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Radiologic bone adaptations on a cementless short-stem shoulder prosthesis

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Background: This study evaluated the timing and location of radiologic bone adaptations related to shoulder arthroplasty using a single type of cementless short-stem shoulder prosthesis.
Methods: Uncemented short-stem shoulder arthroplasties were evaluated in 52 patients at a mean age of 71.6 years (range, 58.1-86.6) with a minimum clinical and radiologic follow-up of 2 years (mean, 32 months; range, 23-52 months). All radiographs were analyzed for inclination of the stem, filling ratio of metaphysis and diaphysis, bone remodeling around the stem, radiolucent lines around the glenoid, and subsidence of the humeral stem. Finally, the radiographic and clinical findings were compared between patients with low and high bone adaptations.
Results: At final follow-up, no loosening, subsidence, or osteolysis was seen. High bone adaptations were present in 27 patients (51.9%). Cortical thinning and osteopenia in the medial cortex (82.7%) and spot welds in the lateral cortex (78.6%) were the most frequently occurring bone adaptations. Patients with high bone adaptations had significantly higher metaphyseal (0.60 ± 0.05 vs. 0.56 ± 0.06; $P = .024$) and diaphyseal filling ratio (0.66 ± 0.04 vs. 0.61 ± 0.06; $P = .019$) at 2-year follow-up than patients with low bone adaptations. Clinical outcome was not influenced by the radiographic changes.
Conclusion: The clinical and radiologic results of the short-stem shoulder arthroplasty are comparable to those with the third and fourth generations of standard stem arthroplasty. Higher filling ratios in the metaphysis and the diaphysis were significantly associated with the occurrence of high bone adaptations.
Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Total shoulder arthroplasty; short stem; stress shielding; bone adaptations; metaphyseal fixation; filling ratio; bone resorption

Total shoulder arthroplasty (TSA) with uncemented humeral stems has become established as a standard treatment for advanced shoulder osteoarthritis.[5,30] There are, however, some concerns about the long-term performance of shoulder prostheses.[17,27] Although much of the

Institutional Review Board/Ethical Committee approval was not required. Patients gave informed consent.

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discussion about failure modes of TSA has focused on the glenoid component, aseptic loosening of the humeral implant is another potential long-term problem after TSA.[26]

Early studies of the press-fit stems that were usually used for cemented TSA revealed loosening rates in up to 56% of cases at medium- and long-term follow-up.[21,24,30] Revision surgery in uncemented stemmed prostheses is challenging and often accompanied by high complication rates.[2]

Therefore, multiple humeral designs with various fixation systems and special surface configurations have been developed to provide better bone integration. In the third and fourth generations of TSA, loosening of uncemented humeral stems was no longer a problem, but internal bone remodeling was common with uncemented stems.[12] Raiss et al recently reported that 62.7% of uncemented humeral stems showed features of stress shielding at 8.2 years of follow-up.[20]

Stress shielding is characterized by adaptation of the bone to the altered stress distribution following Wolff's law, resulting in the bone's becoming either thinner (external remodeling) or more porous (internal remodeling).

Efforts to reduce the occurrence of stress shielding and to facilitate stem removal during revision surgery have led to the design of novel implants with shorter stems or stemless, metaphyseal fixed humeral components. Not only long-term clinical results but also detailed radiographic analyses are lacking for stemless and short-stem prostheses.

Therefore, the primary aim of this study was to first establish a method for standardized radiographic evaluation of a cementless short-stem shoulder prosthesis. The secondary goal was to radiographically assess the timing and location of bone reactions related to shoulder arthroplasty using a single type of cementless short-stem shoulder prosthesis. Possible risk factors for bone resorption and the potential consequences for shoulder function were also investigated.

Materials and methods

Study population

Data collected prospectively in 2 specialized shoulder centers were reviewed retrospectively in a level IV study. Between October 2010 and July 2012, 68 primary shoulder arthroplasty procedures were performed on patients with primary osteoarthritis by the 2 senior authors (M.L. and G.W.), 1 at each center.

Sixteen patients (23.5%) were lost to follow-up. Of these, 1 patient (1.5%) died of unrelated causes and 9 patients (14.7%) were not able to participate in the follow-up examination. Six patients (8.8%) had already undergone radiologic examination elsewhere in a nonstandardized technique that did not allow detailed analysis. For legal reasons related to radiation protection, the radiographs were not repeated in these patients.

Therefore, 52 patients (76.5% of the study group), 31 women (59.6%) and 21 men (40.4%) with a mean age of 71.6 years (range, 58.1-86.6), were available for clinical and radiologic follow-up for a minimum of 2 years (average, 32 months; range, 23-52 months). Twenty-seven patients (51.9%) were right handed. The dominant shoulder was treated in 27 cases (51.9%).

The inclusion criteria were (1) presence of primary glenohumeral osteoarthritis, (2) treatment with the same cementless short-stem shoulder prosthesis (Aequalis Ascend Monolithic; Tornier, Grenoble, France) with a cemented (Palacos R + G) keeled glenoid component (Aequalis Glenoid, Tornier), and (3) minimum follow-up of 2 years.

Patients with prior surgery on the same shoulder, posttraumatic conditions, avascular necrosis of the humeral head, rheumatoid arthritis, or neurologic or infectious diseases that required total shoulder replacement were excluded. In these circumstances, bone remodeling and adaptation may be different because of alterations in metabolism.

All the study data were collected on the basis of a normal standardized clinical investigation. All patients provided written consent for the use of their anonymized data. The patients' inclusion in the study did not influence their treatment, so the trial did not require approval from the local Ethics Committee.

Implant design and surgical technique

All joints were replaced by a cementless monolithic short-stem (Aequalis Ascend Monolithic) and a cemented (Palacos R + G) keeled glenoid component (Aequalis Glenoid), enabling anatomic reconstruction for different indications with bone-sparing implantation technique and easy stem removal in the event of revision.[22] The anatomic short-stem prosthesis is available in shaft sizes of 66 to 98 and in 3 different angles of inclination (127.5°, 132.5°, and 137.5°). The stem is made of titanium. Fixation of the stem is achieved by bone ingrowth of the compacted metaphyseal cancellous bone.

The surgical technique has already been described elsewhere.[22] Briefly, after exposure of the humeral head, resection of the humeral head is accomplished with a special resection gauge. The compactor for preparation of the marrow cavity has a smooth, slightly indented surface so that the cancellous bone is compacted and condensed but not removed from the metaphysis. The appropriate size for the shaft is found when stable fixation in the metaphysis is achieved. The implant is inserted orthograde, respecting the predetermined inclination and reclination into the prepared medullary cavity. Control under fluoroscopy confirms the correct fit of the prosthesis.

Radiographic evaluation

True anteroposterior radiographs of the shoulder were obtained immediately after surgery, after 6 weeks, after 1 year, and at the most recent follow-up. Axillary radiographs were also regularly obtained at follow-up. In each patient, the radiologic changes were ascertained by comparing the anteroposterior radiographs obtained immediately or 6 weeks after surgery with the later examinations.

All radiographs were analyzed for (1) inclination (alignment) of the stem, (2) filling ratio of the metaphysis (FRmet) and diaphysis (FRdia), (3) radiologic changes in the 6 zones, and (4) subsidence of the humeral stem. The zone system was adopted from Nagels et al[17] and modified according to the shorter stem design (Fig. 1). The measurement procedures for stem alignment