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REVIEW ARTICLE

Stress shielding of the humerus in press-fit anatomic shoulder arthroplasty: review and recommendations for evaluation

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Uncemented press-fit humeral stems were developed with the goal of decreasing operative time, preserving bone stock, and easing revision. In recent years, short stems and stemless humeral implants have also become available. These press-fit humeral implants have varying designs that can lead to changes in stress distribution in the proximal humerus. Such stress shielding manifests as bony adaptations and may affect long-term functional outcome and the ability to perform revision. However, current studies of humeral fixation during total shoulder arthroplasty are complicated because a variety of classification systems have been used to report findings. The purpose of this report is to review the current literature on press-fit fixation of the humeral component during total shoulder arthroplasty and propose minimum requirements for radiographic descriptions of stress shielding.
Level of evidence: Narrative Review
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Keywords: Glenohumeral arthritis; stress shielding; total shoulder arthroplasty; short stem; stemless; radiographic adaptations; humeral stem

The goal of anatomic total shoulder arthroplasty (TSA) is to reduce pain and reproduce native anatomy as closely as possible to restore function. TSA is successful in most patients, with implant longevity of approximately 90% at 10 years postoperatively and 70% to 80% at 20 years.[9,18] However, the rate of radiographic loosening, particularly of the glenoid, is much higher. With the increasing volume of TSA, the need for revision will increase in coming years. Although much focus has been directed toward the glenoid, the humerus plays an important role because revision of the glenoid often requires revision of the humeral component.

Cemented stems were traditionally used to gain fixation in TSA. Cemented fixation led to homogenous stress distribution of the humeral component, and consequently, stress

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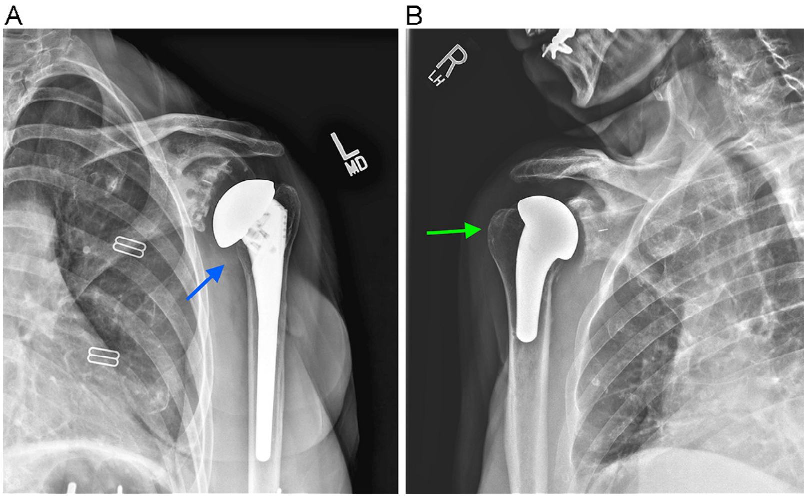

Figure 1 Stress shielding. (**A**) Left shoulder with a standard-length press-fit stem demonstrates medial calcar osteolysis (*blue arrow*) 2 years after a total shoulder arthroplasty. (**B**) Right shoulder with a short press-fit stem demonstrates osteopenia and proximal lateral cortical thinning (*green arrow*) 2 years postoperatively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

shielding was not common. However, cemented fixation increases operative time and can be highly problematic in revision. Uncemented press-fit humeral stems were developed with the goal of decreasing operative time, preserving bone stock, and easing revision.

In recent years, shorter uncemented humeral stems and stemless humeral implants have also become available. These press-fit humeral implants have varying designs that can lead to changes in stress distribution in the proximal humerus. Such stress shielding manifests as bony adaptations and may affect long-term functional outcome and the ability to perform revision. However, assessing current studies of humeral fixation during TSA is complicated because a variety of classification systems have been used to report findings. The purpose of this report is to review the current literature on press-fit fixation of the humeral component during TSA and to propose minimum requirements for radiographic descriptions of stress shielding.

Stress shielding concepts

A variety of terms have been used to radiographically describe stress shielding, including tuberosity resorption, cortical thinning, or medial calcar osteolysis. All of these are manifestations of the same concept (Figs. 1 and 2). According to Wolff's Law, bone remodels in response to stress. After TSA, the proximal humerus shares its load with the prosthesis. However, the modulus of elasticity (Young's Modulus) varies between metal and bone, leading to a change in how the forces are distributed. Stress shielding in TSA is therefore the consequence of the change in load to the bone after the prosthesis is implanted. By definition, stress shielding occurs in every case after uncemented TSA because the load to the native bone is changed. The degree to which stress shielding occurs and the location at which it occurs is simply varied according to the prosthesis size and design.

Although the principles of stress shielding are important to consider, stress shielding is not the only cause of radiographic adaptations of the proximal humerus. Polyethylene wear has been associated with proximal humeral osteolysis. Raiss et al[19] evaluated the humerus in TSAs and hemiarthroplasties and noted that osteolysis only occurred in the setting of placement of a glenoid. Osteolysis of the tuberosity or calcar was present in 43% of TSAs and was more frequent in cases with glenoid loosening. Wear particles from polyethylene breakdown can lead to osteolysis and likely

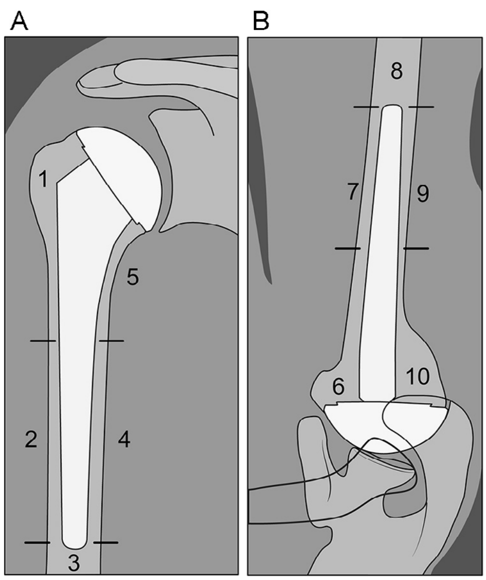

Figure 2 Zones for radiographic evaluation of stress shielding with a standard-length stem on (**A**) anteroposterior and (**B**) axillary lateral radiographs.

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