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.