Treatment of osteochondral lesions in the elbow: results after autologous osteochondral transplantation

L. Weigelt, S. Siebenlist, D. Hensler, A. B. Imhoff, Stephan Vogt

Angaben zur Veröffentlichung / Publication details:

Weigelt, L., S. Siebenlist, D. Hensler, A. B. Imhoff, and Stephan Vogt. 2015. "Treatment of osteochondral lesions in the elbow: results after autologous osteochondral transplantation." Archives of Orthopaedic and Trauma Surgery 135 (5): 627–34. https://doi.org/10.1007/s00402-015-2204-z.

Treatment of osteochondral lesions in the elbow: results after autologous osteochondral transplantation

L. Weigelt[1] · S. Siebenlist[1] · D. Hensler[1] · A. B. Imhoff[1] · S. Vogt[1,2]

Abstract

Background Osteochondral lesions in the elbow still remain a challenging field of surgery. In recent years promising clinical results were described for the osteochondral transplantation technique. The aim of this retrospective study was to evaluate the clinical and radiological outcome in the mid-term follow-up of a large cohort of patients following osteochondral transplantation in the elbow.

Methods 18 patients with advanced osteochondral lesions of the elbow treated by autologous osteochondral autograft cylinders and a minimum follow-up of 36 months were included in the study. The Broberg–Morrey score (BMS) and the American Shoulder and Elbow score (ASES) were used to assess elbow function and pain, respectively. The joint status was analyzed using plain radiographs and MRI scans taken from all patients at recent follow-up. In addition, the ipsilateral knee joint was examined for donor-site morbidity using the Lysholm knee score.

Results 14 patients were evaluated with a mean follow-up of 7 years (range 3–14 years). The mean BMS was 95.1 (range 72–100) points. The ASES score also showed promising results: pain at worst 1.5 (range 0–5) points, pain at rest 0.4 (range 0–5) points, pain lifting loads 2.8 (range 0–8) points, repetitive movement pain 1.5 (range 0–8) points. The range of motion of the injured elbow was free and equal to the contralateral side. Signs of osteoarthritis could be found on plain radiographs in three patients. The MRIs at follow-up showed graft viability in all patients. However, a slight incongruency of the chondral surface could be detected in two patients. The average Lysholm score was 90.9 (range 0–70) points.

Conclusions Osteochondral transplantation in the elbow leads to both clinical and radiographic good-to-excellent mid-term results and therefore represents a reasonable treatment option for advanced osteochondral lesions in the elbow.

Level of evidence Retrospective study; Therapeutic Level IV.

Keywords Osteochondral lesion · Osteochondritis dissecans · Osteochondral transplantation · OATS · Elbow joint

Introduction

Osteochondral lesions in the elbow joint are rare pathologies which predominantly occur in teenage throwing or weightbearing athletes [1, 2]. Repetitive valgus stress with subsequent compression to the radiocapitellar joint is considered the main cause for these elbow lesions [3]. The cartilage stiffness of the humeral capitellum is lower compared to that of the radial head [4]. Consequently, the humeral capitellum is primarily affected in most of the cases. Nevertheless, osteochondral lesions of the trochlea or the radial head are also reported and may subsequently lead to osteoarthritis in the elbow [5–8]. Osteochondral lesions have to be differentiated from Panner's disease, a juvenile avascular necrosis of the humeral capitellum that is usually related to male children at the age of 6–10 years and often shows self-recovery [9].

L. Weigelt and S. Siebenlist have contributed equally.

✉ S. Vogt
stephan-vogt@web.de

[1] Department of Orthopaedic Sports Medicine, Klinikum rechts der Isar, TU Munich, Munich, Germany

[2] Hessing Klinik Augsburg, Augsburg, Germany

Osseous stability and vitality of osteochondral lesions have to be evaluated with magnetic resonance imaging (MRI) in order to define the treatment regime. According to the classification system of Dipaola et al. [10], stable lesions (defined as grade I or II) can be treated non-operatively. The conservative treatment mainly involves activity modification and cessation of sports participation and shows good clinical results, particularly in patients with open growth plates [11].

Unstable defects (grade III or IV according to Dipaola et al. [10]) as well as failed non-operative treatment and the separation and/or fragmentation of the osteochondral lesion require surgical intervention. In the last decade, the autologous osteochondral transplantation method was introduced for the treatment of advanced defects in the elbow joint [2, 12, 13]. In contrast to other surgical treatment options like debridement, microfracturing or drilling [14–18], this technique enables the restoration of both the hyaline cartilage and the subchondral bone. For larger defects involving more than 50 % of the articular surface or cases in which the lateral margin of the capitellum is involved, debridement may show inferior results with a higher risk of subsequent osteoarthritis in long-term follow-ups. Those lesions may be therefore better treated with fragment fixation or osteochondral autograft transfer [19, 20]. Short- to mid-term results of osteochondral autograft transplantation have shown good-to-excellent results [2, 12, 13, 21]. Our study group previously reported on the long-term clinical outcome following autologous osteochondral transplantation in the elbow in a smaller series of patients [22]. These encouraging results served as rationale for further clinical evaluation.

The purpose of this study was to review the clinical and radiological outcome of a larger cohort of patients with advanced osteochondral lesions in the elbow treated by osteochondral autograft transplantation.

Materials and methods

Patients

Between 1996 and 2009, 21 patients with advanced osteochondral lesions in the elbow underwent osteochondral autologous transplantation using an Osteochondral Autograft Transfer System (OATS, Arthrex, Naples, Florida). Failed non-operative treatment for at least 6 months or failed previous surgery in combination with osteochondral defects grade III or IV according to the classification system of Dipaola er al. [10] were indications for osteochondral transplantation in the elbow. Every patient had preoperative radiograph and MRI analysis. 18 out of the 21 treated patients had a minimum follow-up of 36 months after surgery and were consequently enrolled into the study. Two of these patients were lost to follow-up because they could not be located despite an intensive research. Another two patients were not willing to undergo follow-up survey. However, based on a short telephone evaluation, they were satisfied with the surgical procedure and did not complain about any restrictions, either at the operated elbow or at the donor knee. Finally, 14 patients (78 %) were available for clinical and radiological follow-up. One patient had received osteochondral transplantation in both elbows. For reasons of simplicity we handled these two cases like two patients (patient 5 and 7). The mean time interval from surgery to recent follow-up was 7 years (range 3–14 years). At the time of follow-up, there were 9 male and 5 female patients with a mean age of 25 years (range 17–37 years) and a mean age of 18 years (range 12–33 years) at time of surgery. Nine right and five left elbows were affected; the dominant arm was involved in 9 patients. The osteochondral lesions were located in the humeral capitellum ($n = 12$), the trochlea ($n = 1$) and the radial head ($n = 1$). Eleven patients were treated due to failed conservative treatment. The remaining three patients had previous failed surgery: one patient had undergone resection of the synovial fold, another removal of loose bodies after traumatic elbow dislocation. The third patient even had obtained three previous surgical treatments, including repeated removal of loose bodies and failed osteochondral autograft transplantation. Seven patients had been actively engaged in competitive sports (skiing, tennis, gymnastics, soccer), and six patients had been practiced sports at a recreational level (soccer, volleyball, tennis, basketball, handball, swimming). Only one patient had not been actively engaged in sports before surgery.

Surgical technique (tips and tricks)

The surgical procedure was briefly described in our published studies [13, 22]. We recommend the following procedure and consider especially tips and tricks. The patient is positioned supine on the operating table under general anesthesia. A tourniquet is placed on the affected upper extremity. In most cases, a lateral longitudinal incision extending from the lateral epicondyle along the radial head can be used. The approach is between the anconeus and extensor carpi ulnaris muscles. The joint capsule is exposed and longitudinally opened anterior to the radial head. The annular ligament should be preserved. A proximal release of the lateral collateral ligament can be especially necessary to access lesions that were centrally located in the capitellum or in the radial head. The lateral collateral ligament must be repaired at the end of surgery. In cases of a dorsal capitellum lesion, a dorsoradial approach should be used and for an anterior capitellum lesion, an anterolateral approach is advantageous. Usually the defect can be well exposed in elbow extension. However, for dorsal capitellum lesions, the exposure will be better in 90° of flexion. The size of the lesion has to be measured exactly and can be excised with the use of the Osteochondral Autograft Transfer System (OATS) (Arthrex, Naples, Florida) (Fig. 1a). An osteochondral cylindrical donor graft should be harvested from the non-weightbearing area of the proximal lateral femoral condyle of the ipsilateral knee through a small lateral parapatellar arthrotomy (Fig. 1b). The obtained cylinder of appropriate depth (but slightly increased diameter) can be transplanted press-fit into the recipient site of the elbow. Because of different cartilage thicknesses between knee and elbow joints (knee > elbow), it is important to consider this for the implantation of the osteochondral graft to achieve cartilage congruity. As a result the subchondral bone of the graft and the surrounding bone are mostly not congruent. Therefore, it can be advantageous to harvest the cylinder from the most proximal area of the trochlea (adjacent to the periosteum) where the cartilage thickness is reduced and therefore the subchondral bone will be more congruent in the elbow (decreased biomechanical stress).

Evaluation

An independent investigator, not involved in the initial surgical management, carried out the physical examination and study evaluation for the recent follow-up survey. Patients' satisfaction for elbow use was inquired on an ordinary scale between 1 and 5 (indicating 1—"very good"; 2—"good"; 3—"fair"; 4—"poor"; 5—"very poor"). The clinical assessment consisted of the Broberg–Morrey score (BMS) as an objective scoring system including the subcategories pain, range of elbow motion, strength, and stability. Pain was additionally evaluated with the modified American Shoulder and Elbow Surgeons (ASES) score. The ipsilateral knee joint was examined for donor-site morbidity using the Lysholm knee score.

Antero-posterior and lateral radiographs of the operated elbows were taken for analysis of osteoarthritic changes in accordance with the staging system of Kellgren and Lawrence [23]. Moreover, MRI analysis was performed to assess graft viability, integration, joint surface congruency, and degenerative changes like cysts, edema or alterations in the cartilage of the capitellum or radial head.

Statistical analysis

Statistical analysis was performed using Microsoft Excel 2003 and PASW software, version 15.0 (SPSS Inc., Chicago, IL, USA). The Student's *t* test and Mann–Whitney *U* test were used to evaluate the differences between groups where appropriate. A level of $P < 0.05$ was considered significant.

Results

In all patients the osteochondral defect could adequately be filled with a single autograft cylinder. The mean diameter of the defect was 9.5 mm (range 8–11 mm). Patients' demographics and scoring results are illustrated in Table 1.

12 out of 14 patients (86 %) were satisfied with the therapeutic procedure ("very good" in 8 patients; "good" in 4 patients). The mean BMS in these 15 patients was 97.1 (range 95–100). Patient 6 with a BMS of 95 evaluated the treatment as "fair" and patient 14 (BMS 72) as "poor". Except patient 14 everyone would undergo the same procedure again. Overall, the mean BMS was 95.1 (range 72–100).

The range of motion (ROM) of the operated elbow joint was unrestricted in all patients with a mean extension–flexion arc of 133° (range −5° to 140°). No differences were seen as compared with the contralateral arm.

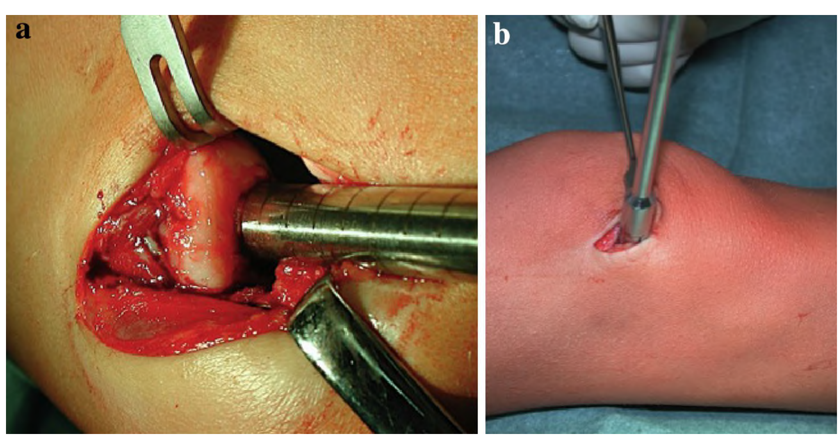

Fig. 1 **a** Measuring of the lesion using the osteochondral autograft transfer system (OATS) (Arthrex, Naples, Florida). **b** Cylindrical donor graft harvesting from the non-weightbearing area of the proximal lateral femoral condyle of the ipsilateral knee through a small lateral parapatellar arthrotomy

Table 1 Demographics and scoring results of evaluated patients

Patient.	Age, years	Defect	Side	Dominant side	Level of sports		Graft size, mm	Broberg–Morrey	ASES worst	ASES rest	ASES weight	ASES repeat.	Lysholm	FU/ years
					Before treatment	After treatment								
1	15	Capitellum	R	R	Soccer (recreational)	Soccer (recreational)	10	95	2	0	4	2	100	14
2	15	Capitellum	L	R	Skiing (competitive)	Mountain infantry	9	100	0	0	0	0	100	10
3	15	Radial head	R	R	Tennis (competitive)	Tennis (recreational)	10	100	5	0	4	4	100	9
4	18	Capitellum	L	R	Gymnastics (competitive)	No sports	11	95	3	0	5	3	100	9
5	15	Trochlea	R	R	Volleyball (recreational)	Volleyball (recreational)	9	95	0	0	3	1	70	8
6	19	Capitellum	R	R	Soccer goalkeeper (competitive)	Body building (recreational)	9	95	0	0	3	0	89	7
7	16	Capitellum	L	R	Volleyball (recreational)	Volleyball (recreational)	9	95	1	0	3	1	70	7
8	30	Capitellum	R	R	Tennis (recreational)	Tennis (recreational)	9	95	0	0	2	0	84	7
9	19	Capitellum	R	R	Basketball (recreational)	Basketball (recreational)	10	95	2	0	2	0	95	6
10	18	Capitellum	L	R	Gymnastics (competitive)	No sports	10	100	1	0	1	0	100	6
11	12	Capitellum	R	L	Gymnastics (competitive)	Gymnastics (competitive)	8	100	0	0	0	0	95	5
12	18	Capitellum	R	R	Handball (recreational)	Handball (recreational)	11	100	0	0	1	0	100	4
13	13	Capitellum	R	R	Gymnastics (competitive)	Gymnastics (competitive)	8	95	3	0	3	2	95	4
14	33	Capitellum	L	R	No sports	No sports	10	72	4	5	8	8	74	3

Moreover, no differences in elbow strength or stability were found between the injured and the uninjured arm.

According to the ASES score the mean pain level was: “at its worst” 1.5 (range 0–5), “at rest” 0.4 (range 0–5), “due to lifting heavy weights” 2.8 (range 0–8) and “due to repetitive movements” 1.5 (range 0–8)

The mean Lysholm score of the ipsilateral donor knee was 90.9 (range 70–100). Seven patients reported on occasional pain during heavy lifting. One patient complained about intermittent locking sensations.

In eleven patients no degenerative changes of the elbow joint were found following plain radiographs (Table 2). Minimal osteoarthritic changes (Kellgren and Lawrence [23] grade I) could be identified in two patients. One patient' s elbow showed signs of degeneration with additional narrowing of joint line (Kellgren and Lawrence [23] grade II) 3 years after surgery (Fig. 2a–d).

The MRI scans showed graft viability and full-thickness integration of the osteochondral cylinders in all patients (Fig. 3a, b) (Table 2). In two patients the articular surface was found slightly incongruent and in four patients a single subchondral cyst could be detected with perifocal subchondral edema in three cases. In addition, cartilage alterations of the capitellum characterized by an increased signal of T2-weighted MRI analysis were noticeable in three patients. Those alterations were also seen in the cartilage of the radial head of seven patients although they did not receive any surgical intervention in this location (Table 2).

11 patients returned to sports after surgery; two patients are currently not engaged in sporting activities for time reasons. Only two out of eight patients who were engaged in sports on a competitive level prior to surgery continued at the same level of intensity postoperatively. The others cited either rising job requirements or their older age as the main reasons for their reduced sports level (Table 1).

Discussion

There is no gold standard for surgical treatment of unstable chondral and/or osteochondral lesions in the elbow and evidence is insufficient to determine the superiority of debridement or osteochondral autograft transfer procedures.

The involvement of the subchondral bone plays a key role in further decision-making. First, the refixation of the osteochondral fragment represents a good therapeutic option [24, 25], but is not practicable in many of the cases. Surgical techniques like debridement, drilling or microfracturing of the defect can lead to a relief of the initial symptoms, but the long-term results are less encouraging [16, 26]. These methods do not replace the subchondral bone and hyaline cartilage, but induce formation of fibrocartilage tissue with less biomechanical properties compared with hyaline cartilage. Subsequent osteoarthritic changes of the elbow joint are frequently described for these methods [19, 27–29]. Brownlow et al. [16] reported on 29 patients with osteochondritis dissecans of the elbow following arthroscopic debridement and removal of loose bodies. At a mean follow-up of 6.4 years most of the patients reported mild or no pain, but 38 % had persistent episodes of locking or catching postoperatively, although less frequently and painfully. In a study of Bauer et al. [19] half of the patients ($n = 31$) were symptomatic after an

Table 2 Results of radiologic analysis

Patient	Integration	Vitality	Incongruency	Cysts	Edema	Cartilage lesion capitellum	Cartilage lesion radius	Osteoarthritis Kellgren–Lawrence, 0–IV
1	Complete	Complete	Yes	Yes	No	1	1	1
2	Complete	Complete	No	Yes	Yes	1	1	1
3	Complete	Complete	No	No	No	0	1	0
4	Complete	Complete	No	No	No	0	0	0
5	Complete	Complete	No	Yes	Yes	0	0	0
6	Complete	Complete	No	No	No	0	1	0
7	Complete	Complete	No	No	No	0	0	0
8	Complete	Complete	No	No	No	0	0	0
9	Complete	Complete	No	No	No	0	0	0
10	Complete	Complete	No	No	No	0	0	0
11	Complete	Complete	No	No	No	0	1	0
12	Complete	Complete	No	No	No	0	0	0
13	Complete	Complete	No	Yes	Yes	0	0	0
14	Complete	Complete	Yes	No	No	1	1	2

Fig. 2 Postoperative **a** T1 coronal and **b** T2 sagittal MRI scans of patient 14 (final follow-up, 3.0 years after re-OATS), showing a vital and fully integrated osteochondral cylinder, but slight joint surface incongruency. AP (**c**) and lateral (**d**) radiographs showing narrowing of the joint space and osteophytes (Kellgren and Lawrence grade II)

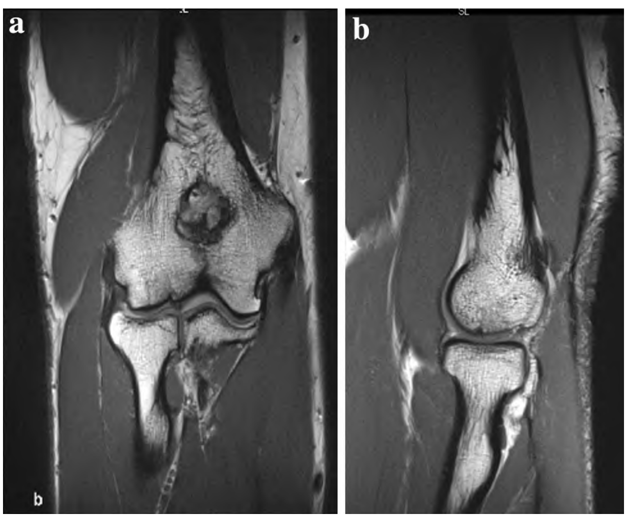

Fig. 3 Postoperative **a** T1 coronal and **b** T1 sagittal MRI scans of patient 7 (7.4 years postoperative), showing a vital and congruent osteochondral cylinder

average of 23 years after debridement, mainly complaining about loss of extension and pain. In more than 50 % of the cases degenerative signs in the radiohumeral joint were found and correlated with clinical symptoms.

Osteochondral autologous transplantation provides immediate restoration of the defect with subchondral bone and hyaline cartilage. In the knee or ankle joint, this procedure is already well established with good-to-excellent mid- to long-term results [30–32]. In the elbow joint, the short- to mid-term results of this intervention are encouraging [2, 12, 33–35]. Shimada et al. [34] reported an excellent outcome after osteochondral transplantation in 8 of 10 patients at a mean follow-up of 26 months, but two patients had poor results. According to the authors these poor results may be due to pre-existing osteoarthritis, which furthermore compromised the approach to the location of the defect. Yamamoto et al. [2] examined 18 baseball players after a mean period of 3.5 years. 89 % of their cohort showed increased functional scores and 82 % regained their previous competitive level of sport. In a study of Iwasaki et al. [12], 18 of 19 athletes, treated with osteochondral mosaicplasty in the elbow joint, yielded good or excellent results with a significant improvement of ROM and function after a mean follow-up of 3.8 years. 17 of 19 patients returned to their preoperative sports level. Only one patient complained about sporadic mild pain in the elbow. The radiologic evaluation did not reveal any signs of degeneration in all cases.

In a previous study, we could report on long-term clinical results following autologous osteochondral transplantation in the elbow, even though only in a small series of eight patients [22]. Thus, the purpose of the present study was to investigate the mid-term results (3–14 years after surgery) in a larger series of patients. In the present study, the Broberg–Morrey score and ASES score were good to excellent and comparable to previous cited studies [2, 19]. Overall 86 % of the patients were satisfied with the surgical procedure and the postoperative course. Moreover, 85 % of patients ($n = 11$) who were engaged in sporting activities before surgery returned to sports.

The most common criticism of this technique is the exposure of the knee and the associated potential risk of donor-site morbidity [36, 37]. This complication has not been seen after osteochondral autograft transplantation in the elbow so far [38, 39] which might have been due to the fact that in all cases only one small osteochondral graft is needed. However, controversial results on the relationship between graft size and donor-site morbidity are reported [30, 40]. Furthermore, evidence is limited due to small case numbers. Considering the fact that no patient had received an intervention at the donor knee before nor had any injury, the preoperative Lysholm score can be compared to a "normal" population without pre-existing knee pathologies as described by Demirdjian et al. [41]. In their study, the mean Lysholm score of 418 knees was 99.1/97.2 for male/female subjects with a mean age of 17.6 years. Thus, the Lysholm score in our study showed a slight deterioration with a mean result of 90.9 at follow-up indicating that there might be also a donor-site morbidity. However, the advanced age of our patients after an average of 7.0 years of follow-up may bias the present results. The patient who had received osteochondral transfer in both elbow joints, represented with the lowest Lysholm score of only 70 points for both knee joints. However, this patient stated that his knee problems did occur several years after surgical interventions. Furthermore, the symptoms mainly occur at work as a waitress. Therefore, since the knee problems are bilateral, one cannot say if these are due to donor-site morbidity or if they are age- or work-related.

It needs to be noticed that the only patient (patient 14) who rated the outcome as "poor" (with the worst BMS of 72) has had three surgical interventions prior to our latest osteochondral transfer procedure. After two previous interventions with removal of loose bodies in the elbow in another hospital we performed a first osteochondral autograft transplantation. However, the procedure did not lead to a reduction of symptoms and after 3 months a partial osteonecrosis of the transplanted graft was seen. In a revision procedure 6 months later, we transplanted another osteochondral cylinder harvested from the ipsilateral knee. Even though the graft was vital and fully integrated at follow-up the patient stated that he was never asymptomatic. On the plain radiographs the initial degenerative changes deteriorated to grade II osteoarthritis at final follow-up. Overall, this case can be considered as an insufficient outcome and should let us reconsider our indication for this surgical intervention. In comparison to the other cases, patient 14 had already pre-existing osteoarthritis before the first OATS procedure and he was 33 years old by the time of surgery. These confounding factors may contribute to the poor outcome at the last follow-up. In addition, this was a Re-OATS procedure during a third revision and it is well known from other surgeries that those cases rarely achieve the same outcome as patients after initial surgery.

The plain radiographs revealed no signs of osteoarthritis in all but three patients. Patient 1 showed up with osteoarthritis grade I in the elbow joint and showed a higher pain level compared to the other patients. However, radiological findings did not always correlate with the functional outcome. One the one hand, patient 2 had an excellent clinical outcome (BMS 100, ASES 0) despite grade I osteoarthritis. On the other hand, patient 3 and 4 reported a relatively high pain level, but did not show any radiological signs of osteoarthritis nor MRI alterations like joint incongruency, cysts or edema.

On the present MRI analysis all osteochondral cylinders were vital and fully integrated in the adjacent subchondral bone. In correlation to the osteoarthritic changes on the plain radiographs, patient 1 and 14 showed slight joint incongruency. In four cases subchondral edema or a cyst were detected which did not correlate with the clinical outcome, a fact that was also stated by Han et al. [42] in a study on cysts in the talus.

The present study has several limitations, represented by its retrospective design and the limited sample size. At time of surgery the clinical data (Broberg–Morrey and ASES scores) were not recorded for all patients. Consequently, a comparative evaluation of pre- and post-operative patients' status could not be performed in a valid way. Moreover, due to the limited sample size, a subgroup analysis (differences in duration of follow-up, dominance of injured arm, or sporting activities) lacked for statistical significance and therefore we performed this study in a descriptive manner.

However, this study has also several strengths, including a mean clinical and radiological follow-up of 7 years and a low rate of patients lost to follow-up. Despite the rarity of osteochondral lesions in the elbow joint, this study represents a large case series (14 elbows) on this topic. In addition, we assessed four outcome measures, including Broberg–Morrey score, ASES score, radiographic and MRI scan examination.

To sum up, we do think the autologous osteochondral transplantation is a feasible treatment option for advanced osteochondral lesions in the elbow providing reliable clinical outcome. Nevertheless, prospective randomized trials with a larger number of patients are needed to make progress in the treatment of complex osteochondral lesions in the elbow joint.

References

1. Jackson DWD, Silvino NN, Reiman PP (1989) Osteochondritis in the female gymnast's elbow. Arthroscopy 5:129–136
2. Yamamoto YY, Ishibashi YY, Tsuda EE et al (2006) Osteochondral autograft transplantation for osteochondritis dissecans of the elbow in juvenile baseball players: minimum 2-year follow-up. Am J Sports Med 34:714–720
3. Yadao MA, Field LD, Savoie FH (2004) Osteochondritis dissecans of the elbow. Instr Course Lect 53:599–606
4. Schenck RC, Athanasiou KA, Constantinides G, Gomez E (1994) A biomechanical analysis of articular cartilage of the human

elbow and a potential relationship to osteochondritis dissecans. Clin Orthop Relat Res 299:305–312

5. Barnes DA, Tullos HS (1978) An analysis of 100 symptomatic baseball players. Am J Sports Med 6:62–67
6. Patel N, Weiner SD (2002) Osteochondritis dissecans involving the trochlea: report of two patients (three elbows) and review of the literature. J Pediatr Orthop 22:48–51
7. Popescu D, Alvarez P, Steinbacher G, Cugat R (2007) Bilateral osteochondrosis of radial head. Eur J Orthop Surg Traumatol 17:367–371
8. Bauer M, Jonsson K, Josefsson PO, Lindén B (1992) Osteochondritis dissecans of the elbow. Clin Orthop Relat Res 284:156–160
9. Panner HJ (1929) A peculiar affection of the capitellum humeri, resembling Calve-Perthes disease of the hip. Acta Radiol 10:234–242
10. Dipaola JD, Nelson DW, Colville MR (1991) Characterizing osteochondral lesions by magnetic resonance imaging. YJARS 7:101–104
11. Takahara M, Ogino T, Fukushima S et al (1999) Nonoperative treatment of osteochondritis dissecans of the humeral capitellum. Am J Sports Med 27:728–732
12. Iwasaki N, Kato H, Ishikawa J et al (2009) Autologous osteochondral mosaicplasty for osteochondritis dissecans of the elbow in teenage athletes. J Bone Joint Surg Am 91:2359–2366
13. Ansah P, Vogt S, Ueblacker P et al (2007) Osteochondral transplantation to treat osteochondral lesions in the elbow. J Bone Joint Surg Am 89:2188–2194
14. Ruch DS, Cory JW, Poehling GG (1998) The arthroscopic management of osteochondritis dissecans of the adolescent elbow. Arthroscopy 14:797–803
15. Rahusen FTG, Brinkman J-M, Eygendaal D, van der Geest I (2006) Results of arthroscopic debridement for osteochondritis dissecans of the elbow. Br J Sports Med 40:966–969
16. Brownlow HC, O'Connor-Read LM, Perko M (2005) Arthroscopic treatment of osteochondritis dissecans of the capitellum. Knee Surg Sports Traumatol Arthrosc 14:198–202
17. Bojanić I, Ivković A, Borić I (2005) Arthroscopy and microfracture technique in the treatment of osteochondritis dissecans of the humeral capitellum: report of three adolescent gymnasts. Knee Surg Sports Traumatol Arthrosc 14:491–496
18. Mitsunaga MM, Adishian DA, Bianco AJ Jr (1982) Osteochondritis dissecans of the capitellum. J Trauma 22:53–55
19. Bauer MM, Jonsson KK, Josefsson POP, Lindén BB (1992) Osteochondritis dissecans of the elbow. A long-term follow-up study. Clin Orthop Relat Res 284:156–160
20. Smith MV, Bedi A, Chen NC (2012) Surgical treatment for osteochondritis dissecans of the capitellum. Sports Health 4:425–432
21. Ovesen J, Olsen BS, Johannsen HV (2011) The clinical outcomes of mosaicplasty in the treatment of osteochondritis dissecans of the distal humeral capitellum of young athletes. J Shoulder Elbow Surg 20:813–818
22. Vogt S, Siebenlist S, Hensler D et al (2011) Osteochondral transplantation in the elbow leads to good clinical and radiologic long-term results: an 8- to 14-year follow-up examination. Am J Sports Med 39:2619–2625
23. Kellgren JH, Lawrence JS (1957) Radiological assessment of rheumatoid arthritis. Ann Rheum Dis 16:485–493
24. Takahara M (2007) Classification, treatment, and outcome of osteochondritis dissecans of the humeral capitellum. J Bone Joint Surg Am 89:1205
25. Takeda H, Watarai K, Matsushita T et al (2002) A surgical treatment for unstable osteochondritis dissecans lesions of the humeral capitellum in adolescent baseball players. Am J Sports Med 30:713–717
26. Baumgarten TE, Andrews JR, Satterwhite YE (1998) The arthroscopic classification and treatment of osteochondritis dissecans of the capitellum. Am J Sports Med 26:520–523
27. Kim HK, Moran ME, Salter RB (1991) The potential for regeneration of articular cartilage in defects created by chondral shaving and subchondral abrasion. An experimental investigation in rabbits. J Bone Joint Surg Am 73:1301–1315
28. Von Keudell A, Atzwanger J, Forstner R et al (2012) Radiological evaluation of cartilage after microfracture treatment: a long-term follow-up study. Eur J Radiol 81:1618–1624
29. Custers RJH, Saris DBF, Dhert WJA et al (2009) Articular cartilage degeneration following the treatment of focal cartilage defects with ceramic metal implants and compared with microfracture. J Bone Joint Surg 91:900–910
30. Marcacci M, Kon E, Delcogliano M et al (2007) Arthroscopic autologous osteochondral grafting for cartilage defects of the knee: prospective study results at a minimum 7-year follow-up. Am J Sports Med 35:2014–2021
31. Hangody L, Dobos J, Balo E et al (2010) Clinical experiences with autologous osteochondral mosaicplasty in an athletic population: a 17-year prospective multicenter study. Am J Sports Med 38:1125–1133
32. Imhoff AB, Paul J, Ottinger B et al (2011) Osteochondral transplantation of the talus: long-term clinical and magnetic resonance imaging evaluation. Am J Sports Med 39:1487–1493
33. Nakagawa Y, Matsusue Y, Ikeda N et al (2001) Osteochondral grafting and arthroplasty for end-stage osteochondritis dissecans of the capitellum a case report and review of the literature. Am J Sports Med 29:650–655
34. Shimada K, Yoshida T, Nakata K et al (2005) Reconstruction with an Osteochondral Autograft for Advanced Osteochondritis Dissecans of the Elbow. Clin Orthop Relat Res 435:140–147
35. Tsuda EE, Ishibashi YY, Sato HH et al (2005) Osteochondral autograft transplantation for osteochondritis dissecans of the capitellum in nonthrowing athletes. Arthroscopy 21:1270
36. Hangody L, Füles P (2003) Autologous osteochondral mosaicplasty for the treatment of full-thickness defects of weight-bearing joints: ten years of experimental and clinical experience. J Bone Joint Surg Am 85(A Suppl 2):25–32
37. Marshall KW, Marshall DL, Busch MT, Williams JP (2009) Osteochondral lesions of the humeral trochlea in the young athlete. Skeletal Radiol 38:479–491
38. Nishimura A, Morita A, Fukuda A et al (2011) Functional recovery of the donor knee after autologous osteochondral transplantation for capitellar osteochondritis dissecans. Am J Sports Med 39:838–842
39. Iwasaki N, Kato H, Kamishima T et al (2007) Donor site evaluation after autologous osteochondral mosaicplasty for cartilaginous lesions of the elbow joint. Am J Sports Med 35:2096–2100
40. Paul J, Sagstetter A, Kriner M et al (2009) Donor-site morbidity after osteochondral autologous transplantation for lesions of the talus. J Bone Joint Surg 91:1683–1688
41. Demirdjian AM, Petrie SG, Guanche CA, Thomas KA (1998) The outcomes of two knee scoring questionnaires in a normal population. Am J Sports Med 26:46–51
42. Han SH, Lee JW, Lee DY, Kang ES (2006) Radiographic changes and clinical results of osteochondral defects of the talus with and without subchondral cysts. Foot Ankle Int 27:1109–1114