Mobile Application for Flap Design & Projection

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PURPOSE: Markings for planning incisions in reconstructive surgery are commonly drawn free-hand and to the surgeon’s best estimate, leading to potential mistakes that can lead to increased procedure time and patient risk. A previous study performed by our group has shown that flap marking can be improved by designing accurate flaps on Google SketchUp and projecting the image as a stencil onto a patient using a handheld projector. The purpose of the manuscript is to introduce a new surgical planning mobile application developed by our group that allows for surgeons to select, modify and personalize a database of local flaps. These flaps can then be projected onto a patient requiring reconstruction to offer a more accurate and personalized flap design.

MATERIAL AND METHODS: A mobile application was developed with a variety of flaps including but not limited to Rhomboid, Bilobed, Z-plasty, W-plasty, and nipple reconstruction markings. Using the mobile interface, photographs of areas requiring reconstruction were taken and uploaded onto the device. The application was then used to superimpose a flap and modify it to best fit the area requiring reconstruction in the photograph. The personalized and accurate flap was then projected using a wireless projector onto the patient. Projected flaps were then analyzed and compared based on expected geometric parameters.

DATA: Using the mobile application accurate and personalized flaps were created for Rhomboid, Bilobed, Z-plasty, W-plasty, and nipple reconstruction. All flaps served as accurate stencils with 0% deviation in each angles and limb measured.

SUMMARY OF RESULTS: Using our mobile application flap can be designed and projected onto an area requiring reconstruction with 0% deviation from expected measurements.

CONCLUSION: We have developed a surgical planning mobile application for reconstructive surgeons that allows for selection, modification and personalization of a database of local flaps. These flaps can then be projected wirelessly onto a patient’s defect requiring reconstruction serving as an accurate stencil.

Extending the Utility of 3D Printing in Your Practice: A Novel Technique for Complex Cases, Combining CT and MR Imaging into a Single 3D Print

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PURPOSE: The value of 3D printing for surgical planning has become well recognized in craniofacial surgery. Tangible 3D replication of patient-specific anatomy provides surgeons with immediate understanding of complex dysmorphology, enables accurate surgical planning and creation of customized implants, and aids in intraoperative orientation. However, to date, 3D printing in craniofacial reconstructive surgery has focused on replication of bony anatomy based on CT imaging.

METHODS: Over the past two years, we have utilized a novel method for overlaying CT and MRI images to simultaneously 3D print both hard and soft tissue anatomy in complex craniofacial cases. To construct each 3D model, MR and CT imaging are first reviewed to identify complementary imaging sets with similar slice thickness and similar patient position. CT and MR images are imported into Materialise Mimics as separate files, and anatomy of interest is isolated into masks. The masks of isolated anatomy from the CT are copied into the MR segmentation file and a simulation engineer manually registers the CT to the MR using a 3D-positioning panel. A radiologist reviews the imaging overlay prior to printing the fused data set.

RESULTS: Over the past two years, we have utilized this 3D printing technique for six patients with the following diagnoses: arachnoid cyst (n=1), myxoma (n=1), occipital
encephalocele (n=1), nasopharyngeal meningocele (n=1), and a large mandibular tumor (n=2). In each case, the 3D print of the CT/MR overlay improved visualization of aberrant anatomical relationships. The highlighted structures particularly included abnormal vasculature and the full extent of lesions that were difficult to appreciate on standard 2D imaging, and the 3D prints helped preoperatively plan and intra-operatively guide complex interventions.

**DISCUSSION/CONCLUSION:** 3D printing from multiple imaging modalities clarifies anatomic relationships in a way not previously possible. It utilizes the best assets of both imaging modalities: segmenting structures such as bones from the CT and using the MR imaging for excellent soft tissue contrast, to enables better differentiation and delineation of important vasculature or soft tissue tumor margins, for example. This novel technique can enhance advanced hard and soft tissue planning in the most complex craniofacial operations.

**Modeling Tissue Expansion with Isogeometric Analysis: Skin Growth and Tissue Level Changes in the Porcine Model**

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**PURPOSE:** Tissue expansion (TE) often has high complication rates, particularly in anatomically critical regions such as the scalp and the extremities. The aim of the present study is to differentiate the levels of skin growth vs. skin stretch at various time points after a single large volume expansion and to correlate biomechanical growth to histologic and transcriptional changes during TE.

**METHODS:** Four 5–6 week old minipigs were each tattooed with 4 grids, with a tissue expander implanted under 2 of these grids and the contralateral side serving as an internal control. Each of the 4 expanders were inflated once with 60cc of saline 1 hour, 24 hours, 3 days, and 7 days prior to sacrifice. 3D photographs were obtained immediately before and after each expansion and the day of sacrifice, both in vivo and ex vivo. Isogeometric analysis of reconstructed 3D skin grids was performed to calculate skin growth and stretch. Prestrain was calculated by amount of “snap-back” of control patches after being excised. In expanded patches, the “snap-back” after skin excision determines stretch. After controlling for natural growth, the remaining skin surface area increase following tissue expander removal determines growth. Tissue expander port pressures were recorded before and after expansion and prior to sacrifice. Pentachrome stained tissue sections for corresponding control and experimental skin samples were evaluated for histological changes. Immunohistochemical staining for cell division (Ki-67) and apoptosis (Tunel) was performed. RNA was purified from expanded and control samples and then sequenced.

**RESULTS:** Skin growth was correlated with increased latency period after expansion (1.12 for 1 hour, 1.11 for 24 hours, 1.06 for 3 days, 1.34 for 7 days; p < 0.0001). Collagen fibers appeared shorter and more randomly oriented in apical expander skin compared to control skin, where fibers were oriented parallel to the epidermis. However, at 7 days after expansion, collagen fibers began to align parallel to the epidermal surface. A significant increase in epidermal thickness was observed 3 and 7 days after expansion (p < 0.0001). This difference was greater for expanders placed anteriorly vs. posteriorly (118% vs. 52%; p < 0.001), corresponding to higher filling pressures (199mmHg vs. 86.8mmHg, p < 0.0001) over the rigid ribcage. Interestingly, significantly more epidermal undulation was observed at 3 and 7 days post expansion (p < 0.0001). Transcriptome analysis identified >4000 genes as differentially expressed in skin under TE. Bioinformatics and statistical analysis preliminarily identified 12 genes, consistently changed in all tested conditions of stretch, suggesting they are responders to mechanical forces. Further evaluation will be performed to identify skin cells that express these genes and molecular mechanisms involved in response to stretch.

These genes are related to stem cell differentiation, heat shock protein stress response, and extracellular matrix remodeling.

**CONCLUSION:** Skin growth was correlated with increased latency after a single expansion and first observed 7 days after expansion. Histological and gene transcriptome changes precede this and were observed as early as 1 hour after expansion.