

Pioneers of Stemless Reverse Shoulder Replacement - A Review of Design Concepts and Outcomes

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Abstract

The Reverse shoulder prostheses have gained popularity in the recent decades and has become the procedure of choice for treatment of glenohumeral arthropathy with deficient rotator cuff such as: rotator cuff arthropathy, rheumatoid arthritis, trauma sequela (e.g. proximal humerus fractures and dislocations), massive irreparable rotator cuff tears, and failed shoulder replacement. Mid and long-term patient outcomes have been good, with most patients restoring a functional range of motion. Complication rates vary significantly between 24 - 50%, some requiring revision surgery. Many of these complications, both intraoperative and postoperative, occur around the humeral diaphyseal stem. Revision arthroplasty has a higher rate of complications, with specific complications related to revising the humeral diaphyseal stem and loss of bone stock. Stemless metaphyseal cementless implants have been developed to preserve bone, with only minimal bone resection needed for implant. Since 2005, stemless reverse Total Shoulder Arthroplasties (TSA) have been in clinical use, with the Verso shoulder [Innovative Design Orthopedics, London, UK (formerly Biomet, UK)] and the TESS reverse shoulder (Biomet, France). This review examines the introduction of the metaphyseal prosthesis, the principles of their design, indications, biomechanical considerations, and clinical and radiological outcomes in the 15 years since they were introduced.

Keywords: Reverse TSA; Stemless; Metaphyseal; Cementless; Glenoid Notching; Bone Preserving

Abbreviations

rTSA: Reverse Total Shoulder Arthroplasty; IDO: Innovative Design Orthopedics; TESS: Total Evolutive Shoulder System; ROM: Range of Motion; CS: Constant Score; SSV: Subjective Shoulder Value; ADLEIR: Activities of Daily Living External and Internal Rotations; ADL: Activities of Daily Living; IR: Internal Rotation; ER: External Rotation; ASES: American Shoulder and Elbow Score

Shoulder replacement over the years

Shoulder replacement was first attempted for cases of infection (Emil Pean, 1893) [1] and tumor to deal with the considerable loss of bone and soft tissue (Jackson-Borrows) [2]. These implants involved constrained stemmed prostheses. Neer, *et al.* [3] developed a

stemmed unconstrained humeral prosthesis specifically for the treatment of four-part fractures. The underlying concept for both designs, was a diaphyseal stem to serve as a scaffold around which bone formation can occur. Neither were designed to treat arthritis, which has different characteristics considering bone loss. Neer’s prosthesis design had considerable success, and thus was later developed for treating shoulder arthritis. Glenoid components pursued with time [4].

In the mid-1980’s Stephen Copeland introduced the concept of a cementless surface replacement arthroplasty for treating arthritis [5-9]. The basic principle was that a diaphyseal stem was unnecessary for an anatomic TSA [5-7,10-13]. This change in paradigm was, slowly but surely, embraced by shoulder surgeons globally.

Based on the long-term results of the Copeland shoulders, around 15 years after its introduction, resurfacing prosthesis started gaining popularity. Other manufacturers appeared with their own resurfacing designs (Global Cap, Aequalis resurfacing, EPOCA, etc.), and stemless anatomic TSA followed thereafter, such as the TESS (Biomet) in 2004, the Eclipse (Arthrex) in 2005 and many others.

Reverse TSA’s evolution has many similarities to the slow conceptual change and recognition of the anatomic TSA.

The Reverse shoulder prostheses have gained popularity in the recent decades and has become the procedure of choice for treatment of glenohumeral arthropathy with deficient rotator cuff such as: rotator cuff arthropathy, rheumatoid arthritis, trauma sequela (e.g. proximal humerus fractures and dislocations), massive irreparable rotator cuff tears, and failed shoulder replacement. Mid and long-term patient outcomes have been good, with most patients restoring a functional range of motion. Complication rates vary significantly between 24 - 50%, some requiring revision surgery [14-16]. Many of these complications, both intraoperative and postoperative, occur around the humeral diaphyseal stem, which is present in most of the current designs of rTSA [17-19]. Revision arthroplasty has a higher rate of complications, with specific complications related to revising the humeral diaphyseal stem and loss of bone stock. Stemless metaphyseal cementless implants have been developed to preserve bone, with only minimal bone resection needed for implant [20-27].

Since 2005, stemless reverse Total Shoulder Arthroplasties (TSA) have been in clinical use, with the Verso shoulder [Innovative Design Orthopedics, London, UK (formerly Biomet, UK)] (Figure 1 and 2) and the TESS reverse shoulder (Biomet, France) (Figure 3).

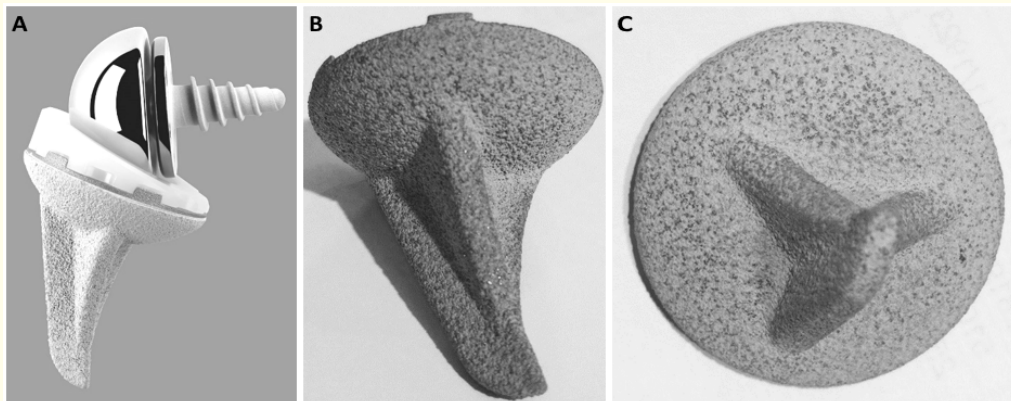


Figure 1: (A-C) Verso stemless metaphyseal reverse TSA (Innovative Design Orthopedics, London, UK), with the unique structure of three metaphyseal tapered thin fins in the stemless humeral component.



Figure 2: The Verso stemless metaphyseal reverse TSA in X-Ray, 3 months post-op. Designed with simplicity and a simple, reproducible surgical technique.

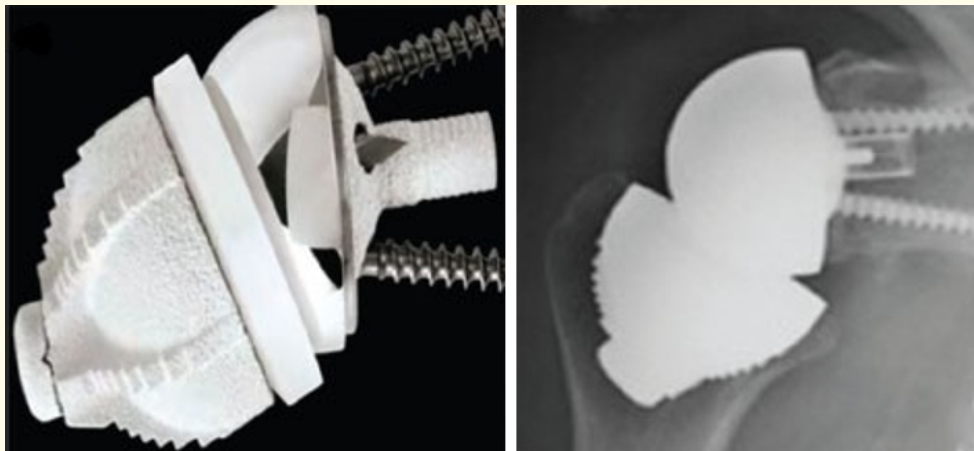


Figure 3: Total Evolutive Shoulder System (TESS) (Biomet, France).

This review examines the introduction of the metaphyseal reverse prosthesis, the principles of their design, indications, biomechanical considerations, and clinical and radiological outcomes in the 15 years since they were introduced, which are equal, if not better, compared with stemmed implants [27,28].

The design rationale of metaphyseal stemless rTSA is to achieve metaphyseal cementless fixation with preservation of bone. Only minimal bone resection is required. The metaphyseal humeral implant is canal sparing, preserves native bone and avoids potential

complications regarding the humeral shaft during, or after, introduction of a diaphyseal stem. This inherent advantage allows for better bone stock in revision surgery, if needed. Operating time is also shortened since humeral shaft preparation is not needed, and alignment of the implant is not bound to the anatomic characteristics of the diaphyseal shaft.

Metaphyseal stemless rTSA share the same indications as their stemmed counterparts - rotator cuff arthropathy, proximal humerus fracture sequela, irreparable massive rotator cuff tears, rheumatic arthritis, as well as revision from a failed stemmed shoulder replacement.

Metaphyseal rTSA are not suitable in cases where there is an inherent metaphyseal bone deficiency, such as acute proximal humerus comminuted fractures, fracture non-unions, and some revisions of stemmed implants, mainly when a well-fixed stem is present and needs extraction.

Verso and the TESS stemless rTSA - Concepts and technique

Verso reverse TSA

The Verso was designed with simplicity in mind, both in design and in surgical technique. It is designed either for the deltoid preserving antero-superior approach, enabling an enface view of the glenoid [29], or the deltopectoral approach.

The humeral component utilizes a short triple-tapered metaphyseal design with three thin fins (Figure 1). It is small in volume, but the unique design achieves a high surface area for a 3-dimensional press-fit into the cancellous humeral metaphysis. Load sharing to the bone is good, and further biological fixation (bone ingrowth) is facilitated through the titanium porous and hydroxyapatite coating. The implant can accommodate any size of metaphysis through its four available sizes, with the size of the fins being the only variable changed.

The key feature of the Verso rTSA is bone preservation. The Humeral cut is minimal, and the bone resected is used for bone graft impaction in the humerus. This has a two-fold advantage - providing high quality bone graft and bone density and achieving excellent primary press-fit stability of the prosthesis.

Direct load transfer to the cancellous metaphyseal bone reduces stress shielding, a known problem impacting cementless stemmed implants. It has also been shown to improve bone quality and density below the level of the prosthesis [26].

Therefore, a bony defect under the humeral cut, any inadequate or soft bone or osteoporotic bone are not a contraindication for the use of the Verso prosthesis [20,22,23,25,26].

The Verso humeral cut is performed at a 155° neck-shaft angle. The 10° inclined liner allows for a final implant angle of 145°. Version and offset can be determined by dialing the liner in 30-degree increments. This allows patient specific adjustments, even after the metallic components have been fixed to their bony counterparts.

The polyethylene liner is designed as a 10° angled rim dialable liner to reduce glenoid notching and improve rotational movements. The inferior and medial walls of the polyethylene walls were trimmed, giving a final design of an angled rim shape. This results in a very low profile medially, which reduces the potential impingement between the polyethylene liners to the glenoid neck and provides larger arc of impingement free rotation movements.

The Verso baseplate fixation to the glenoid bone relies on a central tapered screw (hydroxyapatite-coated titanium) which is 9 mm core diameter at its largest, with the two additional screws serving as anti-rotational screws, superiorly and inferiorly. Altogether, the

baseplate has four additional screw holes that can be used in case of fracture or deficient glenoid for osteosynthesis. The glenosphere is fixed with a Morse taper to the baseplate with 3 mm of lateralization from the glenoid face.

The Verso glenoid baseplate design has shown the best fixation in a study comparing six different reverse shoulder designs by Hopkins, *et al.* from Imperial College London [30].

Preparation of the humerus

A 20-mm slice of proximal humeral bone is resected in 155° neck-shaft angle in 30° of retroversion, utilizing the Verso cutting guide. The resected bone serves as bone graft impacted into the humerus before the final prosthesis is put in place.

Sizing of the humeral shell can be determined either by pre-operative templates or intraoperatively. The fins on the humeral punch should incorporate the cancellous metaphyseal bone, without protruding into the cortical bone.

The humeral punch is impacted using the humeral inserter. While preparation of the glenoid is performed, a forked retractor is positioned under the inferior part of the glenoid and depresses the humeral punch (with a plastic protective cover) with constant pressure resulting in better impaction into the cancellous metaphyseal bone.

Glenoid preparation

A meticulous release of the capsule and labrum around the glenoid rim ensures tension free movement and no soft tissue interposition within the glenoid components.

The center of the lower portion of the glenoid is identified and drilled with a 5-mm stop drill bit at an inclination of 10°.

A stepwise preparation of the glenoid surface is performed, starting with the glenoid face reamer and the step removal reamer. Any peripheral osteophyte or uncut bone is trimmed.

The cortex around the central glenoid face hole is enlarged using a glenoid peg reamer.

The glenoid tap is used carefully, by hand, to prepare the thread for the baseplate central screw.

The definitive glenoid baseplate is then screwed gently into the tapped hole until the baseplate is in contact with the bone face and good purchase of the glenoid bone. Two titanium anti rotation screws (superior and inferior) are drilled and placed.

A trial reduction is performed with a trial glenosphere and liner to assess the best size, position (version), stability and range of motion.

Bone graft impaction with morselized bone from the resected humeral head is impacted into the proximal humeral metaphysis. Alternatively, bone graft substitute mixed along with the patient's blood, can be used as graft, although autograft is preferred and is generally sufficient.

The humeral shell is impacted into place, matching the size of the punch and the metallic glenosphere is inserted into the glenoid baseplate and impacted firmly.

After a final trial with the liner in the desired position and size, the selected definitive humeral liner is impacted and locked into the humeral shell.

The joint is reduced, and the any remnants of the rotator cuff are reattached into the proximal humerus.

TESS

Either the anterosuperior or the deltopectoral approaches may be used.

The TESS prosthesis was designed based on Grammont's concept [31]. The prosthesis is made of four parts: 1) a humeral reverse stemless cup (reverse corolla); 2) a central pegged glenoid baseplate with four surround screws; 3) corresponding glenosphere; 4) and a polyethylene liner.

The TESS intended humeral cut is at a 155° - 150° neck-shaft angle. The humeral cup is made of cobalt-chrome coated with hydroxyapatite. The outer surface has six anti-rotational shallow ridges for achieving a press fit with the metaphyseal bone and further biological fixation to the titanium porous and hydroxyapatite coating. Sizing of the cup is achieved through four cup sizes, and an optional stem with an angulation of 150°.

The TESS glenoid baseplate is designed with a central peg, though solid fixation relies on four surrounding locking screws: superior, inferior, anterior, and posterior.

The glenosphere is fixed with a taper and secured with a central screw to the baseplate, with a 3 mm lateral offset relative to the glenoid surface.

Preparation of the humerus

The upper part of the proximal humeral bone is resected in 155° - 150° neck-shaft angle and 20° of retroversion. The humeral metaphysis is reamed from the metaphysis to allow sufficient space for the reverse corolla. The prosthesis is then impacted into the remaining metaphyseal bone. Insufficient bone around the corolla-stem junction that covers at least 2/3 of the prosthesis a contraindication to use the TESS system.

Glenoid preparation

The glenoid is exposed and a thorough release is performed. A central drill hole is prepared and the glenoid face reamed.

The glenoid baseplate central peg is inserted and secured by four locking screws. The glenosphere taper is inserted and the glenosphere secured with a central screw to the baseplate.

The polyethylene liner must match the sizing of the reverse corolla and glenosphere. After its insertion, the joint can be reduced, and closure of the chosen surgical approach preformed.

Clinical and radiographic outcomes

There are over 15 years of clinical experience with the Verso rTSA and the TESS. These stemless prostheses have shown clinical and radiographic outcomes that are at least as good as, if not superior, to their counterpart stemmed implants [22,25,26,28,31-37].

Preliminary short-term results of 31 patients with a Verso stemless metaphyseal prosthesis were reported by Atoun, *et al.* [22], with a mean follow-up of 36 months (range, 24 - 52 months). The average Constant score (CS) improved significantly from 12.7 to 56.2 (17.8 to 80.2 age/sex adjusted). Examining the different subgroups of the: pain, activity of daily living, range of motion and power, all showed statistically significant improvement ($P < 0.0001$). The Subjective Shoulder Score (SSV), or shoulder satisfaction rate, increased from 2.4 to 8.5/10.

A longer follow-up (2 - 7 years) in 102 consecutive patients treated with the Verso rTSA found these outcomes are maintained [26]. Ninety-eight (20 men, 78 women) were available for follow-up. Mean age was 74.4 years (range, 38 - 93 years). The average follow-up was 50 months (4 years and 2 months) (range, 24 - 82 months). The cohort was operated for various indications: 65 for cuff tear arthropathy, 13 rheumatoid arthritis, 12 fracture sequelae, 3 revisions from a loose anatomical prosthesis, 3 failed rotator cuff repairs and 2 for acute trauma (dislocation accompanied by a massive rotator cuff tear). Of the 17 revision arthroplasties in the cohort, 16 were revisions of resurfacing prostheses and one revision of a stemmed prosthesis. SSV improved from 0.8/10 to 8.5/10. CS improved from 14 to 59 [age/sex adj. = 86] ($P < 0.0001$). ROM improved from 47° to 129° in elevation, 10° to 51° in external rotation (in adduction), and 21° to 65° in internal rotation. All patients apart from one resumed their normal daily activities. Patients could return to their normal leisure activities with ease. Meticulous data collection including video recordings of the ROM of all patients were taken as baseline (preoperative) and on regular follow-up examinations - at 3 weeks post-operatively, 3 months, 6 months, 12 months and annually thereafter (Figure 4).



Figure 3: Total Evolutive Shoulder System (TESS) (Biomet, France).

Radiographic analysis performed at latest follow-up were satisfactory, showing no radio lucent lines around either the humeral or glenoid components. There was no implant migration, no signs of loosening of either the stemless reverse humeral or the glenoid components. There was no evidence stress shielding (proximal bone resorption around humeral shell) or subsidence of the prosthesis (Figure 4). On the inferior glenoid neck, a minimal traction osteophyte could be seen in some patients, but no glenoid notching.

Two cases had a crack of the humeral metaphysis due to excessive bone impaction, these were treated conservatively and healed completely with bone formation around the implants seen at three months. Their follow-up, both clinically and radiographically was uneventful with no effect on patient reported outcome measures.

Long-term follow-up of 5 - 11 years has shown the good outcome is sustainable [27], with a cohort of 172 patients that underwent rTSA between 2005 and 2011. One hundred forty-nine patients were implanted with a stemless metaphyseal prosthesis, and 23 with a

stemmed implant. The average follow up was 89 months (range 60 - 138 months). There were 41 males and 131 females; the mean age at surgery was 74.3 y (range, 38 - 93 y). Indications were as follows: 86 for cuff tear arthropathy, 24 for rheumatoid arthritis, 19 for fracture sequelae, 18 for revision of a failed anatomic shoulder, 16 patients for a massive irreparable cuff tear or a previous failed rotator cuff repair, 4 for glenohumeral osteoarthritis accompanied by cuff deficiency or eroded glenoid, and 5 for acute fractures. Within the cohort follow-up timeline, 13 patients underwent rTSA bi-laterally, in a staged manner. 50 patients were operated as a revision arthroplasty, with 21 patients revised from a stemmed prosthesis to a stemmed reverse prosthesis. 3 of the revision surgeries were from a stemmed prosthesis to a stemless metaphyseal rTSA.

Subjective shoulder value improved from 1.1/10 to 9.3/10. The average CS improved from 15.9 ± 8.6 pre-operatively to 59.7 ± 20.4 at last follow-up (22.6 ± 12.3 to 89.2 ± 30.3 age/sex adjusted). These improvements were statistically significant ($P < 0.0001$). Active ROMs were measured in all patients, with a mean improvement in forward flexion from 53.8° to 131.9° , 20.7° to 34.6° external rotation and 32.3° to 68.8° internal rotation. Radiographic outcomes were generally satisfactory, with no subsidence or stress shielding, no lucent lines around the glenoid or humeral components. Glenoid notching was noticed in 40 patients (23.2%), of these, 34 were grade 1 - 2 and 6 were classified as grade 3.

Ballas and Beguin [24] published the results of a prospective, single-surgeon series of 56 TESS stemless implants performed between 2004 and 2009. Mean follow-up was 58 months (range, 38 - 95 months). The CS improved from 29 to 62 points. ROM improved from 79° to 140° forward flexion. One fracture occurred at the metaphyseal-diaphyseal border. This was treated conservatively and did not affect outcome. Radiographically, no lucencies were seen around the humeral component, no subsidence, or loosening of the reverse humeral cup in the metaphysis. The greater tuberosity suffered significant lysis in one case, however the humeral corolla remained well fixed. Scapular glenoid notching was found in 9% of the cases, all of these marked as grade 1. Dissociation of the glenoid components occurred in 3 cases, with only one case of early instability. There was a total of 7% revision rate in the cohort.

Kadum., *et al.* [34] reported the results of 40 shoulders which underwent either a stemmed or stemless TESS rTSA between 2007 - 2011. 37 patients entered the study (23 women and 14 men), with a mean age of 72.0y (range, 60 - 88y). The mean follow-up was 39 months (15 - 66 months). 14 cuff tear arthropathies, 10 glenohumeral arthritis with a deficient rotator cuff, 7 rheumatoid arthritis, and 9 fracture sequelae.

The indications for either a stemmed or stemless prosthesis were the same. The main criteria to decide, intraoperatively, on the prosthesis to be used was the bone quality and the primary stability of the humeral component. If stability was questionable, a stemmed prosthesis was chosen. In above 60% of the cases, a stemmed TESS was chosen. This included 9 fracture sequelae and 15 additional cases. Only 16 cases had stemless TESS, with two (12.5%) suffering from an early failure due to corolla displacement and had to be revised only a few days postoperatively. Subsequently the authors concluded that only stemmed prostheses should be used in fracture sequela, due to questionable stability in the osteoporotic bone. Nonetheless, in their cohort, shoulder function, pain levels and quality of life improved in all patient groups.

In 2015, Teissier, *et al.* described 101 patients with 105 stemless TESS implants, with a minimum follow-up period of 2 years [31]. 10 patients were lost to follow-up, and the remaining 87 patients (61 men and 26 women, mean age of 73y), were followed for an average of 41 months (range, 24 - 69 months). CS significantly improved from 40 preoperatively to 68 at last follow-up ($P < 0.001$). ROM improved as well, with active forward flexion 143° (range, $90^\circ - 170^\circ$), and external rotation 39° (range, $20^\circ - 70^\circ$). On the subjective shoulder scale, 96% rated their shoulder as good or excellent.

Glenoid notching was evident in 17 cases (19%). Factors relating to increased notching were increase in the gleno-metaphyseal angle ($P < 0.001$); insufficient inferior tilt ($P = 0.003$); and with an increase in the neck-shaft angle. There was no radiographic evidence of component loosening.

In 2015, Von Engelhardt, *et al.* showed a prospective study on 67 patients (56 stemless TESS, 11 stemmed TESS) with a mean follow-up of 17.5 months [37]. CS and DASH scores improved significantly (11.3 vs. 78.8, and 73.7 vs 31.8 respectively). One of the stemless prosthesis in the revision group showed loosening. Glenoid notching was observed in 9 cases (13.4%).

Discussion

There are over 15 years of clinical experience with the stemless prostheses discussed in this review, with clinical and radiographic outcomes that are at least as good as, if not superior, to their counterpart stemmed implants.

They have been designed as a bone preserving prosthesis, with only a minimal resection of bone from the humeral head, and without the need for a diaphyseal stem. The humeral shaft is not violated, resulting in less bone loss, shorter operating time, and avoids complications that are a major concern when preparing the shaft.

The rTSA is mainly performed in the older population, which are prone to recurrent falls. Any fall may carry the risk of a traumatic periprosthetic fracture. The tip of a stemmed prosthesis acts as a stress riser in the diaphysis, and therefore many fractures tend to arise in this area of bone. In contrast, a stemless prosthesis, which is fixed into the metaphysis significantly reduces the risk of a diaphyseal fracture, which may need further fixation or revision. Metaphyseal fractures also have the potential to heal better with conservative treatment than diaphyseal fractures due to better blood supply. Although management of risk of falls is not in the scope of this review, surgeons must keep in mind the “worst case” scenario in case of a fall, and how their choice of implant strategy, initially, may affect the need for revision surgery if such a fall may occur.

Levy, *et al.* [27] in their series had eight patients (of 149) that sustained periprosthetic fractures of the proximal humerus (metaphyseal fractures) following a fall. Six of them were treated conservatively and all healed with good to reasonable functional outcome (Figure 5). 2 patients suffered a displaced meta-diaphyseal periprosthetic fracture and had to be revised to a stemmed reverse prosthesis. Of note, they were indeed revised to a “regular” stemmed prosthesis. The ability to revise a patient to a stemmed implant from a stemless prosthesis effectively allows for another “revision stage”. This is especially important in young patients who may need to be revised in their lifetime.

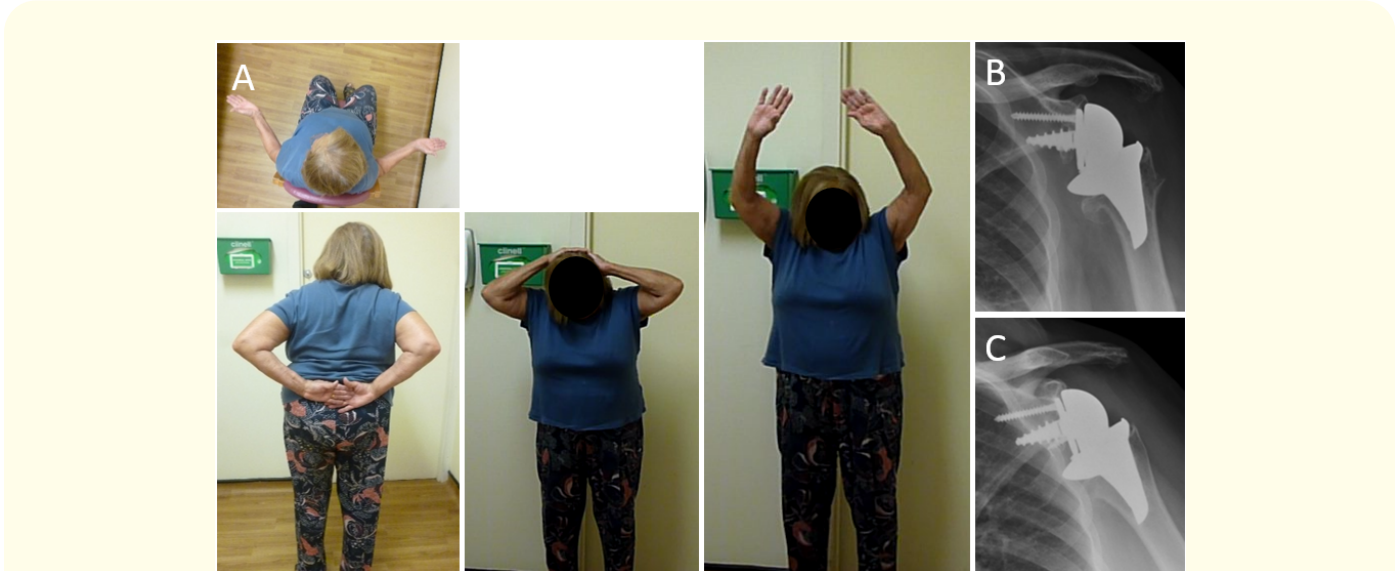


Figure 5: 80-year-old lady with a Verso rTSA (LT). Range of motion (A); Traumatic periprosthetic metaphyseal displaced fracture 7 years ago, treated conservatively (B); Immediate post-operative x-ray following Verso rTSA.



Figure 6: Clinical and radiographic outcomes of a 78-year-old lady with bilateral Verso rTSA.

Natera., *et al.* [38] assessed the long-term clinical outcomes of the Verso metaphyseal rTSA in young patients aged 65 or younger. 44 patients (29 F, 15 M) were followed for 2 to 11 years with a mean age for operation of 59 ± 6 years (range, 39 - 65 years). 17 cases were revision arthroplasties. The mean CS improved from 18.1 ± 11.9 to 60.1 ± 18.6 ($P < 0.001$) and SSV increased from 0.79/10 to 8.5/10 ($P < 0.001$). Active forward flexion improved by $82.7^\circ \pm 39.9^\circ$ reaching a mean of $141.1^\circ \pm 41.9^\circ$. Active abduction improved by $87^\circ \pm 39.9^\circ$ to a mean of $136.8^\circ \pm 44.7^\circ$. External rotation improved to $36.9^\circ \pm 21.4^\circ$ and internal rotation to $66.2^\circ \pm 23.1^\circ$. All improvements in ROM were found significant ($P < 0.001$). All patients reported a subjective improvement, with 68% rating their shoulder as “excellent”. Interestingly, outcomes at 12 months post-op and last follow-up were not significantly different. No differences were observed between primary and revision cases. No lucencies, subsidence, stress-shielding, glenoid notching, or implant loosening were evident radiographically at last follow up. The good clinical and radiological results were maintained over time.

Many of the activities of daily living (ADL) require sufficient rotations in the shoulder, such as peroneal hygiene. Although rTSA consistently show an improvement in forward flexion, improvement in rotational movements is less predictable. Concerns remain regarding bilateral rTSA over lack of rotations bilaterally and resultant difficulties with ADLs.

Levy., *et al.* [28] examined the outcome of 19 patients (15 women, 4 men; 38 shoulders) with bilateral rTSA in return to normal function and the ability to perform ADLs. The mean follow-up was 48.4 months (range, 24 - 75 months). The operations were performed in a staged manner, with duration of 18.2 months (range, 3 - 46 months) between operations. The CS improved from 18.7 to 65.1 points (age/sex adjusted - 100.2). Forward flexion improved from 57.5° to 143° , internal rotation (IR) from 9° to 81° (30 shoulders could reach the lumbar spine and further) and external rotation (ER) from 20° to 32° (in adduction). When measured in abduction, 31 shoulders achieved a full ROM. SSV improved from 2.1 to 9.2/10. The ADLEIR (Activities of Daily Living External and Internal Rotations), which was developed specifically to assess the rotational activities in ADL, was 33 of 36. Most patients resumed their leisure and sport activities at a nearly the same level. The authors concluded that bilateral Verso rTSA results in significant pain relief, predictable restoration of movements and ADLEIR scores, good to excellent functional outcomes and high patient satisfaction (Figure 6).

Patients with 'weightbearing' shoulders, using wheelchair or crutches for mobility are another population of concern. In theory, the extended range needed, and the constant loading of the shoulder prosthesis make it prone to dislocation and loosening. Arealis., *et al.* [32] assessed the long-term results of stemless Verso rTSA in 24 patients (30 shoulders) with 'weight-bearing' shoulders. The results in this group were identical to the non 'weight-bearing' shoulders group. CS improved from 9.4 (range, 2 - 26) points preoperatively to 59.8 (range, 29 - 80) points at final follow up ($P = 0.001$). The ADLEIR score was 32.4/36 at last follow-up. Forward flexion improved from 46° to 130°, ER from 13° to 35°, and IR from 29° to 78°. These were all statistically significant ($P < 0.001$). No dislocations occurred in this cohort. Radiographically, no sign of loosening or stress shielding were noticed. 6 cases of glenoid notching were found, 3 of them grade 1, and 3 grade 2. No intraoperative, early, or long-term complications were noted. Rehabilitation protocols do differ, however, in this subgroup of patients, as care should be taken to avoid any excess load through their shoulders while hoisted to the wheelchair. Some restrictions were therefore in place for the first 6 weeks.

To conclude, numerous studies have shown, reproducibly and reliably, that the stemless reverse implants discussed in this article achieve excellent and predictable outcome, with less invasive systems and a low rate of complications [26,27,31].

Moroder, *et al.* [39] investigated the short to mid-term results of stemless reverse shoulder arthroplasty in a selected patient population compared to a matched control group with stemmed implants, using the stemless TESS reverse prosthesis between 2009 and 2013. In only 18.4% of cases, a stemless prosthesis was applicable, due to poor bone quality. Clinically, the groups shared similar outcomes. At 35 months follow-up (range, 24 - 75 months), no significant difference was found in CS, ASES, SSV, pain, strength, and ROM between the groups. One patient in the stemless group suffered a traumatic dislocation. Radiographically, the stemless group had slightly better outcomes. Glenoid notching grade 1 was detected in two cases, compared with five grade 1 notching and four grade 2 notching in the stemmed group. No loosening of the humeral component was found. Beck., *et al.* [40] reviewed 49 shoulders who underwent rTSA with the TESS between the years 2006-2009 with a mean follow-up of 101.6 ± 24.6 months (range, 75 - 142 months). Survivorship at 101 months was 93.1%, with a revision rate of 17.2%. Scapular notching was found in 72.3% of patients. No cases of loosening occurred with the reverse corolla. All clinical scores - pain (VAS 7.5 ± 1.2 to 1.4 ± 1.5), quick-DASH (70.9 ± 12.0 to 28.9 ± 22.9), and CS (13.0 ± 3.7 to 60.5 ± 16.8), improved significantly. Both above authors concluded stemless rTSA with TESS show comparable clinical and radiographical results as its stemmed counterpart and conventional stemmed reverse shoulder arthroplasty.

Conclusion

Stemless metaphyseal implants growing in popularity amongst other manufacturers in recent years, based on the good results from the pioneer implants discussed in this article [41,42]. The percentage of usage of stemless reverse prostheses is constantly growing, though this is geographically afflicted, with future prospect of introducing these implants to the United-States health systems.

The inherent advantages of the stemless metaphyseal implants - bone preservation and providing an easier revisable system, if needed, along with the ground basis of excellent clinical and radiographic results for over more than 15 years of certain stemless reverse TSA designs, stand behind the constant rise in popularity of these implants. Surgeons should choose the implants they use with diligence, and on implants that have shown proven long-term evidence, longevity, and excellent results.

Conflict of Interest

O Levy receives equity and royalties from Innovative Design Orthopedics (IDO) as designing surgeon.

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