EMBRY-RIDDLE Aeronautical University

Mechanical Engineering

Discovery Day Presentation

INFANT HIP DYSPLASIA MEDICAL TRAINER

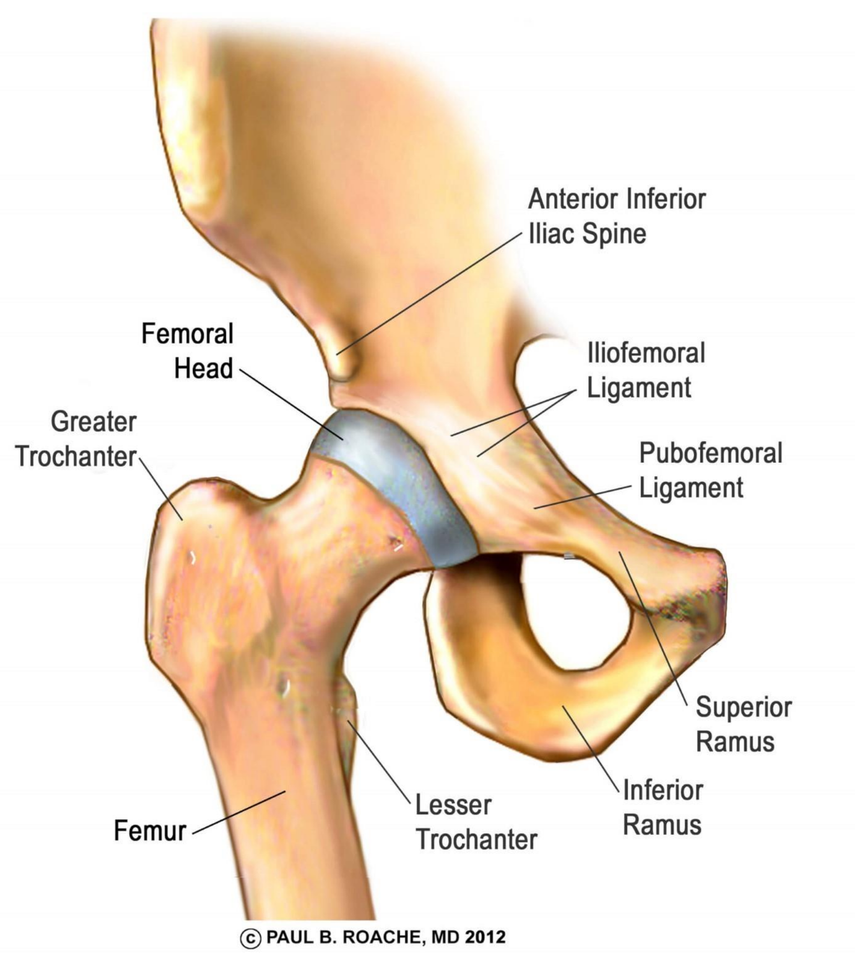
Seth Eaby, Sheridan Perry, Joe Sauerbrun

Embry Riddle Aeronautical University, Department of Mechanical Engineering, Daytona Beach, FL 32114

PERRYS8@my.erau.edu

INTRODUCTION

Developmental Dysplasia of the Hip (DDH) is a disease where the acetabulum and the femoral head have been improperly formed due to external factors. The exact cause of DDH is unknown but it has been attributed to numerous factors including improper breech position, genetic condition affecting the ligaments, and improper evaluation using the Barlow and Ortolani maneuvers. Since physical examinations are typically the best way for physicians to find out if an infant has DDH, assistance devices have been made to help teach residents and interns. These devices allow the residents to feel the difference between a healthy hip and a hip suffering from a shallow acetabulum by allowing them to dislocate a rubber model of an infant's pelvis and femur. Unfortunately, many residents and interns have a hard time feeling how the dislocation should feel through the thick layers of elastomer. This has brought in the need for a model that is see-through with realistic bones and ligaments



BONE STRUCTURE

The basic model used for the 3D printing of the bones were sourced from CT Scan images from the University of Padua. These images came from cadaveric samples of a 6-month-old fetus. These CT scans were then imported into Simpelware ScanIP, a images processing software. After importation, a mask was formed based off the images; the mask could be modified in 3D space, which made post-processing simpler. The images originally contained three different material types consisting of cortical bone, trabecular bone, and cartilage. However, when segmenting the images, the three materials were combined into one mask to simplify the model and the 3D printing process. The mask was then cleaned, as 3D printers require simpler geometry to print accurately. For example, the ligamentum teres, had to be removed from the hip socket so that the femoral head could properly fit in the socket. There were also points on the mask that were deformed due to decomposition of the original samples. These areas were then corrected by painting in new material in each layer of the mask.

After completion of the mask, a model composed of small triangles in the IGES file format was exported into SolidWorks. From SolidWorks, the model could be separated into three different parts. These parts were then exported as STL files, which are 3D printable files.

ABSTRACT

Developmental dysplasia of the hip (DDH) is the most common abnormality in infant hip joints. The Barlow and Ortolani maneuvers help to detect this abnormality by dislocating and relocating the femoral head in the acetabulum. Improper training of these two procedures can decrease the chances of detecting this abnormality in infants, therefore, creating a proper model to practice performing these maneuvers on is important. The team is developing a model that will improve upon the existing model that is currently used. This will help to more accurately detect DDH in infants so they can receive the proper care to correct the issue.

DESIGN REQUIRMENTS

- Design shall allow the user to visually observe the inner workings (bone and ligament anatomy) of the model.
- Design shall maintain the arthrokinematics of an infant's hip.
- Design shall have anatomically correct locations of bones and ligaments.
- Design shall model the anatomical behaviors of both bones and ligaments.
- Design shall have ligaments that withstand at least 100 fatigue cycles before failure.
- Design shall mimic the size of the average infant.
- Design will have one hip fixed in the socket (Acetabulum) and one hip capable of total dislocation.
- Design shall have one healthy hip and one hip with unilateral DDH.
- Design shall not exceed 3.5lbs.

FUTURE WORK

Next semester, tensile testing on the 3D printed ligaments will be conducted to validate the requirement stating that the ligaments must go through 100 fatigue cycles. To do this, a stress strain curve will be generated using the experimental data from the tensile test. The minimum stress will be the ligament's preloaded stress, and the maximum stress will be the stress in the ligament at the same deformation that it would experience during a medial maneuver. From these two values, a midline stress and an amplitude stress can be calculated. In conjunction with a ductile failure theory equation, the number of fatigue cycles can then be calculated.

LIGAMENT MODELING

The ligaments in the prototype serve to both connect and stabilize the femur to the pelvis. They were designed to be anatomically correct which in turn will maintain the arthrokinematics of an infant's hip. The ligaments length, cross sectional area, and stiffness were considered when modeling the 3D printed ligaments.

Ligament	E (N/mm^2)	A (mm^2)	k (N/mm)
Superior Illiofemoral	52.07	44.69	97.8
Inferior Illiofemoral	52.07	44.69	100.7
Superior Ischiofemoral	31.33	17.27	36.9
Inferior Ischiofemoral	31.33	17.27	36.9

When determining the dimensions of the model ligaments, the governing equation used was the stiffness equation.

$$K = \frac{EA_c}{L}$$

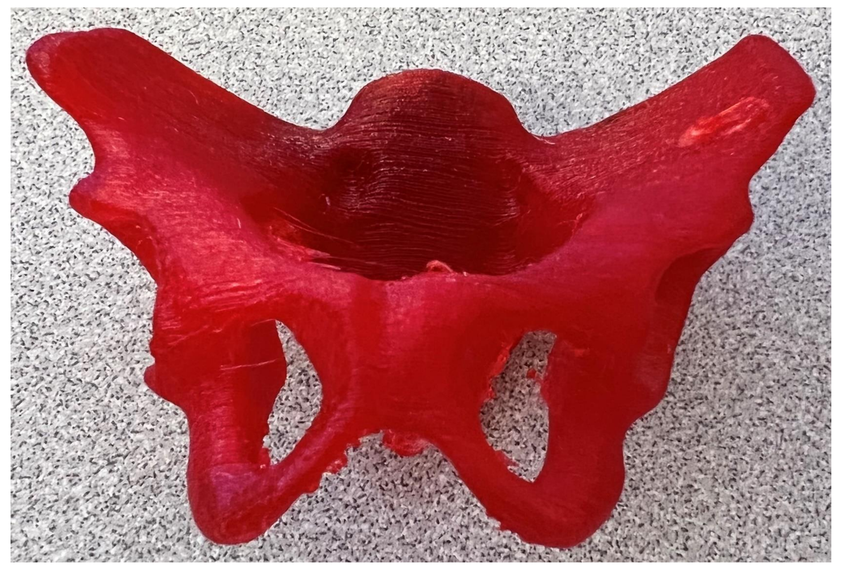
The major assumption when using this equation is that the stiffness is a constant and that the ligaments behave as liner springs. However, ligaments behave as nonlinear springs due to their nonuniform cross sectional area, and their nonconstant modulus of elasticity.

Since the ligaments were 3D printed, the modulus of elasticity must be adjusted for the 3D printing material. The anatomical cross-sectional area was held constant by selecting a representative value, leaving length as the only variable. Using this logic, the following dimensions were calculated.

Ligament Name	Length (cm)	Ac (mm^2)	K (N/m)
Superior Illiofemoral	10.225	50	97.8
Inferior Illiofemoral	9.930	50	100.7
Superior Ischiofemoral	10.840	20	36.9
Inferior Ischiofemoral	10.840	20	36.9

3D PRINTING

Pelvis



The printer the pelvis was printed on is the FlashForge Creator Max 2, however the team has recently concluded the purchase of an Ultimaker S5 printer to further expand their 3D printing capabilities. The pelvis was printed using SainSmart 95A Red TPU Filament.

ACKNOWLEDGMENTS

Dr. Victor Huayamave, Assistant Professor of Mechanical Engineering, ERAU

Dr. Charles Price, Orthopedic Surgeon, Arnold Palmer Hospital for Children