Reverse shoulder arthroplasty with a cementless short metaphyseal humeral implant without a stem: clinical and radiologic outcomes in prospective 2- to 7-year follow-up study

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Background: Reverse shoulder prostheses are increasingly used in recent years for treatment of glenohumeral arthropathy with deficient rotator cuff. Bone preservation is becoming a major goal in shoulder replacement surgery. Metaphyseal humeral components without a stem were developed to minimize bone resection and preserve bone. This study evaluated the clinical and radiologic outcomes at 2 to 7 years using a novel short metaphyseal reverse total shoulder arthroplasty (rTSA) prosthesis without a diaphyseal stem.

Methods: Between 2005 and 2010, 102 consecutive patients underwent rTSA with this implant, and 98 (20 men, 78 women) were available for follow-up. Mean age was 74.4 years (range, 38-93 years). Indications were cuff tear arthropathy, 65; fracture sequelae, 12; rheumatoid arthritis, 13; failed rotator cuff repair, 3; cuff deficiency with loosening of anatomic prosthesis, 3; and acute trauma, 2; with 17 of these as revisions.

Results: Patients’ satisfaction (Subjective Shoulder Value) improved from 8 of 100 to 85 of 100. The Constant score improved from 14 to 59 (age- and sex-adjusted, 86; \( P < .0001 \)). Range of motion improved from 47° to 129° in elevation, 10° to 51° in external rotation, and 21° to 65° in internal rotation. Radiographic analysis showed no lucencies, subsidence, or stress shielding around the humeral or glenoid components. Glenoid notching was found in 21 patients (18 grade 1-2; 3 grade 3).

Conclusions: The short metaphyseal rTSA design without a diaphyseal stem shows encouraging short- to midterm results, with excellent pain relief and shoulder function, restoration of good active range of motion, and high patient satisfaction scores. The design of this implant seems to result in improved rotational movements, low incidence of glenoid notching, and no implant loosening, subsidence, or stress shielding.

Level of evidence: Level IV; Case Series; Treatment Study

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Reverse shoulder prostheses are increasingly used in recent years for the treatment of glenohumeral arthropathy with a deficient rotator cuff, including rotator cuff arthropathy, rheumatoid arthritis, proximal humeral fractures sequelae, irreparable rotator cuff tears, and failed shoulder replacement. Good mid- and long-term results with many of these required further surgery. However, early studies showed relatively high rates of complications (range, 24%-50%), and many of these required further surgery. Preservation of bone has therefore become a major goal. Metaphyseal cementless implants without a diaphyseal stem have been developed to preserve bone and resect only a minimal amount of bone. Analyzing the results of new designs with close surveillance and follow-up is crucial.

Information about the midterm clinical and radiologic outcomes associated with uncemented metaphyseal reverse total shoulder arthroplasty (rTSA) is currently limited. The aim of this prospective study was to report the 2- to 7-year clinical and radiologic results with rTSA with a short metaphyseal humeral design, without a diaphyseal stem, discuss the design rationale, and determine the safety and complication rate of this design.

Materials and methods

Patients

This prospective study included 102 consecutive patients who underwent cementless press-fit rTSA with a novel, short metaphyseal humeral design, without a diaphyseal stem (Verso; Innovative Design Orthopaedics, London, UK; formerly, Biomet, Swindon, UK), for the treatment of glenohumeral arthropathy with deficient rotator cuff by a single surgeon (O.L.) in our institution between 2005 and 2010. The indications for surgery were disabling pain and poor function in patients in whom nonoperative treatment had failed. We always try conservative treatment first with the deltoid rehabilitation regimen. All patients with indication for rTSA were included. All patients gave informed consent.

Exclusion criteria included patients with any evidence of infection or neurologic disease and patients who needed a stem as a scaffold: acute fractures, surgical neck nonunions, and revision of stemmed implant with deficient metaphyseal bone. Of the 102 patients, 98 (20 men, 78 women) were available for follow-up analysis. Two patients did not return for later follow-up appointments due to unrelated medical and social reasons (but were contacted by telephone), and 2 patients died of unrelated causes within a year after surgery. The average follow-up was 50 months (range, 24-82 months).

The mean age at surgery was 74.4 years (range, 38-93 years). Sixty-five patients were operated on for cuff tear arthropathy (including 11 revisions of resurfacing with cuff deficiency), 12 for fracture sequelae (including malunion and tuberosity malunion, deformity, and 1 failed hemiarthroplasty for fracture), 13 for rheumatoid arthritis (including 2 revisions of resurfacing with cuff deficiency), 3 for failed rotator cuff repair, 3 for cuff deficiency with glenoid loosening of an anatomic prosthesis, and 2 for acute trauma (dislocation with massive rotator cuff tear and preceding arthritis). Five patients underwent bilateral (staged) rTSA. Seventeen patients were operated on as revision arthroplasty: 16 were revisions of resurfacing prostheses, and 1 was a revision of a stemmed prosthesis to stemless rTSA. All of these revisions were due to rotator cuff tears and cuff deficiency. During the same period, the study excluded 8 patients who were treated with the stemmed Verso press-fit cementless rTSA due to acute fractures, surgical neck nonunions, and revision of stemmed implant with deficient metaphyseal bone.

Description of the implant

The humeral component is a short metaphyseal implant with 3 tapered thin fins that give immediate metaphyseal press-fit fixation when impacted into the cancellous humeral metaphysis with bone graft from the resected humeral head (Fig. 1). The implant does not violate the humeral diaphysis and does not have a diaphyseal stem. These fins have titanium porous and hydroxyapatite coatings to improve the biologic fixation of the implant. The metaphyseal bone quality or osteoporosis is not a contraindication for the use of this metaphyseal implant when the bone graft impaction technique is used.

The glenoid baseplate has a central tapered screw (hydroxyapatite-coated titanium) with the largest core diameter of 9 mm and 2 additional antitrotational screws, superiorly and inferiorly (Fig. 1, A and Fig. 2). The glenoid sphere is fixed with a Morse taper to the baseplate. The glenoid sphere is lateralized 3 mm from the glenoid face, this is built in the thickness of the baseplate and the gap between the baseplate and the glenoid sphere. The polyethylene humeral liners have 10° inclined shape, achieved by removing the redundant polyethylene walls inferiorly-medially and respectively on both sides. This provides a very low profile medially, which reduces the impingement between the polyethylene liners to the glenoid neck (Fig. 3, A). The humeral cut is performed at a 155° angle, with the final implant angle of 145° using the inclined liner.
The humeral liners can be dialed in a way that the correct version and offset of the liner can be determined and changed, and adapted to each patient even after the definitive metal implants have been implanted.

There are 2 glenoid sphere diameters and 4 different humeral liner offset options for each diameter.

Surgical technique

The procedure is performed through the anterosuperior approach to the shoulder (Neviaser-MacKenzie approach).\(^{35,38,43}\) In revision cases where the deltopectoral approach was used in the primary operation, the old skin incision is extended and the anterosuperior approach is used subcutaneously.\(^{37}\) A guide is used to resect a 20-mm slice of proximal humeral bone in 30° of retroversion. The resected bone is used for bone graft impaction into the humerus. The tapered triple-finned humeral component is impacted into the humeral metaphysis.

Good initial press-fit fixation in conjunction with bone graft impaction technique was achieved in all patients, regardless of osteoporosis or poor bone quality (Fig. 1). The glenoid component is implanted in 10° downward inclination at the inferior border of the glenoid with good initial press-fit fixation (Fig. 2).

Data Collection

Data were collected prospectively on a computerized database. All patients were monitored clinically and radiographically. A standardized video recording of range of motion and function was obtained for all the patients preoperatively and at regular intervals after surgery at all of the follow-up appointments. The video recordings were standardized with the same sequence of recording for all of the patients. This included filming from the frontal and lateral views with the patients performing all movements: forward elevation, abduction, external rotation with the arms beside the body and with the hands above the head and behind the neck, with the elbows pointing forward and backwards, as well as internal rotation with the hand behind the back. The external rotation with the hands beside the body was recorded on stills from above, and the internal rotation with the hands behind the back were recorded on stills from behind. A goniometer was used to assess the range of motion. The patients were assessed clinically and radiographically by independent experienced shoulder surgeons who were not involved in the operations.

Clinical assessment

Patient demographics, including the preoperative diagnosis, previous surgery, and preoperative shoulder function using the Constant score\(^{7}\) (pain, activities of daily living, active range of motion, and shoulder strength), were obtained. Patient satisfaction was assessed using the Subjective Shoulder Value (SSV)\(^{20}\) or Single Assessment Numeric Evaluation (SANE).\(^{58}\)

Operative findings, complications or revision surgery were recorded.

Patients were assessed postoperatively with the Constant score,\(^{7,36}\) the patient satisfaction score (SSV or SANE score),\(^{20,36,58}\) a functional questionnaire assessing return to work, sport, and leisure activities;\(^{36}\) and the video recording at 3 weeks, 3, 6, 9, 12, 18, and 24 months, and annually thereafter.

Radiographic assessment

All radiographs were assessed by 2 independent experienced shoulder surgeons. Preoperative radiographs were assessed for the severity of radiographic changes of cuff tear arthropathy according to the Hamada-Fukuda classification\(^{24}\) for massive rotator cuff tear with arthropathy. The progression in severity of the Hamada-Fukuda classification\(^{24}\) can be applied to all patients with massive rotator cuff tear and arthropathy (including after arthroplasty). Postoperative
Radiographic analysis was performed using a true anteroposterior view of the shoulder and an axillary view. Bone density was assessed using plain digital radiography in the trabecular bone around the implant, as described by Kind et al. \(^{31}\)

A standardized template was used to critically assess postoperative radiographs for displacement, migration, or subsidence of the implant and appearance of radiolucent lines, osteolysis, or signs of stress shielding. The Nerot-Sirveaux glenoid notching classification \(^{50}\) was assessed as well (Fig. 4).

**Statistical methods**

Data were collected prospectively and recorded using a dedicated Access database (Microsoft Corp, Redmond, WA, USA). Improvement or gain in functionality (Constant score) and patient satisfaction (assessed by the SSV \(^{20}\) or SANE \(^{58}\)) was calculated for each patient by comparing the latest observed postoperative value against the corresponding preoperative value, and the significance of the difference was tested using the paired \(t\) test. Improvement in the Constant score was assessed preoperatively, immediately after the operation, 3 weeks, then 3, 6, 9, and 12 months, and yearly thereafter. Statistical analysis was performed using SAS 8.2 software (SAS Institute Inc, Cary, NC, USA).

**Results**

At the most recent follow-up, patient satisfaction (SSV) improved from 8 of 100 preoperatively to 85 of 100 postoperatively (95% confidence interval, 77-94) after rTSA with this short metaphyseal prosthesis without a diaphyseal stem. The mean Constant score (for all diagnoses) improved from 14 preoperatively to 59 at the last follow-up. The age- and sex-adjusted Constant score improved from 21 preoperatively to 86 at the last follow-up (\(P < .0001\) by paired \(t\) test).

No clinical infections were observed in this study. Patients were monitored for infection with C-reactive protein, erythrocyte sedimentation rate, and intraoperative intra-
articular specimen collection. Prophylactic antibiotic treatment was withheld until the specimens were collected. A single dose of teicoplanin and gentamicin was used for prophylaxis.

For the cuff arthropathy patients ($n = 65$; including 11 with revision of resurfacing with cuff deficiency), the Constant score improved from 15 to 62 points (age- and sex-adjusted, 22 to 93); for fracture sequelae ($n = 12$), from 12 to 49 (age- and sex-adjusted, 17 to 71); for rheumatoid arthritis ($n = 13$; including 2 with revision of resurfacing with cuff deficiency), from 14 to 54 (age- and sex-adjusted, 19 to 78); for patients with revision of loosening of resurfacing arthroplasty ($n = 3$), from 27 to 83 (age- and sex-adjusted, 37 to 115); and for acute trauma ($n = 2$), improved to 58 points (age- and sex-adjusted to 86). All of these gains were statistically significant ($P < .0001$ by paired $t$ test, comparing postoperative to preoperative; Fig. 5). The Constant score continued to improve over time in this series (Fig. 6).

At the most recent follow-up, pain was rated mild or none in 95 shoulders (96.9%). The mean visual analog scale pain score (from 0 to 15) decreased from 12 to 2 points. The mean active range of motion improved from $47^\circ$ to $129^\circ$ elevation, $10^\circ$ to $51^\circ$ external rotation (in adduction with the arm beside the body), and $21^\circ$ to $65^\circ$ internal rotation (in abduction). All patients but 1 resumed normal or functional daily and leisure activities according to their reply in the questionnaires.

Radiographic analysis

The Hamada-Fukuda classification for cuff tear arthropathy on the preoperative radiographs showed 40 patients with grade 5, 34 with grade 4b, 18 with grade 4a, 8 with grade 3, and 2 with grade 2.

The postoperative radiographic analysis using an assessment chart (Fig. 4) showed no radiolucencies around the humeral or glenoid components at the latest follow-up. There was no prosthetic humeral or glenoid migration, change in position over time, or loosening of the short metaphyseal reverse humeral and the glenoid components. There was no subsidence of the prostheses and no evidence of proximal resorption of bone around the humeral implant to suggest stress shielding. Increased bone density was measured using plain digital radiography in the trabecular bone around the implant (Fig. 7).

Figure 5  The preoperative and postoperative follow-up Constant scores. $P < .0001$ by paired $t$ test. RC, rotator cuff.

Figure 6  Improvement of Constant score with time postoperatively (PO).
We observed glenoid notching in 21 patients (21.4%), which appeared later (>1-2 years) after surgery. Glenoid notching in 18 of these patients was grade 1 or 2 (Neron-Sirveaux), and only in 3 patients was grade 3 glenoid notching found (retentive liners were used in these patients).

We have noticed development of an inferior glenoid traction osteophyte (along the triceps insertion) in 46 shoulders. This did not seem to affect the clinical outcome.

Complications

Two patients had an undisplaced fracture of the humeral metaphysis due to excessive bone impaction in very soft bone, and 1 glenoid rim was cracked during preparation (in revision cases). These healed around the implants at 3 months with conservative treatment. The Constant scores of these patients were similar to the rest of the treated group, with final raw Constant scores of 76, 68, and 74, respectively. No lucencies or loosening was seen at the follow-up.

There were 2 early dislocations; 1 patient put weight on his shoulder in extension of the shoulder (to push himself out of chair) 1 week after surgery. The other was caused by an inferior osteophyte that hinged the liner to dislocate. Both were reoperated and made a remarkable recovery, with final raw Constant scores of 75 and 84.

In one patient, early in the series, the glenoid head disengaged from the baseplate during the first 3 weeks after surgery due to soft tissue interposition between the baseplate and the glenoid sphere that was unnoticed during surgery. The glenoid sphere was reinserted in revision surgery with uneventful recovery (final raw Constant score, 59).

Pathologic fracture of the acromion developed in 2 patients after surgery. One patient made a full recovery with conservative treatment (final raw Constant score, 88). She regained full range of motion and function with no pain within a month. The other patient fractured the base of the acromion in the scapular spine 2 months postoperatively. She was operated on with plating of the spine of the scapula and the acromion and made a moderate recovery with almost no pain but limited function (final raw Constant score, 37).

Six patients sustained late traumatic periprosthetic fractures caused by falls. Two glenoid fractures and three proximal humeral (metaphyseal) fractures. Of the 2 glenoid fractures: One patient refused further surgery with limited outcome, and the other patient was revised with good outcome (final raw Constant score, 81).

The patients with the proximal humeral fractures were treated conservatively, and all healed with good function (final raw Constant scores of 62, 51, and 66). One patient sustained displaced metaphyseal-diaphyseal periprosthetic fracture of the proximal humerus and had revision to a stemmed reverse prothesis. She made moderate recovery with no pain and restoration of limited function (final raw Constant score, 38).

There were no infections or other intraoperative or postoperative complications.

Discussion

The midterm (2-7 years) clinical and radiographic results with this short metaphyseal reverse shoulder prosthesis (without a diaphyseal stem) are encouraging. All patients had good pain relief and almost all of the patients were very satisfied with their shoulder (85 of 100 on the SSV). Good clinical outcome was observed for all the diagnoses, with improvement of the Constant score from 14 preoperatively to 59 (age- and sex-adjusted, 86) at the last follow-up.

The prosthesis fixation is entirely metaphyseal, with no stem in the humeral shaft. Good initial press-fit fixation was achieved in all patients, regardless of osteoporosis or poor bone quality, with the tapered triple-finned implant (Fig. 1) in conjunction with the bone graft impaction technique. The titanium porous and hydroxyapatite coatings provide further biologic fixation. We have seen good integration of the bone graft with increased bone density of the metaphysis around the prosthesis already at 3 weeks postoperatively (Fig. 7).

Complications related to the humeral stem with stemmed reverse prostheses accounted for 10% to 20% of complications, including periprosthetic fracture, shaft perforation, disassembly, and loosening. Zumstein et al. reported 16 intraoperative humeral fractures and 24 intraoperative complications (67%) related to the humeral stem. Two patients in our series had an undisplaced fracture of the humeral metaphysis intraoperatively. These healed completely around the implants with conservative treatment over 3 weeks, with no effect on the functional outcome. They did not show any lucencies or loosening at the latest follow-up.

Melis et al. found radiologic signs of stress shielding in substantial numbers of stemmed reverse prostheses, with 5.9% of cemented and 47% in uncemented implants, as well as partial or complete resorption of the greater and lesser tuberosities (greater tuberosity resorption in 69% of cemented and 100% in uncemented implants and lesser tuberosity resorption in 45% of cemented and 76% of uncemented.
implants. Similar findings have been reported with other types of stemmed rTSA prostheses as well.

No lucencies or resorption of bone around the humeral component suggestive of stress shielding was seen in this series. An explanation may be that because the entire fixation of the prosthesis is metaphyseal (without distal fixation), there is direct load transfer to the humeral metaphysis. This reduces the risk of stress shielding. Furthermore, use of the tapered triple-finned humeral component combined with the bone graft impaction technique may improve the density and resistance of the metaphyseal bone.

Scapular notching has been observed in more than 50% of patients in most series with reverse shoulder prostheses. This is a common radiographic finding at early follow-up. In the Boileau et al series, notching at the inferior aspect of the glenoid was present in 74% of the patients and extended to or beyond the inferior screw (Nerot-Sirveaux grade 3) in 30%. Glenoid notching is a result of impingement of the medial aspect of the polyethylene humeral cup on the scapular neck inferiorly and posteriorly as well as further osteolysis due to the wear particles. The Levigne et al study confirms that scapular notching after Grammont-type reverse shoulder arthroplasty is frequent, 62%, similarly to some previously published reports. Their study also confirms the previous report by Werner et al that notching occurs early after surgery, because 68% of the latest follow-up notches were already visible 1 year after the operation.

Melis et al reported 88% glenoid notching in a series of patients with Grammont-type rTSA with follow-up over 8 years. They observed an increase in the incidence and severity of notching over time, with 62% of the notching being Nerot-Sirveaux grade 3 and 4 (49% grade 4).

Favard et al and Zumstein et al in meta-analyses, noted a negative effect of radiographic scapular notching on the clinical outcome: if the notch was large (extending beyond the inferior screw), the Constant score was significantly lower and the risk for loosening was high in their series. The rate compares favorably with most of the published series, with 44% to 96% in different series.

The rate of glenoid component loosening reported for rTSA ranges between 2% and 5%. No radiolucent lines have been seen around the glenoid component in our series so far. Hopkins et al assessed the glenoid components of 6 different reverse shoulder prostheses and compared the primary stability through the minimization of interface micromotions. The glenoid baseplate of this stemless rTSA design was the most stable, with peak micromotions of less than 48 μm. When the relative displacement of the bone-implant interface (termed “micromotion”) is below a threshold of 150 μm, it is assumed that the implant will not induce the generation of unwanted fibrous tissues and micromotions below 50 μm are considered low enough to allow bone ingrowth.

Some authors raised concerns that use of the Grammont-type reverse arthroplasty may lead to deficient or absent external rotation and internal rotation. This may affect the functional ability of patients to perform their simple daily activities.

We have found significant improvement in the rotational movements in our series compared with published series with other reverse prostheses. Karlse et al described the hinging movement of the rTSA humerus around the center of rotation compared with the anatomic shoulder that spins around the center of rotation. Karlse et al showed that there are limitations of rotation movements with rTSA due to impingement of the hinging humeral cup component around the glenoid head. In the adducted position, the contact between the inferior edge of the humeral component and the body of the scapula limits the range of adduction; similarly, with internal and external rotation—limiting the range of rotational motion. Removing the edges of the polyethylene liner increases the range of the humeral component rotational movement before impingement of the liner on the scapula occurs as well as reduced glenoid notching. Indeed, asymmetric polyethylene wear has been observed on most retrieved humeral reverse prostheses liners (Fig. 3, B).

The use of the 10° oblique dialable liners of this implant (Fig. 3, A), combined with 3-mm lateral offset of the glenoid sphere and insertion of the humeral shell in 30° of retroversion, may explain the improved rotation. Furthermore, the humeral liners can be dialed in a way that the correct version and offset of the liner can be determined and changed, adapted to each patient, even after the definitive metal implants have been implanted. Besides reduction of the impingement on the glenoid, these may position the vectors of action of the most anterior and the most posterior fibers of the deltoid muscle in a more horizontal position and recruit them as internal and external rotators, respectively.

Reverse TSAs are usually implanted in elderly patients, who have tendency to suffer from trips and falls. They therefore have an increased risk to suffer late traumatic periprosthetic fractures.

If a stemmed prosthesis is used, the periprosthetic humeral fracture tends to happen at midshaft of the humerus at the metal-bone interface stress riser. Andersen et al concluded that periprosthetic fracture around a humeral stem implant is a difficult clinical problem involving complex decision making and a difficult surgery, with frequent complications and high reoperation rate. Zumstein et al observed a negative effect on the clinical outcome in patients with postoperative periprosthetic humeral shaft fractures after stemmed rTSA that had to be revised with longer stems.

Using stemless metaphyseal prosthesis reduces the risk of diaphyseal periprosthetic fracture. If fracture is to happen, it will involve the metaphysis rather than the humeral shaft. Metaphyseal fractures may heal better than diaphyseal fractures with conservative treatment, as shown in this study.
Indeed, the incidence of intraoperative humeral fracture for primary reverse arthroplasty and in revision of a resurfacing device to a reverse is low. However, the risk is clearly higher when using stemmed implants requiring preparation and reaming the humeral shaft for the prosthesis compared with no need at all to touch the shaft in stemless/metaphyseal prostheses.

Furthermore, intraoperative humeral fractures are more of a problem in revision surgery. We are seeing an exponential increase in revisions of both anatomic and rTSA in recent years. By using prosthesis without a stem, we reduce the risk of intraoperative humeral fracture if revision will be necessary.

There are limitations to the use of stemless reverse implants, because they are not suitable for treatment of patients with acute fractures, fracture nonunions, or revision of stemmed prostheses. For these patients, a stemmed implant should be used.

A limitation of the study is that there was no control group treated with a stemmed rTSA. However, we can correlate our results to published series with stemmed rTSA.

Conclusions

The bone-preserving short metaphyseal rTSA design without a stem shows encouraging short- to midterm results, with excellent pain relief and shoulder function, restoration of good active range of motion, and high patient satisfaction scores. No implant loosening, subsidence, or stress shielding was observed on radiographs. The design of this implant seems to result in a low incidence of glenoid notching (with low grade of notching) and improved rotational movements compared with the Grammont-type prostheses.

Disclaimer

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