Virtual Surgical Planning & CAD/CAM Modeling for Precision Craniofacial Surgery

Plastic surgeons at Penn Medicine are employing computer-aided design and manufacturing (CAD/CAM) technology for virtual surgical planning (VSP) for precision complex craniofacial plastic and reconstructive surgeries in patients with orthognathic, cranio-orbital and other facial and skull deformities.

VSP has been shown to improve the predictability of outcomes in complex cranio-maxillofacial surgery and to decrease total operating time, thereby reducing the duration of intraoperative general anesthesia and wound exposure time.\(^1\) For patients, moreover, virtual surgical planning has the potential to offer optimal cosmesis and reduce donor site morbidity.

VSP for craniofacial reconstruction involves collecting data prior to surgery as a foundation for diagnosis and the creation of a treatment plan that can be precisely reproduced in the operating room. Thus, Penn plastic surgeons first collect cephalometric measurements to generate anatomically accurate, three-dimensional CAD/CAM stereolithographic models of a patient’s bone structure. Once complete, these models are used to design osteotomy guides for planned surgery. Precise to within 1 mm, the guides increase intraoperative efficiency and accuracy, streamline decision-making and produce optimal aesthetic results.

CASE STUDY
Ms. C, a 23-year-old woman, was referred to Penn Medicine for facial and reconstructive surgery to correct orbital hypertelorism, which is defined by excessive distance between the eyes and orbits and vertical orbital dystopia, a condition where the eyes are not level. Ms. C’s CT scans and 3-D imaging at presentation revealed anterior and inferior displacement of the orbital bones and bilateral nonalignment.

To address her deformities, Ms. C’s surgery would require precise osteotomies to separate the orbits from the facial bones and remove a segment of bone. The halves of her midface would then be rotated in three dimensions to differential degrees to bring the eyes into closer proximity.

To ensure surgical accuracy and an optimal result, Ms. C received a cranial CT scan prior to surgery. Converted into CAD format (Figure 1) to create a composite digital 3-D model, the model was the source of cephalometric measurements that were then configured and refined to produce and manufacture prefabricated jigs for the surgical procedure.

In the operating room, these guides allow for precise cuts and repositioning of the facial bones, significantly increasing the accuracy of the procedure and reducing the overall duration of surgery.

There were no complications or unexpected findings at surgery. Ms. C recovered well and returned to work four weeks after discharge. Post-operative photographs and 3D-CT scans (Figure 2) at this time demonstrated a marked improvement in her appearance.

References
FACULTY TEAM
The Penn Plastic Surgery craniofacial reconstruction program is recognized for excellence in surgery for orthognathic, cranio-orbital, and other facial and skull deformities and malformations of congenital, traumatic or disease-related origin. Comprised of surgeons from Penn Plastic Surgery and the Department of Otorhinolaryngology-Head and Neck Surgery, the program uses the latest technology, including CAD-CAM technology for cranial, facial and jaw surgery, and microsurgical innovations to visualize and re-attach severed blood vessels and nerves and optimize post-surgical feeling and function. To ensure the safety and efficacy of the latter, the Department of Neurosurgery is a consultatory partner in many facial and skull-based reconstructive surgeries.

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