

Glenoid - Ream and Run Study

JOHN M. CLARK, M.D., PH.D., KRISTI GIBBS, B.S., JOHN A. SIDLES, PH.D., ANTHONY NORMAN, B.S., AND FREDERICK A. MATSEN III, M.D.

The pain relief and functional improvement provided by total shoulder replacement surpass any other available treatment for shoulder arthritis. Unfortunately, the durability of these improvements is compromised by early failure of the polyethylene glenoid replacement component. The human glenoid is small, and in the case of arthritis, deformed by erosions. For this reason, the bony support for a glenoid component is limited. Loosening compounds the bone loss and salvage of a failed component can be prohibitively difficult. Younger, active patients are particularly vulnerable to these limitations.

As an alternative to replacement, surgeons at the University of Washington and other centers have adopted the strategy of *non-prosthetic glenoid arthroplasty*. In this approach, the glenoid is reamed to fit the prosthetic head of the humerus (Figure 1). The reaming removes minimal bone, and allows the surgeon to deepen, redirect, or enhance the concavity. To date, many patients return to a high level of activity, but the outcome has been variable. The reasons for this variable response have not been elucidated by existing clinical and experimental studies.

To define factors that might affect the outcome of such a metal on bone arthroplasty, and to establish a model for testing methods that could enhance remodeling of the glenoid, an animal model of non-prosthetic glenoid

arthroplasty was developed.

METHODS

Animals

Twelve, skeletally mature, female hounds, (Covance, Kalamazoo, MI), one year of age and weighing approximately 50lbs, were used in this study. Through a posterolateral approach, a custom made, stemmed humeral head replacement (DePuy, Warsaw, IN) was inserted into one shoulder of each of the dogs. All surgeries were performed under general anesthesia, and by the same orthopaedic surgical team. The study was performed under the approval of the Institutional Animal Care and Use Committee (IACUC) at Ethicon Endo-Surgery in Cincinnati, Ohio, where the study took place.

The right glenoid of twelve, skeletally mature, female dogs was reamed to a 30 mm diameter, removing all cartilage to bleeding trabecular bone. The native humeral head was excised and replaced with a stemmed, 28 mm diameter prosthesis (Figure 2).

Post-surgery, the operated limbs were loosely immobilized in a sling for seven days, and allowed ad libitum activity for the remaining study period. Fluorescent bone labels were administered monthly to identify bone formation. Six animals were sacrificed at 10 and 24 weeks each, and the intact glenohumeral joints were evaluated by gross examination, assessment of intrinsic stability, measurement of

glenoid concavity (depth) and light microscopy of sections embedded in methylmethacrylate. Intact contralateral glenoids, and two that were freshly reamed, were also prepared for microscopy. The sections were evaluated for evidence of bone and soft tissue remodelling at the interface with the prosthetic humeral head (Figure 3).

Histomorphometry Technique

The structure of the glenoid articular surface articulating with the prosthetic humeral head was quantified by the following technique: each slide was scanned at a resolution of 1200 pixels per inch using a flatbed scanner (Epson Perfection 3200, Seiko Epson, Japan) and the image was exported to Photoshop. An arc with a 14 mm radius was fitted to the new glenoid surface on each scanned image of the reamed glenoids. A second, concentric arc with a 19 mm radius was then drawn, and the tissue captured by the parallel lines was analyzed by the following measurements (Figure 1B): 1) Maximum width of the surface; 2) Length of the contact surface articulating with the prosthesis; 3) Percentage of the contact surface consisting of reamed bone; 4) Percentage of the contact surface consisting of soft tissue; 5) Average thickness of the soft tissue measured at five standardized points; 6) Bone density (percent of total tissue area staining as bone) within the 5 mm arc; and 7) Bone density in an arc between 2 and 5mm

Group	Angle β	Tissue Area (mm ²)	Bone Fraction %	Soft Tissue Thickness (mm)	Percent Surface Exposed Bone	Bone Density Beneath Surface
Normal glenoid*	79.3	114.2	28.3	0.56 +/- 0.03	0	14.85
Freshly Reamed	82.5	118.8	23.4	0.02 +/- 0.03	97.7	18.53
10 week Reamed	79.7	114.7	27.4	1.31 +/- 0.8	33.2	33.13
24 week Reamed	87.7	126.2	39.1	1.57 +/- 0.3	2.9	42.98

Table 1: Quantitative analysis of the response to reaming of the glenoid. *Contralateral shoulder of 24-week animals.

(A)



(B)



Figure 1: Non-prosthetic resurfacing of the glenoid. (A): Spherical reaming deepens the concavity, corrects any posterior erosion and corrects version. The result is an articular surface congruent with the humeral prosthesis and which optimizes stability. (B): In clinically successful cases, bony remodeling and a congruent "joint space" are observed over time.

from the articular surface. This second measurement excluded the layer of soft tissue that had formed on the surfaces of the 10 and 24 week specimens. For the intact "normal" glenoids, the thickness of articular cartilage was measured at five comparable points. To simulate reaming in this group, the 14 mm arc was positioned at the minimum

depth necessary to exclude all articular cartilage. The socket width and bone density were measured exactly as had been done in the reamed groups. Mean values were calculated for all groups, and compared using unpaired t-tests. Significance was set at $p < 0.05$.

RESULTS

All twelve joints remained located until the designated endpoints, with no deaths, dislocations or signs of infection. All animals limped, but shoulder girdle weight and motion improved between 10 and 24 weeks. Physical measurements showed that the depth and intrinsic stability of the glenoid had increased significantly by 24 weeks, when compared to both the intact and freshly reamed specimens.

Histological Findings

At 10 weeks, trabecular bone exposed by the reamer was partially covered by vascular, fibrous tissue that maintained a concave surface congruent with the implant. Where bone was still exposed, the severed trabeculae were viable up to the level of resection, and new lamellar bone deposited around them. The width of the articular surface was enlarged by new bone formed at the margins, and the density of the periarticular trabecular bone had increased by the deposition of appositional new bone. These changes were consistently more advanced at six months (Table 1). At 6 months, the articular surface was completely covered by soft tissue, and much of this tissue was fibrocartilage rather than the fibrous tissue, which predominated at 10 weeks (Figures 4, 5, 6; Table 1).

DISCUSSION

Hemiarthroplasty, in which the convex side of a joint is replaced with a polished metal surface, has been a common orthopaedic procedure for over a half century. For the arthritic hip and shoulder, some have achieved remarkable function and durability. Prosthetic replacement of the socket was added because such "total"



Figure 2: The 28 mm diameter humeral component articulated with a dog glenoid.

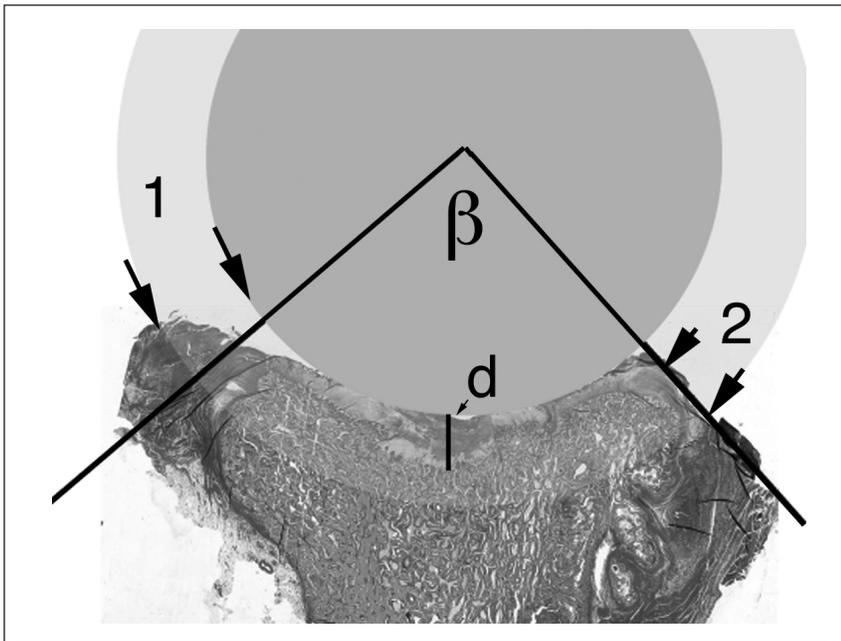


Figure 3: Method for quantitative analysis of the reamed glenoid surfaces. The width of the bony glenoid was defined as the bone captured by the angle β . Thickness of any soft tissue covering the surface (d) was measured at five equally spaced points. The area fraction of trabecular bone was measured in the arc within five millimeters of the articular surface (1) and between 2 and 5 mm from the surface.

Specifically, the articular surface was smooth, congruent with the metallic implant and supported by new bone formation peripherally and centrally. Of equal importance, the bone was replaced by soft tissue that, by six months, resembled fibrocartilage by morphological criteria. Normal articular cartilage is unsurpassed as a bearing surface, because it is avascular aneural (insensate) and smooth, but fibrocartilage, such as that found in tendon pulleys and the menisci, seems to tolerate compression and motion adequately. For this reason, the histologic appearance of the six-month specimens is highly encouraging.

This was a short study. The biological surface formed at six months in this nonprosthetic arthroplasty was evolving. Therefore, longer periods of observation, including attention to the function of the dog's forelimb will be needed. Comparable studies in animals used the hip joint, and

replacements provided more consistent improvements in pain and motion, and gave the surgeon an additional means to correct deformities. Also, total joint replacement was thought to prevent further erosion of the bone, a common problem with hemiarthroplasty. Interest in hemiarthroplasty has resurged as the limitations of polyethylene components have been recognized. Yet, at this time, we do not clearly understand why this procedure works well in some patients and fails in others.

Large clinical series and limited animal studies indicate that the living tissue articulated against a metallic hemiarthroplasty generally responds in one of two ways: (1) in successful cases, a stable soft tissue layer lines the socket; (2) in failures, any existing soft tissue interface dies or is eroded, and the bony socket also erodes. A poor fit between ball and socket probably plays a central role in the failures. Reaming allows the surgeon to control congruity, but removes remaining cartilage or other soft tissue and places the metal prosthesis directly against freshly cut bone.

This is the first study to show the fate of reamed bone articulated with a metallic prosthesis. Remarkably, the interface not only remained viable, but also demonstrated a remodeling response with several desirable features.

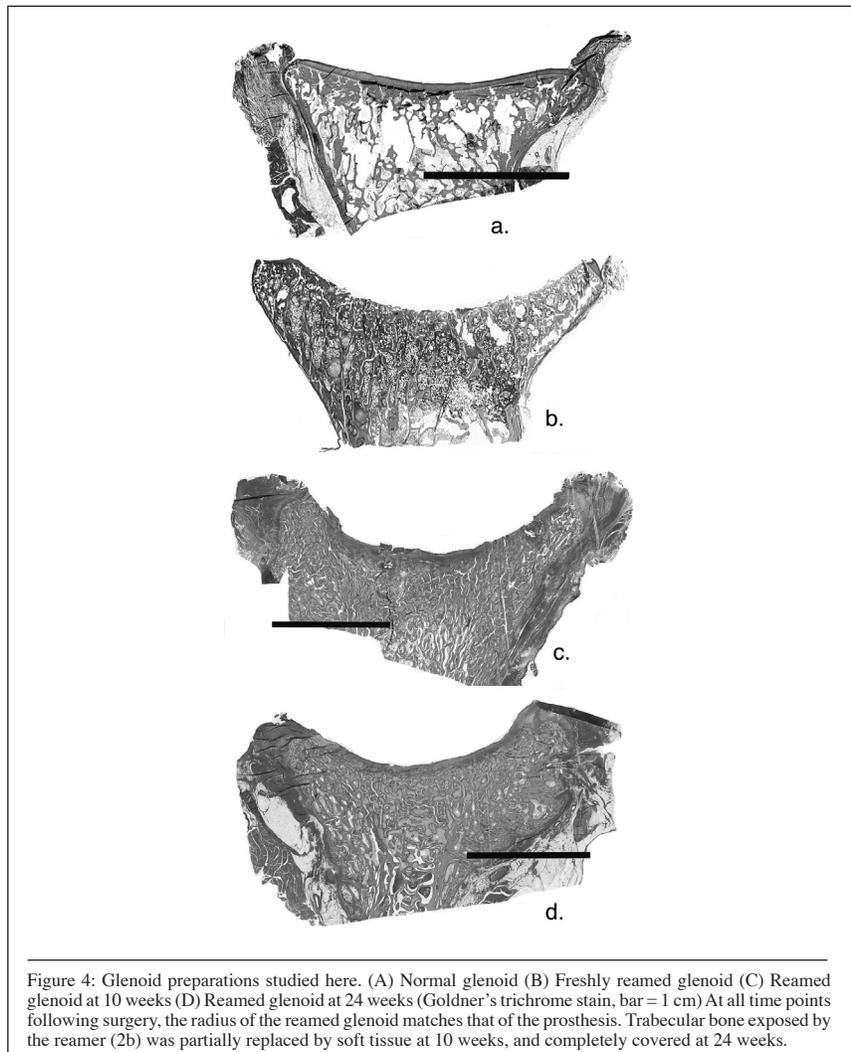


Figure 4: Glenoid preparations studied here. (A) Normal glenoid (B) Freshly reamed glenoid (C) Reamed glenoid at 10 weeks (D) Reamed glenoid at 24 weeks (Goldner's trichrome stain, bar = 1 cm) At all time points following surgery, the radius of the reamed glenoid matches that of the prosthesis. Trabecular bone exposed by the reamer (2b) was partially replaced by soft tissue at 10 weeks, and completely covered at 24 weeks.

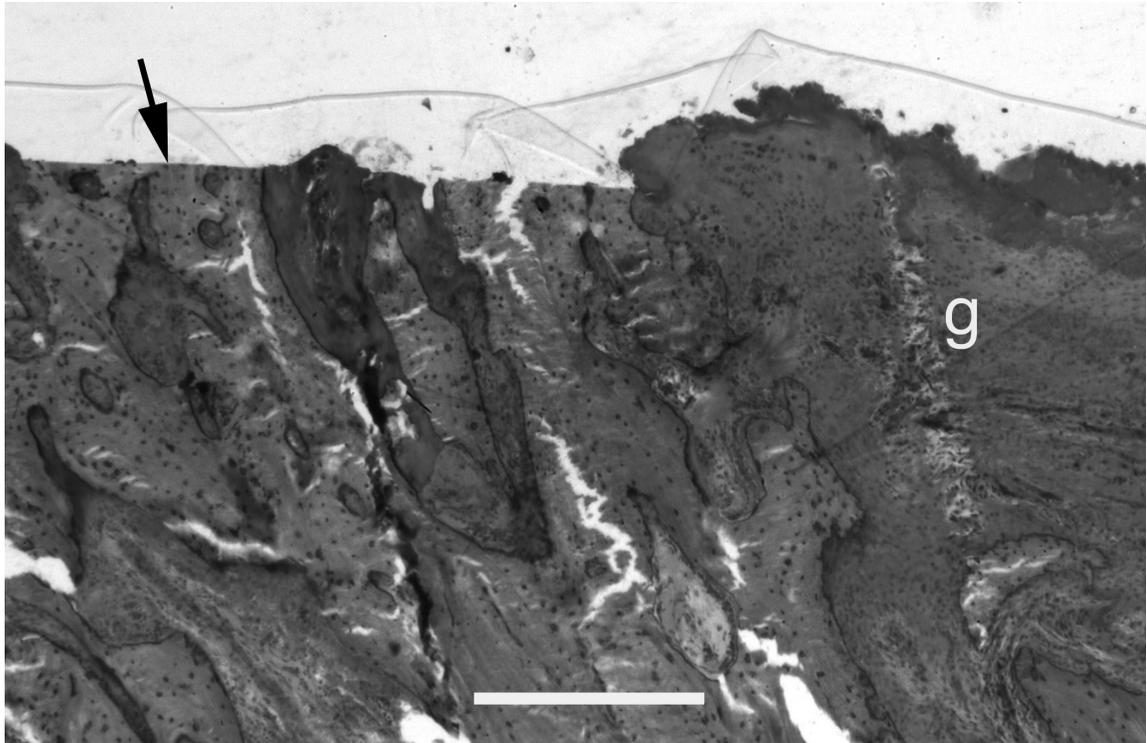


Figure 5: Exposed trabecular bone at articular surface, 10 weeks. Where bone was in contact with the prosthesis, the exposed trabeculae (arrow) were still cleanly transected. Tissue in the marrow spaces usually was structurally similar to the fibrous, vascular granulation tissue (g) that covered the surface in other locations (bar = 100 μ m)

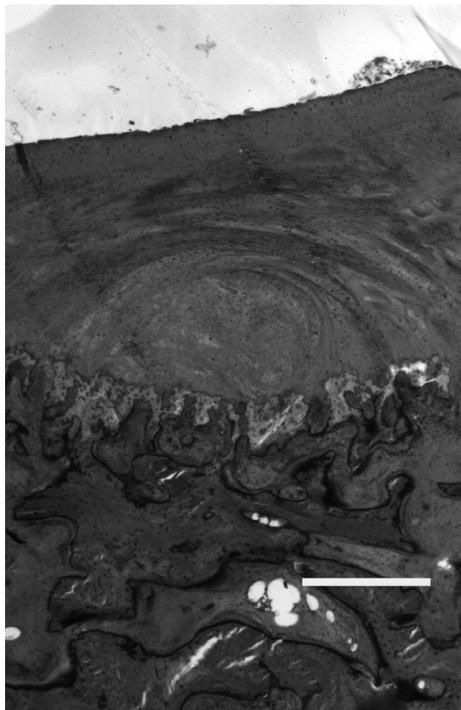


Figure 6: Soft tissue on articular surface of a 24-week specimen with histological features typical of fibrocartilage: round cells in lacunae; yellow background stain and distinct red collagen fibers that assume tangential orientation at surface. Calcified fibrocartilage is visible at base (bar = 100 μ m).

suffered from complications such as dislocation, infection and component migration. This shoulder model avoided technical problems, and generated a consistent biological response. As such, it provides a solid foundation for further investigation.

RECOMMENDED READING

Fehringer E, Kopjar B, Boorman R, Churchill R, Smith K, Matsen F. Characterizing the functional improvement after total shoulder arthroplasty for osteoarthritis. *J Bone Joint Surg Am* 2002;84-8:1349-53.

Sperling JW, Cofield RH. Revision total shoulder arthroplasty for the treatment of glenoid arthrosis. *J Bone Joint Surg Am* 1998;80-6:860-7.

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