Effect of Stem Length on Prosthetic Radial Head Micromotion
Shukla, DR; Fitzsimmons, JS; An, KN; O’Driscoll, SW +
+ Biomechanics Laboratory, Division of Orthopedic Research, Mayo Clinic, Rochester, MN
Senior author: odriscoll.shawn@mayo.edu

Introduction:
The maintenance of long-term fixation and stem stability for radial head implants depends on multiple factors, including obtaining adequate stability by minimizing initial stem-bone micromotion. Previous micromotion analyses have demonstrated impaired interdigitation and formation of an impeding fibrous tissue layer with implant micromotion over 100-150 µm. Biomechanical studies have examined the influence of radial head stem properties on press-fit stability, including the type and extent of surface coating, as well as geometry. It has been shown that the diameter of a polished, smooth stem is more important than length for initial stability. However, for porous-coated stems designed for osseous ingrowth, the stability may be affected by the length of the stem inside the canal and the level of the cut on the radius. The latter could impact bony contact inside the canal and total implant length (head+neck) outside the canal, significantly affecting cantilever moments on the stem. We hypothesized that increasing the level of bone resection can affect initial press-fit stability, as indicated by increased micromotion at the bone-implant interface.

Methods:
11 fresh frozen human radii without evidence of bony pathology were implanted with grit-blasted titanium stems. Of these, the large medullary canal size in two specimens precluded stability testing. A porous coated, fluted radial head stem that was 25 mm long was inserted into each radius after resecting 10 mm of radial head and neck. The rasps and stems were inserted starting with the smallest (5.5 mm rasp, 6.0 mm stem) and working up sequentially. At each stage micromotion of the stem was measured. If it was greater than 95 µm, the next sized rasp and stem were inserted until a tight fit was achieved. Tactile estimation of tightness was confirmed by testing the micromotion of the stem, and by a micromotion value of less than 95 µm. After stem insertion, the radial neck around the implant was resected in increments of 2, 5, 10, and 15 mm. The actual values were converted to quotients. The cantilever quotient describes the length of bone resected divided by the total implant length a) cantilever quotient – C.Q. = 0.3 (0 mm), .35 (2 mm), .4 (5 mm), .6 (10 mm), .7 (15 mm) (Figure 2). Prosthetic tip micromotion was measured using a custom-made device. The potted radius with the implant was rigidly fixed and two loads were pneumatically applied; a 100 N axial load and a 45 N radial load (Figure 1). A mounted laser displacement sensor recorded vertical displacement of the metal plate, and stem micromotion measurements were calculated using simple geometry. All data were analyzed using repeated measures ANOVA. All data are presented as mean ± SEM.

Results:
The initial micromotion values after optimal stem size insertion averaged 35 ± 5 µm. Removal of 2 mm of bone from under the collar (total bone resection = 12 mm) did not significantly affect micromotion. After 15 mm of bone removal (5 mm under the collar; C.Q. = .4) a threshold affect was seen, and micromotion increased to 85 ± 25 µm. After total bone resection of 20 mm (10 mm under the collar; C.Q. = 0.6) the stem was too unstable to test in 2 of 9 specimens, with 7 exhibiting a significant increase in micromotion (170 ± 75 µm). Further loss of stability occurred with total bone resection of 25 mm (15 mm under the collar). 4 of the 9 specimens remained grossly stable within the canal and were able to be tested for micromotion, which increased to 230 ± 5 µm, with 2 of 9 specimens having micromotion in excess of 100 µm (p < 0.05).

Figure 3.
Mean micromotion values are shown. Data are shown as the means ± SE of the mean (error bars). *Sample sizes for the 20 mm (n = 7) and 25 mm (n = 5) were not large enough compare to the 10, 12 and 15 mm groups using repeated measures analysis.

Discussion:
This study showed that micromotion of a prosthetic radial head stem within the neck of the radius is dependent on the resection level of the bone and the length of stem within the bone. We observed a corresponding increase in stem micromotion with increasing length of radial neck resection and decreasing length of stem inside the canal. In fact, we found that it is possible for an implant to have a combined head and neck length that is too long compared to its stem. We expressed this concept using a term that reflects the amount of bone resected in relation to the total length of the prosthetic head and neck (Cantilever Quotient). A critical threshold was seen with a C.Q. of 0.4. Implants with a C.Q. of .35 were stable in the canal, while implants with a C.Q. of .6 or greater were unstable and would be expected not to develop bone ingrowth. In between (.35 < C.Q < .6), implants would be at risk of failing to attain bone ingrowth. We found that stem-bone contact was more important than collar-bone contact, as the micromotion did not significantly increase after 2 mm of bone resection under the collar.

Radial head stem length’s influence on stability has been studied, but only with a) a smooth prosthesis not designed for osseous ingrowth and b) without regard to the importance of the initial radial head/neck cut in relation to the total implant length.

Significance: Our study carries important implications for prosthesis design and surgical technique. Of the currently available implants in the United States, the range of maximum C.Q. values is .4 to .6, and surgeons should consider the combined head and neck length in light of the length of stem inside the bone.

Acknowledgments: This study was funded by the Mayo Foundation.