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Effect of stem length on prosthetic radial head micromotion

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Background: Osteointegration of press-fit radial head implants is achieved by limiting micromotion between the stem and bone. Aspects of stem design that contribute to the enhancement of initial stability (ie, stem diameter and surface coating) have been investigated. The importance of total prosthesis length and level of the neck cut has not been examined.
Methods: Cadaveric radii were implanted with cementless, porous-coated radial head stems. We resected 10, 12, 15, 20, and 25 mm of radial neck in each specimen. Stem-bone micromotion was measured after each cut. Values were expressed in terms of quotients (cantilever quotient).
Results: A threshold effect was observed at 15 mm of neck resection (cantilever quotient, 0.4), with a significant increase in micromotion observed between 12 mm (40 ± 10 μm) and 15 mm (80 ± 25 μm). A cantilever quotient of 0.35 or less predicted implant stability, whereas implants with a cantilever quotient of 0.6 or more were unstable. In between, the stems were "at risk" of instability.
Conclusion: Initial stem stability of a porous-coated, cementless radial head implant is dependent on length of the implant stem within bone and the level of the cut (amount of bone resected). Stability may be compromised by an implant with a combined head and neck length that is too long compared with the stem length within the canal. We found a critical ratio of exposed prosthesis to total implant length (cantilever quotient of 0.4), which puts the prosthesis at risk of inadequate initial stability. These data carry important implications for implant design and use.
Level of evidence: Basic Science Study, Biomechanical Study.

Keywords: Radial head implant; radial head arthroplasty; stem length; radial head stability; implant geometry; implant micromotion

Prosthetic replacement is indicated for unfixable radial head fractures in the setting of complex elbow or forearm instability.[6,11] A variety of implant and stem designs are available, each with its own advantages and disadvantages. Initial stability of cementless implants is important for osseous interdigitation and long-term fixation. Minimizing bone-implant micromotion promotes bone ingrowth. Studies have shown bone in-growth onto porous surfaces with micromotion levels between 40 and 70 μm, with fibrous tissue formation in the presence of micromotion exceeding 100 to 150 μm.[9,13]

Several aspects of porous-coated cementless radial head stems contribute to initial stability. Biomechanical

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The Mayo Clinic Institutional Review Board that convened on December 17, 2010, approved the project, entitled "Prosthetic Radial Head Stability" (protocol number 01-008186).

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investigations have been performed analyzing the influence of radial head stem properties on press-fit stability, including the type of surface coating,[4] the extent of surface coating,[3] and stem geometry.[7,10] Currently, there are no studies analyzing the impact of stem length on initial stability or fixation. Ferreira et al[7] suggested that stem diameter was more important than stem length in enhancing cortical contact in the proximal radius, but the implant that they used was a smooth stem designed to be loose, not a press-fit ingrowth stem.

It is possible that the initial press-fit stability of a radial head prosthetic stem might be affected not only by the length of the stem inside the canal but also by the level of the cut on the neck of the radius. The latter would potentially impact not only bony contact inside the canal but also the total length of the prosthesis (head plus neck) outside the radius. For monopolar prostheses, this would change the moment arm and affect cantilever moments on the stem. This study was conducted to test the hypothesis that increasing the level of bone resection can affect initial press-fit stability, as indicated by increased micromotion at the bone-implant interface.

Methods

Nine fresh-frozen human cadaveric radii, obtained from our institutional cadaver donor program, were analyzed in this study. The donors' mean age was 77 years (range, 58-88 years). Each specimen was thawed overnight at room temperature before preparation.

Specimen preparation

Each sample was prepared in an identical fashion. After visual inspection to confirm the absence of bony pathology, the proximal third of the radius was resected, and all soft tissue was dissected by layer. The radius was securely potted in an aluminum tube with polymethyl methacrylate. To maintain visualization of the bicipital tuberosity for consistent alignment, the cement level never extended beyond the level of the tuberosity. The radius was potted such that the long axis of the radial neck was vertical. A caliper was used to measure 10 mm from the highest point of the radial head, and the head was excised perpendicular to the long axis of the radial neck with a micro-sagittal saw.

Radial head implant

The Anatomic Radial Head System (Acumed, Hillsboro, OR, USA) was used in this study. The titanium, grit-blasted stems are 25 mm in length and range from 6 to 10 mm in diameter, in 1-mm increments. The fluted, tapered stem is manufactured with collar size options of 0, 2, 4, and 8 mm. Only the 2 mm collared stem was used.

Implantation technique

Implantation of the stem followed canal preparation by a 0.5-mm undersized rasp, as specified by the manufacturer. A previously described slap hammer with changeable weights was used.[4] A weight of 0.5 kg was dropped from a height of 10 cm repeatedly until the rasp or stem was fully inserted. The rasp was considered fully inserted when it advanced to a notch that was pre-designated by the manufacturer. The stem was considered fully inserted when the collar was seated flush against the radial neck.

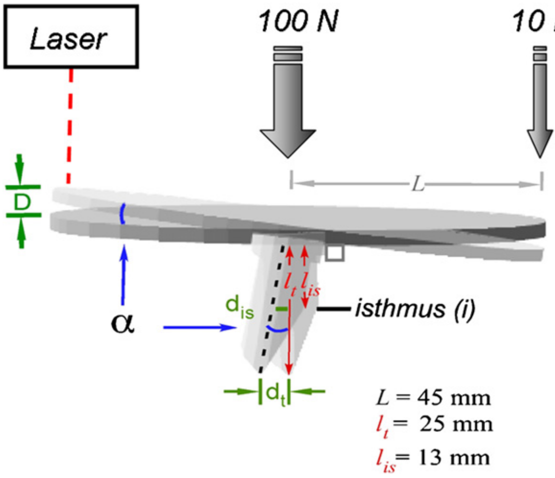

Figure 1 Schematic showing geometric modeling of laser displacement to plate and stem micromotion. The tilt was assumed to occur at the center of the component. In a right triangle, the tilting angle (α) was calculated from the laser displacement (D) ($\sin \alpha = D/L$). In an isosceles triangle, the stem micromotion at the level of the isthmus (d_{is}) and micromotion at the stem tip (d_t) were calculated from α ($\sin \alpha/2 = [d_{is}/2]/l_{is} = [d_t/2]/l_t$). L, Radius of plate (45 mm); l_{is}, length from center to isthmus (13 mm); l_t, length of stem (25 mm). (Modified with permission from the Mayo Foundation from Chanlalit C, Shukla DR, Fitzsimmons JS, An KN, O'Driscoll SW. Effect of hoop-stress fracture on micromotion of textured ingrowth stems for radial head replacement. J Shoulder Elbow Surg. In press 2011. doi:10.1016/j.jse.2011.05.001.)

Micromotion testing

A previously reported custom-made device was used to measure micromotion between the stem and bone[4,10] (Fig. 1). A metal plate (6.5 mm thick, 100 mm in diameter) was fitted onto the top of the stem and secured with a bolt. The plate-specimen construct was rigidly secured in the device. Possible motion within the testing device itself has been previously analyzed.[5] To ensure that the observed micromotion represented solely the implant-bone micromotion, additional measures were taken to secure the device. The aluminum tube that housed the cemented radius was secured into a thicker aluminum tube (sleeve). We tightened a collar clamp around the top of the sleeve for additional containment of the specimen.

Within the machine, the sleeve-pot construct rested flush against a flat surface so that no downward motion occurred once the axial load was applied. Finally, we secured a modified collar clamp around the base of the sleeve-pot construct to ensure that the radial head stem movement was the only motion occurring within the system. A 100 N pneumatically applied load was