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Mechanical Evaluation of Metal on Metal Total Hip Arthroplasty

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BACKGROUND

Metal on metal (MoM) total hip arthroplasty describes hip joint replacement where a metal (titanium or cobalt chromium) femoral head articulates against a metal (titanium or cobalt chromium) socket (acetabulum). This implant scenario has generally been successful until more recently when larger (> 36 mm) metal heads have been increasingly used to reduce the incidence of hip joint dislocation. Today, the number of clinical failures (described by fretting corrosion) of MoM total hip arthroplasty is increasing at alarming rates.

OBJECTIVES

The objective of our research is to investigate three potential factors that may lead to fretting corrosion. These factors include the horizontal lever arm (HLA), the length of taper engagement, and the trunnion manufacturing tolerances. We hypothesize that a combination of these factors is creating a state of stress and unacceptable motion of the femoral head relative to the trunnion that increases wear and leads to undesirable revision rates

FINITE ELEMENT ANALYSIS

The finite element analysis (FEA) was conducted to determine the maximum stresses on the taper and trunnion of the implant. Results show that for a walking up the stairs loading scenario, there is a direct correlation between head size and the stresses on the tapers and trunnions (see Figure 2).

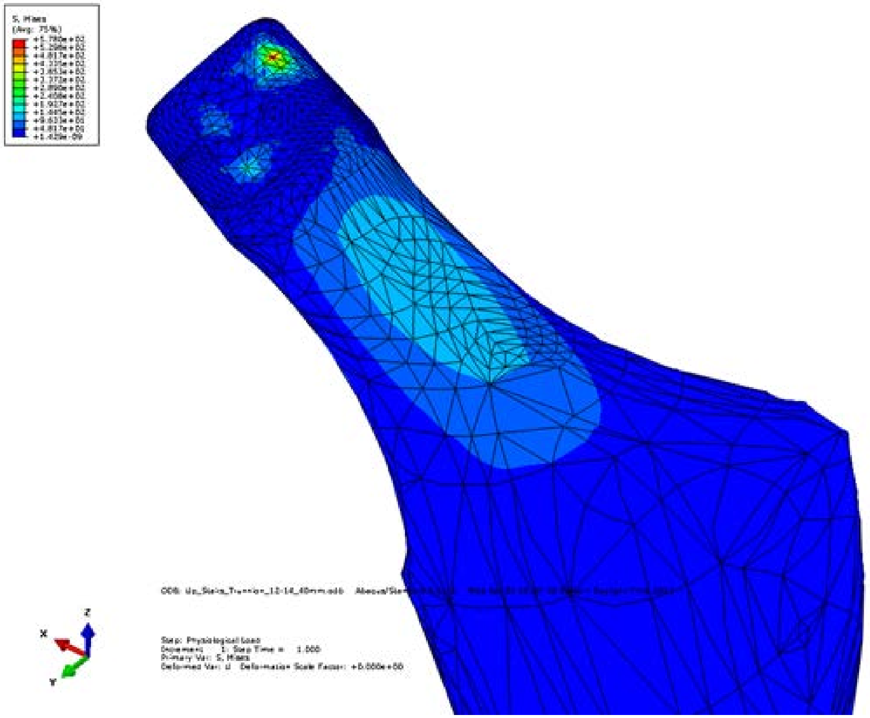

Figure 1: *Finite Element Model Results. The red area indicates the location of highest stress while the blue indicates a point of lower stress*

FEA was also conducted to determine the displacement of the head relative to the neck of the implant (see Figure 3). Results also show that there is a direct correlation between head size and displacement of the head with respect to the neck of the implant.

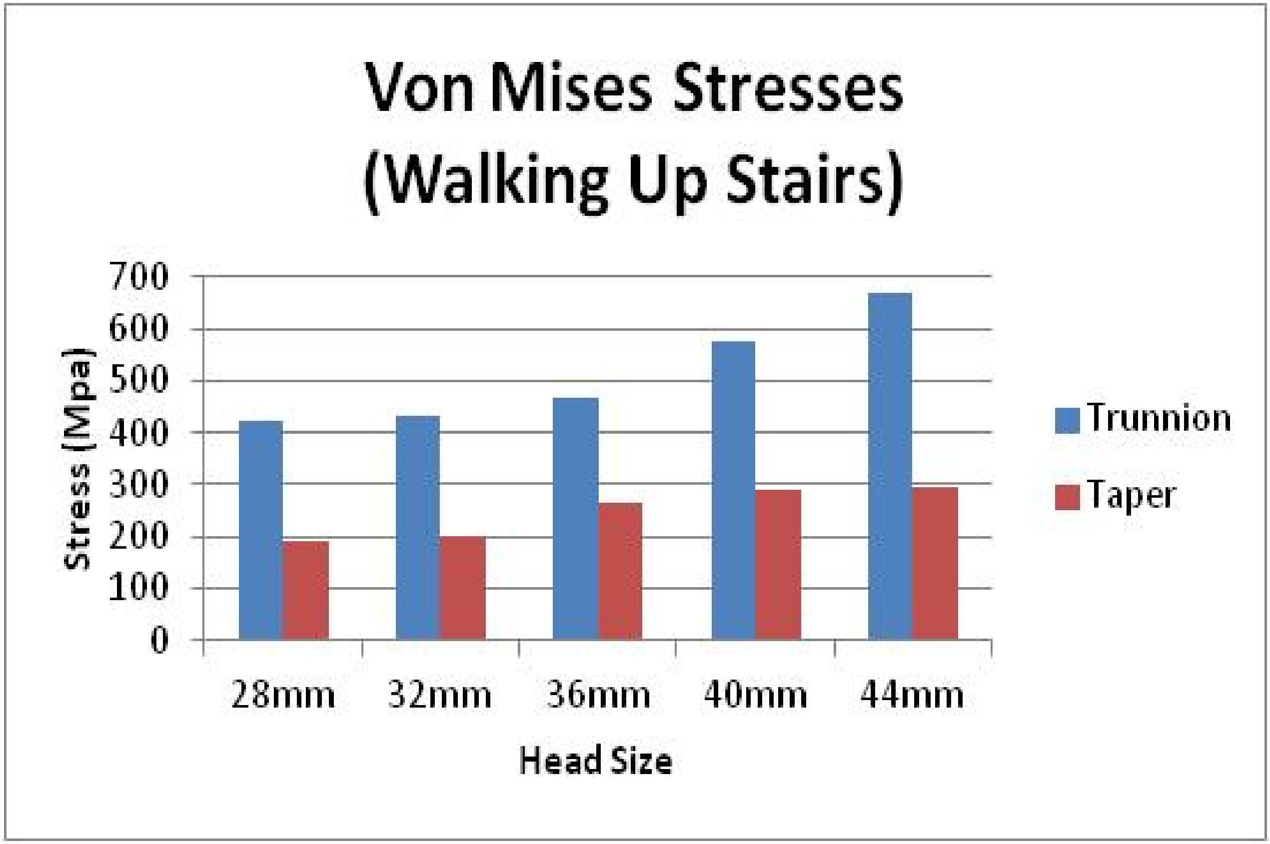

Figure 2: *Maximum Von Mises stresses on the taper and trunnion of a 12/14 taper implant.*

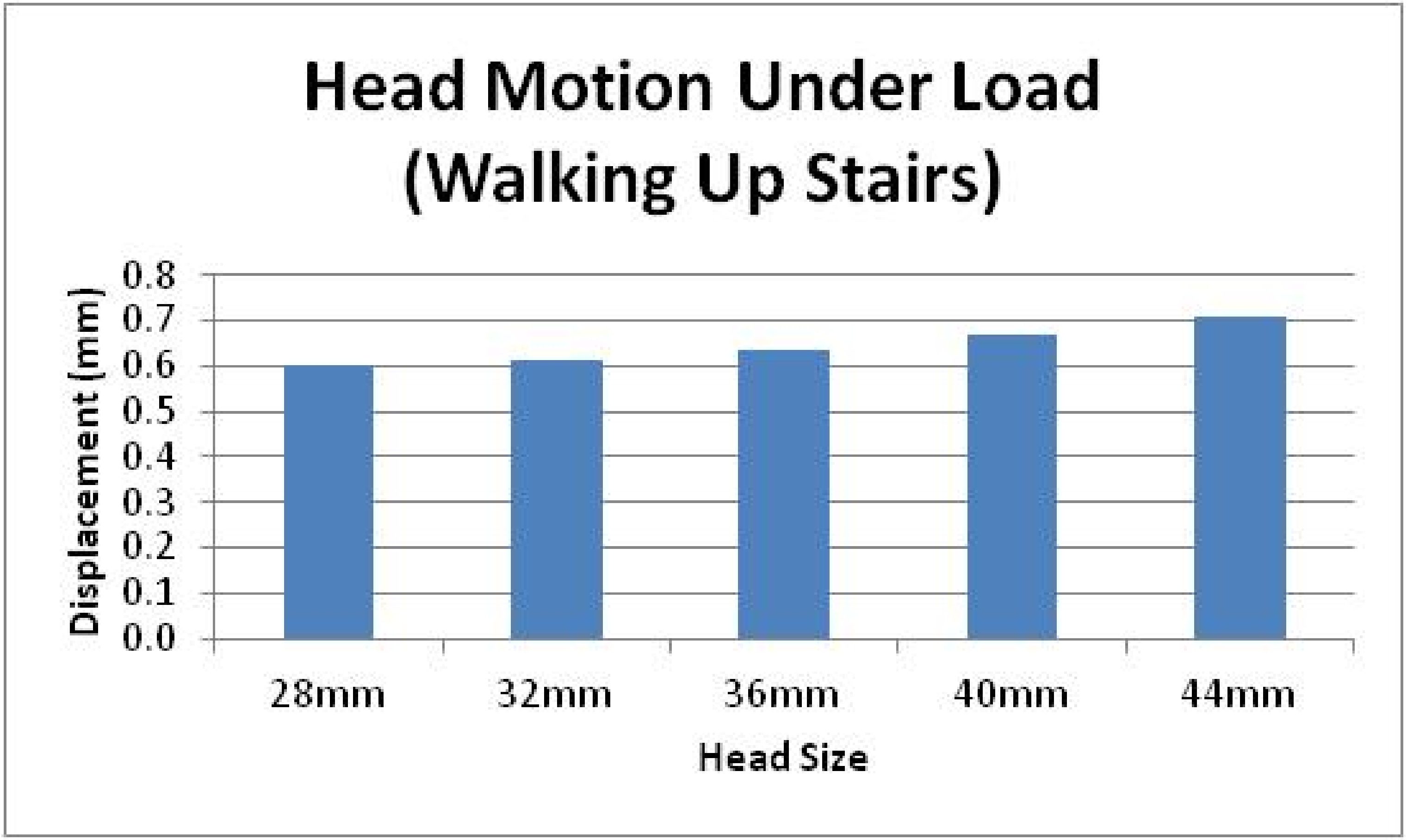

Figure 3: *Motion of the femoral head relative to the neck of the 12/14 tapered implant.*

DEFINITIONS

- Trunnion: the male part of the implant that sits on the end of the neck and inserts into the taper of the femoral head.

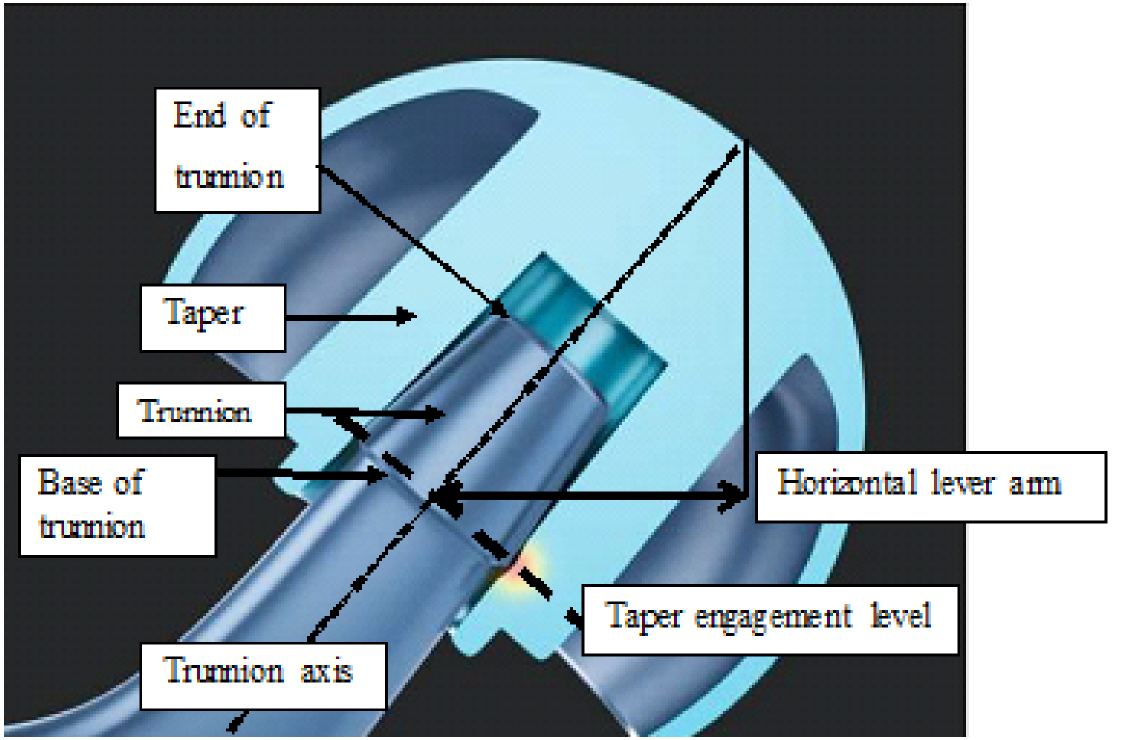

Figure 7: *This figure shows the femoral head labeled with the definitions used in this presentation*[2]

- Taper: the female part of the head that is friction fitted to the trunnion.

- Horizontal Lever Arm (HLA): horizontal line from the tip of the bearing surface to the center of the taper engagement level.
- Taper Engagement Level (TEL): the point at which the taper engages the trunnion.
- Physiological Loading: loading seen by the hip in vivo in different scenarios (i.e. walking, stumbling, etc.) See Figure 8.

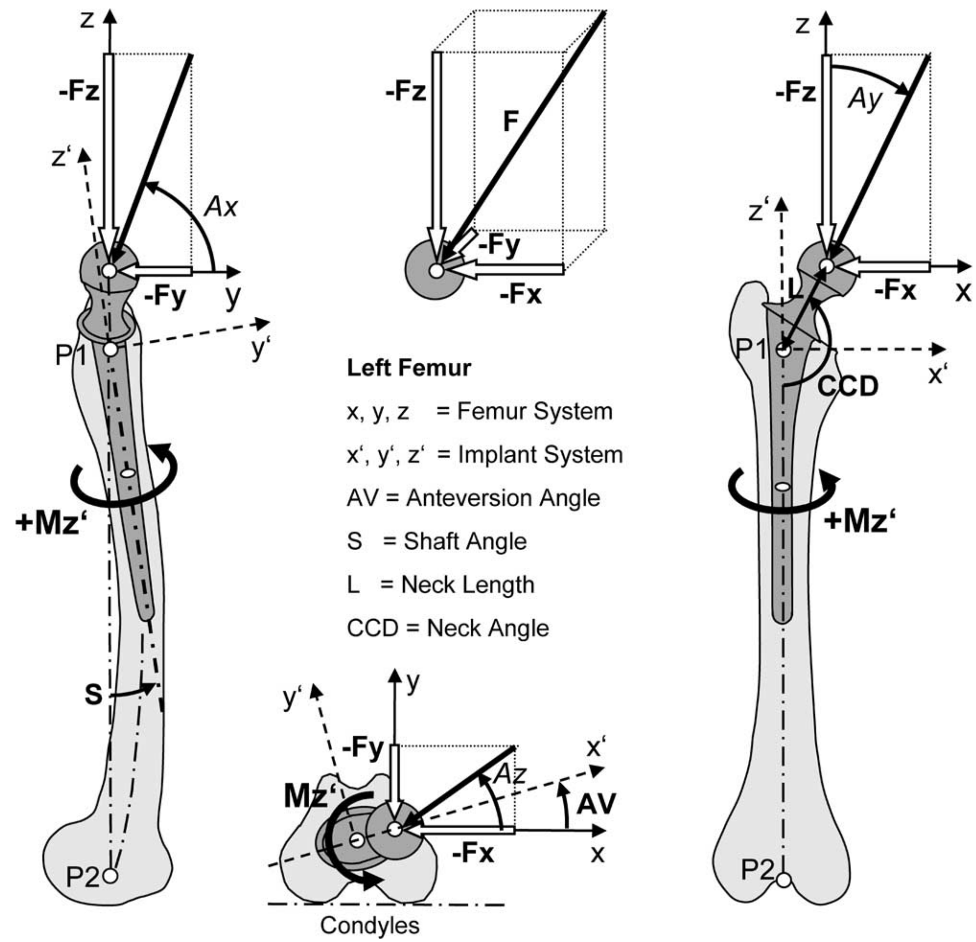

Figure 8: *Physiological loading conditions of a human hip according to Bergmann et. al.*[1]

STATIC TESTING

The main purpose of the static testing was to determine the motion of the femoral head with respect to the neck of the implant.

Determining these characteristics and comparing them to the FEA model will provide a validation of the FEA model. We have found that there is a correlation between the FEA stresses and the static testing results. The static testing results also show that there is not only a correlation between head size and stress, but that there is also a correlation between TEL and stress. (See Figures 5 and 6).

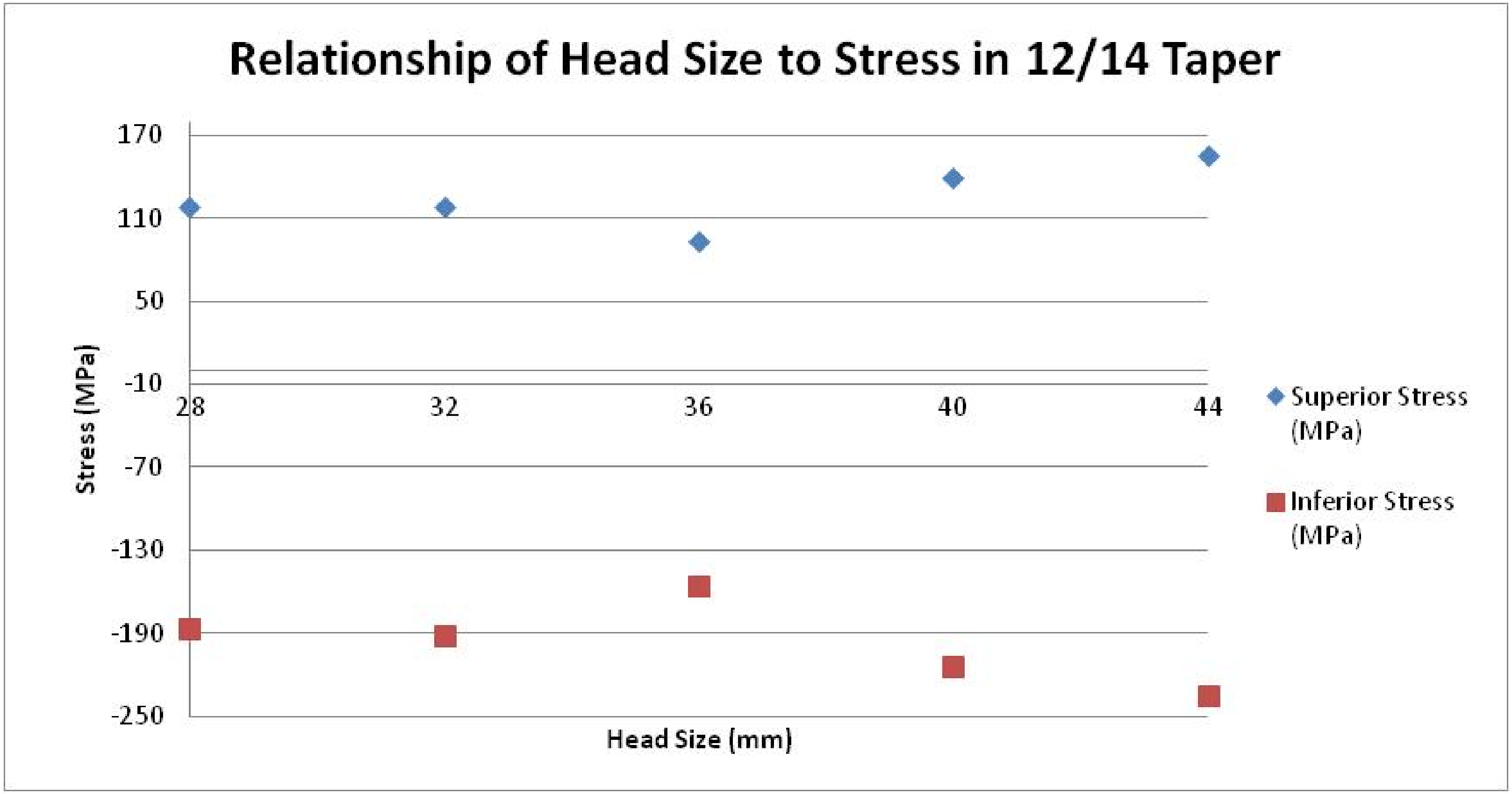

Figure 5: *Stresses on the superior and inferior faces of the implant compared to the size of the femoral head*

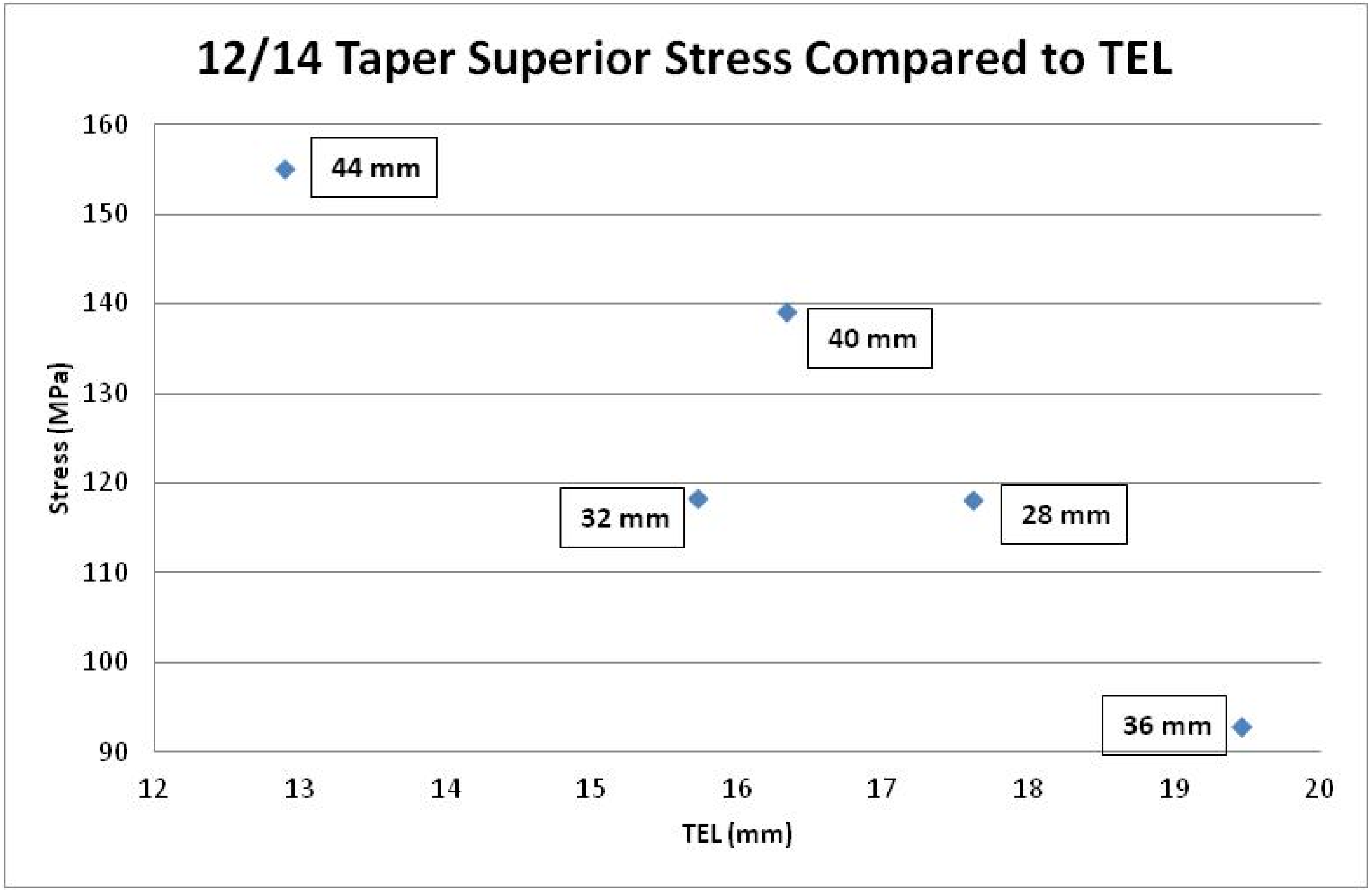

Figure 6: *Stresses on the superior face of the 12/14 tapered implant in comparison to the TEL of the head. Head sizes shown in box next to the data point.*

CONCLUSION

Our findings show that there is a correlation between head size, HLA, and TEL and the stresses in the neck, taper, and trunnion of the implant. The larger the head size and HLA and the shorter the TEL, the more stress there is on the implant.

Our initial findings also show that there is motion of the head relative to the neck of the implant and that this motion is affected by head size. Further tests are being conducted to more thoroughly understand this motion.

SPECIAL THANKS

This team would like to thank Dr. Thomas Fehring of OrthoCarolina for his donation of the implants and femoral heads tested as well as his insight into this field.

REFERENCES

1. Bergmann G., Graichen F., Rohlmann A., Bender A., Heinlein B., Duda G.N., Heller M.O., Morock M.M. Realistic loads for testing hip implants. *Biomed Mater Eng* 2010; 20(2): 65-75.
2. Cohen D. How safe are metal-on-metal hip implants? *BMJ* 2012; 344: e1410.