study was designed to evaluate the surgical management of these injuries.

**METHODS:** A retrospective chart review of GSW injuries to the face from January 2009 to December 2017 was performed using the database of a major metropolitan level 1 trauma center. Inclusion criteria were patients who had a GSW to the face, survived more than 48 hours and received care at the admitting institution. Data collected included demographics, type of firearm, structures injured, bones fractured, antibiotic administration, and surgical details. Complex reconstruction was defined as autologous soft-tissue flap, bone flap, or bone graft. Univariate and multivariate statistical analyses were performed to examine the relationships between injury specifics and surgical treatment.

**RESULTS:** A total of 270 patients met the inclusion criteria for the study. The cohort was predominantly male (82.6%) with an average age of 31.7 ± 15.5 years. The ethnicity breakdown of the group was 40.4% Black, 31.9% White, 19.6% Hispanic, 3.0% Asian, and 5.4% other. The majority of patients (76.7%) had at least 1 facial surgical procedure. The average day of the first surgical procedure was 3.03 ± 4.00 days (range, 1–43). However, 62% of patients went to the operating room within 24 hours of their injury. Of those that had surgery, the average number of procedures was 1.6 ± 1.8. Intermaxillary fixation was used in 40.6% of all patients, and it was highest when the mandible was involved (79.2%). Open reduction internal fixation was necessary in 45.4% of patients and occurred on day 9.9 ± 9.97. An external fixation device was used in 12.6% patients. Complex reconstruction had the following breakdown: soft-tissue flaps were required in 11.1% of patients, bone grafts in 7.2%, and bone flaps in 5.3%. Factors that resulted in a higher likelihood for surgery were teeth involvement (89%), oral cavity involvement (86%), mandibular fracture (86%), and comminuted fracture (86%). All patients who had a shotgun or rifle injury required operative management. On multivariate analysis, patient age \((P = 0.019)\), injured teeth \((P = 0.018)\), and oral cavity involvement \((P = 0.009)\) were associated with higher number of surgeries.

**CONCLUSIONS:** Surgical intervention is often an integral part to the management of GSWs to the face. An aggressive, early initiation of care is the rule with injuries resulting from a gunshot or rifle, those involving the teeth and oral cavity and comminuted injuries, more likely to require operative management. Multiple procedures are often required with a delayed approach to definitive management of the comminuted facial skeleton.

**Three-dimensional Printed Rhinoplasty Simulator With Replaceable Nasal Module**

**Presenter:** Michael K. Boyajian, MD  
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**BACKGROUND:** Surgical simulation serves as a key tool in medical training. Three-dimensional (3D) printing technology may be useful in this effort by allowing for rapid prototyping of affordable, custom anatomic models which can be optimized to target specific surgical skills. Carefully designed simulators can accelerate the learning curve of junior residents, especially for procedures that may be difficult to learn in the live operative setting. One procedure that is particularly difficult to master in early training is rhinoplasty; residents often report lack of comfort with performing the osteotomy portion of the procedure. Herein, the purpose of this project was to develop a 3D printed osteotomy training model that is cost-effective and durable, providing educational utility that can be translated to the operating room.

**METHODS:** Our osteotomy trainer consists of 3 parts: a reusable facial bone base, a replaceable nasal bone cartridge, and a reusable soft tissue envelope. Data obtained from a healthy patient’s head CT scan were used to segment relevant bony structures (orbits, nasal bone, maxilla) to create the reusable facial bone base, and Blender Software (Amsterdam, The Netherlands) was used to design the nasal bone cartridge. Both of these units were printed from ABS Filament on a UPrint SE+ 3D printer (Stratasys, Eden Prairie, MN). The nasal bone cartridge, which is meant to be broken with an osteotome, is firmly fastened to the facial bone base via digitally incorporated pegs and can be easily replaced for repeat use. Finally, to generate the silicone-based “soft tissue” of the face, we designed and 3D printed a mold derived from the same patient CT scan. Once cured, these reusable silicone soft tissue envelopes were draped over the bony structures (facial bone base with fastened nasal cartridge) to complete the setup of our osteotomy trainer. For a beginner model, we used transparent silicone to allow for easy visualization of the underlying bones. For an advanced model, we used skin-colored silicone, which removes the
handicap of direct visualization and challenges users to rely on a foundational understanding of anatomy and tactile feedback.

RESULTS: To test durability of the model, 10 osteotomies were performed. Preliminary trials demonstrated the silicone soft tissue construct to be durable enough to withstand multiple osteotomies without breakdown, and osteotomy manipulations yielded noticeable changes in the overlying nasal soft tissue appearance. Additionally, the nasal bone cartridges felt anatomic when broken during the osteotomy simulations, and they were easily replaced for cost-efficient, repeat practice. The total cost of material for the reusable soft tissue envelope and reusable bony base was $25, and the replaceable nasal bone cartridges cost $5.

CONCLUSIONS: This pilot study determined that 3D printing and silicone casting can be used to produce a cost-effective and reproducible training tool to practice the osteotomy during rhinoplasty. Future directions include validating this 3D printed training model for educational utility among plastic surgery residents.

Corneal Neurotization: A Meta-analysis of Outcomes and Patient Selection Factors

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BACKGROUND: Neurotrophic keratopathy (NK) is a well-described process caused by impairment of trigeminal corneal innervation leading to corneal epithelial damage, poor healing, and ulceration. Etiologies can vary from congenital anomalies to acquired injury of the ophthalmic trigeminal nerve division. Corneal neurotization has continued to show promising results in restoring corneal sensation. Multiple techniques of corneal neurotization have now been described, whether direct or indirect with varying donor and recipient nerves. This study aims to report a meta-analysis of outcomes as well as characterization of patient selection factors in order to better elucidate the indications for corneal neurotization.

METHODS: Following PRISMA guidelines, the MEDLINE and EMBASE databases were searched to screen and extract all studies available on corneal neurotization. Only primary literature with patients and outcomes was included. All literature reviews and animal and cadaveric studies were excluded.

RESULTS: Eighty-one studies were screened and 18 studies met our inclusion criteria, totaling 57 patients and 64 eyes. Forty-nine percent were female, mean age at neurotization was 37.2 years, mean denervation time was 70.1 months. NK was congenitally caused in 21% and acquired in 79%. Acquired causes varied from tumor or iatrogenic (45%), herpetic (39%), trauma (11%), to other causes (5%). Neurotization was direct (38%), either ipsilaterally (52%) or contralaterally (48%), using the following donors: supraorbital nerve and supratrochlear nerve in 96% and great auricular nerve in 4%. For indirect neurotization, recipient nerves utilized were supraorbital nerve and/or supratrochlear nerve (95%) and infraorbital nerve (ION) in 5%. Donor nerve grafts were sural nerve (98%) and lateral antebrachial cutaneous nerve (2%). No difference was noted between techniques and outcomes. Average follow-up differed between congenital (8.5 months) and acquired (35.8) cases ($P < 0.05$). Time to reinnervation was faster in congenital (6 months) than in acquired (14 months) cases ($P = 0.01$). NK Mackie staging improved in 84%, remained the same in 16% and did not worsen in any patient. Best-corrected visual acuity improved in 77%, remained the same in 20%, and only worsened in 1 patient due to poor compliance. Pre-LogMAR was $1.36 \pm 0.78$ and post-LogMAR $0.98 \pm 0.80$ ($P < 0.001$). Corneal sensation improved in all patients with $0.68 \pm 3.13$ mm and $44.82 \pm 17.2$ mm pre- and postneurotization ($P < 0.001$), respectively. NK Mackie Stage improved in all patients with $2.46 \pm 0.77$ and $0.84 \pm 0.79$ pre- and postneurotization ($P < 0.001$), respectively. Complications reported were persistent epithelial defect (8%) and subgaleal hematoma (1.5%). Age and denervation duration were predictive of disease severity ($R^2 = 0.25; P = 0.001$). Age <20 years lead to higher sensation improvement ($P = 0.04$) and age >20 years lead to higher visual acuity improvement.

CONCLUSION: Given the low complication rates, remarkable improvement in visual acuity, corneal sensation, and NK Mackie stage irrespective of etiology, corneal neurotization should be considered for all patients with NK early on in disease course before irreversible corneal damage occurs, such as scarring or amblyopia, which limits clinical improvement. More standardized outcomes reporting and further study are needed to better delineate the impact of preoperative factors, technique, and specific etiologies on outcomes.