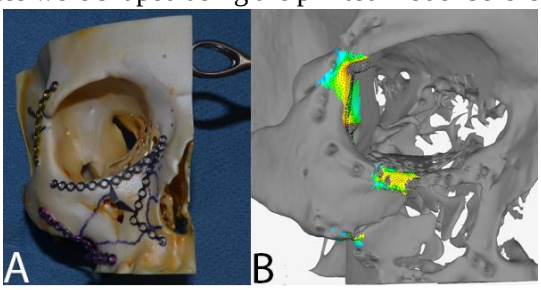
Quantitative Evaluation of 3D Printed Models for Craniofacial Reconstructive Surgery

Scotty A Chung[1], Caroline Bergeron[2], Lyfong S. Lor[3], Christopher M. Runyan, M.D.[4], Philip J. Brown, Ph.D.[1]

1. Biomedical Engineering, Wake Forest Baptist Health 2. Biological Engineering, Louisiana State University 3.Wake Forest University School of Medicine 4. Plastic & Reconstructive Surgery, Wake Forest Baptist Medical Center

Introduction: Trauma-related craniofacial defects often result in facial deformity and significant functional limitations. The craniofacial region contains numerous tissue types and structures that vary between patients which makes surgical planning and treatment challenging[1]. For unilateral facial trauma, creating a 3D printed physical model of the mirrored unaffected side can generate an "ideal" representation of the post-operative affected region[2]. Although these models appear beneficial, there is limited quantitative investigation into their use. Some approaches compare the distances of a limited number of user-defined anatomical points of the affected and unaffected side[3]. This method is susceptible to variability, especially when large changes in orientation can result in small changes in distance. Another approach is to allow users to define regions of interest which contain numerous points. By increasing the number of points used, this region selection method reduces variability and is more sensitive to changes in orientation. This study aims to use the region selection method to evaluate the benefits of a physical model for craniofacial reconstruction surgery.

Materials and Methods: To develop and evaluate this metric a total of 7 cases of zygomaticomaxillary complex (ZMC) fracture were considered. All cases received a pre-surgical CT scan using a 0.60mm slice thickness. A full skull segmentation was performed to produce a pre-surgical Standard Tessellation Language (STL) file. This pre-surgical STL model was smoothed, trimmed, and mirrored across the estimated sagittal plane to produce an anatomical template model. The STL model was printed by a Carbon® M1 printer in urethane methacrylate. Fractures were labeled on the printed model by a plastic surgeon. Plates were shaped using the printed model before being sterilized. The anatomical model was brought into the operating room and available throughout the entire procedure. Following surgery, all cases were re-imaged by a 0.625 mm slice thickness CT scan. A post-surgical STL model was segmented and aligned to a pre-surgical model using Geomagic's best fit alignment tool which minimizes the deviation of randomly selected points. Four critical regions of the zygoma considered in plastic surgery were identified for each case including the zygomaticofrontal (ZF) suture, zygomaticosphenoid (ZS) suture, superior zygomaticomaxillary (ZM1), and inferior zygomaticomaxillary (ZM2). The shortest distance between every point of the anatomical reference and the pre- or post-model was calculated. If no deviation shorter than 5mm was found, the value was set to 5mm. The root-mean-square (RMS) of the magnitudes of deviations of all regions were calculated for both pre- and post-surgical models. The same method was applied to a symmetrical control group (n=8) in which no trauma occurred to the ZMC to generate a symmetry baseline.



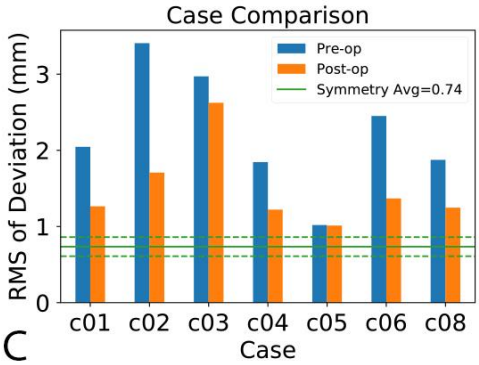


Figure 1: (A) 3D printed model with shaped plates. (B) Post-surgical deviation analysis. (C) Deviation comparison of all cases

Results and Discussion: The RMS of deviations from all regions combined are shown in Figure 1. The average difference between pre- and post-surgical was 0.74mm. The average number of points used for each case was 2338, and the RMS of deviation between the two groups significantly decreased ($p=0.011$) when using a paired sample two-tailed t-test. The average deviation for the symmetrical control group was 0.74±0.12mm.

Translational Impact: This deviation metric can be used to quantitatively evaluate a reconstruction procedure. Future work will compare injury cases without anatomical models and region specific analysis to better further identify the benefits of 3D printing technology in the field of reconstructive surgery.

Disclosure Statement: No conflicts of interest are associated with this study.

References: [1] Nyberg EL et al., *Ann Biomed Eng*, 2017, 45(1):45-57. [2] Jacobs CA et al., *Plast Reconstr Surg*, 2017, 139(5):1211-1220. [3] Feng F et al., *Oral Surgey 2011, 108(5):661-666*