bilobed flap from

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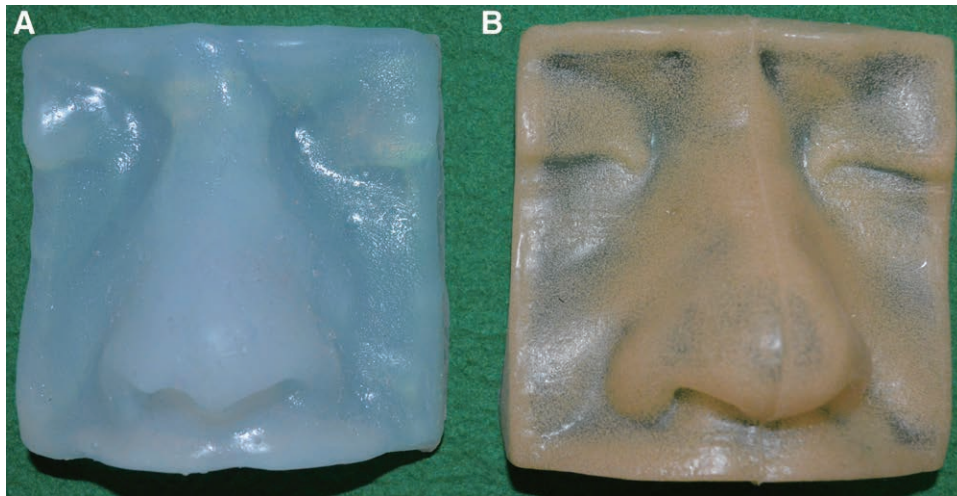


Fig. 1. Inner layer model made of silicone (A) and detached surface layer model made of polyurethane (B).



Fig. 2. A nasal defect with a diameter of 15 mm was made in the surface model for simulation surgery of tumor resection.

the left side, and a bilobed flap from the right upper dorsal area were chosen as candidate flaps. Simulation surgery was performed by their 3 methods. The surface layers were detached from the inner layers of the models, and observations were made of distortion, deforming, and tension during suturing of the flaps of the surface layer.

RESULTS

A simulation model of a Limberg's flap from the left side showed a big depression and distortion in the nasal dorsum and a dog ear in the left cheek (Fig. 3). The model was shrinking up and down (left). A simulation model of a

bilobed flap from the left side had a dog ear on the nasal dorsum, and the tip of the nose was left-leaning. The tension of the flap was strong, and the lower left side of the model was bent (center). A simulation model of a bilobed flap from the right upper dorsal area had slight distortion of the nose, and almost no shrinkage (right). We chose a bilobed flap from the right upper dorsal area from the 3 reconstruction methods because it had the least nasal deformation and distortion of the surface layer.

We observed the model carefully and noticed that the tension of the second lobe was strong, and part of it was depressed (Fig. 4). Then, we planned to delay removing of the stitches at the same places in the actual patient.

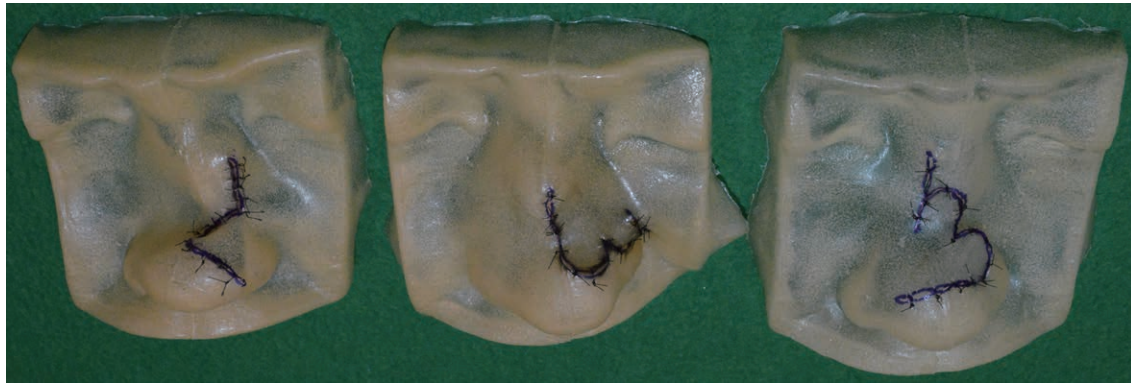


Fig. 3. Simulation surgery was performed with 3 local flaps, and the surface layers were detached from the inner layers of the model. We selected a bilobed flap from the right upper dorsal area whose surface model showed the least deformation and distortion (right).

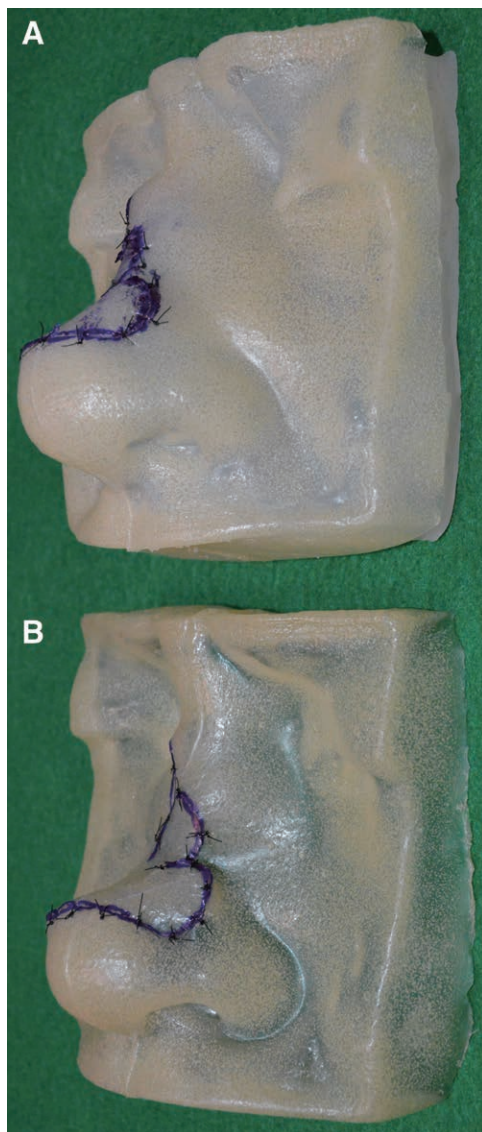


Fig. 4. A, The 2-layered model after simulation surgery with a bilobed flap. The deformity is not conspicuous. B, The deformity and distortion of the surface model become conspicuous after detachment from the inner model. Especially, the tension of the second lobe was strong, and part of it was depressed.

CLINICAL APPLICATION

Nasal reconstruction in the patient after tumor resection was carried out smoothly on the basis of the preoperative simulation by the model. At suturing, the tension was similar to that at the simulation surgery of the model. The postoperative result was similar to that in the model. Four days after surgery, removal of the stitches was begun, but it was delayed in the second lobe because of the results in the preoperative simulation. Postoperative scar contracture was not observed, and there was no distortion 3 months after surgery.

DISCUSSION

Flap movement does not occur on the flat plane, but it is always present with 3-dimensional changes. The basis for understanding common local flap designs has been based only on geometrical paper constructions.⁵ However, rigid-paper models cannot show abnormalities of the skin because of its elasticity.^{6,7}

In recent years, the finite element method for the design of local skin flaps has been developed and has made it possible to capture the 3-dimensional surface after the flap movement. The finite element method provided a good simulation of Z-plasties on skins with complex properties like a pig skin.⁸ And using the finite element analysis, the lengthening effect was always less than what was predicted by geometric calculation.⁸⁻¹⁰

In 1971, Furnas and Fischer⁹ performed laboratory studies with many Z-plasties of different designs in dogs. The studies showed the dimensional lengthening effects of Z-plasties. And they also reported distortions by Z-plasties and 3-dimensional movement of Z-plasties on the web sites.

We reported on realistic 3-dimensional 2-layered elastic models of the face.³ We have made a new type of the model whose surface layer can be detached from the inner layer. Reconstruction with local flaps is always accompanied by 3-dimensional movement and distortions, even if performed on a flat plane. When several different local flaps are applied to the face on several complicated 3-dimensional planes, we cannot foretell the results after operation. Our models can show 3-dimensional movement, distortion, and deforming. Most facial defects are

unknown in size, shape, and dimension before the actual excision. This modeling technique would also be applicable for delayed reconstruction of defects. Furthermore, we can notice mechanical strain during suturing. There are no models that can visually capture the stereoscopic deformation of the face. Using our models, we can review the best choice of several local flaps and the timing and order of the removal of stitches. We must improve the model further to make it more realistic. The present model has the surface layer with 1 kind of elasticity. We plan to make a soft type of surface layer for the older in the future.

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