Biomechanical factors influencing the reduction of dislocated hips with the Pavlik harness in patients of Developmental Dysplasia of the Hip (DDH) were studied using a simplified three-dimensional computer model simulating hip reduction dynamics in (1) subluxated, and (2) fully dislocated hip joints. The CT-scans of a 6 month-old female infant were used to measure the geometrical features of the hip joint including acetabular and femoral head diameter, acetabular depth, and geometry of the acetabular labrum, using the medical segmentation software Mimics. The lower extremity was modeled by three segments: thigh, leg, and foot. The mass and the location of the center of gravity of each segment were calculated using anthropometry, based on the total body mass of a 6-month old female infant at the 50th length-for-age percentile. A calibrated nonlinear stress-strain model was used to simulate muscle responses. The simplified 3D model consists of the pubis, ischium, acetabulum with labrum, and femoral head, neck, and shaft. It is capable of simulating dislocated as well as reduced hips in abduction and flexion.

Five hip adductor muscles were identified as key mediators of DDH prognosis, and the non-dimensional force contribution of each in the direction necessary to achieve concentric hip reductions was determined. Results point to the adductor muscles as mediators of subluxed hip reductions, as their mechanical action is a function of the degree of hip dislocation. For subluxated hips in abduction and flexion, the Pectineus, Adductor Brevis, Adductor Longus, and proximal Adductor Magnus muscles contribute positively to reduction, while the rest of the Adductor Magnus contributes negatively. In full dislocations all muscles contribute detrimentally to reduction, elucidating the need for traction to reduce Graf IV type dislocations. Reduction of dysplastic hips was found to occur in two distinct phases: (a) release phase and (b) reduction phase.

To expand the range of DDH-related problems that can be studied, an improved three-dimensional anatomical computer model was generated by combining CT-scan and muscle positional data belonging to four human subjects. This model consists of the hip bone and femora of a 10-week old female infant. It was segmented to encompass the distinct cartilaginous regions of infant anatomy, as well as the different regions of cortical and cancellous bone; these properties were retrieved from the literature.

This engineering computer model of an infant anatomy is being employed for (1) the development of a complete finite element and dynamics computer model for simulations of hip dysplasia reductions using novel treatment approaches, (2) the determination of a path of least resistance in reductions of hip dysplasia based on a minimum potential energy approach, (3) the study of the mechanics of hyperflexion of the hip as alternative treatment for late-presenting cases of hip dysplasia, and (4) a comprehensive investigation of the effects of femoral anteversion angle (AV) variations in reductions of hip dysplasia.

This thesis thus reports on an interdisciplinary effort between orthopedic surgeons and mechanical engineers to apply engineering fundamentals to solve medical problems. The results of this research are clinically relevant in pediatric orthopaedics.

Major: Mechanical Engineering/Mechanical Systems

Educational Career:
Bachelor's of Mechanical Engineering, BS, 2008, Florida State University

Committee in Charge:
Dr. Alain J. Kassab, Chair, Department of Mechanical & Aerospace Engineering
Faissal Moslehy, Department of Mechanical & Aerospace Engineering
Eduardo Divo, Department of Mechanical & Aerospace Engineering

Approved for distribution by Dr. Alain J. Kassab, Committee Chair, on March 14, 2013.
The public is welcome to attend.