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Patterns of proximal humeral bone resorption after total shoulder arthroplasty with an uncemented rectangular stem

Christoph Spormann, MD[a,b], Holger Durchholz, MD[a], Laurent Audigé, PhD[a,*], Matthias Flury, MD[a], Hans-Kaspar Schwyzer, MD[a], Beat R. Simmen, MD[a,b], Christoph Kolling, MD[a]

[a]*Upper Extremities, Schulthess Clinic, Zürich, Switzerland*
[b]*Hirslanden Clinic, Endoclinic Zürich, Zürich, Switzerland*

Background: The aim of this study was to assess the timing and location of cortical bone resorption after total shoulder arthroplasty with an uncemented rectangular stem and investigate its effect on shoulder function up to 5 years after implantation.
Methods: Between June 2003 and September 2006, 183 consecutive total shoulder arthroplasties were performed, 133 of which received a cementless rectangular stem as indicated by primary or post-traumatic osteoarthritis (OA). The 5-year postoperative follow-up rate was 80%. Standardized radiographic controls and clinical assessments were performed at 6 weeks, 6 months, and 1, 2, and 5 years.
Results: Twenty-two patients (17%) showed full-thickness cortical bone resorption, 21 of whom were diagnosed with Sperling zone 2 resorption. The maximum craniocaudal distance of full resorption averaged 19.1 mm (range, 5.6-46.7 mm). The median distance progressed significantly from 9.6 mm to 13.8 mm between 6 and 12 months ($P = .005$). The risk of bone resorption was 3.1 times higher for post-traumatic OA patients than for those with primary OA. The occurrence of bone resorption increased significantly with increasing stem diameters relative to the humeral diameter. There was no significant effect of bone resorption on functional outcome.
Conclusion: Full-thickness cortical bone resorption in the proximal posterolateral humerus after receipt of a cementless rectangular stem has a prevalence of 17%, mostly occurring within the first year after surgery. Risk factors include age, post-traumatic conditions, and larger stem sizes relative to the humerus. This is a radiographic phenomenon without significant impairment of function or need for revision within 5 years after surgery.
Level of evidence: Level II, Retrospective Design, Prognosis Study.

Keywords: Proximal humerus; cortical bone resorption; total shoulder arthroplasty; rectangular stem prosthesis; uncemented; shoulder function

Institutional review board/ethics committee approval was granted by the following institution: Cantonal Ethics Committee of Zürich, Zürich, Switzerland. Approval for the study (19/2001, Quality Management and Outcome Measurement of the Upper Extremity [QUOMUEX]) was granted on December 18, 2001.

*Reprint requests: Laurent Audigé, PhD, Upper Extremities, Schulthess Clinic, Lengghalde 2, CH-8008 Zürich, Switzerland.
E-mail address: laurent.audige@kws.ch (L. Audigé).

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Fixation of humeral components in total shoulder arthroplasty can be achieved with cemented or uncemented stems.[13,23,25,27] To accomplish the fixation of uncemented stems in humeral bone, different designs have been used, varying from circumferential porous coating for tissue ingrowth to cylindrical stems for diaphyseal fixation or stems with a tapered metaphyseal component for press-fit fixation in the humeral metaphysis.[13,15,17,23,25,27] After stem implantation, remodeling of the cortical bone can result in full-thickness resorption in the humerus.[17] Nagels et al[17] assessed 70 humeral hemiarthroplasties in a mixed patient population with rheumatoid arthritis and osteoarthritis (OA) after a mean follow-up period of 5.3 years; a reduction of cortical bone thickness was observed in 6 cases (9%) whereas 3 were reported to have full-thickness resorption. This phenomenon of bone resorption was also more frequently associated with larger stem sizes relative to the humeral diameter as well as in osteoporotic bone of rheumatoid arthritis patients.

Adaptive bone remodeling that can lead to varying degrees of bone loss has also been studied and quantified in the femur.[7,11,10,24,28] When the femur is fixed with an intramedullary stem, the bone shares its load-carrying capacity with the implant and, as a consequence, reduces stress, which in turn causes bone to reduce its mass.[5,7,11,28] These studies have led to the understanding that bone remodeling is a ubiquitous phenomenon that may occur with cemented and uncemented implants.[5,8,7,24,26] However, an increased prevalence of adverse effects such as loss of function, femoral fractures, or loss of fixation has not been documented.[5,8,26]

To our knowledge, the extent to which resorption of full cortical bone in the humerus appears and how it develops over time are unknown. The purpose of this study was to radiographically assess the timing and location of humeral cortical bone resorption related to shoulder arthroplasty using a cementless rectangular stem. Possible risk factors for bone resorption, as well as the potential consequences for shoulder function, were also investigated.

Materials and methods

Patient selection

Between June 2003 and September 2006, 183 consecutive total anatomic shoulder arthroplasties were performed and documented at our institution in 147 patients. Of these arthroplasties, 149 used a cementless stem after primary or secondary OA. A total of 34 arthroplasties were excluded because of treatment received for revision arthroplasty (n = 4), acute fractures (n = 8), and rheumatoid arthritis (n = 16), as well as arthroplasty after OA with a cemented stem (n = 4) or hemiarthroplasty (n = 2). The 133 eligible patients comprised 84 women with a mean age of 70 years (range, 53-88 years) and 49 men with a mean age of 64 years (range, 23-80 years) at the time of the index surgery. Of 133 patients, 96 had degenerative (primary) OA and 37 had post-traumatic (secondary) OA. Bilateral total shoulder replacement was performed in 16 of the 133 patients, and only the first surgery was considered in these cases.

Five years after surgery, 106 patients (80% follow-up rate) were available for clinical and radiographic assessment. Ten patients died of causes unrelated to the index surgery, and 17 were lost to follow-up. One patient had no available follow-up radiographic records and was excluded from the evaluation of osteolysis. One patient was lost to follow-up and radiographic assessment after the 6-week examination.

Prosthesis implantation

A deltopectoral approach was used to implant a Promos prosthesis (Smith & Nephew Orthopaedics, Rotkreuz, Switzerland) in all patients. The humeral component of this prosthesis consists of a titanium alloy stem with a grit-blasted surface. A rectangular body is inserted at the top of the stem, which allows the height of the humeral head to be modified while serving as the base for the inclination part. Inclination of the humeral head may thus be adapted to the anatomic requirements. The humeral head is added to the inclination part in an eccentric position, so as to reconstruct the former anatomic orientation. The humeral stem has a rectangular cross section and tapers lengthwise to a thin tip. It is inserted by manual hammering until press-fit is achieved in the zone of the meta-diaphyseal junction. The prosthesis is assembled in situ after fixation of the humeral stem.[22]

Follow-up examinations

All patients underwent regular examinations by use of standardized assessment tools,[1,21] which included radiographic and clinical evaluation preoperatively as well as at 6 months and 1, 2, and 5 years after surgery. The functional outcome instruments used for clinical assessment were the Constant-Murley score[6]; Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire[9]; Shoulder Pain and Disability Index[4]; and clinical American Shoulder and Elbow Surgeons Standardized Shoulder Assessment (CASES) and patient American Shoulder and Elbow Surgeons Standardized Shoulder Assessment[14] questionnaires. Radiographs were also taken at 6 weeks and 3 years postoperatively.

Radiographic assessment

Radiographic examinations were performed in 3 standard planes. Two anteroposterior (AP) views were taken with the patient in an upright position: the scapula of the affected side was flat against the x-ray plate, and the contralateral side was held at an angle of 30° with the forearm in flexion and supination. The x-ray beam was tilted 20° craniocaudal and centered on the joint so that the joint line was visible as a symmetrical line. The first AP-view radiograph was taken with the arm in internal rotation and the second in external rotation. The third radiograph was taken in the axillary view with the patient sitting and the arm held in abduction with the x-ray film lying under the axilla. The central beam was oriented perpendicularly to the middle of the axilla and parallel to the thorax. All digital radiographs were evaluated with a picture archiving communications system.

One trained, independent observer (H.D.) retrospectively examined all radiographs for signs and measurements of full-thickness bone resorption using digital measuring tools (VISUS Technology Transfer, Bochum, Germany) (Fig. 1). The location of full cortical bone resorption was assessed by measuring the distance from the base of the stem component to the starting point of