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SHOULDER

Arthroscopic partial shoulder resurfacing

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Abstract
Purpose The purpose of this study was to report patients' clinical and subjective outcomes 2 years after arthroscopic-assisted partial resurfacing of the humeral head.
Methods In this prospective case series, 11 patients (4 females, 7 males; median age, 59 years; range 47–72) underwent arthroscopic-assisted partial shoulder resurfacing between April 2010 and March 2011. Clinical conditions and subjective assessments were evaluated before surgery and at 6 weeks, 3 and 6 months, and then annually after surgery using the Constant score (CS), active range of motion (ROM), the visual analogue scale (VAS) for pain, the American Shoulder and Elbow Surgeons scale (ASES), and the subjective shoulder value (SSV). Radiological outcomes and major complications were monitored.
Results The mean CS improved significantly from 54.6 ± 13.6 preoperatively to 72.9 ± 17.2 points 6 weeks postoperatively ($P = 0.009$). At the 2-year follow-up, the mean CS had further increased to 86.5 ± 14.3 points ($P < 0.001$). Trends towards increasing ROMs were detected. VAS, ASES, and SSV significantly improved from baseline to the first follow-up and maintained improvement after 2 years. One patient required revision surgery owing to a technical failure and two patients because of rapidly progressive osteoarthritis. Ten of 11 patients (91 %) claimed that they would undergo arthroscopic partial shoulder resurfacing again.
Conclusion Arthroscopic-assisted partial humeral head resurfacing, which has the advantages of bone stock preservation and the maintenance of an intact subscapularis tendon, allowed immediate postoperative mobilization and provided significant improvements in subjective outcomes, especially for pain relief in active patients without severe glenoid cartilage wear.
Level of evidence Therapeutic case series, Level IV.

Keywords Arthroscopic shoulder resurfacing · Focal chondral defect · Partial humeral head resurfacing · Glenohumeral arthritis · Subscapularis preservation · Clinical outcomes

Introduction

Other than total shoulder arthroplasty, current options for managing cartilage defects of the humeral head include debridement [5, 31, 34, 42], microfracture [13, 22, 28], autologous chondrocyte implantation [33], osteochondral transfers [37], and partial resurfacing implants [41]. Despite inconsistent outcome data, algorithms for non-arthroplasty treatments of cartilage lesions in young patients have been reported [2, 6, 11, 17, 27]. In the elderly population, arthroplasty is the preferred treatment option and has been associated with successful outcomes [12, 30], whereas in patients younger than 50 years, Sperling et al. [39] reported only a 48 % success rate. Furthermore, the majority of the aforementioned procedures require an open surgical approach with subscapularis detachment, which requires a long rehabilitation phase and is associated with potential complications such as tendon retear, fatty muscle

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infiltration, and decreased function [38]. As encouraging results have been described in the literature with open complete or partial humeral head resurfacing [36, 41], the author's idea was to further develop arthroplasty to an arthroscopic-assisted humeral head resurfacing technique.

The clinical advantages of such an arthroscopic technique were expected to include early postoperative mobilization allowing for outpatient surgery because of subscapularis tendon preservation as well as minimal bone stock sacrifice and soft-tissue damage, enabling possible revision surgery in the future. Thus, the purpose of this study was to report clinical and subjective 2-year results after arthroscopic-assisted partial resurfacing of the humeral head.

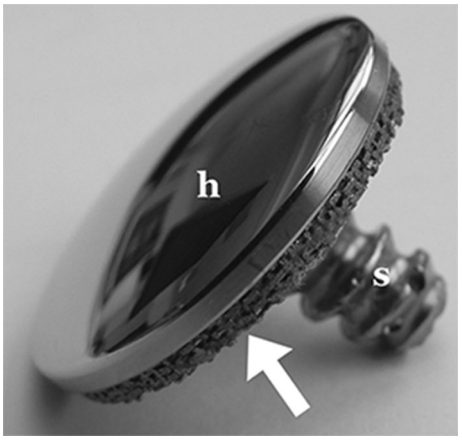

Fig. 1 The humeral Partial Eclipse™ prosthesis consists of a humeral head component (h = head) with a bottom porous titanium mesh (*arrow*) and a threaded stem component (s = stem)

Materials and methods

From May 2010 to March 2011, a total of 11 patients (4 female, 7 male) with an average age of 59.7 ± 9.0 years underwent minimally invasive arthroscopic-assisted arthroplasty. Patients were considered for this surgery if they presented with persistent, severe pain after non-operative treatment for at least 6 months or if they had failed previous surgical treatment, such as debridement, microfracture, autologous chondrocyte implantation, or osteochondral transfer, and were unwilling to undergo shoulder replacement. Further preoperative inclusion criteria for the index procedure were an active range of motion (ROM) of at least 130° forward flexion (FF), 90° abduction (ABD), and 20° external rotation (ER) as well as the psychological and cognitive ability to complete the questionnaire. Only patients with an intraoperatively confirmed focal chondral defect of the humeral head (grade IV according to Outerbridge [29] and with a diameter of at least 20 mm) were included in the study. Patients with accompanying shoulder pathologies requiring postoperative immobilization were excluded. Focal glenoid wear of grade IV according to Outerbridge was not an exclusion criterion. All 11 patients, who underwent arthroscopic-assisted partial humeral head resurfacing, signed the written informed consent and were prospectively enrolled.

Surgical technique

Two experienced surgeons (W.A., B.K.) performed all surgical procedures using the new humeral Partial Eclipse™ prosthesis (Arthrex Inc., Naples, FL, USA), which is a cobalt–chromium alloy implant consisting of a head component with a porous titanium mesh on the bottom section for bone ingrowth and a threaded stem component (Fig. 1). The resurfacing component is available in diameters of 20 or 25 mm and has a curvature similar to the humeral head, as described by Iannotti [20] for reconstruction of the damaged humeral anatomy. The stem component is threaded and cannulated, and it engages with the resurfacing component. The threaded stem component is configured to be inserted through a transhumeral channel.

The surgical procedures were performed under interscalene block and general anaesthesia with patients in the lateral decubitus position. A standard posterior portal was used to enter the glenohumeral joint. After creating the standard anterior portal, diagnostic arthroscopy was performed to evaluate chondral defects and identify any additional pathology. The rotator cuff was intact in all patients. None of the patients presented with symptomatic acromial spurs or shoulder instability. Additional procedures were performed in some patients, which included inferior osteophyte removal ($n = 5$), capsular release ($n = 6$), labrum debridement ($n = 2$), and tenotomy ($n = 2$) or tenodesis ($n = 1$) of the long head of the biceps tendon.

Next, all soft tissue of the rotator interval was removed with the shaver in order to create space for the introduction of the instruments and the implant. The anterior portal skin incision was extended up to 2.5 cm. Blunt dissection was performed to spread the deltoid fibres and widen the portal. A rectangular drill guide (Fig. 2a) was then introduced via the extended portal. The drill guide was placed over the lesion and a transhumeral drill pin was introduced from the lateral side. The centre of the drill guide marked the centre of the defect. At the lateral aspect (outside the joint), a 1–2-cm-long skin incision was made where the drill pin was to enter the upper arm. The deltoid muscle was bluntly dissected to the bone (Fig. 2a). In order to protect branches of the axillary nerve, all further instrumentation was performed only through tissue protectors.

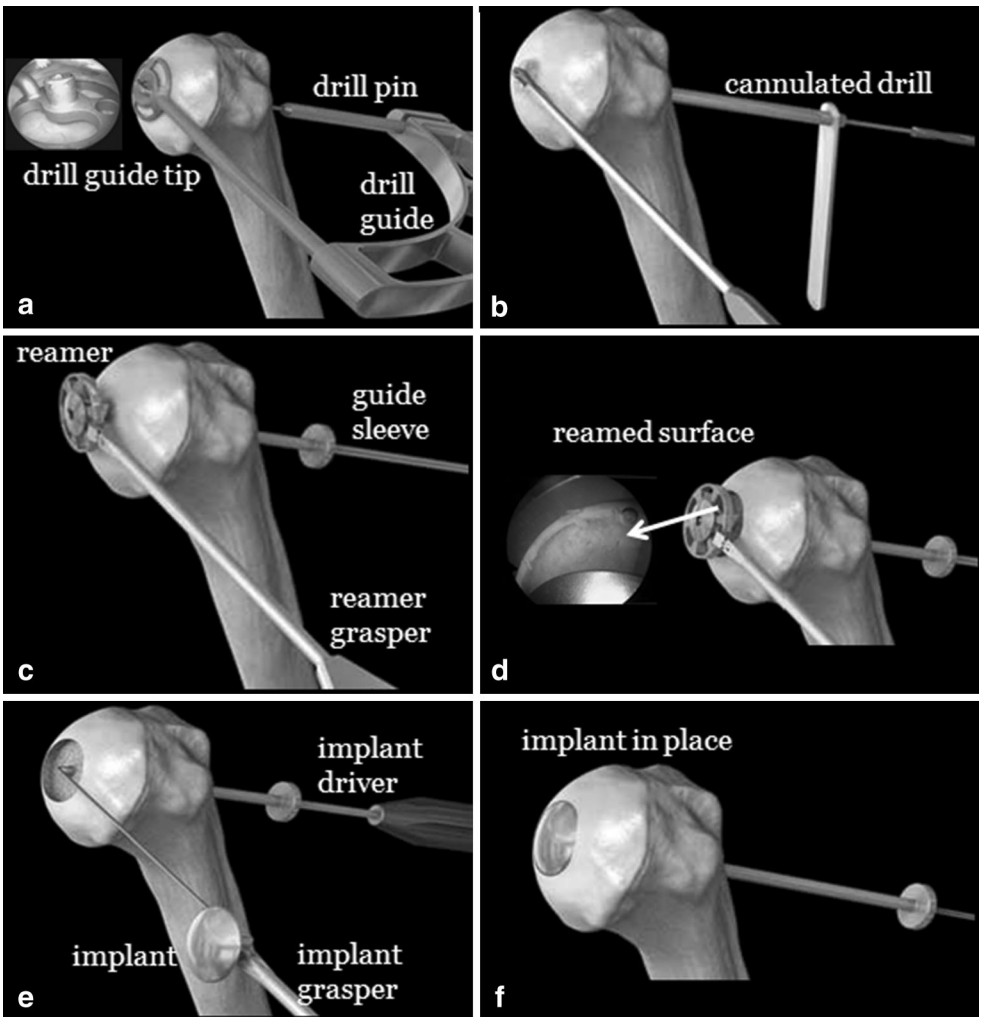

Fig. 2 Surgical steps involved in the arthroscopic implantation of the humeral Partial Eclipse™ prosthesis (modified from the manual 'Humeral preparation and implantation' by Arthrex)

A 2.4-mm drill pin was then advanced through the transhumeral canal to hit the drill guide tip. Over the drill pin, the final transhumeral canal was prepared with a 4-mm cannulated drill (Fig. 2b). Next, a guide sleeve was introduced into the transhumeral canal to avoid widening while humeral preparation (Fig. 2c). Initially, to facilitate reaming, the sclerotic bone around the lesion was cut with a rounded burr. Thereafter, a threaded pin was placed through the sleeve and into the joint; it was then connected to the reamer, which was introduced through the anterior portal with a special grasper (Fig. 2c). The special design of the retrograde reamer—with a self-adjusting ball-bearing like connection—always allows reaming rectangular to the humeral surface. With a power tool, the humeral head surface was reamed until the reamer's collar indicated the stop for the correct implant seating. Reamer windows allowed for monitoring and control under arthroscopic vision (Fig. 2d).

Having prepared the subchondral bone bed, the reamer and threaded pin were removed and the implant driver was introduced through the sleeve. Through a shuttle system, the definitive implant was then brought into the joint through the rotator interval and connected to the implant driver. The implant was fit into the humeral head under retrograde screwing (Fig. 2e). The average focal chondral defect was 24.2 ± 3.5 mm in size (median, 25; range 20–25). To fit defect size, we used more 25 mm ($n = 7$) than 20 mm implants ($n = 4$) in this series. When the implant was fully seated into the bone bed, ideally slightly beneath the intact cartilage surface, the implant driver and the sleeve were removed (Fig. 2f; Video 1). Finally, the skin incisions were closed. Intraoperative fluoroscopic control of the implant positioning is recommended. Postoperatively, full active motion exercises can be started immediately.

Clinical and subjective assessment

Data collection before surgery included patients' age at surgery, gender, prior treatment, as well as operative and dominant arm. Preoperative magnetic resonance images (MRI) were available for diagnosis in all patients. Pre- and postoperative standard radiographs were performed anteroposterior in internal rotation (IR) and ER, outlet, and axillary views. Preoperative osteoarthritis was graded according to the classifications established by Samilson and Prieto [35], Kellgren and Lawrence [21], Weinstein [42], and Guyette [18]. Postoperative radiological images were assessed for signs of implant loosening and progression of osteoarthritis.

Subjective and objective assessments were performed before surgery as well as 6 weeks, 3 and 6 months, and yearly thereafter. Clinical investigation utilized the Constant score (CS) and its subgroups: pain, activities of daily living (ADL), ROM, and strength, which was measured with a spring balance [7]. At every visit, active ROM in FF, ABD, and ER at 0° abduction were assessed. Subjective measurements included the 10-point visual analogue scale (VAS) for pain (best, 0; worst, 10), the American Shoulder and Elbow Surgeons scale (ASES; best, 100 points; worst, 0 points) [16, 32], and the subjective shoulder value (SSV, expressed as a percentage of a 100 % normal shoulder) [15]. Additionally, patients were asked to rate (yes or no answer), whether they would undergo the same procedure again.

The study was approved by the local ethics committee of the St. Vincent Hospital (Vienna, Austria).

Statistical analysis

In this study, the total CS was used as the primary outcome measure. A sample size of seven patients was calculated considering 25 points as a clinically important difference between baseline and follow-up total CS and a standard deviation (SD) of 15 points at a significance level of $\alpha = 0.050$ with 95 % power. The pre- and postoperative CS difference and SD were chosen according to our experience with other shoulder prostheses. We increased the number of patients by approximately 50 %, to a total of 11 patients, to enable compensation for an eventual loss of patients during follow-up. Descriptive statistics were used to present patients' characteristics. Paired t tests were performed to compare pre- and postoperative differences in clinical and subjective outcome measures, including the CS, active ROM, VAS, ASES, and SSV. A post hoc power analysis ($n = 8$; $P < 0.050$; mean difference between pre- and 6-week postoperative total CS of 18; SD of 10) resulted in an estimated power of 99.9 %. All data were analyzed using SPSS software (PAWS Statistics 18; SPSS Inc., Chicago, IL). Statistical significance was set at the conventional P value of <0.050 (two-sided).

Results

Four patients underwent partial humeral resurfacing for severe pain after non-operative treatment, five patients had previously undergone an arthroscopic debridement, and one patient had undergone an arthroscopic microfracture prior resurfacing. The dominant arm (in all cases the right arm) was involved in eight patients. All patients had humeral head chondral damage of IV° according to Outerbridge (Fig. 3b). While the majority of patients' glenoid damage ($n = 8$) was graded below Outerbridge II° (Fig. 3b), three patients had glenoid cartilage lesions of IV° according to Outerbridge. Radiographic grading for osteoarthritis is presented in Table 1.

No intraoperative complications were reported. No infections, dislocations, or neurological complications were detected postoperatively. Figure 3 shows images of the same patient before (Fig. 3a), during (Fig. 3b), and after (Fig. 3c, d) successful arthroscopic-assisted partial shoulder resurfacing. However, revision surgery was indicated in three of the 11 patients (27 %). The first revision was the very first patient to undergo surgery with the humeral Partial Eclipse™ implant. Shoulder function deteriorated within 4 months postoperatively, and radiographs showed progressive osteoarthritis with radiolucency under the component. Thus, revision surgery to a total shoulder arthroplasty was indicated. Two other patients, who required conversion to total shoulder replacement showed deteriorating shoulder function within 6 months postoperatively. Postoperative radiological images showed progression of their osteoarthritis, but no radiolucency of the implant. On follow-up after revision surgery, all three patients showed similar outcomes (total CS of 75, 83, and 95 points), which are comparable with those seen in patients after primary shoulder arthroplasty [9].

Clinical and subjective assessment

The remaining eight patients were followed for an average of 23.3 ± 1.8 months (median, 22.5; range 22–27). Significant improvements in the mean total CS were observed between baseline and all follow-up visits (Table 2). While the CS subgroups pain and ADL significantly improved from baseline to follow-up, patients' strength significantly improved after the 3 month follow-up. Active ROM improved, but not significantly, from baseline to final follow-up: from 162.5° ± 8.9° to 167.5° ± 4.6° FF, from 132.5° ± 37.3° to 167.5° ± 4.6° ABD, and from 47.5° ± 13.9° to 51.9° ± 18.5° ER.

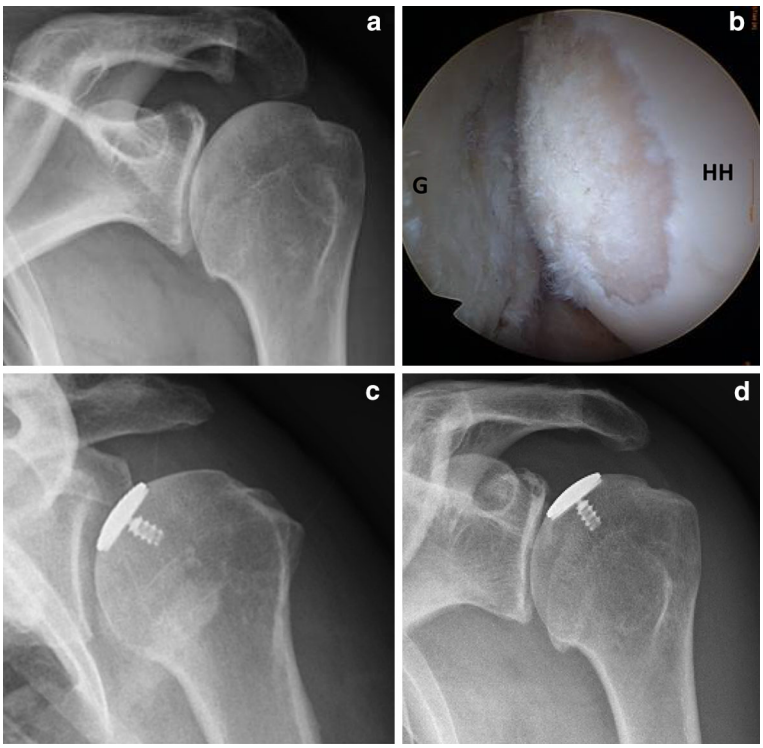

Fig. 3 Case 6 (47-year-old male patient's left shoulder). **a** Preoperative anteroposterior plain radiograph. **b** Arthroscopic image showing chondral damage of Outerbridge grade IV on the humeral head (HH) and Outerbridge grade II on the glenoid (G). Postoperative plain, anteroposterior radiographs from day one (**c**) and after 24 months (**d**) demonstrating no radiolucent lines at the implant–bone interface after arthroscopic-assisted partial shoulder resurfacing

Table 1 Radiological osteoarthritis grading obtained from preoperative radiographs

	Samilson and Prieto [35]	Kellgren and Lawrence [21]	Weinstein [42]	Guyette [18]
No OA	Grade 0	Stage 0	Stage I	Stage 0
	4 (36.4 %)	4 (36.4 %)	2 (18.2 %)	2 (18.2 %)
Mild OA	Grade 1	Stage 1	Stage II	Stage 1
	3 (27.3 %)	4 (36.4 %)	3 (27.3 %)	4 (36.4 %)
Moderate OA	Grade 2	Stage 2	Stage III	Stage 2
	2 (18.2 %)	1 (9.1 %)	4 (36.4 %)	3 (27.3 %)
Severe OA	Grade 3	Stage 3	Stage IV	Stage 3
	2 (18.2 %)	2 (18.2 %)	2 (18.2 %)	2 (18.2 %)

The VAS for pain, ASES, and SSV significantly improved from baseline to the first follow-up and maintained improvement 2 years after partial resurfacing (Table 2). With the exception of one case, all other patients (91 %) claimed that they would undergo arthroscopic partial shoulder resurfacing again.

Discussion

The most important findings of the present study are that arthroscopic-assisted partial humeral head resurfacing enables immediate postoperative full active shoulder mobilization and significantly improves subjective outcomes. The humeral Partial Eclipse™ prosthesis was developed as a minimally invasive treatment option for repairing cartilage defects of the humeral head that maintains joint biomechanics, preserves the intact cartilage as well as the subscapularis tendon and bone stock.

Non-arthroplasty minimally invasive treatment options to restore cartilage are limited, and results rely on the biological healing response. Microfracture has been reported to be an effective short-term (average, 28 months) treatment for full-thickness chondral defects of the shoulder, but only for small humeral lesions not involving the glenoid [13, 28]. Regarding open treatment options, Scheibel et al. [37] reported fairly good results for osteochondral transfers in a case series of eight patients, but a donor site morbidity of 50 % was described. For autologous chondrocyte transplantation, only case reports are available [3, 33]. All of these studies point to the fact that the progression of pre-existing osteoarthritis cannot be altered.

Table 2 Comparison of clinical and subjective measurements between baseline and up to 24 months after implantation

	Baseline	6 weeks	*P* value	3 months	*P* value	6 months	*P* value	12 months	*P* value	24 months	*P* value
Constant score *(0–100 points)*	54.6 ± 13.6	72.9 ± 17.2	0.009	76.9 ± 20.2	0.015	77.3 ± 23.7	0.015	78.6 ± 27.4	0.026	86.5 ± 14.3	<0.001
Pain	6.3 ± 3.5	11.9 ± 2.6	0.002	11.9 ± 4.6	0.007	13.8 ± 3.5	0.003	12.5 ± 5.3	0.011	13.8 ± 2.3	<0.001
ADL	10.5 ± 4.1	15.3 ± 3.6	0.022	16.0 ± 5.2	0.025	15.4 ± 5.3	0.024	15.9 ± 5.9	0.041	17.5 ± 3.1	0.003
ROM	26.8 ± 6.0	31.5 ± 7.0	n.s.	34.3 ± 6.5	0.050	32.3 ± 9.8	n.s.	33.0 ± 9.4	n.s.	35.3 ± 8.3	n.s.
Strength	11.1 ± 4.5	14.3 ± 6.5	n.s.	14.8 ± 5.2	n.s.	15.9 ± 7.1	0.031	17.3 ± 7.3	0.014	20.0 ± 5.0	0.001
VAS (0–10)	6.0 ± 2.4	2.1 ± 2.0	0.005	2.9 ± 2.4	0.037	2.5 ± 1.9	0.005	2.9 ± 2.8	0.023	3.0 ± 2.4	0.039
ASES *(100–0 points)*	55.2 ± 21.1	77.5 ± 22.1	0.048	76.0 ± 20.1	n.s.	76.5 ± 20.2	n.s.	77.3 ± 24.0	0.044	78.1 ± 18.5	0.042
SSV (%)	46.9 ± 25.2	72.5 ± 15.6	0.022	70.6 ± 23.4	0.040	75.6 ± 19.2	0.012	77.4 ± 18.2	0.010	78.1 ± 17.3	0.016

ADL activities of daily living, *ASES* American Shoulder and Elbow Surgeons scale, *ROM* range of motion, *SSV* subjective shoulder value, *VAS* visual analogue scale for shoulder pain

Arthroplasty treatment options for full and partial resurfacing of the humeral head [1, 4, 24, 25, 36, 40] have reported similar favourable outcomes compared with the present study. However, during the long-term follow-up of patients younger than 50 years of age, who underwent arthroplasty, only approximately half were reported to be satisfied with the procedure [39]. For open partial humeral head resurfacing, Uribe et al. [41] described good clinical results with the technique of covering only the chondral defect, preserving the intact cartilage. Furthermore, a biomechanical study suggested that anatomical humeral head resurfacing better replicates the geometric centre of rotation compared with hemiarthroplasty [19].

Subscapularis detachment may lead to repair failures and/or muscular changes such as atrophy and fatty infiltration, which are commonly detected after open procedures [10, 14, 26, 38]. With our method of arthroscopic-assisted partial humeral head resurfacing postoperative subscapularis dysfunction was avoided, so physical active patients were able to return to their pre-injury activities shortly after the procedure.

Other potential advantages of partial humeral head resurfacing are its potential to be an outpatient procedure, decreased blood loss, and minimal soft-tissue trauma; these qualities, together with the procedure's ability to preserve proximal humeral bone stock, provide a more favourable situation for later revision surgery, if necessary.

Despite all of the advantages this technique offers, three patients in our study had to be revised. The very first patient needed revision surgery because of an unrecognized—despite fluoroscopic control—intraoperative technical failure. A too proud implant position led to glenoid erosion and consequently to secondary osteoarthritis of the glenoid. Three other patients showed deteriorating shoulder function and progressive osteoarthritis within 6 months postoperatively. All of them were female; while two patients over 70 years of age converted to total shoulder arthroplasty, the much younger patient refused revision surgery. Hindsight failure analysis revealed a glenoid chondral defect of grade IV according to Outerbridge in all three cases. Regarding concomitant pathologies, a recent case series reported better short-term outcomes after partial humeral head resurfacing in patients with isolated chondral defects [8], while failure rates were similar (27 vs. 26 %). Another recent study [23] showed a 27 % revision rate due to secondary glenoid-based pain after hemiarthroplasty during long-term follow-up. Thus, leaving the glenoid untreated appears to be an important point to be addressed in partial humeral head resurfacing. Further limitations of this study included a small sample size, short follow-up time, and heterogeneity regarding indications for the procedure, as the threshold between focal chondral damage and cartilage degeneration in osteoarthritis is not clearly allocable.

On the basis of this study, instruments have been improved to minimize technical errors, implant sizes have been modified to cover larger defects, and arthroscopic glenoid resurfacing is under development at our institution. Our early clinical experience with this minimally invasive technique has produced promising results; however, we are also aware that partial humeral head resurfacing needs further study in a larger cohort and over a longer time period before comprehensive conclusions can be drawn regarding its efficacy.

Conclusion

In conclusion, arthroscopic-assisted partial humeral head resurfacing, which has the advantages of bone stock preservation and the maintenance of an intact subscapularis tendon, allowed immediate postoperative mobilization and provided significant improvements in subjective outcomes, especially for pain relief in active patients without severe glenoid cartilage wear.

Conflict of interest The Partial Eclipse Prosthesis was designed by Arthrex in cooperation with the senior author, who will receive royalties for his contribution regarding the design of the implant. W.A. is a consultant for Arthrex. However, Arthrex had no influence on study design, data collection, interpretation of the results, or the writing of the final article.

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