

Investigating the Mechanical Stresses and Potential Stress Shielding Effect in Radial-Prosthesis Assemblies with Overstuffing and Understuffing of the Elbow Joint

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Introduction / Objective

While radial head arthroplasty can achieve elbow stability following comminuted radial head fractures, bone resorption with aseptic loosening is observed in the long term. A possible mechanism is bone resorption from peri-prosthetic stress shielding, which is currently not well-studied in radial head arthroplasty. This study utilizes finite element (FE) modelling to characterize stress shielding in the elbow following radial head implantation at varying levels of joint overstuffing and understuffing. We hypothesize that radial head implantation will increase stress shielding, which is exacerbated and alleviated by overstuffing and understuffing, respectively.

Materials & Methods

A digital model of a cadaveric elbow was generated via CT scanning and image segmentation. Virtual implantation of a prosthetic radial head was performed at varying levels of overstuffing and understuffing. FE modelling was utilized to apply rotational displacements at the distal forearm to simulate pronation and supination.

Results / Discussion

Implant insertion caused a stress shielding effect in the proximal radius of around 16% in magnitude. Overstuffing exacerbated stress shielding, with a maximum magnitude of 22.8% observed at 5mm of overstuffing. Understuffing demonstrated the opposite result, with a stress shielding magnitude of 11.6% observed at 2mm of understuffing.

Conclusion

To our knowledge, this is the first study to utilize FE methods to demonstrate stress shielding related to a radial head prosthesis, which may contribute to aseptic loosening via bone resorption. This effect is intensified by overstuffing, which concentrates stresses on the radiocapitellar surface, leading to capitellar erosions and resultant bone resorption. While understuffing minimizes stress shielding in the proximal radius, it may cause acute elbow and forearm instability. Thus, radial head arthroplasty should aim to restore native radial lengths, to avoid possible instability. Further studies are recommended to examine alternative prosthesis redesigns, to optimize stress levels around the bone-prosthesis interface and improve long-term clinical outcomes of radial head replacements.