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Clinical and radiographic outcomes after total shoulder arthroplasty with an anatomic press-fit short stem

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Background: There is limited information assessing outcomes after total shoulder arthroplasty (TSA) with a press-fit short stem. The purpose of this study was to evaluate early clinical and radiographic outcomes and complications after TSA with an anatomic press-fit short stem.
Methods: We identified 118 TSAs completed with press-fit short stem and minimum 2-year follow-up; 85 of these patients had a grit-blasted (GB) short stem placed, whereas 33 patients had short stems with proximal porous coating (PPC). Shoulder function scores, active mobility measurements, and radiographs were assessed.
Results: The average age at surgery was 66.7 years, with average follow-up of 3 years. Significant improvements were noted for all shoulder function scores and active mobility measurements from the preoperative state to final follow-up ($P < .001$). There was no stem loosening in any patients with minimum 2-year follow-up; however, 3 female patients with GB stems had gross loosening of their humeral components before 1 year, 2 requiring revision. Radiolucent lines around the humeral component were found in 5.9% without evidence of loosening. Osseous resorption at the medial cortex was noted in 9.3%. Of patients with PPC stems, no patients were observed to have radiolucent lines compared with 8.2% in the GB group ($P = .09$).
Conclusion: TSAs with anatomic press-fit short stem showed significant clinical improvements from the preoperative state to final short-term follow-up, with few complications and minimal radiographic changes. Lack of PPC may contribute to early loosening in patients with poor bone quality. The authors now use a short stem with PPC.
Level of evidence: Level II; Prospective Cohort Design; Treatment Study

Keywords: Total shoulder arthroplasty; short stem; press fit; outcomes; anatomic; mini-stem; glenohumeral arthritis

Anatomic total shoulder arthroplasty (TSA) provides significant functional improvements and pain relief with good long-term survivorship.[3,25,26] Failure of the glenoid component is the most common long-term complication in TSA,

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whereas humerus-sided problems are uncommon.[1,6,16,26,28,29,31] Humeral stem fixation with cement has been the traditional "gold standard" for shoulder replacement, with decreased loosening rates and increased survivorship compared with early-designed press-fit humeral components in initial long-term outcome studies.[20,21,26]

Modern press-fit stem designs have shown promising results[10,13,19,25] and may offer potential advantages over cemented stems. Newer designs replicate the internal geometry of the proximal humerus and achieve metaphyseal fixation rather than diaphyseal fixation. Press-fit stems preserve bone stock and facilitate revisions.[13,25] Revision of cemented stems poses several challenges from the difficulty of extraction, increased operative time, and bone loss.[25] These obstacles create the need for an implant that exhibits proven long-term results with primary fixation while also offering benefits in the revision setting.

The press-fit short stem was introduced to preserve host bone, potentially to decrease operative time, and to simplify revision procedures. Press-fit short-stem implants have the same advantages offered by long-stem components with variable neck-shaft inclination and variable humeral head offset for anatomic TSA. Potential concerns with a short stem include malalignment and compromised fixation.[2,9,10] There are currently no long-term studies for short-stem press-fit implants in anatomic TSA, and short-term data are limited.[2,10,15,23,27] The purpose of this study was to evaluate early clinical and radiographic outcomes and complications after TSA with an anatomic press-fit short stem.

Materials and methods

Patient inclusion criteria and demographics

Our investigation identified all TSAs with an anatomic press-fit short stem performed from June 2009 to October 2012 in a prospectively collected shoulder arthroplasty registry. All cases were performed at a single, high-volume shoulder arthroplasty center by a single surgeon (T.B.E.). All patients received an anatomic press-fit short stem (66-98 mm), Aequalis Ascend or Ascend Flex (Wright Medical, Memphis, TN, USA). The Aequalis Ascend is an older-generation, anatomic press-fit grit-blasted (GB) short stem that was used from June 2009 to June 2012 in 85 cases (Fig. 1, *A*). Grit blasting is used to promote ongrowth. The Aequalis Ascend stem lacked proximal porous coating (PPC) during its early use.[2] A proximal titanium plasma spray porous coating was added to the stem as part of a newer generation of the anatomic press-fit short stem (Aequalis Ascend Flex) to increase the surface area for bone ingrowth to enhance fixation. The Aequalis Ascend Flex with PPC was used for the remainder of cases (33) up to October 2012 (Fig. 1, *B*). A minimum 2-year follow-up was required for inclusion.

We identified 118 TSAs completed with a press-fit short stem and a minimum of 2 years of clinical and radiographic follow-up. Specific demographic and clinical characteristics of the patients included age, gender, duration of follow-up, smoking status, body mass index, history of chronic back pain, depression, diabetes, and heart disease. Indications for surgery included primary glenohumeral arthritis (100), instability arthropathy (10), post-traumatic arthritis (4), failure of prior arthroplasty (3), and inflammatory arthropathy (1).

Shoulder function scores evaluated preoperatively and at final follow-up included the Constant score,[4] the American Shoulder and Elbow Surgeons score,[14] the Western Ontario Osteoarthritis Shoulder index,[12] the Single Assessment Numeric Evaluation (SANE),[30] and active mobility measurements. All intraoperative and postoperative complications were recorded. Any patient receiving a cemented or long stem was excluded from the study.

Surgical technique and postoperative rehabilitation

The Aequalis Ascend or Ascend Flex anatomic TSA system was used for all patients during the study period. Manufacturer stem modifications occurred during the study period, as described before. The

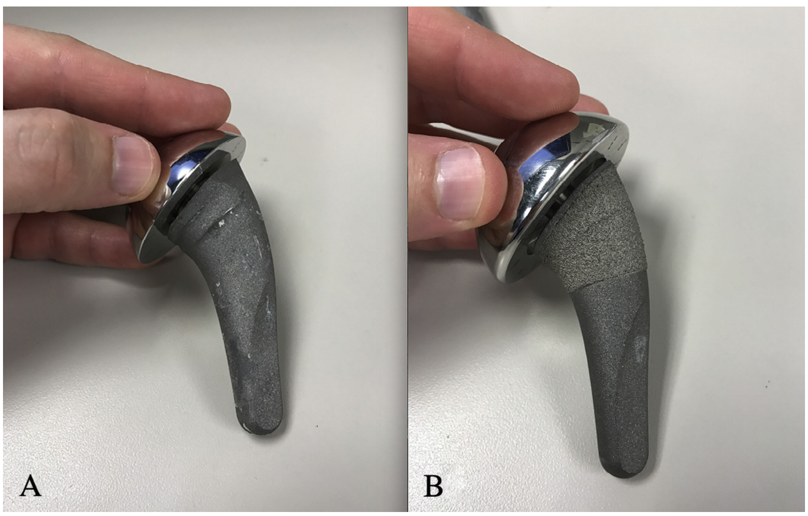

Figure 1 (**A**) Anatomic press-fit short stem, grit blasted (Aequalis Ascend). (**B**) Anatomic press-fit short stem, proximal porous coating (Aequalis Ascend Flex). (Published with permission from Tornier, Inc., an indirect subsidiary of Wright Medical Group N.V.)

TSA technique used during the study period is well described,[5,7] and a standardized postoperative rehabilitation protocol was followed.[11]

A standard deltopectoral approach was employed in all cases. A subscapularis tenotomy was performed at the anatomic neck of the humerus. The subscapularis tendon was mobilized by releasing the glenohumeral ligaments and glenohumeral capsule. The humeral head was then dislocated, and peripheral osteophytes were removed. The humeral head cut was made along the anatomic neck of the humerus.

Next, an awl or humeral canal finder was used, followed by sounders designed to compact bone and to determine the upper size limit of the proximal humerus. During these steps, care was taken to maintain a lateral entry point, preventing varus malalignment of the final implant. The proximal humerus was then prepared by use of humeral compactors designed to conserve metaphyseal bone in the humerus. Each humeral stem trial has 3 variable neck inclination angle options (127.5°, 132.5°, 137.5°) designed to match the humeral cut. To improve head coverage of the anatomic humeral resection, both high-offset (3.5-4 mm) and low-offset (1.5 mm) options were available for each head size. The appropriate size was selected for anatomic restoration of the humeral head, and a cut protector was placed. The proximal humerus was then retracted posteriorly with a humeral head retractor.

Attention was then turned to implantation of the glenoid component. After creation of a centering hole, the glenoid face was prepared with a concentric reamer chosen in relation to the glenoid component size. Glenoid biconcavity, if present, was corrected to physiologic version as judged by the surgeon through reaming. A peripheral hole drill guide was inserted into the centering hole, and the 3 peripheral holes were drilled to the same dimensions as the pegs. Cementing was performed with modern pressurization techniques,[5,18] and the glenoid component was then impacted. The proximal humerus was dislocated, and the cut protector was removed. Three No. 2 transosseous permanent high-tensile-strength sutures were placed through the lesser tuberosity and through the stump of subscapularis. The final humeral implant was impacted in place. The glenohumeral joint was reduced and glenohumeral stability evaluated, allowing up to 50% posterior translation with spontaneous reduction. The subscapularis was repaired with the transosseous sutures. Next, the rotator interval was reapproximated with No. 2 nonabsorbable sutures in an interrupted figure-of-8 fashion. The wound was then closed in layers. The standardized rehabilitation protocol[11] was instituted at 1 week postoperatively.

Clinical assessment

Patients were prospectively enrolled in a shoulder arthroplasty outcomes registry and observed clinically. Preoperatively, patients were examined by the senior surgeon (T.B.E.); examinations were performed postoperatively at 1 week, 6 weeks, 3 months, 6 months, and 12 months and then annually thereafter. Active mobility measurements were determined with a goniometer, and strength of abduction was measured with a hand-held digital dynamometer (Chatillon Digital Force Gauge 200 lbf; AMETEK, Inc., Largo, FL, USA).

Radiographic analysis

Radiographs were obtained at the initial postoperative appointment and yearly thereafter. This included anteroposterior in the plane of the scapula, scapular Y, and axillary views. Preoperative and postoperative radiographs of each patient were analyzed with a digital radiographic viewer (Swiss Vision Workstation; Swissray, Piscataway, NJ, USA), which allowed manipulation of the image for evaluation. A complete radiographic assessment was performed on 2 occasions by 2 authors (B.W.S. and T.B.E.), who reached a consensus. Radiographs were evaluated for the presence of radiolucent lines around the humeral component according to Sperling et al,[24] subsidence of the humeral stem,[28] and medial osseous resorption.[6]

Statistical analysis

Means and standard deviations were calculated for age of the patient and follow-up data as well as for shoulder function scores and range of motion measurements; dominant shoulder and comorbidities are presented as percentages. A 1-tailed, paired sample *t*-test was used to evaluate preoperative to postoperative (final follow-up) improvement in shoulder function and range of motion measurements. A χ^2 test was used to evaluate patient satisfaction levels. All differences were considered statistically significant if $P < .05$.

Results

Demographics of the patients including age, gender, duration of follow-up, smoking status, body mass index, history of chronic back pain, depression, diabetes, and heart disease are noted in Table I. The average clinical follow-up for the entire cohort was 36 months (±1.2 years; range, 2-5 years).

Radiographic outcomes

The overall inter-rater reliability was similar ($\kappa = 1$). No loosening or subsidence was observed. Resorption at the medial cortex was noted in 11 patients (9.3%) (Fig. 2). Radiolucent lines around the humeral component at final follow-up were found in 7 (5.9%) patients without evidence for loosening. Of the 7 patients with radiolucent lines, 5 (71.4%) of them also had osseous resorption present at the medial cortex (Fig. 3). Of patients with a PPC stem, no patients were observed to have radiolucent lines (0/33 [0%]) compared with 7 patients (7/85 [8.2%]) with a GB stem ($P = .09$). In

Table I Patient demographics

No. of patients (gender)	118 (74 M/44 F)
Age at surgery (y)	66.7 ± 10.7 (25-93)
Follow-up (y)	3.0 ± 1.2 (2-5)
Dominant shoulder	53 (44.9)
Active smoker	1 (0.8)
History of chronic back pain	37 (31.4)
Depression	6 (5.1)
Diabetes	12 (10.2)
Heart disease	13 (11.0)
Body mass index (kg/m^2)	29.5 ± 5.8

Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation (range).

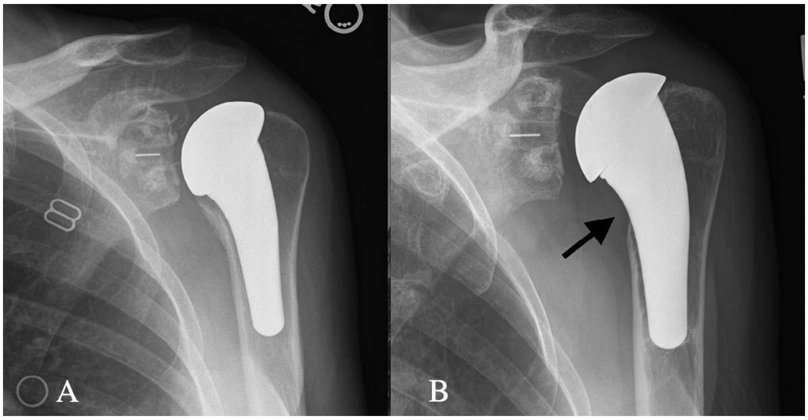

Figure 2 (**A**) Anatomic press-fit short stem, initial postoperative radiograph. (**B**) Anatomic press-fit short stem with medial osseous resorption (*arrow*), 5-year postoperative radiograph.

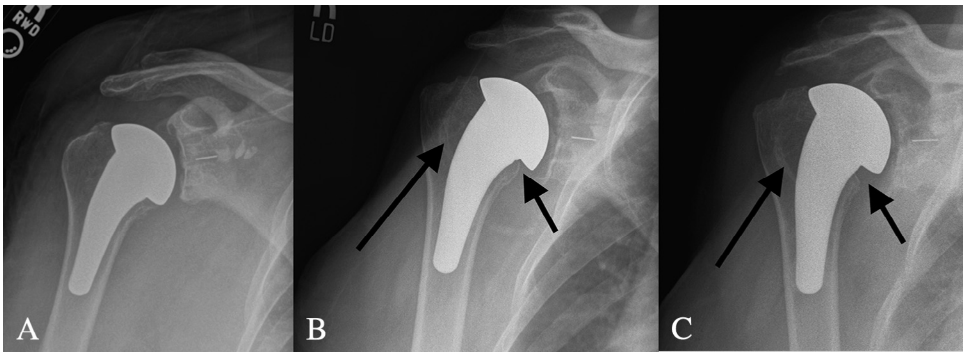

Figure 3 (**A**) Anatomic press-fit short stem, initial postoperative radiograph. (**B**) Anatomic press-fit short stem, 1.5 years postoperatively with radiolucency (*long arrow*) and medial osseous resorption (*short arrow*). (**C**) Anatomic press-fit short stem, 5 years postoperatively with progressive radiolucency (*long arrow*) and medial osseous resorption (*short arrow*).

addition, of the patients with a PPC stem, 1 patient (1/33 [3.0%]) showed evidence of medial osseous resorption compared with 10 patients (10/85 [11.8%]) in the GB group ($P = .14$). Follow-up for patients with PPC stems was significantly shorter (2.03 ± 0.26 years) than for those with GB stems (3.50 ± 1.08 years; $P < .001$). Of note, there were 3 patients with GB stems with gross loosening noted before 1-year follow-up. This is further discussed later in this section.

Clinical outcomes

The cohort significantly improved on all shoulder function scores and active mobility measurements from the preoperative state to final postoperative follow-up ($P < .001$) (Table II). Patient satisfaction ratings significantly improved at final postoperative follow-up, with 94.6% of patients reporting they were satisfied or very satisfied with their shoulder ($P < .001$) (Table III). There was no difference in clinical outcomes scores in comparing patients with radiolucent lines or medial osseous resorption with patients without these radiographic findings at the most recent follow-up.

Table II Shoulder functions and active mobility outcomes

	Preoperative	Postoperative	*P* value
Constant score			
Pain	4 ± 3	13 ± 3	<.001
Activity	7 ± 4	17 ± 4	<.001
Mobility	10 ± 8	35 ± 6	<.001
Strength	4 ± 7	14 ± 7	<.001
Total	25 ± 115	80 ± 15	<.001
Adjusted	32 ± 19	106 ± 20	<.001
ASES	42 ± 18	88 ± 16	<.001
ASES—pain	5 ± 3	1 ± 2	<.001
WOOS	67 ± 17	13 ± 18	<.001
SANE	33 ± 24	73 ± 34	<.001
Forward flexion	79° ± 37°	160° ± 19°	<.001
Abduction	75° ± 37°	160° ± 20°	<.001
External rotation	7° ± 14°	45° ± 14°	<.001

ASES, American Shoulder and Elbow Surgeons; *WOOS*, Western Ontario Osteoarthritis Shoulder index; *SANE*, Single Assessment Numeric Evaluation.

Complications

There were 4 intraoperative complications. A nondisplaced fracture of the anterior cortex occurred on impacting humeral compactors in 2 patients and required no additional treatment. A lesser tuberosity fracture occurred in 2 patients intraoperatively. One patient required a cemented stem and the other patient received a reverse prosthesis because the subscapularis was irreparable. Two postoperative complications occurred. One patient had a deep infection that was treated with serial débridement and staged revision. One patient had a traumatic posterior dislocation that was later revised to a reverse prosthesis. These patients were excluded from radiographic and clinical analysis but were included in analysis of complications. Three patients who did not reach inclusion criteria because of inadequate follow-up showed early stem loosening <1 year after surgery. These patients had GB stems placed at their index procedure. Significant varus stem position was noted in all 3 patients. All were elderly women with a known history of osteoporosis (Fig. 4). Two patients were revised to long-stem anatomic shoulder arthroplasty with cementation, and 1 patient elected nonoperative management.

Discussion

Our investigation demonstrated that patients undergoing TSA with an anatomic press-fit short stem had significant short-term clinical improvements from the preoperative state to final follow-up, with few complications. Radiographic changes were seen in a minority of patients during this study period.

A significant advancement in press-fit stem design came with the development of a metaphyseal taper from the anatomic neck to the diaphysis. This allowed cancellous fixation within the metaphysis rather than within the cortical bone of the diaphysis. The use of cancellous fixation within the metaphysis decreases regional stresses and may therefore decrease risk of periprosthetic fracture as well. Matsen et al[13] found no evidence of subsidence or change in position of 131 humeral components with a metaphyseal taper at an average 3-year follow-up. This fixation method was the basis for the use of press-fit short-stem humeral components, a design that has been further modified with the addition of PPC to achieve better ingrowth.

Concerns with the use of press-fit short-stem humeral components have included malalignment and higher rates of loosening compared with more conventional implants. There is a relative paucity of data when it comes to the use of these stems.[2,9,10,15,22,23] Among the studies evaluating clinical results with short stems, all have shown significant improvements in clinical outcomes and active mobility outcomes.[10,15,22,23,27] This is consistent with our data, as significant improvements were seen in patient satisfaction, clinical outcomes, and active mobility outcomes, with minimal complications.

Casagrande et al[2] showed radiolucent lines in 71% of patients with the same Aequalis Ascend GB press-fit short stem without PPC that was used in the early part of our study (85 patients). This contrasts with our study, as we found radiolucent lines in only 7 patients (7/85 [8.2%]) in the GB group compared with no patients with radiolucent lines in the PPC group at an average of 36 months of follow-up. A key distinguishing feature in our study is the use of the same press-fit short stem, with PPC in 28% of the patients studied. All 7 instances of humeral radiolucent lines in our study were found in patients in the GB group (without PPC). There were no instances of humeral radiolucent lines in patients with PPC stems. This did not reach statistical significance; however, a trend toward more radiolucent lines in the GB group was

Table III Patient satisfaction

	Postoperative*
Very dissatisfied	1 (0.9%)
Dissatisfied	5 (4.5%)
Satisfied	33 (29.7%)
Very satisfied	72 (64.9%)

* Patient satisfaction significantly improved from the preoperative state to postoperative follow-up ($P < .001$).

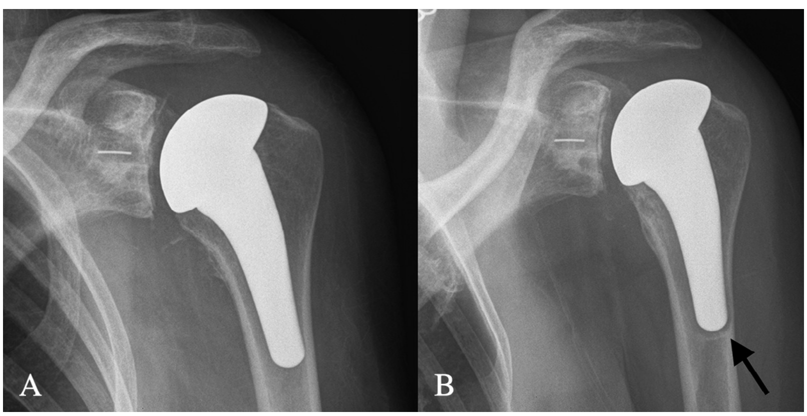

Figure 4 (**A**) Anatomic press-fit short stem, initial postoperative radiograph. (**B**) Anatomic press-fit short stem, 1-year postoperative radiograph with gross loosening (*arrow*).

observed in our study. PPC stems were placed later during the study period; therefore, follow-up was significantly shorter in these patients, which may affect our results. However, the observed trend is consistent with the recent 2-year data from Morwood et al[15] with press-fit short stems. The authors found 2.6% loosening, 10.2% subsidence, and 15.4% at risk for loosening in press-fit short stems without PPC. Results were compared with those of patients with PPC stems, noting no instances of loosening, subsidence, or risk of future loosening.

Whereas other studies have reported rates of loosening with long press-fit humeral stems (up to 9.7%) in the first 5 years,[8,16,17] less is known about medial osseous resorption and whether these characteristics may be associated with an increased risk of implant failure or periprosthetic fracture due to cantilever loading.[19,28] Medial osseous resorption can be caused by an adaptation of the bone to the changed stress distribution following Wolff's law, resulting in bone resorption.[16] Raiss et al[19] found stress shielding in 63% of patients with a long press-fit stem with a mean follow-up of 8.2 years. No association was found between the occurrence of internal stress shielding and an inferior clinical outcome. The percentage of medial osseous resorption found in our study is considerably lower at 9.3% and consistent with another recent report using a press-fit short stem at 8.8%.[23] However, on retrospective review of sequential radiographs for patients in whom medial osseous resorption was observed, cortical bone loss at the medial calcar was slowly progressive over time, with only subtle initial changes. Long-term follow-up is necessary to determine whether the rate of medial osseous resorption increases or whether progression of bone resorption has a negative impact on clinical outcomes and implant longevity.

Jost et al[10] reported on 49 "mini-stem" shoulder replacements with a minimum 2-year follow-up. Varus stem placement was found to be >5% in the series, although outcomes were not affected, with good short-term results noted. The authors concluded that short-stem components were an effective option for TSA. Although varus-valgus position was not a primary outcome in this study, varus positioning was noted in 3 elderly women with poor bone quality, resulting in clinical and radiographic failure. Varus malposition, poor bone quality, and lack of PPC may have contributed to these failures. We have not observed this with the use of PPC stems and a more lateral entry point when broaching the humeral canal.

The use of a short stem for TSA has several advantages over the more traditional long stem. The short-stem implant preserves more bone in the humeral canal while decreasing the need for reaming and broaching. This may also allow more anatomic placement of the humeral component, as the canal does not dictate its placement with the use of a short stem. More proximal fixation facilitates implant removal in revision cases, which may decrease operative time and potentially prevent perioperative fractures or the need for humeral osteotomy. A short-stem component may also be a better option in patients with certain pre-existing conditions, such as a previous humeral shaft malunion, pre-existing humeral hardware, or long stemmed elbow arthroplasty. Based on our data, press-fit short-stem humeral components are effective options in anatomic arthroplasty of the shoulder, with PPC stems likely providing a more reliable fixation option than GB stem components.

There are several limitations to this study. Our relatively short follow-up is noted, given the expected longevity of the TSAs. Long-term follow-up will be necessary to determine whether this implant design will continue to achieve ideal clinical results and to provide stable fixation beyond 2 years. A prospective study comparing the short stem with a more conventional implant is also needed. The addition of PPC to the stem during the study period created a significant change in the implant, potentially improving metaphyseal ingrowth. Larger numbers will be needed to determine what effect this change has on clinical and radiographic results. Although this is 1 of the largest cohorts assessing the effects of a press-fit short-stem TSA, the relatively small number of patients is noted.

Several strengths were noted in the study. First, a single surgeon performed all TSAs using a standardized surgical technique and postoperative rehabilitation. In addition, multiple validated shoulder function scores were gathered prospectively at preoperative and postoperative follow-up to allow accurate evaluation of clinical outcomes.

Conclusions

TSAs with an anatomic press-fit short stem showed significant clinical improvements from the preoperative state to final short-term follow-up with few complications and minimal radiographic changes. Lack of proximal coating may contribute to early loosening in patients with poor bone quality. The authors now use a short stem with PPC when performing TSA.

Disclaimer

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