



# Prospective midterm results of a new convertible glenoid component in anatomic shoulder arthroplasty: a cohort study

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## Abstract

**Purpose** The purpose of our study was to evaluate the clinical and radiological results of a new anatomic convertible cementless glenoid component.

**Methods** Forty-eight patients with a mean age of 67.3 years were clinically and radiologically followed-up with a mean of 49 months. Indications for glenoid replacement were A2 glenoid wear in 21.7%, B1 glenoid wear in 28.3%, B2 glenoid wear in 28.3%, B3 glenoid wear in 13%, D glenoid wear in 2.2%, and glenoid component loosening in 6.5%.

**Results** The Constant-Murley score improved significantly ( $p < 0.0001$ ) from 50% pre-OP to 103% post-OP. Patients with a B3 glenoid type according to Walch achieved a significant ( $p = 0.044$ ) lower Constant-Murley Score post-OP compared to patients with a B1 glenoid type (88% vs 106%). The mean subluxation index changed significantly ( $p < 0.0001$ ) from 0.54 pre-OP to 0.46 post-OP. At the metal–back bone interface an incomplete radiolucent line  $< 1$  mm was observed in two cases (4.2%) and an incomplete radiolucent line  $< 2$  mm was observed in another two cases (4.2%). PE dissociation occurred in two cases. No glenoid loosening was observed. The implant related revision rate was 4.2% (2 cases). All components ( $n = 612.5\%$ ) requiring conversion to reverse were converted without any further complications or loosening.

**Conclusion** Good functional results can be achieved in cases with a B1 and a B2 glenoid after anatomic shoulder arthroplasty using the described metal back glenoid. A conversion from an anatomic to a reverse glenoid component were possible in all cases without any further complications. Conversion of the anatomic glenoid component to a reverse system alleviates revision surgery.

**Keywords** Shoulder arthroplasty · Cementless glenoid · Convertible glenoid · Midterm results

## Introduction

Cemented all-polyethylene glenoid replacement in anatomic shoulder arthroplasty represents the gold standard until now. Fox and coworker [1] as well as Raiss et al. [2] reported a midterm radiographic loosening of about 34% of cemented glenoid components after 10 years, resp. 36% after a mean of 11 years with an expected glenoid loosening of 100% after 14 years and concluded that the high frequency of late radiographic changes dictates the need for innovation [1].

Results of cementless glenoid components were not reliable. The best long-term results reporting a survival of 94% at 10 years and 89% at 15 years were achieved with the Neer-II-metal back component with a conforming radius of curvature [3]. Over the years, there were some inventions of cementless glenoid components with several modes of primary fixation into the bone, of PE inlay fixation at the metal back and overall construction height of the glenoid

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component leading to a three-times higher revision rate compared to cemented all PE components [3–8]. Another problem of anatomic shoulder arthroplasty represents the high rate of rotator cuff deficiency (13–68%) after mid- to long-term follow-up requiring revision to a reverse total shoulder arthroplasty [2, 9–12]. Revising a cemented glenoid component is frequently accompanied with glenoid bone loss requiring bone grafting to provide good primary stability for the metal-backed baseplate of the reverse system.

The development of convertible platform systems for glenoid replacement in 2003 ushers in a new era of cementless glenoid replacement especially for patients with a high risk for early rotator cuff deficiency and revision surgery for loosening of a cemented glenoid component with glenoid bone deficiency [13]. The first 3- and 6-year results of convertible glenoid components reported in the literature show promising results [13, 14] in anatomic shoulder arthroplasty. The aim of our study was to evaluate the clinical and radiological results of a new anatomic convertible metal back glenoid component with a minimum follow-up of 2 years.

## Materials and methods

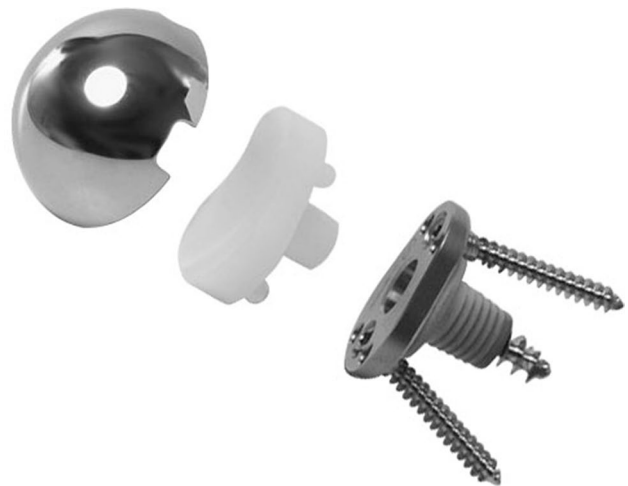
Between 2011 and 2016, 53 patients were treated using a single type of a cementless convertible glenoid component (Universal Glenoid™, Arthrex Inc., Freiham, Germany) for anatomic total shoulder arthroplasty and were prospectively followed-up clinically and radiographically with a minimum of 2 years. The design objective of Universal Glenoid™ was to develop an anatomic metal-backed glenoid component with a high primary stability and the option to convert it to a reverse glenoid to avoid glenoid bone loss, which might compromise the primary stability of the revision implant.

The Universal Glenoid™ device may be utilized in circumstances to address both anatomic (TSA) and reverse (RSA) indications. The baseplate of the device (metal back) is constructed from a single billet of Titanium alloy (ASTM F136). The pear-shaped form, flat two-stage backing, and cone-shaped central post, contribute to minimizing the effect of the “Rocking Horse” phenomenon. Additionally, backside surface treatment consists of a Titanium plasma spray (TPS) substrate with an enhancement of Bonit® CaP coating. A single, central cannulation through the central post, accommodates the utilization of both locking and non-locking 6.5 mm screws to generate primary compression. The screws are available in multiple lengths, which permit the surgeon to securely engage the contralateral cortex of the glenoid vault. Additionally, 4.5 mm screws are located polyaxially in the superior and inferior positions to provide additional security and stability for counter rotation. For indication of TSA, an ultra high molecular weight polyethylene (UHMWPE) liner consisting of four peripheral pegs

and central cone is secured to the metal back. The liner owns a minimum height of 2.5 mm at the bottom and 4 mm at the edge. Together with the baseplate with a 4 mm thickness, the overall thickness of the glenoid implant measures 6.5 mm at the center of the glenoid liner. An alternate liner is available in an additional 1 mm of thickness to address soft tissue tensioning. For indication of subsequent RSA, the liner is easily revised with the use of an extraction tool. Subsequently, an appropriately sized glenosphere may be selected and engaged via Morse taper into the central post of the metal back (Fig. 1).

Indication for the implantation of Universal Glenoid™ component in anatomic shoulder arthroplasty were concentric glenoid wear (type A2) [15] combined with protrusion stage II and III according to Lévine [16], eccentric glenoid wear (type B1, B2, B3 glenoid) [15] with a decentering of the humeral head and/or a high risk for an early development of rotator cuff deficiency after surgery as well as revision surgery for glenoid loosening in TSA. The retroversion of B2 and B3 glenoids were corrected by anterior reaming (lowering the high side) up to 15° of retroversion. Bone grafting was not performed.

Out of the 53 cases, 4 patients were followed-up by a questionnaire and 1 patient deceased. Forty-eight patients, comprising 20 women and 28 men, with a mean age of 67.3 years (range 46–77 years) presented for clinical and radiological follow-up at a mean of 49 months (range



**Fig. 1** The Universal Glenoid™ component consists of a calcium phosphate coated monobloc two-stepped flat backed metal back with a cone central peg, which is fixed with a 6.5 mm compression screw through the central peg in the glenoid bone and a superior and inferior 4.5 mm peripheral non-locking screw. The anatomic UHMWPE polyethylene inlay is fixed to the metal back component by a cone central peg and four peripheral pegs. In case of revision surgery to reverse shoulder arthroplasty the anatomic PE inlay can be replaced by a standard, inferior or lateral offset glenosphere

24–77 months) and were included in this prospective cohort study.

In 44 cases, a primary implantation of the glenoid component was performed and in 4 cases, this implant was used as revision implant for glenoid loosening in TSA.

The clinical results were documented using the absolute and the age- and sex-normalized Constant-Murley score [17, 18]. Abduction strength was measured using the ISO-BEX dynamometer (MDS Medical Device Solutions AG, Oberburg, Switzerland) according to the recommendation of Constant et al. [18]. Standardized digital X-ray images were examined in three planes (true anteroposterior [AP], axillary, and scapular Y views) to assess radiolucent lines around the humeral and glenoid components, to monitor stress shielding, to measure the subluxation index according to Walch [19] in the transversal plane.

The assessment of the radiolucent lines around the glenoid component was performed in the AP and the axillary views by dividing the implant–bone interface in three different zones (Fig. 2). Indications for glenoid replacement were A2 glenoid wear in 21.7%, B1 glenoid wear in 28.3%, B2 glenoid wear in 28.3%, B3 glenoid wear in 13%, D glenoid wear in 2.2%, and cemented PE-glenoid component loosening in 6.5%. The preoperative measurement of the subluxation index according to Walch [19] detected a centered humeral head in 52.5%, a posterior decentered humeral head in 40.0% and an anterior decentered humeral head in 7.5%.

Indications for shoulder arthroplasty are provided in Table 1. Six patients underwent a TSA using a single type of standard stem humeral head component (Univers 3D™, Arthrex Inc., Freiham, Germany) and the remaining 42 patients received a stemless, metaphyseal fixed humeral head

**Table 1** Indications for the implantation of a convertible cementless glenoid component in anatomic total shoulder arthroplasty

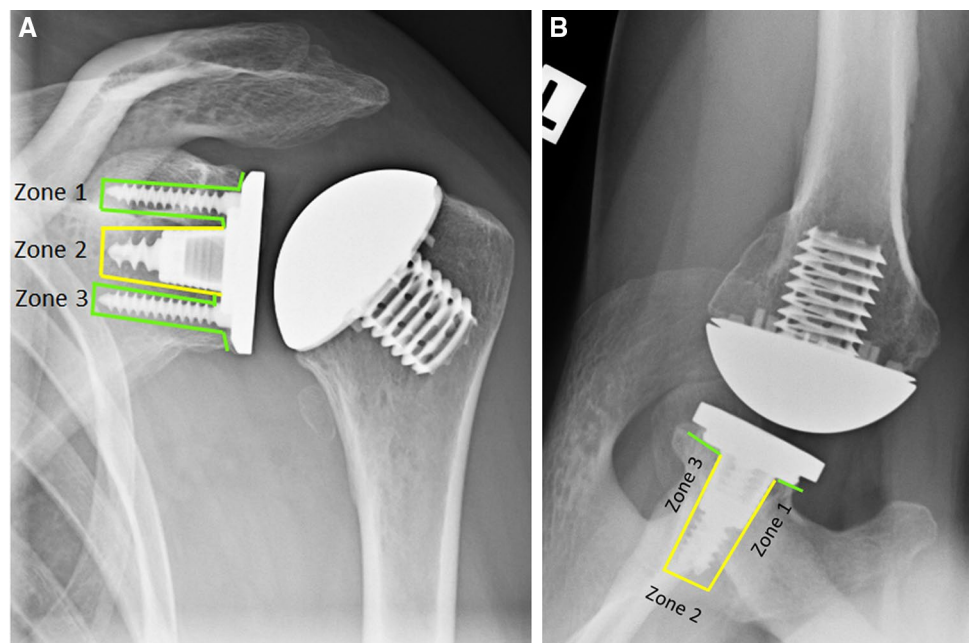
Indications for convertible cementless glenoid implantation	No. patients
Primary osteoarthritis	32
Posttraumatic arthritis	6
Arthritis due to instability	4
Secondary glenoid wear in HSA	1
Glenoid loosening in TSA	4

component (Eclipse™, Arthrex Inc., Freiham, Germany). The dimensions of the diameters of the prosthetic head and the prosthetic head height of both humeral components are identical, so that the prosthetic mismatch and the load on the glenoid component by the standard stem humeral component and the stemless humeral component do not differ. A prospective randomized study comparing both humeral components showed radiologically and functionally no statistical differences between both humeral implant types for the change of the inclination angle, the medial offset, the lateral offset, the Constant score and active range of motion at the 2-year and 5-year follow-up [20]. For this reason, we do not differentiate between the results of the standard stem and the stemless humeral component.

## Statistics

Statistical analysis was performed with SPSS 19.0 software (IBM Corp, Ehningen, Germany). The level of significance was set at  $p < 0.05$ . Differences of preoperative and

**Fig. 2** Assessment of radiolucent lines around glenoid implant in three different zones (1, 2, 3) in the AP (a) and axillary views (b)



postoperative nonparametric metrical data were analyzed using the Wilcoxon signed-rank test. Analyses between different groups of patients were done using the Mann–Whitney *U* test.

This study was approved by the Institutional Review Board of the ATOS Clinics Heidelberg and Munich (Study No. 4/18).

## Results

### Functional results

Shoulder function improved significantly at the latest follow-up (Table 2). Analyzing the functional results according to the preoperative glenoid morphology, shoulder function improved in patients for glenoid morphology types A2, B1, and B2 significantly regarding active range of motion and the Constant-Murley score as well as its subcategories at the latest follow-up. In patients with a B3 glenoid, we observed no significant improvement of active flexion and abduction, as well as for strength at follow-up examination. The pre- and postoperative results for each type of glenoid wear are shown in Table 3. Comparing the different types of glenoid morphology, we observed no significant differences for age and follow-up period between A2, B1, B2 and B3 glenoid types. Patients with a B3 glenoid achieved a significantly ( $p=0.044$ ) lower age and gender normalized Constant-Murley score post-OP compared to patients with a B1 glenoid type (88% vs 106%).

### Radiologic results

An incomplete radiolucent line  $< 1$  mm at the metal–back bone interface of the glenoid component was observed in two (4.2%) patients. One patient had a B1 glenoid morphology and one patient had a B2 glenoid morphology before TSA.

Another two (4.2%) patients (one B1-type glenoid, one B3-type glenoid) presented an incomplete radiolucent line  $< 2$  mm located in zone 3 in the true-AP view.

None of the glenoid components were judged “at risk” and none of the glenoid components were loose. Screw loosening or screw breakage was not observed.

The subluxation index (SI) according to Walch changed significantly ( $p < 0.0001$ ) from 0.54 (SD  $\pm$  0.08) preoperatively to 0.46 (SD  $\pm$  0.05) postoperatively for all patients. Posterior subluxation decreased significantly ( $p = 0.009$ ) from 40% preoperatively to 4.5% postoperatively. In patients with an A2 glenoid wear, the SI did not change after surgery (0.49 (SD  $\pm$  0.03) pre-op; 0.47 (SD  $\pm$  0.03) post-op;  $p = 0.109$ ). In patients with a B1 glenoid the SI decreased significantly ( $p = 0.009$ ) from 0.52 (SD  $\pm$  0.08) to 0.44 (SD  $\pm$  0.04), and in patients with a B2 glenoid the SI changed significantly ( $p = 0.001$ ) from 0.59 (SD  $\pm$  0.08) to 0.45 (SD  $\pm$  0.05) at the latest follow-up. In patients with a type B3 glenoid the SI remained unchanged (0.57 (SD  $\pm$  0.04) pre-op, 0.52 (SD  $\pm$  0.05) post-op;  $p = 0.109$ ).

An incomplete radiolucent line  $< 1$  mm around the humeral component were observed in one case (2.1%) and another two cases (4.2%) showed an osteolysis at the medial humeral calcar. No loosening of the humeral component was observed.

### Complications and revisions

Loosening of the cementless convertible glenoid component was not observed in the study. One glenoid component was explanted because of late infection 6 months after surgery. PE dissociation occurred in one case due to rotator cuff deficiency 43 months postoperatively resulting in conversion to RSA and in another case after lifting a heavy weight (refrigerator) 26 months postoperatively, leading to exchange of the anatomic PE inlay without further revision surgery until now.

Prosthetic instability occurred in one case 26 month after TSA and was converted to a reverse shoulder arthroplasty.

**Table 2** Pre- and postoperative functional results

	Preoperative (Standard deviation)	Postoperative (Standard deviation)	<i>p</i> -value pre-op versus post-op
Rel. Constant Murley score (%)	50.1 (22.6)	103.1 (20.2)	$< 0.0001$
Absolute Constant Murley score (points)	38.5 (17.6)	77.2 (12.5)	$< 0.0001$
Constant Murley score pain (points)	5.8 (3.0)	13.7 (2.1)	$< 0.0001$
Constant Murley score ADL (points)	9.3 (4.3)	18.2 (2.7)	$< 0.0001$
Constant Murley score ROM (points)	17.9 (7.8)	31.6 (5.9)	$< 0.0001$
Constant Murley score strength (points)	2.0 (5.5)	12.1 (7.3)	$< 0.0001$
Active flexion	112.2° (32.7)	151.7° (25.4)	$< 0.0001$
Active abduction	92.2° (38.6)	145.5° (30.4)	$< 0.0001$
Active external rotation	19.6° (20.0)	51.4° (15.7)	$< 0.0001$

**Table 3** Functional results related to preoperative glenoid morphology according to Watch [15, 19]

	Type A2 glenoid pre-operative (Standard deviation)	Type A2 glenoid post-operative (Standard deviation)	Type A2 glenoid <i>p</i> -value post-op versus pre-op	Type B1 glenoid pre-operative (Standard deviation)	Type B1 glenoid post-operative (Standard deviation)	Type B1 glenoid <i>p</i> -value post-op versus pre-op	Type B2 glenoid pre-operative (Standard deviation)	Type B2 glenoid post-operative (Standard deviation)	Type B2 glenoid <i>p</i> -value post-op versus pre-op	Type B3 glenoid pre-operative (Standard deviation)	Type B3 glenoid post-operative (Standard deviation)	Type B3 glenoid <i>p</i> -value post-op versus pre-op
Rel. Constant Murley score (%)	45.1 (21.7)	101.1 (14.1)	0.008	53.7 (25.3)	105.8 (19.8)	0.002	53.8 (18.9)	104.5 (23.4)	0.001	40.7 (18.4)	87.5 (22.4)	0.028
Absolute Constant Murley score (points)	35.1 (18.5)	73.7 (9.0)	0.008	41.2 (18.0)	79.3 (11.8)	0.002	41.2 (13.7)	77.9 (12.8)	0.001	31.8 (16.2)	69.3 (17.1)	0.028
Constant Murley score pain (points)	3.7 (2.1)	13.9 (1.6)	0.008	6.6 (2.5)	14.3 (0.9)	0.001	6.4 (3.6)	13.4 (2.8)	0.001	4.7 (2.7)	12.2 (3.2)	0.028
Constant Murley score ADL (points)	9.3 (5.3)	17.9 (2.3)	0.015	9.5 (4.4)	18.8 (2.5)	0.002	8.4 (3.6)	17.9 (3.6)	0.002	9.2 (3.7)	16.8 (2.8)	0.027
Constant Murley score ROM (points)	16.9 (8.6)	29.1 (6.6)	0.012	19.8 (8.5)	32.5 (5.0)	0.002	18.9 (5.6)	32.5 (5.7)	0.002	15.3 (6.3)	29.7 (7.7)	0.043
Constant Murley score strength (points)	2.1 (5.2)	12.3 (8.4)	0.046	3.8 (8.3)	13.6 (8.2)	0.021	1.7 (3.7)	11.5 (6.3)	0.043	0 (0)	8.9 (5.7)	0.068
Active flexion	104.4° (30.5)	141.1° (28.5)	0.049	123.1° (40.1)	153.9° (22.6)	0.003	119.2° (19.8)	157.7° (19.2)	0.004	100.0° (24.5)	145.0° (28.1)	0.072
Active abduction	83.3° (37.1)	133.3° (35.0)	0.034	96.9° (47.0)	150.8° (18.9)	0.003	104.6° (28.8)	149.6° (21.5)	0.007	75.0° (31.5)	136.7° (32.7)	0.08
Active external rotation	11.1° (11.7)	50.0° (13.2)	0.007	27.7° (17.4)	55.4° (13.9)	0.005	18.3° (18.0)	46.2° (19.4)	0.003	20.0° (27.7)	52.5° (14.1)	0.042

Four patients (8.3%) (4 cases: 1 × A2, 1 × B2, 2 × B3 glenoid morphology) with rotator cuff deficiency required a conversion to reverse shoulder arthroplasty after a mean of 44.5 months (range, 23–58 months). The converted glenoid components underwent follow-up investigation at 2, 2, 4, 6, 13 and 36 months without any further complications or loosening. The implant related revision rate was 4.2%.

## Discussion

Glenoid component loosening represents 25% of all complications related to anatomic total shoulder arthroplasty [21]. Often, glenoid component loosening is combined with a rotator cuff tear, glenohumeral instability or component malposition [22].

Convertible glenoid systems of the latest generation are based on the experience gained with the anchorage technique for the glenospheres in reverse shoulder arthroplasty. The modern convertible glenoid implants provide a much higher anchoring stability than the non-convertible metal-backed glenoid components of the first generation.

The metal-backed systems of the first generation were developed in the late 80 s and early 90 s of the last century and showed serious conceptual errors [2, 3, 5, 7, 23, 24]. The metal-backed trays were either too thick (up to 10 mm) or too thin, sometimes not stable enough. The anchoring mechanism in the bone consisted of a keel, non-cylindric cone, expansion dowel, hollow screw, with mostly too weak pegs or additional screws which were arranged only in a vertical row. These anchorage techniques were not able to withstand the shear forces that occurred, resulting in micro instability and/or fatigue fracture.

These problems were compounded by failure of the capture mechanism of the PE inlays from the tray, by the known polyethylene wear and by overstuffing of the rotator cuff due to too much lateralization by the height of the glenoid implant. Therefore, the failure and revision rate of the metal-backed components were significantly higher than that of the cemented PE implants [25].

The new generation of convertible metal-backed trays feature a highly stable anchorage mechanism of the metal carrier in the glenoidal vault as a significant design improvement, which are the flat two-stage backing results in a larger contact area at the metal–back bone interface and improves stability against shear forces, the central 6.5 mm tension screw produces a higher compression than conventional systems with only one cone.

The construction height of anatomic metal-backed implants is controversially discussed. In cases with concentric glenoid wear (type A2) combined with late-stage protrusion, the construction height might compensate the medialization of center of rotation. Another advantage of

the construction height may be the fact that most of our cases have been posteriorly decentered. The stretching of the posterior capsule will be equalized by the height of the glenoid component. Out of the New Zealand National Joint Registry Clitherow et al. [26] reported a rate of rotator cuff tear of 35.5% after a mean follow-up of 3.5 years in patients with anatomic shoulder arthroplasty using a cementless glenoid component. With a comparable follow-up, we observed a lower rate of rotator cuff tears (10.6%) in our study, so it seems that the construction height of our used component does not lead to an increased rate of rotator cuff tears.

Another indication using this new generation of convertible metal back glenoid component in anatomic shoulder arthroplasty represents eccentric glenoid wear (type B1, B2, B3 glenoid) with a decentering of the humeral head and/or a high risk for an early development of rotator cuff deficiency after surgery as well as revision surgery for glenoid loosening in TSA.

At midterm follow-up the convertible cementless glenoid component achieved good functional results in patients with eccentric glenoid wear and a high risk for development of rotator cuff deficiency in our study. Related to the glenoid morphology patients with an A2, B1 und B2 glenoid morphology according to Walch showed comparable functional results. Patients with a B3 glenoid deformity achieved a lower age- and gender normalized Constant-Murley score compared to patients with a B1 glenoid morphology. An incomplete radiolucency < 2 mm was observed in 8.3% of our patients, none of the glenoid components were judged “at risk” and none showed loosening. PE dissociation occurred in two cases (4.2%). The back surface of the PE inlay has a central cone and four small pegs that fit exactly into the metal back. In the two cases of PE dissociation, we inserted a new PE inlay into the metalback base plate via the cone plug system. The reasons for the dissociation can be the following:

- The metalback base plate was not cleaned and something was interpolated so that dissociation can occur.
- The PE liner was not inserted deep enough and did not snap back.
- Adequate trauma.
- The metal-backed glenoid component had been introduced with too much upward tilt or downward tilt, so that shear forces lever out the PE inlay.

Castagna et al. [14] reported comparable functional results of 35 patients with a mean follow-up of 75 months and mainly concentric glenoid wear (A1 42.8%, A2 34.3%, B1 17.0%, B2 5.7%) with a significant ( $p < 0.0001$ ) improvement from a preoperative Constant-Murley score of 35.2 points to 70.8 points postoperatively. The authors observed an incomplete radiolucent line < 2 mm in 22.9% of their

cases after more than 6 years and detected no loosening and no PE dissociation during follow-up. There was no need for revision surgery in their study population. In the present study, a lower rate of incomplete radiolucency was observed, however, the follow-up time was one-third shorter.

Castagna et al. [14] found a higher rate of posterior subluxation with 14.3% at the latest follow-up compared to 4.5% in our study.

Katz et al. [13] followed-up 143 patients radiologically with a mean of 3 years, treated with an anatomic total shoulder arthroplasty using a cementless convertible glenoid component. Out of these 143 patients, functional results were reported for 35 cases at an average follow-up of 38.3 months. A significant improvement of the Constant-Murley score (27 points (36%) preoperatively, 70 points (95%) postoperatively) as well as a significant improvement of active elevation (92° preoperatively, 146° postoperatively) was observed. These results are comparable with the results of the present study group as well as the study group of Castagna et al. [14]. Radiolucent lines and glenoid loosening were not observed in the study of Katz et al. [13], whereas in three cases, a PE dissociation occurred leading to a comparable implant specific complication rate of 2%.

During the study period, five patients underwent conversion of the anatomic glenoid component to reverse shoulder arthroplasty due to rotator cuff deficiency. All glenoid components were well fixed into bone and could be converted without explantation. Kany et al. [27] as well as Valenti et al. [28] reported results of revision of an anatomic platform system (Arrow, FH Orthopedics) to reverse total shoulder arthroplasty with short term follow-up of 28 months of 14 patients as well as of a mean follow-up of 22 months of 13 patients. All well-fixed convertible glenoid components could be converted to reverse without explantation and showed no loosening during short term follow-up. Castagna et al. [29] and Weber-Spickschen et al. [30] reported their experience with another convertible shoulder system (SMR Shoulder System, Lima Corporate) of 8, resp. 15 shoulders with a mean follow-up of 32, resp. 43 months after revision to reverse shoulder arthroplasty. In all cases of both studies, the glenoid could be converted to reverse without explantation and showed no signs of loosening during the follow-up period after revision surgery. Both humeral components used in our study were not designed for a conversion from anatomic to reverse shoulder arthroplasty, so that they could not be kept during revision from TSA to RSA. In the literature, the rate of exchange of the humeral component of convertible platform systems during revision from TSA to RSA is described as between 22 and 76.8% [27, 30, 31].

The weakness of the present study includes the absence of a control group, various indications for total shoulder arthroplasty, including glenoid revision surgery within the patient group, and the small number of patients in the interesting

group of B3 glenoid wear, which is associated with the development of rotator cuff deficiency [2]. Nevertheless, the prospective functional and radiographic results of a convertible cementless anatomic glenoid replacement are reported in patients with a high rate of preoperative eccentric glenoid wear (71.8%) and in patients with an A2 glenoid combined with a rotator cuff “at risk”.

In conclusion, this new convertible cementless glenoid component shows good functional results especially in patients with eccentric glenoid wear after a midterm follow-up. The construction height of this glenoid component seems not to lead to a higher rate of rotator cuff deficiency after midterm follow-up than reported in the literature for total shoulder arthroplasty using a cemented all-polyethylene glenoid component. Patients with a B1 and B2 glenoid morphology were recentered after a mean follow-up of 4 years.

Patients with an B3 glenoid morphology achieved a significant lower age- and gender normalized Constant-Murley score than patients with a type B1 glenoid. No differences could be detected of functional and radiologic results between type B1 and B2 glenoid. In addition, patients with a B3 glenoid morphology showed no significant improvement of shoulder function after anatomic total shoulder arthroplasty, so that implantation of a reverse shoulder arthroplasty might primarily be considered. The most frequent complication in anatomic shoulder arthroplasty requiring revision surgery represents rotator cuff deficiency, so that conversion of the anatomic glenoid component to a reverse system alleviates revision surgery and seems to reduce the complication rate and the re-revision rate after conversion. A longer term follow-up study with a higher number of patients is necessary to confirm the results of this study.

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## Compliance with ethical standards

**Conflict of interest** Petra Magosch and their immediate family, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article. Sven Lichtenberg is a consultant of Arthrex Inc. and receives royalties. Mark Tauber is a consultant of Arthrex Inc. Frank Martetschläger is a consultant of Arthrex Inc. Peter Habermeyer receives patent royalties for the Universal Glenoid™ implant from Arthrex Inc.

**Ethical approval** This study was approved by the Institutional Review Board of the ATOS Clinics Heidelberg and Munich (Study No. 4/18).

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