Is Assembly Technique or Implant Design Vital to Stability of Modern Total Hip Arthroplasty?

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Objective/Aim/Hypothesis

Modularity is the standard choice in total hip arthroplasty (THA) despite recent evidence highlighting modular components with presence of corrosion, leading to implant failure. In THA, modular components consist of a femoral stem and head prosthesis joined by a tapered interlock that is assembled intraoperatively by the surgeon using an impactor and a mallet. With no consensus on assembly technique and the numerous implant designs on the market, we employed computational modeling to identify whether assembly technique or implant design were more vital to the stability of the modular components. We hypothesized that load magnitude and number of assembly strikes would influence mechanical stability (i.e. contact pressure and implant deformation) rather than implant design.

Design/Approach/Methods

A validated two-dimensional, axisymmetric finite element (FE) model of a metal femoral head taper and stem taper was created using median geometrical measurements taken from over 100 retrievals at the Rush Implant Pathology and Biocompatibility Laboratory. To investigate effects of assembly technique on implant mechanics, multiple dynamic loads (4kN, 8kN, and 12kN) were applied to the femoral head taper in either one or three hit sequences. Effects of implant design—stem taper microgroove roughness (rough vs smooth)—were also investigated. Outcome variables were contact pressure and permanent microgroove deformation.

Results

As expected, increasing assembly load led to increases in contact pressure and permanent surface deformation. Models assembled with one hit exhibited the greatest contact pressures and permanent surface deformation (Figure 1) as compared to those assembled with three hits. When considering implant design, the presence of rougher surface geometry (i.e. microgrooves) led to increased deformation compared to smooth tapers. Lastly, smooth tapers exhibited decreased sensitivity to the number of assembly hits as compared to the rough tapers.

Conclusions

Employing one, firm mallet hit led to greater pressures and permanent deformation as compared to tapers assembled with three hits. Residual energy may be lost with subsequent assembly hits, suggesting that one, firm hit maximizes taper assembly mechanics—even if subsequent hits reach the same load magnitude as the single hit. Additionally, interaction effects were observed among the implant designs, where implants with smooth surface finishes required increased assembly load magnitude to exhibit similar contact pressures and surface deformations as rougher surface finishes. The findings from this work suggest surgeons apply one, firm (i.e. greater than 4kN) hit when assembling modular components during THA or consider substituting components with rougher surface finishes when lower assembly magnitudes may be required (i.e. reduce risk of fracture). Furthermore, these findings suggest the introduction of additional mallet hits in tapers with rougher surface finishes may reduce the seating interference strength, possibly due to material hardening.

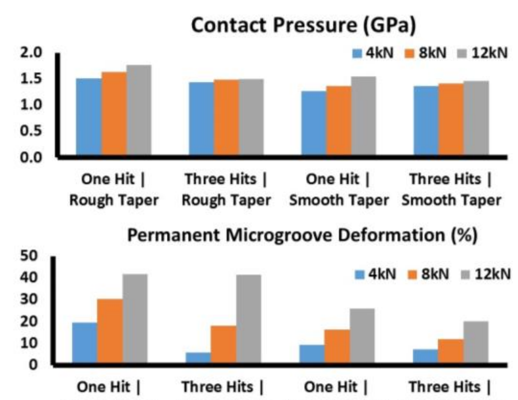

Figure 1: Resulting contact pressures (top) and peak microgroove deformations (bottom) of assembly with 1 or 3 mallet hits across rough and smooth taper designs.