Intramedullary Reaming for Press-Fit Fixation of a Humeral Component Removes Cortical Bone Asymmetrically

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Shoulder arthroplasty is commonly used to manage glenohumeral arthritis and posttraumatic conditions. The humeral component is often press fit to avoid the use of cement. This technique requires sufficiently robust fixation to avoid implant loosening. Since humeral prostheses are generally cylindrical, reaming the endosteal diaphyseal cortex to achieve a cylindrical shape enhances the fit and fixation of the prosthetic stem. The endosteal cortex has been noted to be elliptical in cross section, with varying orientation of the elliptical major axis. Because the cross sections of the medullary canal are not symmetrically aligned, the path taken by the cylindrical reamer is determined by the shape and density of the endosteal bone at each segment all along its length. As a result, cylindrical reaming is likely to remove bone asymmetrically from the diaphyseal endosteal surface. Asymmetric cortical bone removal is a recognized risk factor for humeral periprosthetic fracture both at surgery or with trauma thereafter.

Figure 1: Radiograph of the left shoulder of a 62 year-old man with periprosthetic fracture after a fall.

Periprosthetic fractures account for 20% of all complications associated with shoulder arthroplasty and the incidence has been reported between 1-2.3%. Such fractures are serious, often requiring more extensive and repeat surgery as well as compromising the rehabilitation program. Risk factors for fracture include osteopenia, osteoporosis, rheumatoid arthritis, inadequate operative exposure resulting in excessive manipulation, and overzealous reaming or impaction. Boyd et al noted that in their seven reported cases the fracture pattern involved the humeral shaft at the distal tip of the prosthesis where the amount of bone removed by the cylindrical reaming would be greatest (Figure 1).

The effect of humeral reaming on cortical bone thickness has not been previously studied. This study tested the hypothesis that cylindrical intramedullary reaming removes substantial diaphyseal cortical bone in an asymmetrical manner. We hypothesize that the degree of cortical thinning would not be apparent to the surgeon on an anterior-posterior radiograph typically taken after shoulder arthroplasty.

Material and Methods

Ten unmatched human cadaveric humeri were used for this study (mean age 73 years). All humeri were free of fracture or evident bone disease. Soft tissues were stripped before testing. The humeri were cut at 16 centimeters distal to the proximal aspect of the greater tuberosity and the humeral head was excised at the anatomic neck.

The baseline cross sectional geometry of the humeral cortex was defined using the General Electric Lightspeed vCT scanner (General

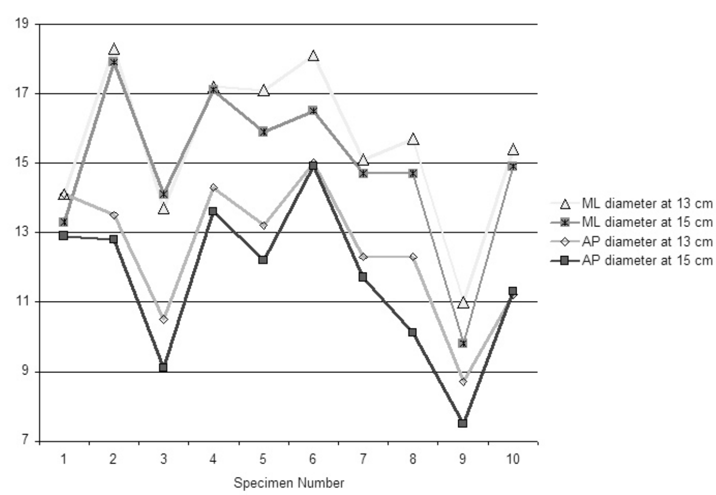

Figure 2: Medial-lateral(ML) and anterior-posterior(AP) diameters of the ten different humeri 13 and 15 cm distal to the proximal tuberosity.

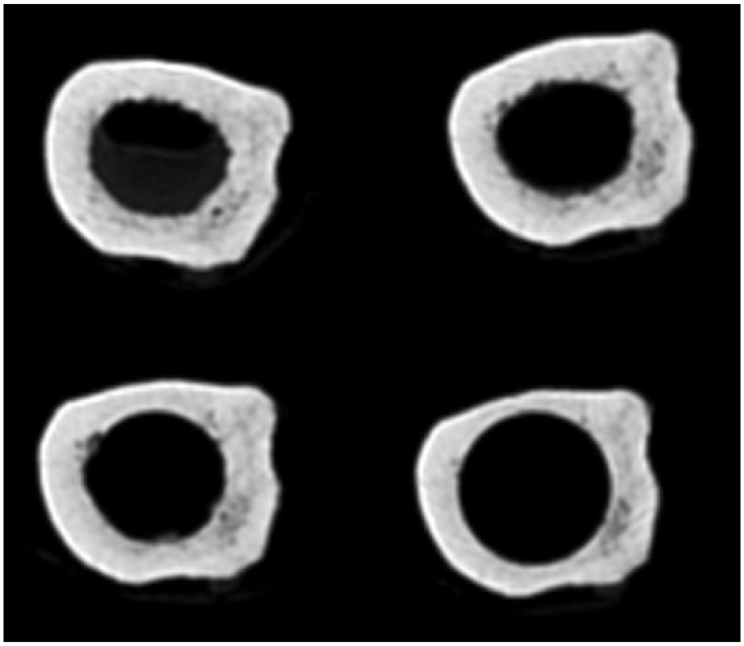

Figure 3: Preferential thinning of the anterior and posterior cortices with sequential reaming. Humerus #7 at 15cm distal to the proximal aspect of the greater tuberosity. Upper left, unreamed; upper right, reamed to 12mm, lower left, reamed to 14mm; lower right, reamed to 16mm.

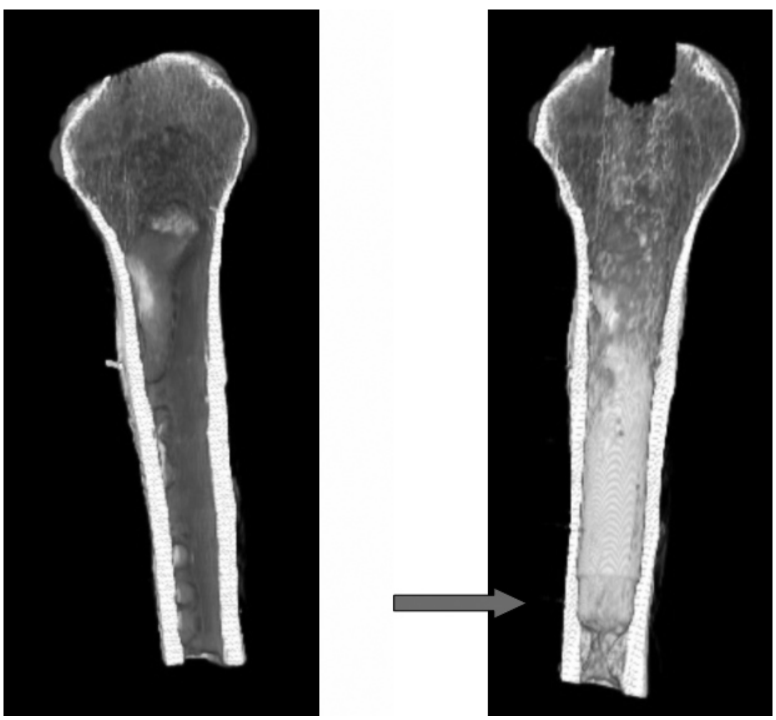

Figure 4: Anterior posterior endosteal notching caused by reaming as seen on the lateral projection in a three-dimensional reconstruction of humerus #7. Left, unreamed; right, reamed.

Electric, Fairfield, CT) at 0.62 mm intervals. Particular attention was directed to the cross sectional anatomy at 13 and 15 cm distal to the proximal tip of the greater tuberosity where fixation of the distal tip of a humeral component is characteristically achieved.

The humeri were then reamed by hand as performed in surgical practice. While no "standard" technique for reaming has been established, it is evident that fixation of the prosthetic stem requires that the diaphysis as the prosthetic tip be shaped to fit the prosthetic stem. In our protocol, reamers were inserted to 15 cm, the depth necessary to accommodate a humeral prothesis. Starting with the smallest reamer, reamers of progressively larger diameter were inserted until endocortical contact was first achieved. Since this first bite would provide fixation for only the distal tip of the prosthesis, reaming was repeated with reamers of a diameter two and then four millimeter greater than the one to first achieve a bite on the endosteal surface. CT scans were obtained after each reaming.

Data analysis of the cortical anatomy was conducted using the OsiriX medical imaging software program (http://homepage.mac.com/rossetantoine/osirix/). The anterior-posterior and medial-lateral endocortical diameters were measured 13 and 15 cm distal to the tuberosity before and after reaming. The significance of the difference in the anterior-posterior and medial-lateral diameters at each level was determined using the two-tailed student's t-test for paired samples. The amount of thinning of each of the anterior, posterior, medial, and lateral cortices at the point 13 cm distal to the tuberosity was determined by subtracting the cortical thickness in each of these directions before and after reaming.

Results

The average medial-lateral diamteter (15.6 $\pm$ 2.3 mm) was significantly greater that the anterior-posterior diameter (12.5 $\pm$ 1.9 mm) at 13cm distal to the tuberosity ($p<0.00005$) (Figure 2). Similarly, the average medial-lateral diameter (14.9 $\pm$ 2.3) was significantly greater than the anterior-posterior diameter (11.6 $\pm$ 2.2 mm) at 15cm distal to the tuberosity ($p<0.0001$). This result indicates that that endocortical contact in the medial-lateral direction cannot be achieved without removal of substantial anterior-posterior cortical bone.

When the diaphysis was reamed to a diameter 4 mm greater than that of the reamer to obtain first cortical bite, the greatest amount of bone removed was from the anterior and posterior endocortical surfaces and least from the medial cortex. This loss of bone from the anterior and posterior cortices would not be apparent on standard anterior-posterior radiographs (Figure 3).

Discussion

In preparation for shoulder arthroplasty surgeons often use the anterior-posterior radiograph to template the size of the humeral prosthetic stem that would fit the humerus without substantial cortical reaming. This study demonstrates that this traditional method of templating may cause the surgeon to overestimate the size of the ideal humeral stem. The medullary canal diameter seen in the plane of the anterior-posterior radiograph at 13 cm and 15 cm distal to the proximal aspect of the greater tuberosity was 3.1 mm and 3.3 mm greater than that which would be seen in the lateral radiograph at these locations.

The results of our study confirm that the endocortical morphology of the humerus is variable as pointed out by Robertson et al. Intramedullary reaming with a rigid cylindrical reamer preferentially removed cortical bone from the anterior and posterior surfaces of the diaphyseal cortex. This creates a notching of the endosteal cortex that may not be recognized on the conventional anterior-posterior radiograph (Figure 4). Asymmetrical thinning may increase the risk of periprosthetic fracture, especially when combined with the abrupt change in material properties that would occur at the point of transition from notched cortex with a prosthesis to the unreamed cortex just below it.

Recommended Reading

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