Clinical and radiological outcome of the Total Evolutive Shoulder System (TESS®) reverse shoulder arthroplasty: a prospective comparative non-randomised study

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Abstract

Purpose The aims of this study were to assess the function and quality of life after the Total Evolutive Shoulder System (TESS) reverse shoulder arthroplasty (RSA), to evaluate the radiological stability of the stemless version and to address the effect of arm lengthening and scapular notching (SN) on the outcome.

Methods This was a prospective comparative non-randomised study. A total of 37 consecutive patients (40 shoulders) underwent TESS RSA between October 2007 and January 2012; 16 were stemless and 26 were stemmed. At a mean follow-up of 39 months (15–66), we evaluated range of motion (ROM), pain and functional outcome with QuickDASH and quality of life with EQ-5D score. Radiologically, component positioning, signs of loosening, SN and arm length difference were documented.

Results We found a significant improvement in functional outcome and reduction of pain in both stemmed and stemless groups. No humeral loosening was evident, but there were four glenoid loosening. In 12 shoulders that developed SN, seven already had scapular bone impression (SBI) evident on initial post-operative radiographs. Glenoid overhang seemed to decrease the risk of SN. Arm lengthening was associated with better EQ-5D but did not influence ROM or functional outcome.

Conclusions Reverse shoulder arthroplasty markedly improved shoulder function. SN is of concern in RSA, but proper positioning of the glenoid component may prevent its development.

Keywords Reverse shoulder arthroplasty · Scapular notching · Stemless shoulder · Arm lengthening

Introduction

Grammont and Baulot revolutionised the treatment of cuff tear arthropathy (CTA) in the 1980s by introducing the concept of reverse shoulder arthroplasty (RSA), which moved the centre of rotation medially and distally [1]. Besides CTA, the indications for RSA include comminuted shoulder fractures, revisions, rheumatoid arthritis (RA) and severe osteoarthritis (OA) [2–4].

The Total Evolutive Shoulder System (TESS, Biomet, Inc., Warsaw, IN, USA) was introduced in France in 2004 and has been used in Sweden since 2007. It consists of an anatomical and a reversed version, both allowing for stemmed and metaphyseal fixed humeral components. The stemless version was developed to decrease shaft-related complications, e.g. fracture and bone loss.

The purposes of this prospective study were to assess the function and quality of life after TESS RSA, to evaluate the radiological stability of the stemless version and to address the effect of arm lengthening and the occurrence of scapular notching (SN) on the outcome.

Materials and methods

During the study period October 2007–January 2012, 37 consecutive patients underwent RSA surgery with TESS (Biomet, Inc., Warsaw, IN, USA) at Sundsvall Hospital in Sweden. Inclusion criteria were as follows: CTA, primary

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OA with rotator cuff dysfunction, RA and proximal humeral fracture sequelae. Painful pseudoparalysis was the main indication to operate on patients with CTA. In OA and RA patients, rotator cuff dysfunction was defined as a stiff shoulder with the intraoperative finding of an irreparable cuff.

Three different orthopaedic surgeons specialised in shoulder surgery performed the procedures. A modified anterosuperior Mackenzie approach as described by Molé et al. was used [5]. The final decision as to whether a stemmed or stemless humeral implant would be used was made intraoperatively depending on bone quality and stability of the humeral component. We chose the stemmed version if primary stability of the humeral implants could not be achieved.

Patients were mobilised with active exercises under the supervision of a physiotherapist the day after surgery. An independent surgeon assessed the patients clinically and radiologically. Pre- and post-operative active range of motion (ROM) was measured by visual estimation in degrees of abduction and flexion, while internal rotation was measured as the ability to reach behind the back. A visual analogue scale (VAS) was used for assessing pain. Functional impairment was evaluated by the QuickDASH index [6], the EQ-5D score was used for the estimation of quality of life and global VAS

for evaluation of overall health status. Radiographic assessment with anteroposterior (AP), axillary and lateral scapular radiographs was performed pre- and post-operatively by standardised views at three months and then annually. The AP view was obtained with the humerus in neutral rotation using fluoroscopy in order to obtain a tangential beam to the glenoid prosthesis and thereby examine the bone-implant interface. With the lateral scapular view, the glenosphere was maintained in profile and the scapular spine and the whole length of the coracoid in view. A 30-mm marker was used to control the magnification. The incidence of SN was assessed on the latest radiograph using the AP view according to Sirveaux [7]. Grade 1 indicated a notch limited to the scapular pillar, grade 2 reached the inferior screw of the baseplate, grade 3 extended beyond the inferior screw and grade 4 reached the central peg of the baseplate.

Glenoid loosening was defined as radiolucency under the baseplate or around the peg or screws, screw breakage or glenoid migration. The peg-glenoid rim distance was measured according to Simovitch et al. [8] as the distance from the uppermost border of the central peg to the inferior glenoid margin on post-operative AP radiographs (Fig. 1a). The craniocaudal glenoid component position was measured as

Fig. 1 **a** The peg-glenoid rim distance (PGRD) was measured as the distance from the uppermost border of the central peg to the inferior glenoid margin on the post-operative AP radiograph. **b** The craniocaudal glenoid component position was measured by drawing two horizontal lines, one from the inferior margin of the glenoid sphere parallel to another line which was drawn from the inferior margin of the glenoid. The distance between the two lines was calculated and values more than 0 mm were regarded as overhang. **c** Glenoid baseplate inclination was described as the angle between the baseplate and a horizontal line drawn from the upper margin of the glenoid

recommended by Nyffeler et al. [9]. Two horizontal lines were drawn, one from the inferior margin of the glenoid sphere parallel to another line which was drawn from the inferior margin of the glenoid (Fig. 1b). The distance between the two lines was calculated and values more than 0 mm were regarded as overhang. Glenoid baseplate inclination was described as the angle between the baseplate and a horizontal line drawn from the upper margin of the glenoid as recommended by Lévine et al. [10] (Fig. 1c). An inferior tilt was defined as an angle measuring more than 90°; a superior tilt was under 90°, while 90° was considered neutral.

A radiographic measurement of arm length was performed using a computed tomography (CT) scout view showing both arms from the acromion to the elbow joint. We excluded three patients where positioning was cumbersome because of excessive body mass index (BMI), making 27 shoulders available for evaluation. All examinations were done with the patient in the supine position, the arm positioned flat against the underlying table and neutral rotation with the palm facing upward. Three lines were defined on the CT scanogram for making the measurements: the distal humeral line, the longitudinal axis of the humerus and the acromial line (Fig. 2). The distal humeral line was defined as a line between the most distal part of the medial and lateral epicondyles. The longitudinal axis of the humerus was defined as the central line of the humeral diaphysis from the humeral head to the elbow joint. The acromial line was drawn from the most lateral and inferior point of the acromion perpendicular to the longitudinal axis line.

Arm length was calculated as the distance from the under-surface of the acromion to the elbow joint line. Arm lengthening was calculated as the difference in arm length between

Fig. 2 Arm lengthening was assessed using a CT scout view showing both arms from the acromion to the elbow joint. Three lines were defined for making the measurements: the distal humeral line (D), the longitudinal axis of the humerus (H) and the acromial line (A). Arm length was defined as the length of the longitudinal axis line from the acromial line to the distal humeral line

the operated and contralateral arm. A positive number indicated arm lengthening of the operated shoulder, while a negative number was considered as a shortening.

The study was performed according to the Declaration of Helsinki, and the protocol was approved by the local Ethics Committee at Umea University (dnr. 2012-201-31 M). The study is registered at Clinicaltrials.gov: NCT01877434.

Statistical analysis

Statistics were obtained using SPSS for Windows statistical program release 21 (SPSS Inc., Chicago, IL, USA). The Wilcoxon signed rank test was used to compare pre- and post-operative values of QuickDASH, EQ-5D, VAS pain and ROM. The Mann-Whitney test was used to compare inclination and overhang between categories of glenoid notching. The Spearman correlation was used to evaluate relations between arm lengthening and outcome. Kruskal-Wallis analysis of variance (ANOVA) was used to evaluate relations between notching and glenoid loosening. Values for continuous data are presented as median (min., max.). The statistical significance level was designated at $P < 0.05$.

Results

The study group comprised 37 patients (23 women and 14 men; mean age at surgery 72.0 years; age range 60–88 years). In total 40 shoulders were operated on. The mean duration of follow-up was 39 months (15–66 months). Indications were CTA ($n=14$), primary OA with rotator cuff dysfunction ($n=10$), RA ($n=7$) and proximal humeral fracture sequelae ($n=9$). Three patients died during the study from causes unrelated to the surgery at 20, 35 and 40 months post-operatively. For these patients, results were obtained from their last follow-up.

There was a marked improvement in shoulder function, quality of life and reduction of pain for both stemmed and stemless versions and for all included diagnoses (Table 1). When we looked at the stemmed and stemless RSA in arthritis patients (i.e. no fracture patients included), we found the two groups to be comparable except that more women received stemmed implants (< 0.05) (Table 2). Of the 16 stemless implants, two (12.5 %) were revised at three and four days post-operatively due to corolla displacement.

At radiological follow-up we found no signs of humeral implant loosening except for one stemmed shoulder where thin zones of resorption of the proximal humerus were detected. There were two RSA dislocations in two patients with fracture sequelae. These were treated with exchange of the polyethylene insert. Also, four glenoid loosening were revised with exchange of the baseplate.

SN was seen in 12 shoulders. Seven shoulders had scapular bone impression (SBI) already on the first post-operative X-

Table 1 Preoperative and post-operative values of EQ-5D, QuickDASH score, pain and ROM for the entire series

Parameter	Preoperative	Post-operative	<i>P</i> value
QuickDASH			
All	68 (4.5–93.2)	30 (2.5–86.4)	<0.01
Stemless	67 (38.6–88.6)	29 (4.5–86.4)	<0.01
Stemmed	56 (4.5–55)	35 (5–80)	<0.01
EQ-5D			
All	0.60 (0.11–1.00)	0.81 (0.18–1)	<0.01
Stemless	0.49 (0.18–0.77)	0.74 (0.3–1)	<0.01
Stemmed	0.43 (0.17–0.80)	0.73 (0.4–1)	<0.01
VAS pain at rest			
All	35 (0–80)	0 (0–20)	<0.01
Stemless	30 (10–80)	10 (0–20)	<0.01
Stemmed	35 (15–60)	0 (0–15)	<0.01
VAS pain during activity			
All	60 (30–90)	10 (0–30)	<0.01
Stemless	65 (40–80)	10 (0–20)	<0.01
Stemmed	70 (50–75)	15 (0–20)	<0.01
Abduction			
All	30 (10–80)	100 (50–170)	<0.05
Stemless	30 (10–60)	110 (60–170)	<0.05
Stemmed	40 (20–80)	90 (70–160)	<0.05
Forward elevation			
All	50 (10–80)	100 (40–170)	<0.05
Stemless	50 (10–80)	110 (80–170)	<0.05
Stemmed	45 (20–80)	90 (60–160)	<0.05
Internal rotation			
All	Sacrum (trochanter L5)	L3 (trochanter L1)	<0.05
Stemless	Sacrum (trochanter L5)	L3 (trochanter L2)	<0.05
Stemmed	Sacrum (trochanter L5)	L4 (sacrum L1)	<0.05

Table 2 Demographic and clinical data for patients with stemless and stemmed implants

	Stemless	Stemmed
Number of patients	16	15
Age	69 (62–76)	72 (60–81)
Male to female ratio	10:6	4:11
Follow-up	35 (15–66)	35 (15–66)
Indications		
CTA	7	7
OA	5	5
RA	4	3
Humeral loosening	0	Resorption zones around proximal humerus
Glenoid loosening	2	2
SN	4	5

ray (day one to four). In the remaining five shoulders, SN appeared at seven months (three to 12 months). SBI was defined as an indentation of the lower border of the scapular pillar on the post-operative AP X-ray, which was absent on preoperative examination (Fig. 3a). Patients with CTA had more SBI than other diagnoses (five of seven) $P<0.01$. All SBI progressed to become slightly larger in size and became grade 1 SN during the first three months (Fig. 3b). Six of seven had further progression at 12 months, while one remained stationary (Fig. 3c). At final follow-up (mean 34 months) five shoulders had grade 2 SN and two had grade 3. Three of five shoulders in the other SN group showed continuous progression over time, while two remained stationary. At final follow-up one shoulder was grade 1 SN, three were grade 2 and one was grade 3.

Three of the four baseplate loosening occurred concurrent with grade 1 SN. The glenoid loosening became evident at 12, 15 and 24 months in cases with SN, while one loosening without SN was noted at 60 months. However, SN was not correlated with glenoid loosening and did not affect final ROM or reported quality of life. A glenosphere diameter of 36 mm was used in 26 shoulders and of that of 41 mm in 14 patients. Neither the incidence nor the severity of SN was related to the size of the glenosphere.

The inclination of the glenoid baseplate was 93° (80–105°): seven with superior tilt, 18 inferiorly tilted and 17 neutrally aligned. No correlation was observed between inclination and SN. The mean glenoid overhang was 1.3 mm (5–6 mm). With no overhang there was a higher incidence of SN (10 of 12 shoulders; $P<0.001$). The peg-glenoid rim distance was 20 mm (15–28 mm). The peg-glenoid distance correlated with SN. When the distance was more than 20 mm, SN was evident in 9/12, while 3/12 occurred when the distance was less than 20 mm ($P<0.01$).

Following RSA, the lengthening of the upper extremity was 16 mm (range 0–32 mm). We compared those with arm lengthening 15 mm or less (15 shoulders) to those with lengthening over 15 mm (12 shoulders). Those with arm lengthening more than 15 mm showed greater improvement in EQ-5D (preoperative =0.41 vs 0.80 post-operatively) as compared with the others (preoperative mean=0.51 vs 0.66 post-operatively; $P<0.05$). However, lengthening did not correlate with degree of post-operative pain, ROM, QuickDASH or SN.

Discussion

The use of a stemless prosthesis is not routine in shoulder arthroplasty. In 2003 the French TESS group developed the TESS prosthesis to avoid stem-related complications and to enhance restoration of individual anatomy. The humeral implant stability was of concern initially. With the numbers given and considering eventual limitations related to the volume of this study, we found encouraging results with adequate

Fig. 3 **a** SBI (indicated by arrow) was defined as an indentation of the lower border of the scapular pillar on the post-operative AP X-ray, which was absent on preoperative examination. **b** At 3 months, it became larger in size and developed SN grade 1. **c** At 1 year, it became grade 2 and the glenoid was loose

humeral fixation in both anatomical and reverse versions [1, 13, 14]. In our study, with a mean follow-up of 39 months (15–66 months), there were no signs of humeral loosening after stemless implantation. In contrast, there were zones around one stemmed implant. Both stemmed and non-stemmed implants showed improvement in clinical outcome in patients having the same diagnoses.

We did not find a specific diagnosis where the use of stemless implants was mandatory. Instead the decision to use stemmed or stemless humeral implants depends on bone quality and judgment of the stability achieved during the initial preparation of the proximal humerus. It would be helpful to develop a tool to assess bone implant fixation properties. Early in this study, we had two post-operative corolla displacements. This could have been due to our early inadequate experience in assessing bone quality. In fracture surgery we recommend that only stemmed implants should be used since implant-bone stability is not expected in osteoporotic bone.

We had two dislocations after fracture sequelae; both of them had proximal humeral bone loss. The failure to achieve appropriate deltoid tension in these cases is a well-known cause of instability [11, 15]. Although good results after RSA are well documented, the problem of SN is of concern. The underlying cause, clinical significance and ways to avoid notching are still under debate.

The incidence of SN was variable, ranging from 0 to 96 %, and increased with longer follow-up [8, 11, 12]. In this study, we found SN in 30 % of our patients. However, SN did not influence the clinical or the radiological outcome. This concurs with the findings of Lévine et al. [10]. On the other hand, Simovitch et al. [8] found that SN resulted in poorer outcome. In a previous report from our institution, we did not observe SN in any patient. This could be explained by the smaller sample size included (21 RSA) and shorter follow-up (mean 14 months).

In this study, we also noticed that some patients already had SBI on the post-operative X-ray that later developed into SN. A possible explanation could be the use of the anterosuperior approach. This approach necessitates retractors to be placed under the glenoid rim to dislocate the humerus downwards creating deformative forces on the scapular edge. Other possible explanations cannot be excluded, e.g. the forward scapular rotation in the early post-operative period or a prominent anatomical notch of the circumflex scapular vessels.

Several studies found that glenoid overhang was a critical factor to avoid SN [7, 16, 17]. We found that overhang and peg-glenoid distance over 20 mm significantly decreased SN. Our findings are consistent with Simovitch et al. [8, 18].

In our study we did not find any correlation between inclination and SN. However, this could be due to the low number of patients with inclination over 10° from the neutral. There are divergent findings about the effect of inferior inclination on the incidence of SN. Some denied its effect [19, 20], while others reported decreased [17, 21] or increased incidence of SN [8].

Another important factor for stability and functional outcome is deltoid tensioning following lengthening of the arm [22, 23]. We found that arm lengthening improved the quality of life, but we were unable to note effects on function, ROM or pain. This is in accordance with previous reports that found that arm lengthening could influence the outcome [22–24].

The limitations of our study were the relatively small sample size and mixed indications for surgery. The two study groups were not equal in size and this may lead to statistical errors. However, all consecutive patients were included and they were operated upon using the same implant and approach. Rehabilitation was standardised and all patients were followed up prospectively. Furthermore, this report included results of the stemless version of RSA, where the available data in the literature are still sparse.

Conclusion

Reverse shoulder arthroplasty using metaphyseally fixed stemless humeral components is reliable if bone quality is adequate. RSA can successfully treat different shoulder problems. Glenoid overhang can reduce SN and arm lengthening has positive effects on outcome. Our method to measure arm lengthening needs further studies to ensure validity.

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References

- Kadum B, Mafi N, Norberg S, Sayed-Noor AS (2011) Results of the Total Evolutive Shoulder System (TESS): a single-centre study of 56 consecutive patients. *Arch Orthop Trauma Surg* 131(12):1623–1629
- Dieckmann R, Liem D, Gosheger G, Henrichs MP, Höll S, Hardes J, Streitbürger A (2013) Evaluation of a reconstruction reverse shoulder for tumour surgery and tribological comparison with an anatomical shoulder arthroplasty. *Int Orthop* 37(3):451–456
- Ortmaier R, Resch H, Matis N, Blocher M, Auffarth A, Mayer M, Hitzl W, Tauber M (2013) Reverse shoulder arthroplasty in revision of failed shoulder arthroplasty-outcome and follow-up. *Int Orthop* 37(1):67–75
- Flury MP, Frey P, Goldhahn J, Schwyzer HK, Simmen BR (2011) Reverse shoulder arthroplasty as a salvage procedure for failed conventional shoulder replacement due to cuff failure—midterm results. *Int Orthop* 35(1):53–60
- Molé D, Wein F, Dézaly C, Valenti P, Sirveaux F (2011) Surgical technique: the anterosuperior approach for reverse shoulder arthroplasty. *Clin Orthop Relat Res* 469(9):2461–2468
- Beaton DE, Wright JG, Katz JN et al (2005) Development of the QuickDASH: comparison of three item-reduction approaches. *J Bone Joint Surg Am* 87(5):1038–1046
- Sirveaux F (1997) Grammont prosthesis in the treatment of shoulder arthropathies with massive cuff tear. Multicenter series of 42 cases (in French). Medical doctor thesis, Nancy I University, 245 p
- Simovitch RW, Zumstein MA, Lohri E, Helmy N, Gerber C (2007) Predictors of scapular notching in patients managed with the Delta III reverse total shoulder replacement. *J Bone Joint Surg Am* 89(3):588–600
- Nyffeler RW, Werner CML, Gerber C (2005) Biomechanical relevance of glenoid component positioning in the reverse Delta III total shoulder prosthesis. *J Shoulder Elbow Surg* 14:524–528
- 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(9):2512–2520
- Scarlat MM (2013) Complications with reverse total shoulder arthroplasty and recent evolutions. *Int Orthop* 37(5):843–851
- Mizuno N, Denard PJ, Raiss P, Walch G (2012) The clinical and radiographical results of reverse total shoulder arthroplasty with eccentric glenosphere. *Int Orthop* 36(8):1647–1653
- Huguet D, DeClercq G, Rio B, Teissier J, Zipoli B, TESS Group (2010) Results of a new stemless shoulder prosthesis: radiographic proof of maintained fixation and stability after a minimum of three years' follow-up. *J Shoulder Elbow Surg* 19:847–852
- 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(9):e1–e6
- Farshad M, Gerber C (2010) Reverse total shoulder arthroplasty—from the most to the least common complication. *Int Orthop* 34(8):1075–1082
- de Wilde LF, Poncet D, Middemacht B, Ekelund A (2010) Prosthetic overhang is the most effective way to prevent scapular conflict in a reverse total shoulder prosthesis. *Acta Orthop* 81(6):719–726
- Gutiérrez S, Greiwe RM, Frankle MA, Siegal S, Lee WE III (2007) Biomechanical comparison of component position and hardware failure in the reverse shoulder prosthesis. *J Shoulder Elbow Surg* 16(3 Suppl):S9–S12
- De Biase CF, Ziveri G, Delcogliano M, de Caro F, Gumina S, Borroni M, Castagna A, Postacchini R (2013) The use of an eccentric glenosphere compared with a concentric glenosphere in reverse total shoulder arthroplasty: two-year minimum follow-up results. *Int Orthop* 37(10):1949–1955
- Kempton LB, Balasubramaniam M, Ankerson E, Wiater JM (2011) A radiographic analysis of the effects of glenosphere position on scapular notching following reverse total shoulder arthroplasty. *J Shoulder Elbow Surg* 20(6):968–974
- Edwards TB, Trappey GJ, Riley C, O'Connor DP, Elkousy HA, Gartsman GM (2012) Inferior tilt of the glenoid component does not decrease scapular notching in reverse shoulder arthroplasty: results of a prospective randomized study. *J Shoulder Elbow Surg* 21(5):641–646
- Gutiérrez S, Walker M, Willis M, Pupello DR, Frankle MA (2011) Effects of tilt and glenosphere eccentricity on baseplate/bone interface forces in a computational model, validated by a mechanical model, of reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 20: 732–739
- Lädermann A, Williams MD, Melis B, Hoffmeyer P, Walch G (2009) Objective evaluation of lengthening in reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 18(4):588–595
- Lädermann A, Walch G, Lubbeke A, Drake GN, Melis B, Bacle G, Collin P, Edwards TB, Sirveaux F (2012) Influence of arm lengthening in reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 21(3): 336–341
- Lädermann A, Edwards TB, Walch G (2013) Arm lengthening after reverse shoulder arthroplasty: a review. *Int Orthop* [Epub ahead of print] PMID: 24271331.