Developmental Dysplasia of the Hip Medical Trainer

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Abstract

Developmental Dysplasia of the Hip (DDH) is a condition that causes an infant's hip to be easily displaced from the socket. Hip abnormalities cause the femoral head to be mechanically unstable within the acetabulum. The Barlow and Ortolani maneuvers detect DDH by dislocating and relocating the femoral head in the acetabulum. Improper training of these two procedures can decrease the chances of detecting DDH, which can result in long term damage to the infant. Current medical trainers, including Laderdal Medical's Hippy Baby, are commonly used to teach the Ortolani and Barlow Maneuvers to physicians and medical students. To improve previous models, a transparent section will be added along the pelvic region to allow the students to observe the dislocation and reduction, TPU will be used to increase flexibility and inherently increase the jerk sign. The prototype trainer will demonstrate a mild case of DDH in both the left and right hip.

Background

DDH is a common condition affecting 1 in every 1000 children born [3]. It is unknown what the exact cause of DDH is, but the leading identifiers are being female, genetics, presenting breech, and being first born or restricted in the womb. The most common case seen is when the acetabulum is formed incorrectly resulting in a shallow socket as shown below in Figure 1, allowing for dislocation of the infant's hip.

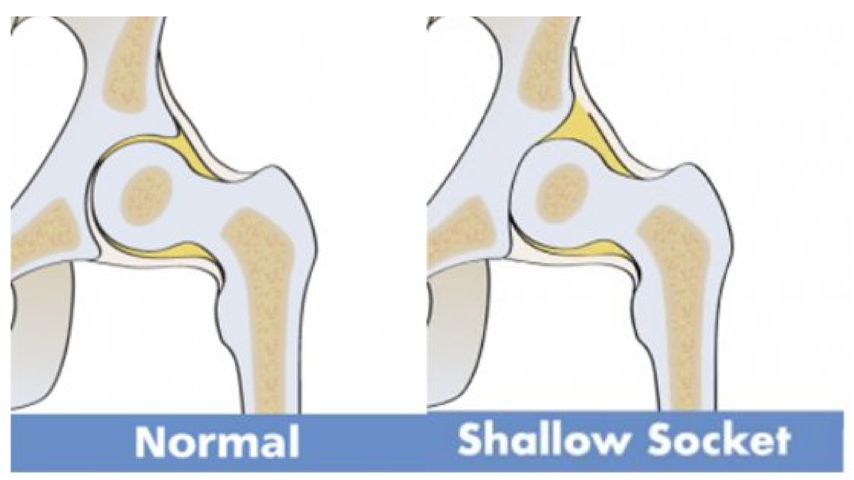

Figure 1: Anatomical Differences in Hip Dysplasia Patients [1]

To detect DDH, a physical examination is performed on newborns before they leave the hospital and at every doctor's appointment until three months of age. The Ortolani and Barlow maneuvers, as seen below in Figure 2, are two dynamic tests performed on the infant to study the movement of the femoral head in the acetabulum. A healthy hip will experience full range of motion with no dislocation.

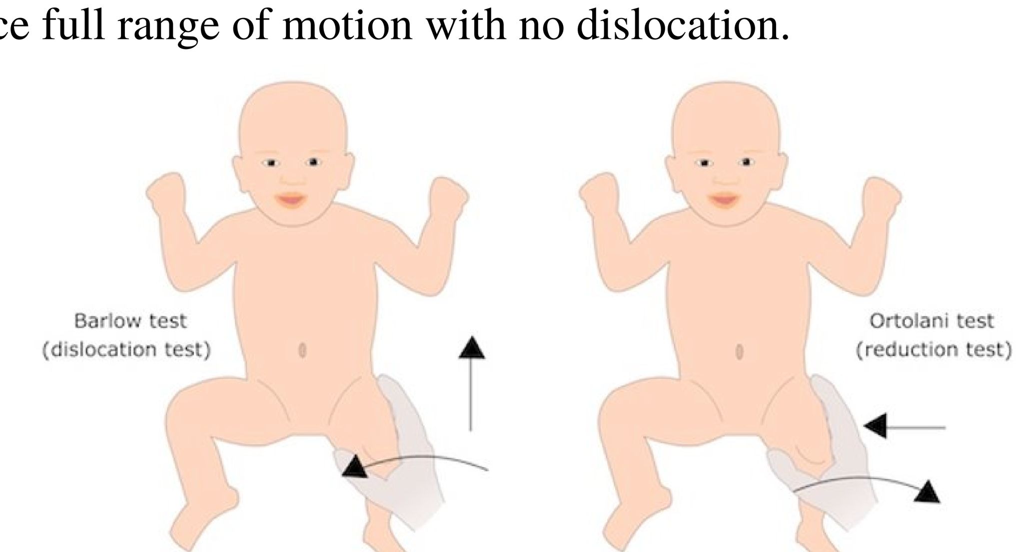

Figure 2: Barlow and Ortolani Test [2]

Design Concepts

Design Requirements

1. The model shall be completely transparent in the pelvic region, allowing students to clearly observe the dislocation and reduction of the hip
2. The model shall replicate the Barlow and Ortolani methods of detecting a Class B case of hip dysplasia on both hips
3. The model shall represent the anatomy and arthrokinematics of the femoral head and acetabulum of a two to three-month-old infant
4. The model shall remain under 5lbs

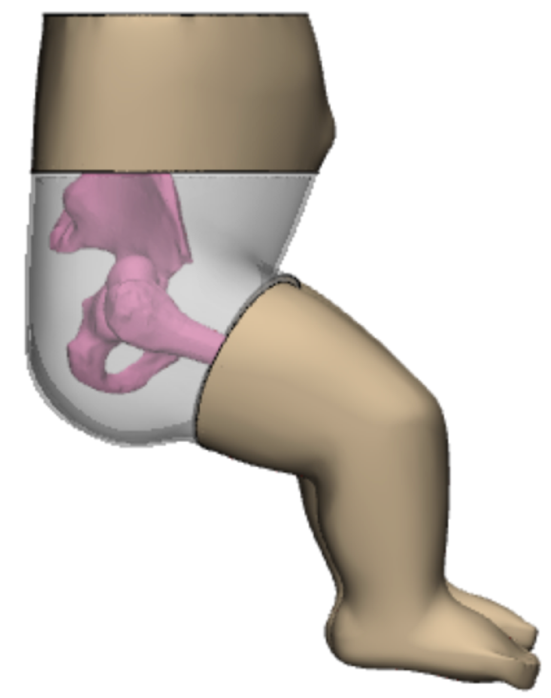

Figure 3: Lateral view of the Proposed Design

Materials

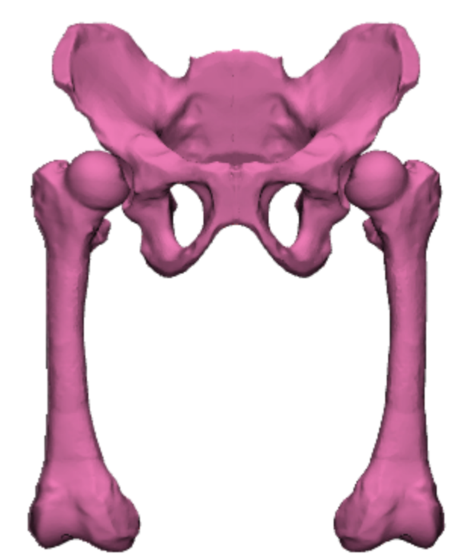

Figure 4: Proposed Skeletal Anatomy

Pelvis and Femurs:

Ultimaker 95A TPU at 100% infill (Density = *1.22 g/cm*)

- Right Femur Volume: 14.83 cm
- Left Femur Volume: 14.62 cm
- Pelvis Volume: 23.96 cm

Total Volume = 53.41 cm

Total Weight = 0.14 lbs

Soft Tissue

SS-3 Stuntman Safe Ice and Glass Silicone (Density = 0.8973 g/cm)

Total Volume = 1209.31 cm

Total Weight = 2.39 lbs

Vertical Rods

- Inserted into posterior pelvis to provide stability

Total Weight = 2.53 lbs

Figure 5: Frontal view of the Proposed Design

Future Steps

- Use a force sensitive resistor to obtain the forces applied during both the Barlow and Ortolani tests
- Complete 3D printing bone samples, assess buckling and reduce hyper-flexibility in the femur
- Create a finite element model in Abaqus to analyze the stresses along the femur
- Receive and test silicon materials

Material Properties

The TPU 95A material that is being used was subjected to tensile testing to determine the modulus of elasticity. The results for 15%-50% infills with a diagonal print and gyroid infill pattern are shown below.

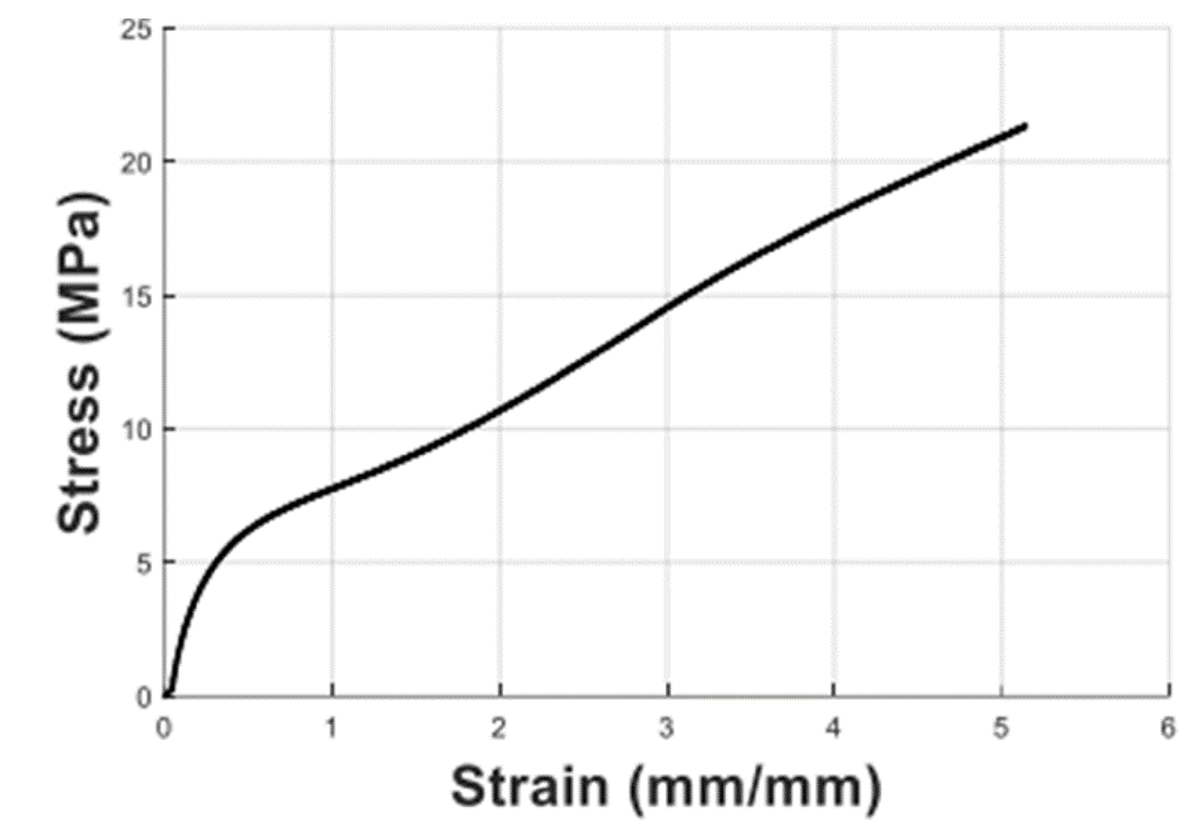

Figure 6: Stress vs Strain Diagram For TPU 95A at 15% Infill [4]

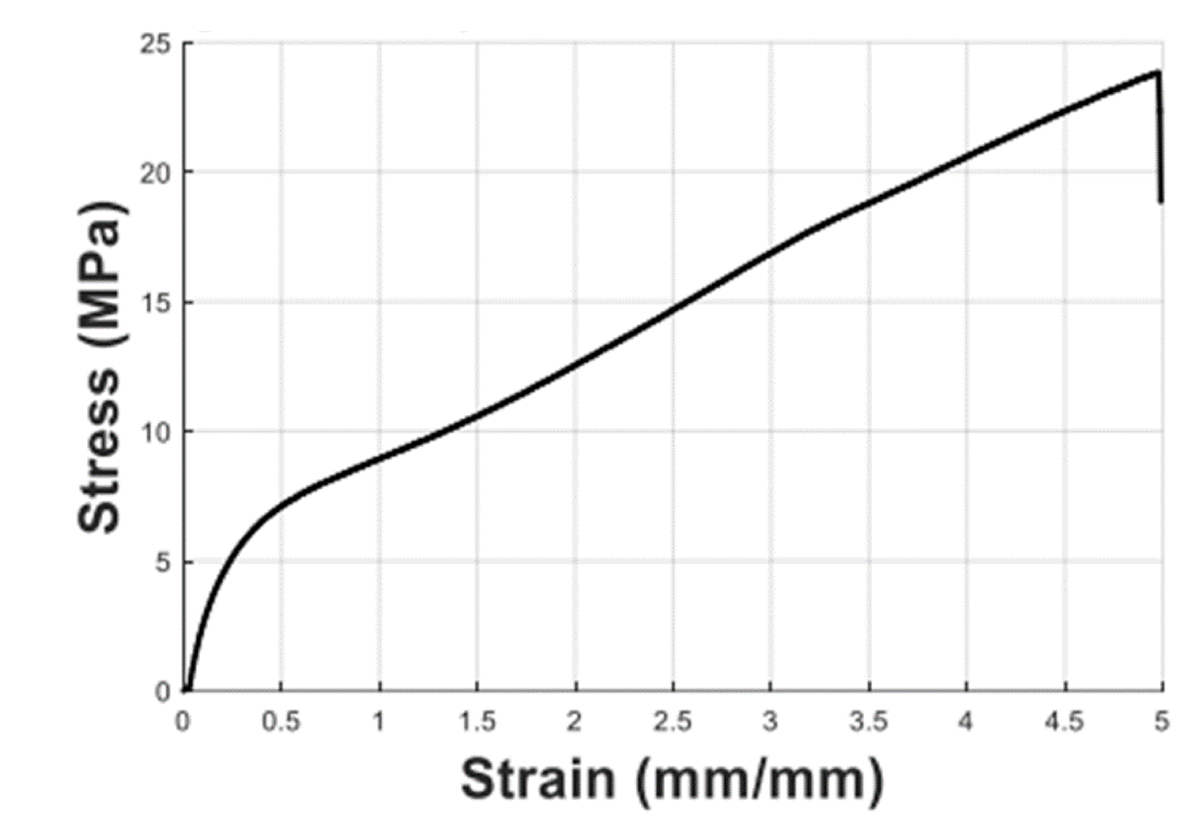

Figure 7: Stress vs Strain Diagram For TPU 95A at 50% Infill [4]

The reason for the sudden drop in stress around the strain of 5 is due to slippage of the dog bone test specimen during the tensile testing. The values of 19.09 and 23.13 MPa for the resulting Young's modulus and 21.50 and 23.92 MPa for maximum stress will be used as the foundation of analysis for future testing of the TPU 95A at 100% infill.

References

[1] Castro, A. P., Altai, Z., Offiah, A. C., Shelmerdine, S. C., Arthurs, O. J., Li, X., & Lacroix, D. (2019). Finite element modelling of the developing infant femur using paired CT and MRI scans. PLoS One.

[2] Stanford Medicine. (n.d.). Barlow and Ortalani Manuevers. Retrieved from Stanford Medicine: https://med.stanford.edu/newborns/clinical-rotations/residents/residents-newborn-exam/barlow-and-ortalani-manuevers .html

[3] Storer, S., & Skaggs, D. L. (2006). Developmental Dysplasia of the Hip. American Family Physician, 1310-1316.

[4] Perry, S., Huayamave, V., Gonzalez, B., Nadeau, Z., & Rodriguez, R. (2022, October). 3D PRINTING MATERIAL TESTING AND APPLICATIONS IN BIOMATERIAL MODELING. Columbus, Ohio.