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ORIGINAL ARTICLE • SHOULDER - ARTHROPLASTIE

Reverse shoulder arthroplasty with a cementless short metaphyseal humeral prosthesis without a stem: survivorship, early to mid-term clinical and radiological outcomes in a prospective study from an independent centre

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Abstract

Introduction The use of reverse total shoulder arthroplasty has increased for the management of cuff-deficient glenohumeral joint arthritis and fractures. With bone preservation being a major target in reverse shoulder arthroplasty, metaphyseal humeral components without a stem were developed. The aim of this study is to present the survivorship, functional and radiological outcomes of a novel short metaphyseal prosthesis without a diaphyseal stem from an independent centre.

Methods Clinical function and radiological features of patients undergoing stemless reverse shoulder arthroplasty were prospectively recorded. Patients' demographics, indications for surgery, complications, functional and radiological assessment at the final follow-up as well as survivorship with the end point of revision for any reason were recorded.

Results Between 2009 and 2016, 36 patients received 37 reverse shoulder arthroplasties with the stemless Verso prosthesis. Mean age of the patients was 76.9 years. The most common indication for surgery was cuff tear arthropathy. Mean follow-up was 3 years (range 1–7 years). Oxford shoulder score improved from an average of 11 pre-operatively (range 2–19) to 44 post-operatively (range 29–48) ($p < 0.0001$). There was one case of a deep post-operative infection that needed washout, liner exchange with retention of the prosthesis. Radiographic analysis showed no lucencies, or stress shielding around the humeral or glenoid components. Constant score at the final follow-up was on average 63 (range 35–86). Activities of daily living with requirement for internal and external rotation score (ADLEIR) was on average 12 pre-operatively (range 0–27) and 31 post-operatively (range 18–36) ($p < 0.0001$). There was 100% survivorship of the prosthesis in this early to mid-term study.

Conclusion This early to mid-term prospective study demonstrates excellent survivorship and radiological results of the Verso reverse shoulder replacement. It needs a simple reproducible technique, and the results have been replicated at an independent centre. This study underlines its survivorship in the early to mid-term and confirms lower incidence of complications such as instability, notching, loosening and the need for revision surgery. Most importantly, it conserves the humeral bone stock for revision arthroplasties in the future. Our results are similar to those of the currently published literature.

Keywords Reverse shoulder replacement · Stemless · Uncemented · Clinical and radiological results · Constant score

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Introduction

The use of reverse shoulder prosthesis has significantly increased for a variety of indications including cuff tear arthropathy, complex proximal humerus fractures in the elderly, failed hemiarthroplasties and total shoulder arthroplasties [1–5]. With increasing use of this design, more complications are coming to light with various studies [6]. Some problems such as notching are exclusive to this prosthesis [7–9]. Many complications such as peri-prosthetic fractures, dislocations and implant disassembly necessitate revision surgery [1, 6, 10, 11].

Systems having stemless humeral components have now been introduced. These implants have uncemented metaphyseal fixation and preserve the humeral bone stock for future surgeries [12–14]. Moreover, the peri-prosthetic fractures with these implants occur in the metaphyseal area and generally require conservative treatment. Very few studies are available on the clinical and radiological results of these implants [12–16]. Also the survivorship of these implants in the long term is still being studied.

In this study, we have reviewed the early to mid-term clinical and radiological results of the Verso (Innovative Design Orthopaedics, London, UK) stemless reverse metaphyseal total shoulder arthroplasty prosthesis. This is one of the few studies done at an independent centre by a non-designer surgeon. The Verso is a stemless reverse shoulder prosthesis, and the original idea behind it was 'less is better' and to plan the journey of the patient through time. The idea was to begin with something simple and build over it if required in the future.

Materials and methods

This study included prospectively collected data for patients undergoing reverse shoulder arthroplasty with the stemless Verso prosthesis (Innovative Design Orthopaedics, London, UK) by a single surgeon (J.R.) at a single centre. There were a variety of indications for the surgery including glenohumeral arthropathy, rotator cuff tear arthropathy, rheumatoid arthritis, post-traumatic sequelae and revision of hemiarthroplasties. The ideal indication for this prosthesis was patients with cuff tear arthropathies or glenohumeral concentric arthropathies with a reasonable metaphyseal bone stock. Contraindications to use the stemless metaphyseal prosthesis included extremely poor metaphyseal bone stock, fractures with significant metaphyseal comminution and fractures with distal extension. However, impaction bone grafting can be done in cases of osteoporosis and metaphyseal bone loss. Patients having infections and neurological involvement were excluded from the study. Any patient who needed a stemmed prosthesis was also excluded. All patients were operated by the modified Neviaser–Mackenzie approach or the anterosuperior approach.

The Verso (Innovative Design Orthopaedics, London, UK) is a stemless, metaphyseal reverse total shoulder arthroplasty prosthesis. It has a short metaphyseal humeral component with three fins which is impacted into the humerus with or without bone graft from the resected humeral head. This achieves press-fit fixation, and along with the porous titanium and hydroxyapatite coatings, it helps achieve biological integration into the humerus. The humeral shell comes in four incremental sizes with the fins progressively increasing in size. This helps the prosthesis to capture a better hold in humeri with larger metaphysis. The glenoid baseplate has a central tapered screw with a recommendation of putting two derotation screws. The polyethylene humeral liner is inclined at 10 degrees with a very low medial profile that helps to reduce impingement against the scapular neck and notching. The glenosphere is available in two diameters (36 mm and 41 mm). The offset of the humeral liner can be changed by dialling it in different directions, thereby providing additional stability in a particular direction when required. There is a retentive deep cup option of the liner which can be used in situations where more stability is desired [12] (Fig. 1).

Fig. 1 Verso (Innovative Design Orthopaedics, London, UK) reverse shoulder prosthesis; **a** ultrahigh molecular weight polyethylene liner with a low medial edge that prevents notching; **b** stemless prosthesis preserves distal humeral bone stock; **c** three finned humeral component to provide metaphyseal hold; **d** tapered glenoid screw

The Oxford shoulder score was recorded pre-operatively and post-operatively at each follow-up visit. The Constant shoulder score which takes into account the pain, activity, range of motion and function was also recorded in the post-operative period. Activities of daily living with requirement for external and internal rotation score (ADLEIR) was also recorded pre-operatively and after surgery. The ranges of motion including forward elevation, abduction and external rotation were recorded as well.

Radiographic analysis was done by an independent shoulder surgeon. The views included a true AP view and an axillary view of the shoulder. A number of parameters including lucencies around the glenoid and humeral components were studied (Fig. 2). The Nerot–Sirveaux classification [7] was used to classify the degree of notching. Serial radiographs were used to assess for evidence of subsidence, migration, osteolysis, loosening and stress shielding.

The data were recorded in an Excel Sheet database (Microsoft Corp, Redmond, WA, USA). Statistical analysis was performed using SAS 8.2 software (SAS Institute Inc, Cary, NC, USA). The paired '*t*' test was used to determine the difference in the pre-operative and post-operative scores. The study was performed in accordance with the ethical standards laid down by the 1964 Declaration of Helsinki and its later amendments.

Between 2009 and 2016, a total of 36 patients underwent 37 reverse shoulder arthroplasties with the Verso reverse total shoulder arthroplasty. Of these, 27 were female while 9 were replacements in male patients. The mean age at which the patients underwent the surgery was 76.9 years.

There were a large variety of indications for the surgery. The most common indication, however, was cuff tear arthropathy. Twenty-two patients had the surgery for cuff tear arthropathy. The other indications included rheumatoid arthritis (5 patients), chronic anterior dislocations (2 patients), failed resurfacing prosthesis (4 patients), late sequelae of proximal humerus fractures (3 patients) and acute trauma (one patient) (Fig. 3). The mean follow-up was 3 years (range 1–7 years) (Table 1).

Results

On clinical assessment post-operatively, mean elevation was 133 degrees (range 60–160), mean abduction 110 degrees (range 60–160) and mean external rotation 30 degrees (range 10–60). Oxford shoulder score improved from an average of 11 pre-operatively (range 2–19) to 44 post-operatively (range 29–48) ($p < 0.0001$). The mean Constant score at the final follow-up was 63 (range 35–86). Activities of daily living with requirement for external rotation and internal rotation score (ADLEIR) was on an average of 12 pre-operatively (range 0–27) and 31 post-operatively (range 18–36) (Fig. 4, Table 2).

On radiological assessment, none of the prostheses showed lucencies or stress shielding around the humeral or glenoid components. Glenoid notching was seen in seven patients and was graded using the Nerot–Sirveaux grading system [7]. Six patients had Grade-1 glenoid notching, while only one had Grade-2 glenoid notching which is erosion up to the inferior screw. One patient with revision arthroplasty for a dislocated hemiarthroplasty showed subsidence and early varus tilt of the stem, which stabilized at the end of 2 years, and the patient was pain free and functional at the 6-year follow-up.

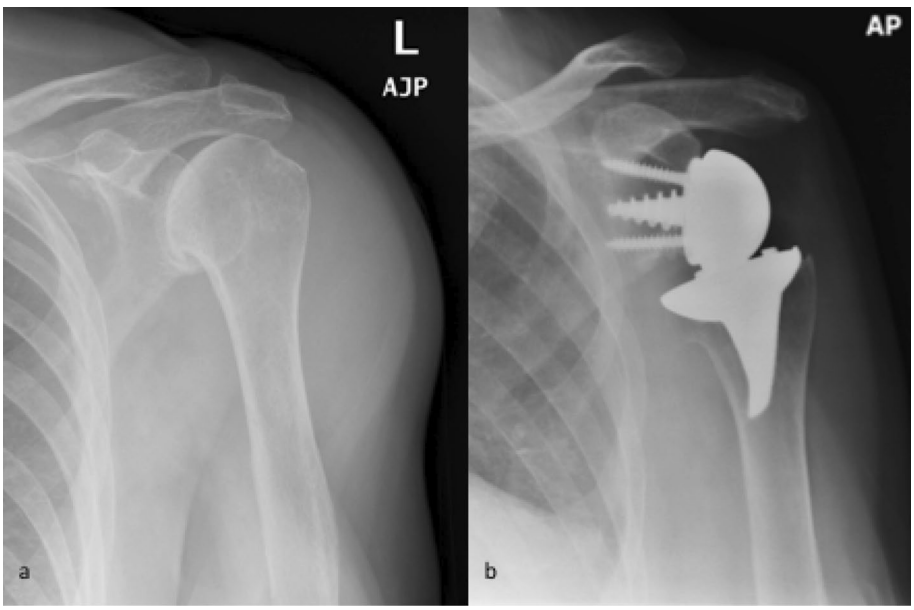

Fig. 2 **a** Pre-operative radiograph of osteoarthritis of the glenohumeral joint; **b** a four-year follow-up of the same patient with verso reverse shoulder replacement. No evidence of loosening, lucencies and notching noted

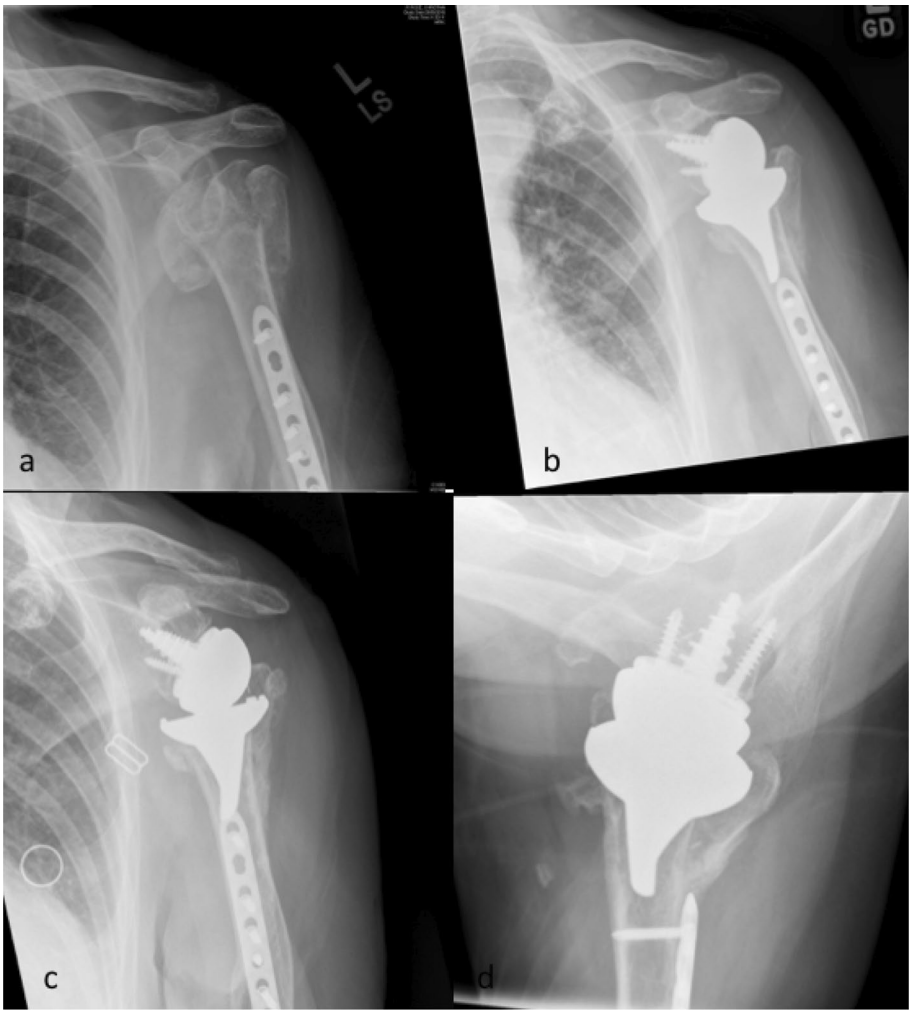

Fig. 3 **a** Comminuted fracture of the proximal humerus with a previous humeral plate in situ; **b** immediate post-operative radiograph after a stemless reverse shoulder replacement; **c** follow-up 3 months after operation showing the prosthesis well seated with healing of the tuberosities; **d** axial view depicting the healing of the tuberosities

Table 1 Demographic data

1	Mean age	76.9 years
2	Gender distribution	
	Male	9
	Female	27
3	Mean follow-up	3 years
4	Diagnosis ($n=37$)	
	Cuff tear arthropathy	$n=22$
	Rheumatoid arthritis	$n=5$
	Chronic anterior dislocations	$n=2$
	Failed resurfacing	$n=4$
	Late sequelae of proximal humerus fractures	$n=3$
	Acute trauma	$n=1$

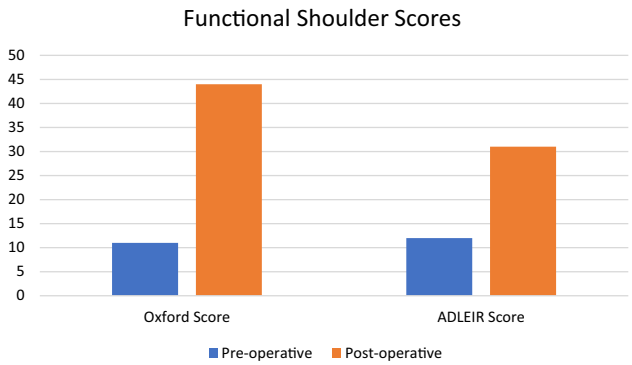

Fig. 4 Pre-operative and post-operative Oxford and ADLEIR shoulder scores ($p<0.0001$) (paired 't' test)

There was a single case of a post-operative deep-seated infection which was managed by irrigation, washout and liner exchange with retention of the prosthesis. Two patients sustained traumatic peri-prosthetic fractures, both of which were located in the metaphyseal region. Both were managed conservatively in a sling for 6 weeks and showed excellent function with the union of the fracture (Fig. 5). Three patients needed revision surgery for glenosphere dissociation from the base plate after significant trauma. These three patients neither had any soft tissue interposition, nor did

Table 2 Clinical results of the stemless reverse prosthesis

	Parameter	Range/score
1	Mean elevation	133°
2	Mean abduction	110°
3	Mean external rotation	30°
4	Mean post-operative Constant score	63
5	Mean Oxford Score ($p < 0.0001$)	
	Pre-operative	11
	Post-operative	44
6	Mean ADLEIR score ($p < 0.0001$)	
	Pre-operative	12
	Post-operative	31

they have a superior glenoid bone ledge that could have possibly led to the dissociation.

Discussion

The early to mid-term results (1–7 years) of the verso stemless reverse shoulder prosthesis in an independent centre are encouraging. There was a significant improvement in the Oxford shoulder score from a mean of 11 pre-operatively to a mean of 44 post-operatively.

The complications in the early to mid-term are no inferior to the conventional prosthesis. The main advantage of the metaphyseal fit appears to be reduced incidence of diaphyseal fractures and easier management of fractures when they occur. Zumstein et al. [6] in their systematic review noted 2% of patients having intra-operative humeral fractures. They also noted 11 fractures in the post-operative period which were almost always after a fall. Of these 11 fractures, 10 patients (90.9%) required revision surgery with a long stem and open reduction, internal fixation with plates and cerclage wires. Boileau et al. [10] in their series of 45 consecutive patients noted one intra-operative and one post-operative humeral fracture. The post-operative humeral fracture was treated with revision for an unstable prosthesis. We report zero intra-operative peri-prosthetic fractures or humeral stem-related complications. They also made a note that these fractures had a negative effect on the final outcome of the patient. Two patients (5.4%) had post-traumatic peri-prosthetic fractures following a fall. However, due the prosthesis being stemless, these were located in the metaphyseal region. As they did not interfere with the stability of the prosthesis, they could be managed with conservative treatment in a sling and healed with satisfactory function.

Scapular notching is a frequently reported occurrence with reverse shoulder arthroplasty, especially when there is medialization of the centre of rotation [17–21]. This is common in the Grammont-type design of the prosthesis. We report an 18.9% (7 patients) rate of scapular notching with all notchings except one being Grade 1 by the Nerot–Sirveaux classification [7]. Levy et al. [12] reported a scapular notching rate of 21.4% in their mid-term follow-up study with the use of the same prosthesis. This is in contradistinction to most studies which show that the rate of notching is very high with the conventional reverse shoulder prosthesis to amount to about 44–96% of the cases [17, 22–35]. The systematic review by Zumstein et al. [6] notes a 35.4% notching, this being the most common complication comprising 51.8% of all observed complications. Notching appears to be an early complication observed in the follow-up. Werner et al. [35] in his series observed that up to 68% of notching seen on long-term follow-up was already visible 1 year after the operation. Favard et al. [27] also noted that severe notching is associated with poor functional outcomes and constant scores. We attribute the low rate of notching in our series to the 10 degree inclined polyethylene humeral liner. This removes the excessive polyethylene on the inferior and medial aspect of the liner, thereby preventing the impingement against the medial scapular column [12].

Radiolucencies around the glenoid component have been reported in various series. A meta-analysis [6] found lucencies around the glenoid component to the extent of 2.5% in the Grammont-type reverse shoulder design [33, 36] and 11.1% in the Encore shoulder system [1, 3, 11, 37]. This is probably due to the differences in the centre of rotation of the prosthesis with it being more medialized in the former, thereby reducing the stresses at the metaglene–bone

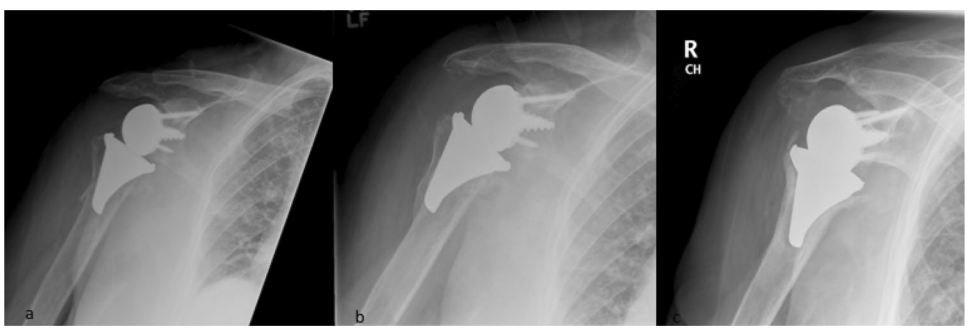

Fig. 5 **a** Fracture near the tip of the prosthesis after mechanical fall 6 weeks after operation; **b** evidence of callus formation after conservative management in a sling; **c** final follow-up radiograph, more than 4 years after the operation

interface. None of the patients in our series at their most recent follow-up appointment showed evidence of radiolucencies around the glenoid component. This could be validated further by the study of Hopkins et al. [38] who found the micromotion at the glenoid baseplate in the stemless reverse shoulder design to be 48 microns which is lower than the 50 microns micromotion suggested to provide optimum bone ingrowth.

Stress shielding and resorption around the humeral component are a common observation with reverse shoulder prosthesis, especially in uncemented fixations. A study by Melis et al. [39] in 2011 showed the extent of stress shielding and radiolucencies around the humeral stem was 5.9% in cemented and 47% in uncemented implants. In many cases, resorption of the greater and lesser tuberosities was noted as well. We did not note any resorption or stress shielding around the humeral component in our study. We suggest this could possibly be due to stemless nature of the prosthesis, whereby the metaphyseal fixation allows direct load transfer to the metaphyseal bone. Furthermore, the impaction bone grafting done before inserting the humeral component helps improve the strength and density of the metaphyseal bone [12]. Preservation of the distal bone stock also provides a good bone for the insertion of a humeral component in revision surgeries. The incidence of revision reverse shoulder replacements is showing significant growth [40, 41]. A previous stemless implant with preserved humeral bone stock is likely to reduce the risk of an intra-operative fracture.

Three patients (8.1%) had a traumatic dissociation of the glenosphere from the metaglene. All these patients were taken up for revision surgery, and the glenosphere was found to be dissociated. However, there was no soft tissue interposition between the two components. A new glenosphere was inserted over the base plate. All patients recovered uneventfully and had a good Constant score and Oxford score at the last follow-up. The rate of glenoid disassembly has been noted to be around 1.5% in a systematic review, and all of them required revision surgery [6]. There were no events of instability or dislocations in out series. The mean incidence of instability has been reported to be about 4.7% [1, 10, 11, 25, 42]. Instability is one of the most common causes of revision surgery [41]. A study reported that in 97.3% of patients with instability, the deltopectoral approach was used [6]. The modified Neviaser–Mackenzie approach was used for all of our arthroplasties in our series.

Recently, few studies have shown encouraging results with the stemless uncemented prosthesis. Micheloni et al. [43] published a study of 19 patients in 2019 with early clinical results of the verso prosthesis. They noted significant improvement in the Constant score and subjective shoulder test (SST) score. Atoun et al. [13] presented a series of 31 patients with a mean follow-up of 36 months in 2014. They noted an improvement in the mean Constant score from 12.7 to 56.2. They also found a significant improvement in the mean patient satisfaction score, ranges of motion and the mean pain score. A series of 102 patients with the stemless prosthesis with mean follow-up of 2–7 years by Levy et al. [12] again noted a significant improvement in the Constant Score ($p < 0.0001$), improved ranges of motion and subjective shoulder value [12].

The improvement in the Oxford shoulder score was significant ($p < 0.0001$). It improved from a mean of 11 to a mean of 44. The ADLEIR score also showed significant improvements ($p < 0.0001$) from a mean of 12 pre-operatively to 31 post-operatively. The mean range of external rotation was 30 degrees. This allowed the patients to carry out most of their daily activities comfortably. It is suggested that the Grammont-type prothesis with a medialized centre of rotation is associated with deficient internal and external rotations because of the poor tension in the external and internal rotators. Our study, however, does show a significant improvement in the ADLEIR score. This could be explained by reducing the edges of the polyethylene liner which prevents impingement between the liner and scapula when the arm is adducted. This mechanism of reduced rotation was postulated by Karlse et al. [44]. This is further validated by eccentric and asymmetric wears noted in liners retrieved from other reverse shoulder arthroplasty systems [2, 30, 45, 46].

Our study does have some limitations. It provides Level IV evidence as it is a case series. Compared to the stemmed prosthesis, the stemless verso is less suitable for use in trauma and traumatic sequelae as the stemmed prosthesis provides more stability in these situations. These results are early to mid-term and the mean follow-up in 3 years. The long-term results are awaited for this prosthesis.

Conclusion

This study shows excellent early to mid-term results of the stemless reverse shoulder replacement. It requires a simple and reproducible surgical technique, and it preserves bone stock. It is a safe implant which is versatile in a way that the metaphyseal hold allows for the implant to be used in severe humeral deformity, with previous intramedullary implants such as intramedullary nail, previous humeral shaft plating and also on top of a total elbow replacement. The metaphyseal stem does not restrict the options of future revisions. In our series, it was evident that peri-prosthetic fractures around the short metaphyseal implant have an excellent healing potential without the requirement for revision surgery. Our results are similar to those of the currently published literature.

Compliance with ethical standards

Conflict of interest The author(s) declare that they have no conflict of interest.

References

1. Cuff D, Pupello D, Virani N, Levy J, Frankle M (2008) Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency. J Bone Joint Surg Am 90:1244–1251. https://doi.org/10.2106/JBJS.G.00775
2. Nam D, Kepler CK, Neviaser AS, Jones KJ, Wright TM, Craig EV et al (2010) Reverse total shoulder arthroplasty: current concepts, results, and component wear analysis. J Bone Joint Surg Am 92(Suppl 2):23–35. https://doi.org/10.2106/JBJS.J.00769
3. Frankle M, Siegal S, Pupello D, Saleem A, Mighell M, Vasey M (2005) The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency. A minimum two-year follow-up study of sixty patients. J Bone Joint Surg Am 87:1697–1705. https://doi.org/10.2106/jbjs.d.02813
4. Matsen FA III, Boileau P, Walch G, Gerber C, Bicknell RT (2007) The reverse total shoulder arthroplasty. J Bone Joint Surg Am 89:660–667
5. Sanchez-Sotelo J (2009) Reverse total shoulder arthroplasty. Clin Anat 22:172–182. https://doi.org/10.1002/ca.20736
6. Zumstein MA, Pinedo M, Old J, Boileau P (2011) Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg 20:146–157. https://doi.org/10.1016/j.jse.2010.08.001
7. Nicholson G, Strauss E, Sherman S (2011) Scapular notching: recognition and strategies to minimize clinical impact. Clin Orthop Relat Res 469(9):2521–2530
8. Gerber C, Pennington SD, Lingenfelter EJ, Sukthankar A (2007) Reverse Delta-III total shoulder replacement combined with latissimus dorsi transfer. A preliminary report. J Bone Joint Surg Am 89:940–947. https://doi.org/10.2106/JBJS.F.00955
9. Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G (2006) Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. J Bone Joint Surg Am 88:1742–1747. https://doi.org/10.2106/JBJS.E.00851
10. Boileau P, Watkinson D, Hatzidakis AM, Hovorka I (2006) Neer award 2005: the Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. J Shoulder Elbow Surg 15:527–540. https://doi.org/10.1016/j.jse.2006.01.003
11. Levy J, Frankle M, Mighell M, Pupello D (2007) The use of the reverse shoulder prosthesis for the treatment of failed hemiarthroplasty for proximal humeral fracture. J Bone Joint Surg Am 89:292–300. https://doi.org/10.2106/JBJS.E.01310
12. Levy O, Narvani A, Hous N, Abraham R, Relwani J, Pradhan R, Bruguera J, Sforza G, Atoun E (2016) 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. J Shoulder Elbow Surg 25:1362–1370
13. Atoun E, Van Tongel A, Hous N, Narvani A, Relwani J, Abraham R et al (2014) Reverse shoulder arthroplasty with a short metaphyseal humeral stem. Int Orthop 38:1213–1218. https://doi.org/10.1007/s00264-014-2328-8
14. Ballas R, Béguin L (2013) Results of a stemless reverse shoulder prosthesis at more than 58 months mean without loosening. J Shoulder Elbow Surg 22:e1–e6. https://doi.org/10.1016/j.jse.2012.12.005
15. Kadum B, Mukka S, Englund E, Sayed-Noor A, Sjödén G (2014) Clinical and radiological outcome of the total evolutive shoulder system (TESS(R)) reverse shoulder arthroplasty: a prospective comparative non-randomised study. Int Orthop 38:1001–1006. https://doi.org/10.1007/s00264-013-2277-7
16. Teissier P, Teissier J, Kouyoumdjian P, Asencio G (2015) The TESS reverse shoulder arthroplasty without a stem in the treatment of cuff-deficient shoulder conditions: clinical and radiographic results. J Shoulder Elbow Surg 24:45–51. https://doi.org/10.1016/j.jse.2014.04.005
17. Levigne C, Boileau P, Favard L, Garaud P, Mole D, Sirveaux F et al (2008) Scapular notching in reverse shoulder arthroplasty. J Shoulder Elbow Surg 17:925–935. https://doi.org/10.1016/j.jse.2008.02.010
18. Nyffeler RW, Werner CM, Gerber C (2005) Biomechanical relevance of glenoid component positioning in the reverse Delta III total shoulder prosthesis. J Shoulder Elbow Surg 14:524–528. https://doi.org/10.1016/j.jse.2004.09.010
19. Barco R, Savvidou OD, Sperling JW, Sanchez-Sotelo J, Cofield RH (2017) Complications in reverse shoulder arthroplasty. EFORT Open Rev 1(3):72–80. https://doi.org/10.1302/2058-5241.1.160003
20. Katz D, Valenti P, Kany J, Elkholti K, Werthel JD (2016) Does lateralisation of the centre of rotation in reverse shoulder arthroplasty avoid scapular notching? Clinical and radiological review of one hundred and forty cases with forty five months of follow up. Int Orthop 40(1):99–108. https://doi.org/10.1007/s00264-015-2976-3
21. Mollon B, Mahure SA, Roche CP, Zuckerman JD (2017) Impact of scapular notching on clinical outcomes after reverse total shoulder arthroplasty: an analysis of 476 shoulders. J Shoulder Elbow Surg 26(7):1253–1261. https://doi.org/10.1016/j.jse.2016.11.043
22. Boileau P, Watkinson DJ, Hatzidakis AM, Balg F (2005) Grammont reverse prosthesis: design, rationale, and biomechanics. J Shoulder Elbow Surg 14:147S–161S. https://doi.org/10.1016/j.jse.2004.10.006
23. Boulahia A, Edwards TB, Walch G, Baratta RV (2002) Early results of a reverse design prosthesis in the treatment of arthritis of the shoulder in elderly patients with a large rotator cuff tear. Orthopedics 25:129–133
24. De Buttet A, Bouchon Y, Capon D, Delfosse J (1997) Grammont shoulder arthroplasty for osteoarthritis with massive rotator cuff tears: report of 71 cases. J Shoulder Elbow Surg 6:197
25. De Wilde L, Mombert M, Van Petegem P, Verdonk R (2001) Revision of shoulder replacement with a reversed shoulder prosthesis (Delta III): report of five cases. Acta Orthop Belg 67:348–353
26. De Wilde LF, Van Ovost E, Uyttendaele D, Verdonk R (2002) Results of an inverted shoulder prosthesis after resection for tumor of the proximal humerus. Rev Chir Orthop Reparatrice Appar Mot 88:373–378
27. Favard L, Lautmann S, Sirveaux F, Oudet D, Kerjean Y, Huguet D (2001) Hemi arthroplasty versus reverse arthroplasty in the treatment of osteoarthritis with massive rotator cuff tear. In: Walch G, Boileau P, Mole D (eds) Shoulder prosthesis: two to ten year follow-up. Sauramps Medical, Montpellier, pp 261–268
28. Favard L, Levigne C, Nerot C, Gerber C, De Wilde L, Mole D (2011) Reverse prostheses in arthropathies with cuff tear: are survivorship and function maintained over time? Clin Orthop Relat Res 469:2469–2475. https://doi.org/10.1007/s11999-011-1833-y
29. Lévigne C, Garret J, Boileau P, Alami G, Favard L, Walch G (2011) Scapular notching in reverse shoulder arthroplasty: is it important to avoid it and how? Clin Orthop Relat Res 469:2512–2520. https://doi.org/10.1007/s11999-010-1695-8
30. Nyffeler RW, Werner CM, Simmen BR, Gerber C (2004) Analysis of a retrieved delta III total shoulder

prosthesis. J Bone Joint Surg Br 86:1187–1191. https://doi.org/10.1302/0301-620X.86B8.15228
31. Rittmeister M, Kerschbaumer F (2001) Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. J Shoulder Elbow Surg 10:17–22
32. Sirveaux F, Favard L, Oudet D, Huguet D, Lautmann S (2001) Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive and non repairable cuff rupture. In: Walch G, Boileau P, Mole D (eds) Shoulder prosthesis: two to ten year follow-up. Sauramps Medical, Montpellier, pp 247–252
33. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Mole D (2004) Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff Results of a multicentre study of 80 shoulders. J Bone Joint Surg Br 86:388–395. https://doi.org/10.1302/0301-620X.86B3.14024
34. Valenti P, Boutens D, Nerot C (2001) Delta 3 reversed prosthesis for arthritis with massive rotator cuff tear: long term results (> 5 years). In: Walch G, Boileau P, Mole D (eds) Shoulder prosthesis: two to ten year follow-up. Sauramps Medical, Montpellier, pp 253–259
35. Werner CM, Steinmann PA, Gilbart M, Gerber C (2005) Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. J Bone Joint Surg Am 87:1476–1486. https://doi.org/10.2106/JBJS.D.02342
36. Delloye C, Joris D, Colette A, Eudier A, Dubuc JE (2002) Mechanical complications of total shoulder inverted prosthesis. Rev Chir Orthop Reparatrice Appar Mot 88:410–414
37. Cuff DJ, Virani NA, Levy J, Frankle MA, Derasari A, Hines B et al (2008) The treatment of deep shoulder infection and glenohumeral instability with debridement, reverse shoulder arthroplasty and post-operative antibiotics. J Bone Joint Surg Br 90:336–342. https://doi.org/10.1302/0301-620X.90B3
38. Hopkins AR, Hansen UN (2009) Primary stability in reversed-anatomy glenoid components. Proc Inst Mech Eng 223:805–812. https://doi.org/10.1243/09544119JEIM557
39. Melis B, DeFranco M, Lädermann A, Molé D, Favard L, Nérot C et al (2011) An evaluation of the radiological changes around the Grammont reverse geometry shoulder arthroplasty after eight to 12 years. J Bone Joint Surg Br 93:1240–1246. https://doi.org/10.1302/0301-620X.93B9.25926
40. Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM (2010) Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg 19:1115–1120. https://doi.org/10.1016/j.jse.2010.02.009
41. Boileau P (2016) Complications and revision of reverse total shoulder arthroplasty. Orthop Traumatol Surg Res 102(1 Suppl):S33–S43. https://doi.org/10.1016/j.otsr.2015.06.031
42. Gohlke F, Rolf O (2007) Revision of failed fracture hemiarthroplasties to reverse total shoulder prosthesis through the transhumeral approach: method incorporating a pectoralis-major-pedicled bone window. Oper Orthop Traumatol 19:185–208
43. Micheloni GM, Salmaso G, Berti M, Bortolato S, Zecchinato G, Momoli A et al (2019) Cementless metaphyseal reverse shoulder arthroplasty: our preliminary experience. Acta Biomed. 90(suppl 1):47–53. https://doi.org/10.23750/abm.v90i1-S.8064
44. Karlse AT, Bhatia DN, De Wilde LF (2008) Prosthetic component relationship of the reverse Delta III total shoulder prosthesis in the transverse plane of the body. J Shoulder Elbow Surg 17:602–607. https://doi.org/10.1016/j.jse.2008.02.005
45. Day JS, MacDonald DW, Olsen M, Getz C, Williams GR, Kurtz SM (2012) Polyethylene wear in retrieved reverse total shoulder components. J Shoulder Elbow Surg 21:667–674. https://doi.org/10.1016/j.jse.2011.03.012
46. Nam D, Kepler CK, Nho SJ, Craig EV, Warren RF, Wright TM (2010) Observations on retrieved humeral polyethylene components from reverse total shoulder arthroplasty. J Shoulder Elbow Surg 19:1003–1012. https://doi.org/10.1016/j.jse.2010.05.014