Development of ex vivo femoral head deformity model to test restorative surgical techniques

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Abstract

Legg-Calve-Perthes Disease (LCPD) is a childhood ischemic osteonecrosis hip disorder which produces femoral head deformity due to weakened trabecular bone structure (1). We hypothesize that a reliable model of deformity comparable to LCPD can be created using porcine cadaver bone by applying compressive force methods (2). Due to the availability of porcine humeral heads in the lab, we performed our preliminary studies using the humeral heads. We tested four mechanical approaches. Our first approach involved the application of static and cyclic compressions to mature humeral heads. However, the method failed to deform the heads due the high compressive strength of the mature bone. Our second approach involved drilling into the mature heads to create stress risers before applying the compression forces. This resulted in an undesirable fracture of the bone. Our third approach used juvenile porcine humeral heads with cyclic compressions which resulted in deformity but was inconsistent in the number of cycles required to achieve the appropriate deformity.
Finally, we successfully achieved a reliable deformity model resembling LCPD by mounting juvenile humeral heads in a specific orientation and applying successive increases in static compression force at 50, 100, 150, 200, and 250 lbs using a Bose Electroforce 3330 test instrument. The amount of collapse after each static compression was measured using calipers. Identical measurements were taken after each compression test, up to 250lbs of force. This method created a 2.3 mm collapse of the humeral head which was reproducible.

Background

The femoral head deformity in LCPD causes pain, stiffness, and debilitating osteoarthritis; if left untreated, a total hip replacement is eventually required. Currently there is no reliable ex-vivo deformity model to develop and test the efficacy of new surgical devices and methods to improve the deformity and to restore the round shape.

Objectives

- To develop a reliable ex-vivo porcine model of femoral head collapse to test future various femoral head restorative techniques.

Materials and Methods

- Normal humeral heads obtained from Yorkshire piglets sacrificed at 12-16 weeks, weighing 37-42 lbs, were used in testing. Juvenile humeri were used due to their similar collapse pattern to pediatric femurs and availability.
- Humeral head was mounted in a custom aluminum fixture during compression testing. (Figure 1)
- Static compression force at 50, 100, 150, 200, and 250 lbs using a Bose Electroforce 3330 test instrument was applied to the humeral heads, with collapse measurements taken after each compression.

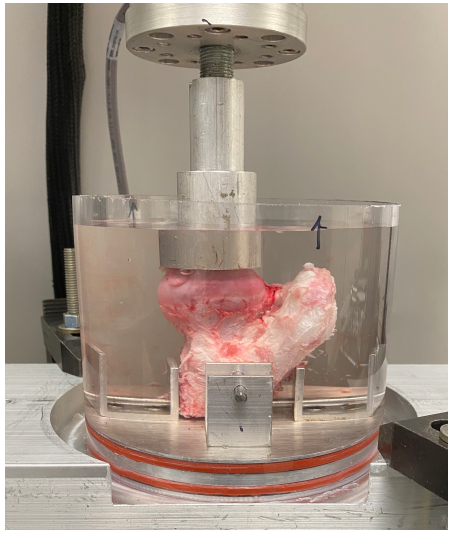

Figure 1. A custom developed aluminum fixture is used to mount the humeral heads in the Bose Electroforce 3330 test instrument and to keep the specimen hydrated

Results

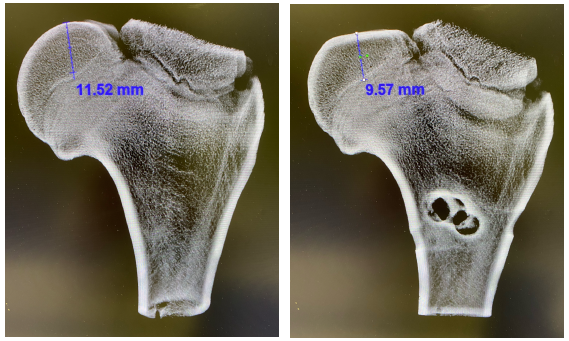

Figure 2. X-rays show the pre-collapsed humeral head (left) compared to the post collapsed humeral head (right).

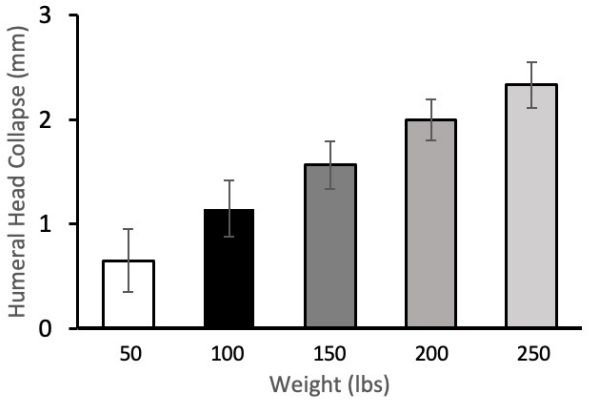

Figure 3. Comparison of the humeral head collapse related to the compression applied to the humeral head.

- 6 porcine humeri were successfully collapsed in the compression testing
- On visual inspection, the collapsed humeri indicated no cracking of the cortical or trabecular bone
- Xray showed no cracks in the cortical or trabecular bone (Figure 2)
- An average of 2.3mm collapse resulted from 250lbs of compression force (Figure 3)
- At 250lbs, the model yielded a standard deviation of 0.21mm
- Collapse of the humeral head linearly increased with increasing compressive force (Figure 3)
- The linear collapse of the had a coefficient of determination of $R^2 = 0.8722$

Conclusions

We developed a novel ex-vivo model of deformity that had a linear relationship between the amount of compression applied (50 to 250 lbs) and the extent of deformity. The collapse produced is representative quantitively and qualitatively to the collapse of an LCPD femoral head. A narrow standard deviation (0.21mm) of the collapse height demonstrates the reproducibility of the model. We believe that this new model can be utilized to develop new restorative surgical devices and techniques to improve the femoral head deformity of LCPD. This easy to create and reliable model is currently being used to test novel restorative techniques. The next objective of the project is to develop effective devices and techniques to restore the shape of the bone.

References

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