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**CURRENT CONCEPTS IN REVERSE SHOULDER ARTHROPLASTY**

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SUMMARY

**Introduction**

Reverse shoulder prostheses are increasingly used in recent years for the treatment of glenohumeral arthropathy with deficiencies of rotator cuff such as: rotator cuff arthropathy, rheumatoid arthritis, proximal humeral fractures sequelae, irreparable rotator cuff tears and failed shoulder replacement.

**Aim**

In this report, it was aimed to expose the surgical procedures towards reverse total shoulder arthroplasty basing on own experience and by a review of relevant literature on this topic.

**Material, methods and results**

Description of the implants, stemless metaphyseal cementless fixation, surgical techniques, clinical and radiographic results, complications as well as late post traumatic (due to the falls) periprosthetic fractures are provided in cases of patients after the total shoulder arthroplasties.

**Conclusions**

The bone preserving short metaphyseal rTSA design without a stem shows encouraging short to midterm results with excellent pain

**AKTUALNE POGLĄDY ODNOŚNIE ODWRÓCONEJ ENDOPROTEZOPLASTYKI BARKU**

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STRESZCZENIE

**Wstęp**

Odwrócona endoprotezoplastyka barku jest często stosowana w leczeniu operacyjnym zmian zwyrodnieniowych stawu ramiennego z masywnym uszkodzeniem ścięgien pierścienia rotatorów (RC) w wyniku zmian zwyrodnieniowych RC, nienaprawialnego uszkodzenia RC, reumatoidalnego zapalenia stawów, złamania bliższego końca kości ramiennej czy nie spełniającej swojej funkcji endoprotezy.

**Cel**

Celem tego doniesienia jest przedstawienie techniki operacyjnej odwróconej endoprotezoplastyki barku w oparciu o doświadczenie własne i dostępną literaturę.

**Materiał i metodyka**

W oparciu o doświadczenie własne przedstawiono konstrukcje implantów odwróconej endoprotezy, bezcementową technikę operacyjną wyróżniającą się budową trzpienia protezy, wyniki badań klinicznych oraz radiologicznych. Omówiono powikłania okołooperacyjne jak również złamania okołoprotezowe.

**Podsumowanie**

Pacjenci u których wykonano odwróconą endoprotezoplastykę z krótkim trzpieniem zgłaszają ustąpienie dolegliwości bólowych,

relief and shoulder function, restoration of good active range of motion and high patients' satisfaction scores. Radiographically, no implant loosening, subsidence or stress shielding are usually observed. The design of this implant seems to result in low incidence of glenoid notching (with low grade of notching) and improved rotational movements compared to the Grammont type prostheses.

**Keywords:** reverse total shoulder arthroplasty, replacement

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poprawę zakresu ruchu i funkcji stawu ramiennego. W badaniach radiologicznych nie zaobserwowano przypadków obluzowania protezy. Konstrukcja prezentowanego implantu ułatwia ruchy rotacyjne w stawie ramiennym w porównaniu od protezy typu Grammont.

**Słowa kluczowe:** odwrócona totalna endoprotezoplastyka barku, wymiana

*Data otrzymania: 6 luty, 2016*
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## Introduction

Reverse shoulder prostheses are increasingly used in recent years for treatment of glenohumeral arthropathy with deficiencies of rotator cuff such as: rotator cuff arthropathy, rhematoid arthritis, proximal humeral fractures sequelae, irreparable rotator cuff tears, and failed shoulder replacement (Neviaser and Neviaser 1981; Levy *et al.* 1999) Good mid-term and long-term results with restoration of active elevation have been reported (Pilliar *et al.* 1986; Grammont and Baulot 1993; Levy *et al.* 1999; Rittmeister and Kerschbaumer 2001; Gilbart and Gerber 2007; Favard *et al.* 2011; Ballas and Beguin 2013). However, early studies showed relatively high rates of complications (24%–50%) (Grammont *et al.* 1987; Frankle *et al.* 2005) and many of these required further surgery (Pilliar *et al.* 1986; Rittmeister and Kerschbaumer 2001; Sirveaux *et al.* 2004; Werner *et al.* 2005; Ballas and Beguin 2013, Teissier *et al.* 2015), therefore preservation of bone has become a major goal.

Due to the difficulties in revision of total shoulder arthroplasties (TSAs), especially in revision of a well-fixed stem (cementless or cemented), surgeons looked for ways to overcome these difficulties. One school introduced the concept of 'Platform systems' or 'Convertible stems' hereby, the stem can remain in-situ in the humerus and only the proximal component can be converted from anatomic to reverse TSA. The other school, led by the Reading Shoulder Unit, followed the same principles of shoulder resurfacing and introduced a stemless reverse TSA. These metaphyseal cementless implants without a diaphyseal stem have been developed to preserve bone and resect only minimal amount of bone (Sirveaux *et al.* 2001; Jacobs *et al.* 2001; Atoun *et al.* 2014; Arealis *et al.* 2015).

In 2005, it was introduced the first stemless reverse TSA clinical use with the Verso (Innovative Design Orthopaedics, London, UK – formerly, Biomet Swindon, UK) in UK and the TESS reverse in France (although in 80% of the cases the TESS was used with a stem) (Sirveaux *et al.* 2001; Jacobs *et al.* 2001; Atoun *et al.* 2014; Arealis *et al.* 2015).

## Aim

This report deals with the 10 years clinical and radiological experience with reverse total shoulder replacement with a novel stemless metaphyseal humeral design, discuss the design rationale and determine the safety and complication rate of this design.

## Materials, methods and results

*Description of the implant*

The humeral component is a short metaphyseal implant with three 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 (Figure 1).

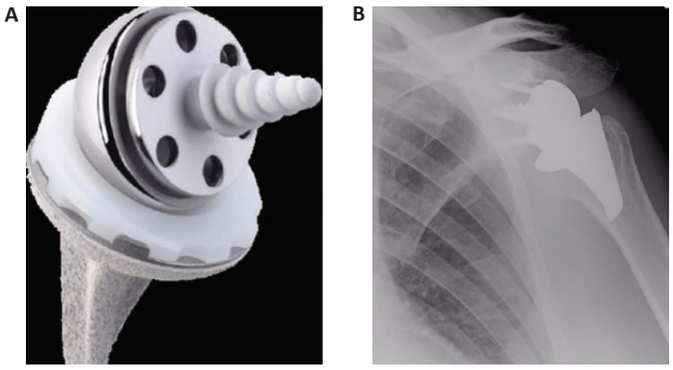


**Figure 1.** (A) Metaphyseal implant (Verso stemless reverse metaphyseal TSA). (B) Position of implant into the cancellous humeral metaphysis with bone graft from the resected humeral head (Verso stemless metaphyseal reverse prosthesis X-ray).

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, utilizing bone graft impaction technique. The glenoid baseplate has a central tapered screw (hydroxyapatite coated titanium) with the largest core diameter of 9 mm and additional 2 anti-rotational screws, superiorly and inferiorly (Figure 1). The glenoid sphere is fixed with 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 very low profile medially, that reduces the impingement between the polyethylene liner to the glenoid neck. The humeral cut is performed at 155° angle, with 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, adapted to each patient even after the definitive metal implants have been implanted. There are two glenoid sphere diameters and four different humeral liner offset options for each diameter.

The Grammont original implant was with inclination angle of 155°, some designs tried to change the angle to 145° or even 135° to try and address the glenoid notching. It seems that the optimal inclination angle is 145°.

The Verso rationale is to have the advantage of 155° humeral cut regarding stability, achieving clearance between the polyethylene liner and the inferior glenoid by using the 10° oblique liners. This way, the depth and stability are preserved, yet less notching and better rotational movement without impingement on the inferior glenoid achieved by removing the unnecessary polyethylene. Design rationale of the Verso Reverse Prosthesis and advantages are as follows: preservation of bone with minimal bone resection, the humeral bone resected is 'recycled' and used for bone graft impaction in the humerus.

*Stemless metaphyseal cementless fixation*
A stemless humeral implant was designed, in order to preserve as much native bone as possible and to avoid any complications relating to the humeral shaft (as fractures). This will allow better bone stock for any future surgery should the need arise.

The humeral implant consists of a short triple-tapered metaphyseal component with 3 thin fins. This structure provides immediate rotational press fit of the prosthesis to the humeral metaphysis and further biological fixation to the titanium porous and hydroxyapatite coating. This design provides direct load transfer to the humeral cancellous bone in the metaphysis, which minimizes stress shielding and leads to improved bone quality underneath the prosthesis. The glenoid baseplate has a tapered central titanium screw fixation with hydroxyapatite coating. The baseplate has 6 screw holes, enables use of 2 antirotation screws superiorly and inferiorly. In case of fracture or deficient glenoid bone these can be used for osteosynthesis as well. This glenoid baseplate structure was proved to provide the best fixation in a study comparing 6 different reverse shoulder designs at the Imperial College London (Teissier *et al.* 2015). The humeral polyethylene liner is designed as 10° angled rim dialable liner in order to reduce the glenoid notching as well as to improve rotational movements.

*Surgical techniques*
The procedure is performed through the anterior-superior approach to the shoulder (Naviaser-MacKenzie approach) (Levy and Copeland 2001; Matsen *et al.* 2007; Levy *et al.* 2013). In the revision cases where deltopectoral approach was used in the primary operation, the old skin incision is extended and the anterior-superior approach is used subcutaneously. Twenty millimeters slice of proximal humeral bone is resected using a guide, in 30° of retroversion. The resected bone is used for bone graft impaction into the humerus. The humeral triple tapered finned component if 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 (Figure 1). The glenoid component is implanted in 10° downwards inclination at the inferior border of the glenoid with good initial press fit fixation.

*Clinical and radiographic results*
Clinical experience with the Verso reverse TSA span over 10 years. The first 102 consecutive patients operated with Verso stemless reverse total shoulder prosthesis have been reported (Sanchez-Sotelo 2009). Ninety-eight were available for follow-up analysis. Two patients did not return for later follow-up appointments due to unrelated medical and social reasons, and two patients died. The average follow-up was 50 months (4 years and 2 months) (range 24 – 82 Months). There were 20 males and 78 females. The mean age at surgery was 74.4 years (range from 38 to 93 years). Sixty-five patients represented cuff arthropathy, 12 fracture sequelae, 13 rheumatoid arthritis, 3 failed rotator cuff (RC) repairs, 3 for loosening of anatomical prosthesis and 2 for acute trauma (dislocation with massive rotator cuff tear and preceding arthritis). Seventeen of these patients were operated as the revision arthroplasty. There were 16 were revisions of resurfacing prostheses and 1 revision of a stemmed prosthesis.

Shoulder functionality was assessed using the Constant Score and patient satisfaction was assessed by the Subjective Shoulder Value (SSV) (Constant and Murley 1987). Video recordings of the range of movement (ROM) of all the patients were taken preoperative and on every follow-up and kept on database. Patients' satisfaction (SSV) improved from 8/100 pre-operatively to 85/100 post-operatively (95% CI 77–94).

Mean Constant Score (for all diagnoses) improved from 14 pre-op to 59 at last follow-up. Age/sex adjusted Constant score

improved from 21 preoperatively to 86% at the last follow-up ($p < 0.0001$, paired t-test).

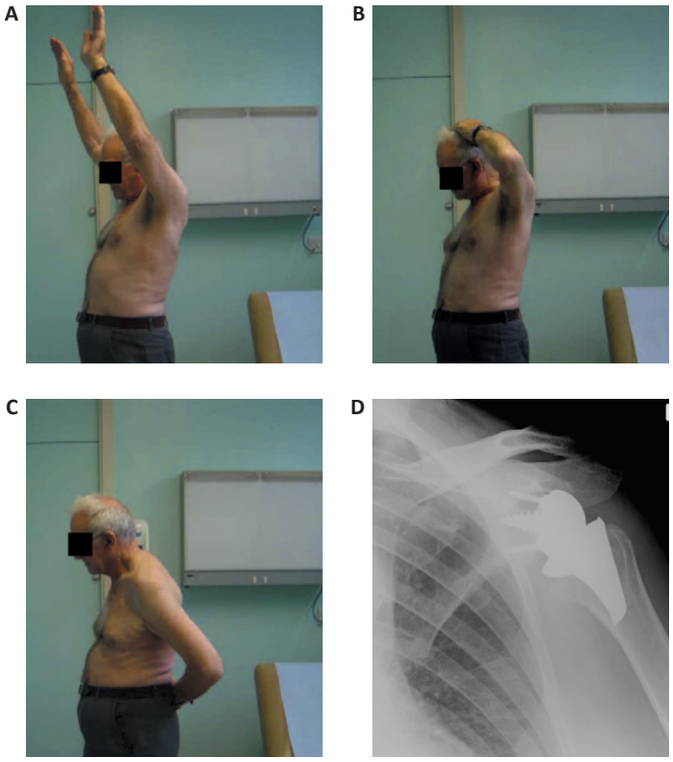


**Figure 2.** (A) Postoperative follow up the patient's range of motion – forward flexion. (B) Postoperative follow up the patient's range of external rotation. (C) Postoperative follow up the patient's range of internal rotation. (D) Postoperative follow up the patient's X-ray.

The mean range of movement improved from 46.8° to 128.5° in forward flexion, 50.8° in external rotation and 64.6° in internal rotation. All patients but one resumed normal or near normal daily and leisure activities (Figure 2).

The postoperative radiographic analysis showed no glenoid notching in 77 shoulders. In 21 patients there were observed glenoid notching (21.4%). Interestingly, these cases appeared only 3 to 4 years after surgery. 18 of these patients had glenoid notching grade 1 or 2 (Nerot-Sirveaux) (De Wilde *et al.* 2001), and only in 3 cases grade 3 glenoid notching. Development of an inferior glenoid traction osteophyte (along the triceps insertion) was noticed in 46 shoulders. This did not seem to affect the outcome. No radiolucency was observed around either the humeral or glenoid components at latest follow-up. There were no prosthetic humeral or glenoid migration, change in position or loosening of the stemless 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.

*Complications*

Two cases had a crack of the humeral metaphysis due to excessive bone impaction in very soft bone and one glenoid rim was cracked during preparation. All these healed completely around the implants at three months with conservative treatment with no effect on the outcome. They did not show any lucencies or loosening at the follow-up.

There were two early dislocations; this was early in the series, most probably as part of the learning curve, one due to wrong

liner version and the patient putting weight on his shoulder in extension of the shoulder (to push himself out of chair) one week post-surgery. The other was due to an inferior glenoid osteophyte that was not removed at time of surgery and hinged the shoulder to dislocate. Both were re-operated and are doing well.

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 that was unnoticed during surgery. The patient was re-operated and the glenoid head reinserted with uneventful recovery.

Two patients developed pathological fracture of acromion, few months after surgery. One patient made a full recovery with no treatment. She regained full range of motion and function with no pain. The other patient fractured the base of the acromion in the scapular spine. She was operated with plating of the spine of the scapula and the acromion and made a good recovery with reasonable function and almost no pain.

*Late post traumatic (fall) periprosthetic fractures*

Six patients sustained the late traumatic periprosthetic fractures due to falls. One patient sustained a glenoid periprosthetic fracture following a fall 3 months after surgery and refused further surgery. In another patient, the glenoid sphere was revised with good outcome. Three patients sustained periprosthetic fractures of the proximal humerus (metaphyseal fractures) following a fall. They were treated conservatively and all healed with good function. One patient sustained displaced periprosthetic fractures of the proximal humerus and had revision to a stemmed reversed prosthesis. She made good recovery with restoration of good function.

Levy *et al.* (2014) evaluated the clinical outcome after bilateral stemless Verso rTSA in restoration of function and ADLs (Daily Living Activities). 15 consecutive patients (30 shoulders) (mean age 75.8y) who underwent staged bilateral rTSA between 2007–2012 with minimum follow-up 1 year were prospectively evaluated. Mean duration between the staged operations was 18.8m (4–46 m). CS improved from 18.7 (2–38) preoperatively to 57.3 (12–87) (89% age/sex adjusted) at last follow-up. Elevation improved from 57.5° to 134.6°, internal rotation (IR) from 9° to 28.6° (in 20 shoulders could reach above SI joint). External rotation (ER) improved from 20° to 68.3°, 22 shoulders had full ER in elevation. SSV improved from 2.1/10 to 8.6/10. Mean ADLEIR Score 31.2/36. Most patients resumed their leisure activities (gardening, golf).

Bilateral stemless Verso rTSA resulted in marked improvement in all movements, pain, and functional outcomes, with high patient satisfaction and high ADLEIR Score. All patients were able to perform perineal hygiene after their rTSA. Most patients had no limitation in ADLs and their activities.

The same authors evaluated midterm results of a stemless rTSA (Verso) in 47 rTSAs patients under the age of 70 years, operated between 2005 and 2012. Mean age of 17 males was 62.7 (range from 38 to 70 years). Twenty-four of the were treated because of the cuff arthropathy, 15 were cases of rheumatoid arthritis, 6 because of fractures sequelae, 1 because of instability arthropathy and 1 because of osteoarthritis (OA). Twenty-six patients had undergone previous surgery. Mean follow up is 33.7 months (range from 26 to 74 months). The adjusted Constant score increased from 20.2 to 84.5 ($p < 0.001$). The subjective shoulder value increased from 0.79/10 to 8.45/10 ($p < 0.001$). Forward elevation improved from 57.5° to 146.4°; external rotation from 22.5° to 40.9° and internal rotation from 35° to 70° ($p < 0.001$). Pain scores decreased from 11.43 to 3.27 and strength increased from 0.3 kg to 3.1 kg ($p < 0.001$). The study demonstrated the excellent midterm clinical and radiographic

results of the Verso stemless rTSA in younger patients.

Arealis *et al.* (2015) assessed the long-term results of Verso rTSA in patients with 'weight-bearing' shoulders, using wheelchair or crutches, which theoretically have higher risks. Twenty-four patients with 'weight-bearing' shoulders using mobility aids were treated between 2005 and 2014, with rTSA for limitation of function and pain, 18 patients were female and 6 had bilateral shoulder problems. In total, 30 shoulders were operated, 21 (70%) of them for cuff arthropathy, 3 (10%) for rheumatoid arthritis, 1 (3.3%) for osteoarthritis with Walch B2 glenoid, 3 (10%) for acute fracture and 2 (6.7%) for fracture sequela. In 4 cases (3 acute fractures and one fracture sequela) stemmed implant was used. In 26 cases stemless rTSA used. All patients had mobility problems, 19 used wheelchair and five used crutches to mobilize. Antero-superior (Neviaser-MacKenzie) approach was used in all cases and postoperatively physiotherapy was commenced immediately. The patients were advised not to push themselves out of chair or bath with the operated arm for 6 weeks. Twenty-one patients (with 27 shoulders) were available for late follow-up at mean follow up of 4.5 years (range from 1 to 10 years). Median age at the day of surgery was 78 years (range from 54 to 90 years). Constant score improved from 8 points (range from 2 to 26) preoperatively to 63 points (range from 29 to 80) at final follow up ($p = 0.001$). Pain improved significantly from median 1/15 preoperative (range 0–8) to 15/15 postoperatively (range 9–15) ($p = 0.001$). Patient satisfaction increased from 0/10 to 10/10 ($p = 0.001$) at final follow up.

Significant improvement in median range of motion from 40° to 125° of elevation, 5° to 30° of external rotation and 30° to 90° internal rotation was recorded ($p = 0.001$). Most patients resumed their normal activities. Final mean ADLEIR score (Activities of Daily Living External and Internal Rotation score) was 33/36 (range 16–36). No dislocations or instability occurred. Radiographically, no lucencies, subsidence, stress shielding or implant loosening were evident on the X-rays both on the humeral and the glenoid side. There were 3 Sirveaux-Nerot grade 1 (10%) and 3 grade 2 (10%) glenoid notching. No intraoperative, early or long-term complications were noted.

Reverse TSA can be used successfully and safely for the treatment of patients with 'weight-bearing' shoulders using wheelchair or crutches. However, this may be the implant specific. Patients return to almost full and pain free movement, resume daily activities and have high satisfaction rate.

*Reverse Total Shoulder Replacement for acute proximal humeral fractures in patients over 70 years*

Good functional outcome of reverse total shoulder replacement (rTSA) in cases that the cuff arthropathy has been reported. In recent years, the use of rTSA for treatment of acute proximal humeral fractures in the elderly is gaining popularity with early and consistent return to pain free activities. Between 2007–2014, 17 patients, 1 bilateral, with acute complex proximal humerus fractures were operated and evaluated (range from 6 months to 8 years post-op). The outcome evaluation included the pain score, constant score (CS), patient satisfaction score (SSV), return to function including daily, leisure and sport activities. Radiologic assessment and video recording of function in every follow-up visit have been performed. The Neviaser-MacKenzie approach with acromioplasty and acromion-claviculare joint excision were used. The tuberosities were reattached to the humeral shaft and around the prosthesis with suture fixation. All patients were discharged within 2 days from surgery. Mobilization was commenced at 3 weeks including deltoid exercises.

Pain significantly improved in the first 3 months (9.5/15) and improving was

observed to be continued at six months (12/15). The patients were pain free at the final follow up (15/15). Patient's satisfaction improved from 6/10 to 8/10 and 9/10 post surgery respectively. Constant and ADLEIR scores were 72 and 36/36 respectively. All patients resumed their normal ADLs as early as 3 months post-surgery. Forward flexion improved to 90° at 3 months and 155° at final follow up. External rotation was scored 40°, 60° and 85° as well as internal rotation 20°, 30° and 42.5° at 3, 6 months and final follow-up, respectively. Radiographically, the tuberosities were healed at 6 months in all the cases. One inferior glenoid traction osteophyte and one of glenoid notching (grade II with sclerotic margin) were seen (5%). No lucencies, subsidence, stress shielding or implant loosening were evident on the X-rays. No intra-operative, immediate or late postoperative complications were noted.

The stemmed rTSA with dialable polyethylene liner with reattaching the tuberosities seem to be safe and successful for the treatment of comminuted and complex proximal humeral fractures in patients over 70 years. Pain-free motion adequate for daily activities can be expected within 3 months from surgery with high satisfaction 9/10 (Figure 3).

**Discussion**

The 10 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 the vast majority of the patients were very satisfied with their shoulders (85/100). Good clinical outcome was observed for all the diagnoses with improvement of the Constant Score from 14 preoperatively to 59 (age/sex adjusted 86) at last follow-up.

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

Complications related to the humeral stem with stemmed reverse prostheses accounted for 10%, 4–20%, including periprosthetic fracture, shaft perforation, disassembly, and loosening (Boulahia *et al.* 2002; De Wilde *et al.* 2002; Steinmann and Cheung 2008; Zumstein *et al.* 2011; Boyle *et al.* 2012). Zumstein *et al.* (2011) reported 16 intraoperative humeral fractures and 24 intraoperative complications (67%) related to the humeral stem. Two cases in our series had an undisplaced fracture of the humeral metaphysis intraoperatively. These healed completely around the implants with conservative treatment over three weeks with no effect on the functional outcome. They did not show any lucencies or loosening at the latest follow-up.

Melis *et al.* (2011) found radiological 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).

Neither lucencies nor resorption of bone around the humeral component suggestive of stress shielding were seen in the presented series. An explanation may be that as 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 triple tapered finned humeral component combined

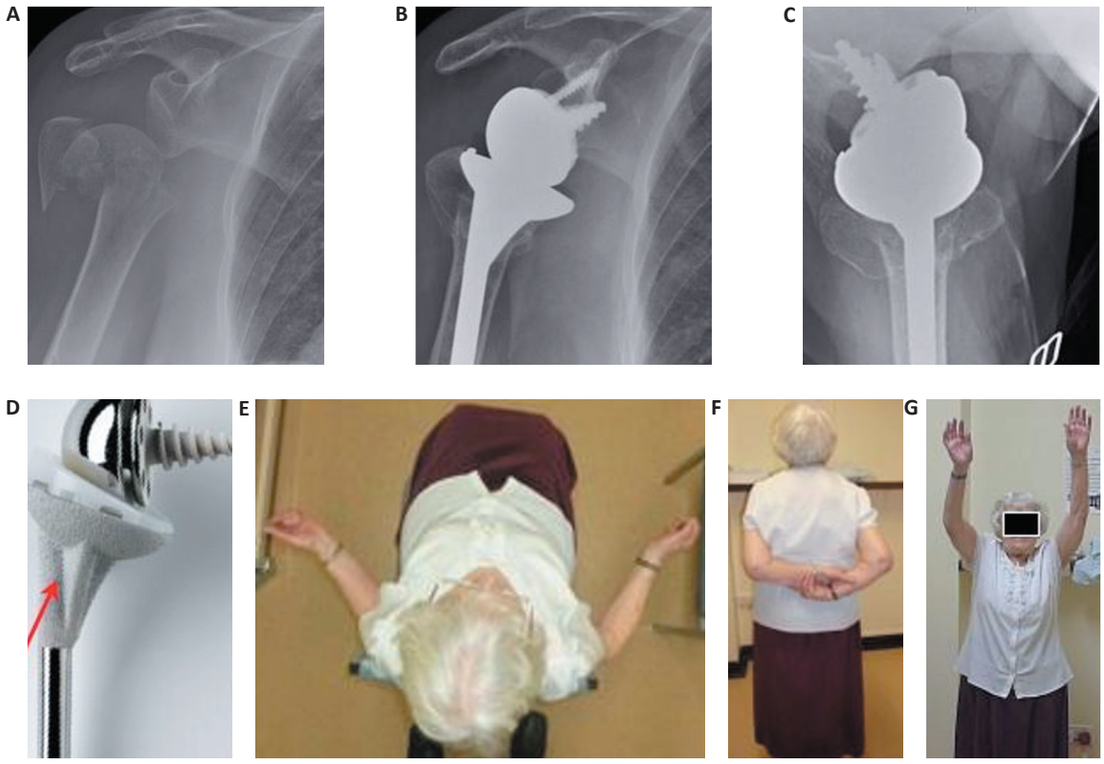


**Figure 3.** An example of the reverse TSA in acute humerus fracture. (A–C) X-rays providing pictures of revision for the stemmed prostheses. (D) Low profile proximal prosthesis with places for attachment of the tuberosities. (E–G) Clinical functional tests for range of movements evaluating the results after surgical treatment.

with bone graft impaction technique may improve the density and resistance of the metaphyseal bone.

Scapular notching has been observed in more than 50% of cases in most series with reverse shoulder prostheses (Pilliar *et al.* 1986; De Buttet *et al.* 1997; De Wilde *et al.* 2001; Nyffeler *et al.* 2004; Sirveaux *et al.* 2004; Rittmeister and Kerschbaumer 2001; Boileau *et al.* 2005; Werner *et al.* 2005; Simovitch *et al.* 2007; Farshad and Gerber 2010; Nam *et al.* 2010; Melis *et al.* 2011; Lévigne *et al.* 2011; Day *et al.* 2012; Levy *et al.* 2014). This is a common radiographic finding at early follow-up (Pilliar *et al.* 1986; De Buttet *et al.* 1997; De Wilde *et al.* 2001; Rittmeister and Kerschbaumer 2001; Boileau *et al.* 2005; Sirveaux *et al.* 2004; Nyffeler *et al.* 2004; Werner *et al.* 2005; Farshad and Gerber 2010; Nam *et al.* 2010; Melis *et al.* 2011; Day *et al.* 2012). In Boileau *et al.* (2005) series, notching at the inferior aspect of the glenoid was present in 74% of cases, and this extended to or beyond the inferior screw (Nerot-Sirveaux grade 3) in 30% cases. 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 (Melis *et al.* 2011). Levigne *et al.* (2011) study confirms that scapular notching after Grammont type reverse shoulder arthroplasty is frequent, 62%, similar to some previously published reports (Rittmeister and Kerschbaumer 2001; Sirveaux *et al.* 2004; Vanhove and Beugnies 2004; Werner *et al.* 2005; Boileau *et al.* 2005; Farshad *et al.* 2010; Kinds *et al.* 2011; Ballas and Beguin 2013; Spormann *et al.* 2014; Teissier *et al.* 2015). Their study also confirms what Wegner *et al.* (2015) previously reported, that notching occurs early after surgery, as 68% of the latest follow-up notches were already visible 1 year after the operation (Teissier *et al.* 2015).

Melis *et al.* (2011) reported 88% glenoid notching in series of patients with Grammont type rTSA with follow-up over 8 years. They observed increase in 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.* (2011) and Zumstein *et al.* (2011) in meta-analysis, have noted a negative effect of radiographic scapular notching on the clinical outcome: if the notch is large (extending beyond the inferior screw), the Constant score was significantly lower and the risk for loosening was high in their series.

The medialization in the center of rotation to the level of the glenoid surface and orienting the humeral cup almost horizontally have been the biomechanical solutions found by Grammont (1987; 1993) to avoid excessive forces on the glenoid component and improve the power of the deltoid. But, the pay off, in return, can be the scapular notching and polyethylene wear.

Other studies with increased lateralized center of rotation prosthetic design have showed lower rates of glenoid notching but higher rate of mechanical glenoid failure (12%, 7/60), requiring revisions (Favard *et al.* 2011; Hamid *et al.* 2011). The use of excessive lateral center of rotation increases the moment at the baseplate-bone interface on the glenoid and can lead to failure of the fixation. In more recent study, the glenoid fixation design was improved (to reduce the glenoid failures) and the glenoid baseplate placed inferiorly with a tilt to decrease notching. Cuff *et al.* (2008) found low rate of glenoid notching with less glenoid failures (but with 24.1% (27/112) of the patients lost to follow-up).

Glenoid notching was observed in 21 cases of presented series (21.4%). In 18 of these patients it was mild glenoid notching (Nerot-Sirveaux grade 1 or 2). In these patients the glenoid notching seemed to be non-progressive with sclerotic margin. Only in 3 cases a Nerot-Sirveaux grade 3 glenoid notching were observed. This low rate compares favorably with most of the published series with 44% to 96% in different series (Pilliar *et al.* 1986; De Buttet *et al.* 1997; De Wilde *et al.* 2001; Rittmeister and Kerschbaumer 2001; Nyffeler *et al.* 2004; Sirveaux *et al.* 2004; Boileau *et al.* 2005; Farshad *et al.* 2010; Nam *et al.* 2010; Melis *et al.* 2011; Day *et al.* 2012; Ballas and Beguin 2013).

The 3 mm lateral offset of the glenoid implant baseplate, may reduce the risk of impingement between the liner and the glenoid neck without increasing substantially moment at the baseplate-bone interface. The use of the 10°-angled dialable polyethylene liner reduces the neck-shaft angle of the humeral component to 145°. The depth of the dialable liner socket is preserved and only the edges of the liner are removed, hence, reducing the impingement of the liner with the scapula inferiorly, as well as anteriorly and posteriorly in rotations, without increasing the risk of prosthetic instability. The shape of the retrieved eroded Delta prosthesis humeral liner during revision surgery resembles our polyethylene liner (Mackenzie 1993; Melis *et al.* 2011; Day *et al.* 2012). The use of the 10°-angled dial-able liner reduces the risk of notching as well as of osteolysis triggered by polyethylene particles (Melis *et al.* 2011).

According to Werner *et al.* (2005) and a large French multicentre study by Lévigne *et al.* (2011), notching occurs early after surgery and progress in severity with time (Favard *et al.* 2011; Lévigne *et al.* 2011). The fact that in the presented sample it was seen only 21.4% of glenoid notching so far in this series with this stemless reverse prosthesis, with a follow up period of 24 to 82 months is very encouraging.

The rate of glenoid component loosening reported in the literature for rTSA range between 2% to 5% (De Buttet *et al.* 1997; Rittmeister and Kerschbaumer 2001; Sirveaux *et al.* 2004; Werner *et al.* 2005; Hopkins and

Hansen 2009; Farshad and Gerber 2010; Nam *et al.* 2010; Day *et al.* 2012). No radiolucent lines were seen around the glenoid component in our series so far, with follow-up of 24 to 82 months. Hopkins and Hansen (2009) assessed the glenoid components of six different reverse shoulder prostheses and compared the primary stability through the minimization of interface micro-motions. The glenoid baseplate of this stemless rTSA design was the most stable with peak micro-motions of less than 48 microns. When the relative displacement of the bone-implant interface (termed 'micro-motion') is below a threshold of 150 $\mu$m, it is assumed that the implant will not induce the generation of unwanted fibrous tissues (Nam *et al.* 2010), and micro-motions below 50 $\mu$m 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 (Levy *et al.* 1999; Frankle *et al.* 2005; Ballas and Beguin 2013; Kadum *et al.* 2014; Wagner *et al.* 2015). This may affect the functional ability of patients to perform their simple daily activities (Frankle *et al.* 2005).

It was found significant improvement in the rotational movements in the presented series compared to published series with other reverse prostheses (Levy *et al.* 1999; Frankle *et al.* 2005; Guery *et al.* 2006; Ballas and Beguin 2013; Kadum *et al.* 2014; Wagner *et al.* 2015). Karlse *et al.* (2008) described the hinging movement of the rTSA humerus around the centre of rotation compared with the anatomic shoulder that spins around the centre of rotation. They 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. Similar observations refer to internal and external rotation – limiting the range of rotational motion (Kadum *et al.* 2014). 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. Indeed, asymmetric polyethylene wear has been observed on most retrieved humeral reverse prostheses liners (Mackenzie 1993; Melis *et al.* 2011; Day *et al.* 2012).

The use of the oblique dial-able liners of this implant 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 dial-able 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. Beside, 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 (Ballas and Beguin 2013).

Reverse TSA are usually implanted in elderly patients, which have tendency to suffer from trips and falls. They therefore, have an increased risk to suffer late traumatic prosthetic fractures (Boulahia *et al.* 2002; Williams and Iannotti 2002; Werner *et al.* 2005; Andersen *et al.* 2013). 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) (Boulahia *et al.* 2002; Werner *et al.* 2005; Andersen *et al.* 2013). Andersen *et al.* (2013) concluded that periprosthetic fracture around a humeral stem implant is a difficult clinical problem involving complex decision-making, difficult surgery with frequent complications and high reoperation rate.

Zumstein *et al.* (2011) observed negative impact on the clinical outcome in cases 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 ones with conservative treatment as shown in the presented 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 prosthesis. Furthermore, intraoperative humeral fractures are more of a problem in revision surgery. It is observed 'exponential' increase in revisions of both anatomic and reverse TSA in recent years (Cuff *et al.* 2008). By using prosthesis without a stem, we reduce there can be reduced the risk of intraoperative humeral fracture if revision will be necessary. There are limitations to the use of stemless reverse implants, as they are not suitable for treatment of cases with acute fracture, fracture nonunion or revision of stemmed prosthesis. For these cases a stemmed implant should be used.

*Platform systems/Convertible stems – do they work?*

The other school of "convertible stems" has gained popularity in the recent years, as it seem appealing to the surgeons that are using stemmed implants. However, this concept that seems at first sight as a good idea is not more than a sales gimmick. When observing industry's nice brochures, it seems quite easy to retain the stem in situ and just revise the proximal component. When looking more carefully, measuring the distance between the glenoid to the proximal humeral cut, it becomes clear that the distance ('soft tissue gap') is double in the reverse TSA configuration (Figure 4).

Therefore, if the primary anatomic shoulder was performed as 'perfect' (the best case scenario), already the revision to reverse TSA while keeping the stem in the same height will cause overstuffing of the soft tissues (may double the tension). This is in the 'best case scenario'.

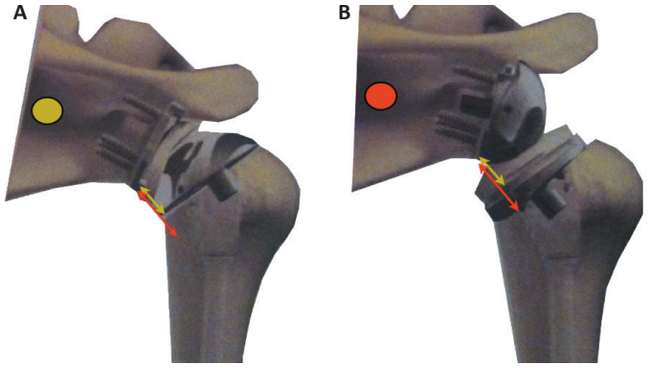


**Figure 4.** (A) 'Platform /Convertible stem'. The measurement of the reverse TSA gap (B) is double than the anatomic gap (A).

The most common reason for revision of a well-fixed stem in shoulders is that the first surgeon got it wrong. Either wrong height or wrong version can be applied, in these cases the stem should be revised and removed (Figure 5 A–D).

## Conclusions

The bone preserving short metaphyseal rTSA design without a stem shows encouraging short to midterm results with excellent pain

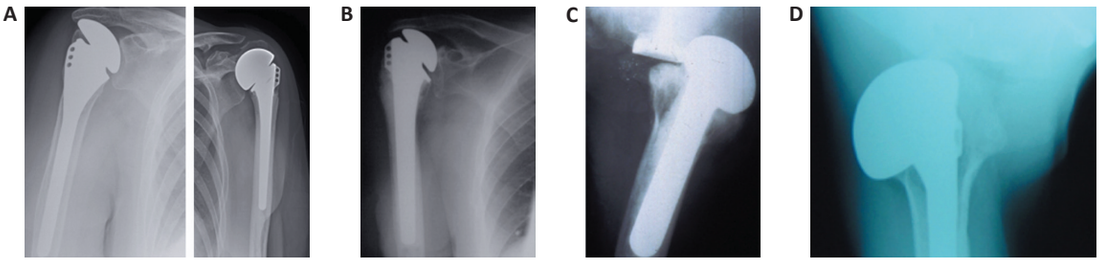


**Figure 5.** Examples of X-rays (A–D) presenting the common reasons for revision of "well-fixed" stem.

relief and shoulder function, restoration of good active range of motion and high patients' satisfaction scores. Radiographically, no implant loosening, subsidence or stress shielding are usually observed. The design of this implant seems to result in low incidence of glenoid notching (with low grade of notching) and improved rotational movements compared to the Grammont type prostheses.

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