The application of three dimensional laser surface scanning and imaging in a case of total nasal reconstruction

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The earliest reports of reconstructive surgery are presented in an ancient Egyptian medical text dating back to 1600 B.C. that describes the treatment of nose, ear, lip, and chin injuries. However, it was Indian surgeons who are credited with employing the first definitive plastic surgery techniques, with specific reports describing Sushruta performing the first rhinoplasty in 500 B.C.

Plastic surgery developed at a time when there was a tremendous need for reconstructive correction of catastrophic deformities: after World War I. Never before had surgeons been presented with such extensive injuries that required complex and innovative reconstructive procedures. The Greek work plastikos, meaning to be capable of being molded, would become used to describe a field where surgeons molded those devastated by the injuries of war.

As technological advances have improved protective gear and medical advances have improved advanced trauma care, the proportion of soldiers dying in combat as a result of their injuries has markedly decreased. Soldiers are currently surviving injuries that would have killed them in any previous conflict, but as a result they are surviving with massive facial and cranial injuries that require complex reconstruction.

PATIENT PRESENTATION

M.F. is a 21-year-old African American war veteran who sustained significant facial and body trauma in Iraq. He was involved in a situation where a vehicle exploded and he ultimately received multiple soft tissue injuries and facial fractures. This resulted in amputation of his left arm and left him with an extremely flattened nose. He presented to Johns Hopkins Hospital seeking nasal reconstruction.

Nasal reconstruction would have to be performed through a midline forehead flap, where a large flap of skin is taken from the middle of the forehead, rotated, and folded down to create a new nose. Due to the lack of underlying cartilage to provide support for the nose, rib cartilage would have to be harvested and a nasal subsurface would have to be recreated. Additionally, a radial forearm free tissue transfer would need to be performed to provide a vascularized internal skin lining for the distal half of the nose.

However, the patient was informed that he was not a good candidate for this procedure due to the need for multiple stages and his elevated risk for failure. Due to his significant facial soft tissue injuries, it is unlikely that the blood supply to this flap would still be intact, which means there was a significant chance of it failing and becoming necrotic.

Despite these risks, the patient felt very strongly opposed to a nasal prosthesis and expresses his desire for surgical reconstruction. Being aware of the significant risk of complications and the need for multiple stages, the patient elected to proceed with surgical reconstruction.

TECHNOLOGICAL PLANNING

The nose is a complex three-dimensional object that must be in harmony with the remainder of the face. The challenge with this case was to create a new nose from nothing. In extensive facial soft tissue injures the surgeon can use the remnants of the nose as a guide in order to create a new nose. In this case, even the cartilage, which serves as a framework for the nose and could act as a guide, was absent.

It was decided that technology could help with this problem by providing the surgeon with two types of guides to aid him in the reconstruction: a two-dimensional template showing the complex area of skin that must be taken as a flap from the forehead, and a three-dimensional plastic mold showing the final shape that the surgeon should strive to achieve during the creation of the subsurface framework of the nose.

The Art as Applied to Medicine division at Johns Hopkins began by taking a plaster mold of the existing condition of the patient’s face. Using this and photographs provided by the patient’s family, a wax model was created of the patient’s nose before his injury. This wax model was then cast in plaster and sent to Direct Dimensions Inc. (Owings Mills, Maryland) for surface scanning and digital manipulation of the resulting 3-dimensional model.

The mold is scanned using a laser surface scanner (Perceptron Laser Scanning Systems, Plymouth, Michigan) that creates a three-dimensional point cloud of data that is converted into a resulting three-dimensional computer model using PolyWorks software (Inovometric Software Inc, Quebec City, Quebec, Canada). In the same manner, the patient’s injured face was then laser surface scanned and created into a three-dimensional computer model (Figure 1).
Figure 2. A three-dimensional translucent plastic model served as a guide for the nasal structure during the procedure, while the two-dimensional shaped served as a guide for harvesting of the flap from the forehead.

The three-dimensional model of the pre-injury nose was then superimposed into the proper position on the patient’s injured face, showing a three-dimensional rendition of what the ideal reconstruction would achieve. From this combined model engineers were able to determine the dimensions of a three-dimensional model molded in clear plastic to be used as a surgical guide, and using complex mathematical simulations engineers were able to unroll the complex shape of the three-dimensional pre-injury nose onto a flat two-dimensional surface. (Figure 2) This served as a guide to the surgeon during the procedure for both the shape and size of the flap of tissue to be harvested from the forehead.

Ultimately, the patient required six separate procedures to complete his reconstruction. His recovery was complicated by an MRSA infection as well as a small degree of distal flap necrosis. Fortunately, total flap necrosis did not occur and the remainder of the flap was salvaged. The patient was extremely pleased with the result and was extremely satisfied that he was able to have both the form and function of his nose restored (Figure 3).

DISCUSSION

More recently, the implementation of three-dimensional object scanning and visualization has been applied in the medical field to provide great benefit to both surgeons and patients alike. By applying this technology, a radiation shield was created to protect adjacent tissues in the treatment of head and neck cancers. The creation of three-dimensional breast models through imaging has become possible in order to help guide surgical management. In more of a mainstream application, surgeons can show patients expected results after surgery in a dynamic three-dimensional view using imaging systems such as the Canfield Vectra M3 (Canfield Scientific Inc, Fairfield, New Jersey) or the Axis Three XS200 (Axis Three Inc, Boston, Massachusetts).

The patient in this case presented with an extremely challenging defect due to a combination of significant facial soft tissue trauma, multiple facial fractures, as well as the absence any subsurface nasal framework. Cases of total or subtotal nasal reconstruction are particularly challenging as the reconstructed structure must be vascular in order to heal predictably, stable in order to withstand the scar contracture and maintain symmetry, yet at the same time be functional enough to be acceptable to the patient’s lifestyle.

The construction of an abstract three-dimensional object such as the nose from a flat segment of tissue is extremely difficult in the absence of a subsurface framework. By using novel technological innovations involving three-dimensional laser surface scanning and imaging, the likelihood of achieving a favorable result is potentially increased. The creation of a custom made translucent template for use during the procedure is achieved by the combined efforts of the patient, the anaplastologist, and the surgeon. The template is created such that it anticipates the thickness of the skin that will be provided by the forehead flap and serves as a surgical guide for the surgeon in the creation of the subsurface framework of the nose.

The application of three-dimensional laser surface scanning and modeling is a powerful tool that can be utilized in order to aid in the visualization of challenging defects as help in the surgical reconstruction of these defects. Although still in its infancy, as this technology evolves and its full potential becomes realized, it will surely find many more applications in medicine and particularly in the field of reconstructive plastic surgery.

REFERENCES


Figure 3: The patient shown from a side-view preoperatively (a) and postoperatively (b).