Osteochondral transplantation to treat osteochondral lesions in the elbow

Patrick Ansah, Stephan Vogt, Peter Ueblacker, Vladimir Martinek, Klaus Woertler, Andreas B. Imhoff

Angaben zur Veröffentlichung / Publication details:

Ansah, Patrick, Stephan Vogt, Peter Ueblacker, Vladimir Martinek, Klaus Woertler, and Andreas B. Imhoff. 2007. "Osteochondral transplantation to treat osteochondral lesions in the elbow." *The Journal of Bone and Joint Surgery* 89 (10): 2188–94. https://doi.org/10.2106/jbjs.f.00299.

Osteochondral Transplantation to Treat Osteochondral Lesions in the Elbow

By Patrick Ansah, MD, Stephan Vogt, MD, Peter Ueblacker, MD, Vladimir Martinek, MD, Klaus Woertler, MD, and Andreas B. Imhoff, MD

Investigation performed at the Department of Orthopedic Sports Medicine, Technical University Munich, Munich, Germany

Background: Effective treatment of osteochondral lesions in the elbow remains challenging. Arthroscopic débridement and microfracture or retrograde drilling techniques are often insufficient and provide only temporary symptomatic relief. The purpose of this study was to evaluate the treatment of these lesions with osteochondral autografts.

Methods: From 1999 to 2002, seven patients with osteochondral lesions of the capitellum humeri (five patients), trochlea (one patient), or radial head (one patient) were treated with cylindrical osteochondral grafts, which were harvested from the non-weight-bearing area of the proximal aspect of the lateral femoral condyle. The patients (three female and four male patients with an average age of seventeen years) were evaluated preoperatively and postoperatively, with an average follow-up of fifty-nine months. The Broberg and Morrey score was chosen for functional evaluation of the elbow (with regard to motion, pain, strength, activities of daily living, and stability), and the American Shoulder and Elbow Surgeons score was used for the analysis of pain. All patients had imaging studies done preoperatively to evaluate the defect and postoperatively to assess the ingrowth and viability of the graft. The ipsilateral knee was examined for donor-site morbidity.

Results: The Broberg and Morrey score improved from a mean (and standard deviation) of 76.3 ± 13.2 preoperatively to 97.6 ± 2.7 postoperatively, and pain scores were significantly reduced ($p < 0.05$). The mean elbow extension lag of 4.7° ± 5.8° was reduced to 0° postoperatively. Compared with the contralateral side, there was a mean preoperative flexion lag of 12.9° ± 13.8°. At the time of the final follow-up, flexion was free and was equal bilaterally in all patients. None of the plain radiographs made at the time of follow-up showed any degenerative changes or signs of osteoarthritis. The postoperative magnetic resonance imaging scans showed graft viability and a congruent chondral surface in all seven patients. No donor-site morbidity was noted at one year postoperatively.

Conclusions: The osteochondral autograft procedure described in the present study provides the opportunity to retain viable hyaline cartilage for the repair of osteochondral lesions in the elbow while restoring joint congruity and function and perhaps reducing the risk of osteoarthritis. These medium-term results suggest that the risks of a two-joint procedure are modest and justifiable. In addition, the described technique provides an option for revision surgery after the failure of other surgical procedures.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Osteonecrosis and chondral or osteochondral lesions in the elbow are a treatment challenge. In most cases, the radiohumeral joint is affected. These conditions have been variably described as Panner disease (juvenile osteonecrosis of the capitellum humeri) or osteochondral lesions or osteochondritis dissecans affecting the capitellum[1-6], the trochlea[7,8], or the radial head. All of these may lead to osteoarthritis.

Panner disease by definition occurs between the ages of

Disclosure: The authors did not receive any outside funding or grants in support of their research for or preparation of this work. Neither they nor a member of their immediate families received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, division, center, clinical practice, or other charitable or nonprofit organization with which the authors, or a member of their immediate families, are affiliated or associated.

A commentary is available with the electronic versions of this article, on our web site (www.jbjs.org) and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM).

TABLE I Magnetic Resonance Imaging Classification of Osteochondral Lesions and/or Osteochondritis Dissecans According to the Staging System Described by Dipaola et al.[22]

Grade	Characteristics on Magnetic Resonance Imaging
I	No break in articular cartilage and thickening of articular cartilage
II	Articular cartilage breached, with low-signal rim behind fragment indicating fibrous attachment
III	Articular cartilage breached, with high-signal T2 changes behind fragment suggesting fluid behind the lesion
IV	Loose body with defect of articular surface

six and ten years with a predilection for males, and it resolves spontaneously[9]. Osteochondral lesions and osteochondritis dissecans primarily affect adolescent and young adult athletes engaged in repetitive overhead and upper extremity weight-bearing activities. The cause of these conditions is unknown. Genetic predisposition, repetitive microtrauma, ischemia, or microvascular thrombosis all have been implicated[9-18]. Usually the dominant side is affected[15]. Schenck et al. showed that the cartilage comprising the lateral aspect of the capitellum is weaker than the medial cartilage. Thus, valgus extension overload may lead preferentially to damage in this area[14].

Patients present with pain in the affected elbow, which increases with activity and is often accompanied by stiffness, pain at night, loss of range of motion, and sometimes clicking and locking.

The diagnosis can usually be made radiographically. In addition to standard radiographs, including anteroposterior and lateral views, tangential radiographs at 45° of elbow flexion[4] should be made to show the extent and stage of the disease. Marked flattening of the lateral aspect of the capitellum humeri can been seen in the early stages[19-21]. Magnetic resonance imaging allows earlier diagnosis and better classification of the lesions with use of the staging system of Dipaola et al.[22,23] (Table I). This staging system was first used for osteochondral lesions and/or osteochondritis dissecans of the knee and talus and has accurately correlated magnetic resonance imaging with arthroscopic findings. More recently, it has been used to classify osteochondritis dissecans of the elbow[24].

Nonoperative treatment[15,17,25,26] may be chosen for young patients before physeal closure in stage-I and II (stable) lesions and in stage-III and IV (unstable) lesions when the symptoms have been present for less than six months. For surgical treatment, various procedures that have been described include arthroscopic débridement, microfracture, retrograde drilling, reattachment of a loose fragment, or even closing-wedge osteotomy of the lateral aspect of the distal end of the humerus to reduce compression forces across the radiohumeral joint[1,19,27-30]. These techniques, however, may be insufficient, provide only temporary relief, and still carry a high risk of subsequent arthritis[20]. Furthermore, none of these techniques can restore hyaline cartilage except for reattachment of a loose fragment. In contrast, osteochondral transplantation can replace the defect with hyaline cartilage. This technique, initially established by Hangody et al. as mosaicplasty[31] for focal cartilage defects in the femoral condyle, has found widespread acceptance and has been used in several joints[32-36]. The aim of this study was to assess whether osteochondral transplantation in the elbow is a reasonable option to treat osteochondral lesions.

Materials and Methods

From 1999 to 2002, seven patients with osteochondral lesions of the capitellum humeri (five patients), trochlea (one patient), or radial head (one patient) were treated surgically with osteochondral transplantation (Table II). Over the same period, this method was used to treat lesions in other joints (femoral condyle, tibial plateau, patella, ankle joint, and glenohumeral joint) in more than 400 patients in our department. Cylindrical osteochondral grafts were harvested from the non-weight-bearing area[37] of the proximal part of the lateral femoral condyle in the ipsilateral knee and were transplanted into the defect zone with use of an osteochondral autotransplantation system (OATS; Arthrex, Naples, Florida). There were three female and four male patients with an average age of seventeen years (range, fifteen to twenty-one years) at the time of surgery. Four left and three right elbows were affected, and all patients were right-hand dominant. The average duration of follow-up was 59.3 months (range, forty-two to eighty-three months). For every patient, plain radiographs were made and magnetic resonance imaging scans were acquired preoperatively, postoperatively, and at the time of the final follow-up to evaluate the lesions and to assess ingrowth, positioning, and viability of the transplanted graft[38]. Five patients had been previously actively engaged in competitive sports, and the other two patients played volleyball at a recreational level. All patients had stage-III or IV[22] lesions on magnetic resonance imaging (Fig. 1). All had either had failure of nonoperative treatment after more than six months or failure of a previous surgery (repeat fixation of a loose fragment in one patient and arthroscopic débridement in another patient). All patients were seen preoperatively and postoperatively and were evaluated in the outpatient clinic during follow-up visits by one of us (P.A.). The Broberg and Morrey score was chosen for functional evaluation of the elbow. This clinical score, suggested by Morrey et al.[39,40], considers motion, pain, strength, activities of daily living, and stability. The completion of an American Shoulder and Elbow Surgeons (ASES) form was used to assess pain[41]. The ipsilateral knee was examined for donor-site morbidity. Radiographs were made on the first postoperative day and at the time of the five-year follow-up

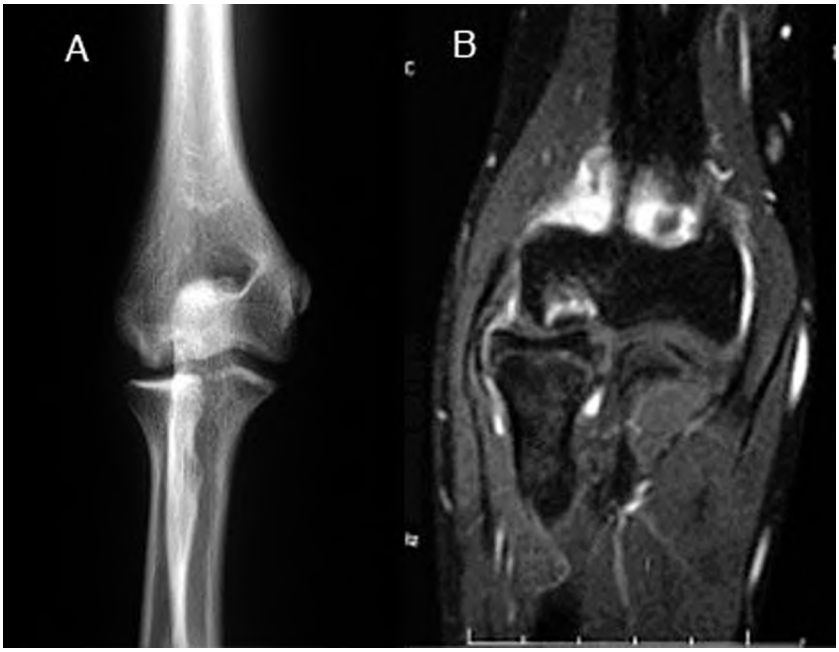

Fig. 1

Preoperative anteroposterior radiograph *(A)* and T2-weighted magnetic resonance imaging scan *(B)* of the right elbow demonstrating an isolated osteochondral defect of the capitellum. The articular cartilage is breached, and there are high-signal changes behind the fragment, suggesting the presence of fluid behind the lesion. This is a grade-III lesion.

and/or the last follow-up visit. A magnetic resonance imaging scan was acquired eight to twelve weeks postoperatively and at five years and/or the final follow-up evaluation.

Operative Technique

Under general anesthesia, the patient is positioned supine on the operating table and a tourniquet is placed on the affected upper arm. The arm and ipsilateral knee are draped and disinfected in a standard manner. Preoperatively, a single dose of antibiotic (1.5 g of cefuroxime) is given intravenously. We use a lateral approach with a longitudinal incision extending from the lateral epicondyle along the radial head and the anconeus muscle. The fascia is split between the anconeus and the extensor carpi ulnaris muscles. The joint capsule is exposed and then longitudinally incised anterior to the radial head. The annular ligament is preserved. Depending on the

TABLE II Patients with Osteochondritis Dissecans in the Elbow

Case	Age *(yr)*	Defect Location	Side	Dominant Side	Level of Sports	
					Before Treatment	After Treatment
1	21	Capitellum	L	R	Basketball (competitive)	Basketball (competitive)
2	15	Capitellum	L	R	Skiing (competitive)	Mountain infantry
3	15	Radial head	R	R	Tennis (competitive)	Tennis (competitive)
4	18	Capitellum	L	R	Gymnastics (competitive)	Gymnastics (competitive)
5	15	Trochlea	R	R	Volleyball (leisure)	Volleyball (leisure)
6	19	Capitellum	R	R	Soccer goalkeeper (competitive)	Fitness sports
7	16	Capitellum	L	R	Volleyball (leisure)	Volleyball (leisure)

*The values are given as the preoperative score/postoperative score.

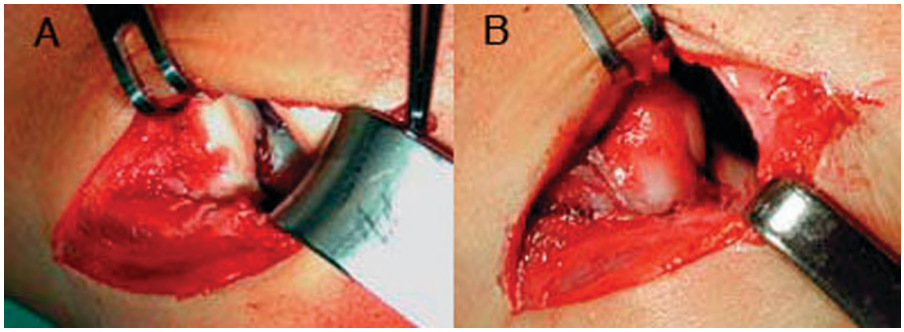

Fig. 2

A: Surgical exposure of the right elbow from the lateral view, demonstrating an osteochondral defect of the capitellum humeri. *B:* The defect has been repaired with use of a single osteochondral autograft cylinder.

location of the lesion, a proximal release (with later repair) of the lateral collateral ligament may be necessary. For anterior lesions, a proximal release for up to 2 to 3 mm is normally sufficient and, for central lesions, a complete release may be required. In the case of a dorsal lesion, a dorsoradial approach is used. With this approach, release of the lateral collateral ligament is not necessary.

Once the radiohumeral joint is well exposed, moving the joint in extension and flexion as well as rotating the radius allows a thorough inspection. Usually the defect in the capitellum is well exposed in full elbow extension. The size of the lesion is measured and the defect is excised as a cylindrical bone plug, with use of a special device (OATS; Arthrex). Subsequently, an osteochondral cylindrical donor graft is harvested from the non-weight-bearing area[37] of the proximal aspect of the lateral femoral condyle of the ipsilateral knee through a small lateral parapatellar arthrotomy. The obtained cylinder of appropriate depth is then press-fit into the recipient site of the elbow, with care being taken to ensure congruity of the chondral surfaces (Fig. 2). The donor cylinder must be cut to the correct length so that its cartilage surface is congruent with that of the host bone. If it is too short, additional cancellous bones should be obtained from the donor site of the knee and packed underneath the graft. The postoperative regimen involves free passive range of motion, emphasizing full flexion and extension for two weeks, and then free active range of motion is allowed. Weight-bearing or lifting of heavy loads is restricted for at least six weeks. Weight-bearing on the donor knee is allowed as tolerated.

Statistical Analysis

Statistical analysis was performed with use of a paired t test to determine the effect of osteochondral transplantation on the treatment of the osteochondral lesion as calculated on the objective and subjective scores. Significance was set at $p < 0.05$.

Results

From 1999 to 2002, seven osteochondral lesions in the elbow (involving the capitellum in five elbows and the tro-

TABLE II *(continued)*

		American Shoulder and Elbow Surgeons Pain Score*				
Diameter of Graft *(mm)*	Morrey Score*	Worst Pain	Rest Pain	Weight-bearing Pain	Pain with Repetitive Movements	Duration of Follow-up *(mo)*
11	79/100	5/2	1/0	5/0	3/0	83
9	87/100	8/0	2/0	8/0	8/0	78
10	48/100	9/0	4/0	6/1	7/1	60
11	79/95	8/3	1/0	8/3	8/2	59
9	78/100	9/0	8/0	8/0	5/0	50
9	76/95	8/4	0/0	8/4	2/0	43
9	87/93	7/4	5/2	7/2	3/0	42

Fig. 3

Case 4. An eighteen-year-old patient with a lesion in the capitellum of the left elbow. Postoperative anteroposterior and lateral radiographs with the elbow in 45° of flexion show no signs of osteoarthritis five years after osteochondral transplantation of the capitellum.

chlea and the radial head in one each) were treated by autologous osteochondral transplantation. The mean duration of follow-up was 59.3 months (range, forty-two to eighty-three months). The diameter of the defect was an average (and standard deviation) of 9.7 ± 1.0 mm (range, 9 to 11 mm). In every case, transplantation of one autologous osteochondral cylinder was sufficient to cover the defect. The Broberg and Morrey score improved significantly from a mean preoperative value of 76.3 ± 13.2 to 97.6 ± 2.7 postoperatively ($p < 0.05$), and pain as measured by the ASES score was significantly reduced (from 7.7 ± 1.4 preoperatively to 1.9 ± 1.9 postoperatively for the worst pain; from 3.0 ± 2.8 to 0.3 ± 0.8, respectively, for pain at rest; from 7.1 ± 1.2 to 1.4 ± 1.6 for weight-bearing pain; and from 5.1 ± 2.5 to 0.4 ± 0.8 for pain with repetitive movements; $p < 0.05$ for all). The mean extension lag was reduced from 4.7° ± 5.8° (range, 0° to 15°) preoperatively to 0° postoperatively. Compared with the contralateral (normal) side preoperatively, the flexion lag was a mean of 12.9° ± 13.8° (range, 0° to 30°). At the time of follow-up, flexion was free and was equal bilaterally in all patients. Postoperatively, no patient demonstrated varus laxity or instability of the elbow joint. None of the final follow-up plain radiographs showed degenerative changes or signs of osteoarthritis (Fig. 3). In every patient, the postoperative magnetic resonance imaging scan demonstrated viability of the graft and a congruent articular surface (Fig. 4). Six of the seven patients had no symp-

Fig. 4

Case 1. A twenty-one-year-old patient with a lesion in the capitellum. Postoperative T1-weighted magnetic resonance imaging scan of the left elbow acquired five years after osteochondral transplantation of the capitellum. The graft appears viable and has a congruent chondral surface.

toms at the donor site, but one patient had mild pain during sports with high impact loads to the knee (tennis and beach volleyball) for one year and then he became asymptomatic. No patient had any additional complications as a result of the surgery. No additional procedure was necessary in any patient. At the time of the final follow-up, all patients returned to sports and did not complain of any restrictions in the activities of daily life. All patients stated that they were satisfied and would undergo the procedure again.

Discussion

Treatment of osteochondral lesions of the elbow remains a challenge. Osteonecrosis of the capitellum (Panner disease) and the early stages of osteochondritis dissecans in young patients often heal with nonoperative treatment[15,17,25,26]. If nonoperative treatment fails[4], patients can have persistent pain and reduced range of motion because of the presence of loose bodies in the joint and surgical intervention may become necessary. Sometimes loose fragments can be reattached[27]. Other methods that have been described, such as arthroscopic removal of loose bodies and débridement, microfracture, or antegrade or retrograde drilling of the defect to induce replacement tissue[1,19,28-30], have not provided satisfactory overall long-term results. Bauer et al. reported on a series of thirty-two elbows (thirty-one patients) with osteochondritis dissecans with high rates of reduced range of elbow motion (eleven of thirty elbows), radiographic signs of osteoarthritis (nineteen of thirty-one elbows), and an increase in radial head diameter (eighteen of thirty-one elbows)[20]. In that study, twenty-three of the thirty-two elbows had been treated surgically (débridement). Brownlow et al. reported on twenty-nine patients with osteochondritis dissecans of the capitellum that was treated by arthroscopic débridement[30]. At a mean of seventy-seven months, the majority of the patients had mild or no pain. However, eleven of the twenty-nine patients had recurrence of locking or catching. Radiographs of eighteen elbows with mild or moderate tenderness over the capitellum demonstrated flattening of the capitellum in twelve elbows, degenerative changes in six, and loose bodies in five.

In this mid-term follow-up study of seven patients, we obtained overall good to excellent results. The radiographs did not demonstrate an increase in radial head diameter, and the postoperative magnetic resonance imaging scans showed graft viability and a congruent chondral surface in all elbows. All elbows achieved a full range of motion and were able to resume weight-bearing activity. While the patients returned to sports without limitation, two of the seven changed discipline and activity level, not because of the clinical outcome of the surgical procedure but because of their age and work requirements.

In recent years, the technique initially developed by Hangody et al. as mosaicplasty[31] to treat focal cartilage defects in the femoral condyle has found widespread acceptance and has been used for several joints[31-36]. Good to excellent results have been reported for both the knee and ankle joints[42]. An obvious disadvantage of the procedure is the need to expose the knee joint to harvest the graft. For the elbow, however, the size of the defect is limited. Compared with the amount of graft that needs to be harvested for the treatment of large osteochondral lesions in the knee or ankle, only one cylinder of graft harvested through a small arthrotomy of the knee was sufficient in all seven of our patients. All of our patients regained excellent function of their knees. Six patients were pain-free after a few weeks, and only one patient complained of mild pain with high-impact loads in sports for one year, and then he became asymptomatic. As in the treatment of lesions in the knee, we believe that the success of this procedure depends on an exact fit of the graft with anatomical alignment of the cartilage surface.

There are few reports in the literature on the treatment of elbow lesions with this technique, and they have described only short-term follow-up. In 2001, Nakagawa et al. reported on osteochondral grafting and osteotomy in one patient with osteoarthritis who achieved a good result at a follow-up of thirty-five months[43]. Yamamoto et al. described osteochondral autograft transplantation for osteochondritis dissecans of the elbow in eighteen juvenile baseball players who had a good outcome after a minimum two-year follow-up interval[24], and Tsuda et al. reported a successful outcome in a series of nonthrowing athletes[44] but with short-term follow-up.

Currently, only the technique of transplantation of autologous osteochondral grafts (e.g., OATS or mosaicplasty) provides the opportunity to repair cartilage defects with hyaline cartilage. At an average follow-up of five years, our results are encouraging and we believe that the congruent repair with autologous hyaline cartilage with use of the osteochondral graft transfer system will reduce the incidence of osteoarthritis and lead to better long-term results than other procedures. According to our results, the risks of performing a two-joint procedure are justifiable because of the limited donor-site morbidity. In addition, this technique provides an option for revision surgery after previously failed attempts with other surgical procedures. We will continue to follow our patients closely to see if any degenerative joint changes occur in the future.

Patrick Ansah, MD
Stephan Vogt, MD
Vladimir Martinek, MD
Andreas B. Imhoff, MD
Department of Orthopedic Sports Medicine, Technical University Munich, Connollystrasse 32, 80809 Munich, Germany. E-mail address for S. Vogt: stephan-vogt@web.de

Peter Ueblacker, MD
Department of Trauma, Hand and Reconstructive Surgery, University Medical Center Hamburg-Eppendorf, Martinistrasse 52, 20246 Hamburg, Germany

Klaus Woertler, MD
Department of Radiology, Technical University Munich, Ismaningerstrasse 22, 81675 Munich, Germany

References

1. Bradley JP, Petrie RS. Osteochondritis dissecans of the humeral capitellum. Diagnosis and treatment. Clin Sports Med. 2001;20:565-90.

2. Bowen RE, Otsuka NY, Yoon ST, Lang P. Osteochondral lesions of the capitellum in pediatric patients: role of magnetic resonance imaging. J Pediatr Orthop. 2001;21:298-301.

3. Takahara M, Ogino T, Sasaki I, Kato H, Minami A, Kaneda K. Long term outcome of osteochondritis dissecans of the humeral capitellum. Clin Orthop Relat Res. 1999;363:108-15.

4. Takahara M, Ogino T, Fukushima S, Tsuchida H, Kaneda K. Nonoperative treatment of osteochondritis dissecans of the humeral capitellum. Am J Sports Med. 1999;27:728-32.

5. Takahara M, Shundo M, Kondo M, Suzuki K, Nambu T, Ogino T. Early detection of osteochondritis dissecans of the capitellum in young baseball players. Report of three cases. J Bone Joint Surg Am. 1998;80:892-7.

6. Mitsunaga MM, Adishian DA, Bianco AJ Jr. Osteochondritis dissecans of the capitellum. J Trauma. 1982;22:53-5.

7. Patel N, Weiner SD. Osteochondritis dissecans involving the trochlea: report of two patients (three elbows) and review of the literature. J Pediatr Orthop. 2002;22:48-51.

8. Vanthournout I, Rudelli A, Valenti P, Montagne JP. Osteochondritis dissecans of the trochlea of the humerus. Pediatr Radiol. 1991;21:600-1.

9. Panner HJ. A peculiar affection of the capitulum humeri, resembling Calve-Perthes disease of the hip. Acta Radiol. 1929;10:234-42.

10. Haraldsson S. On osteochondrosis deformas juvenilis capituli humeri including investigation of intra-osseous vasculature in distal humerus. Acta Orthop Scand Suppl. 1959;38:1-232.

11. Adams JE. Injury to the throwing arm. A study of traumatic changes in the elbow joints of boy baseball players. Calif Med. 1965;102:127-32.

12. Campbell CJ, Ranawat CS. Osteochondritis dissecans: the question of etiology. J Trauma. 1966;6:201-21.

13. Petrie PW. Aetiology of osteochondritis dissecans. Failure to establish a familial background. J Bone Joint Surg Br. 1977;59:366-7.

14. Schenck RC, Athanasiou KA, Constantinides G, Gomez E. A biomechanical analysis of articular cartilage of the human elbow and a potential relationship to osteochondritis dissecans. Clin Orthop Relat Res. 1994; 299:305-12.

15. Barnes DA, Tullos HS. An analysis of 100 symptomatic baseball players. Am J Sports Med. 1978;6:62-7.

16. Jobe FW, Nuber G. Throwing injuries of the elbow. Clin Sports Med. 1986; 5:621-36.

17. Peterson RK, Savoie FH, Field LD. Osteochondritis dissecans of the elbow. Instr Course Lect. 1999;48:393-8.

18. Pappas AM, Zawacki RM, Sullivan TJ. Biomechanics of baseball pitching. A preliminary report. Am J Sports Med. 1985;13:216-22.

19. Baumgarten TE, Andrews JR, Satterwhite YE. The arthroscopic classification and treatment of osteochondritis dissecans of the capitellum. Am J Sports Med. 1998;26:520-3.

20. Bauer M, Jonsson K, Josefsson PO, Linden B. Osteochondritis dissecans of the elbow. A long-term follow-up study. Clin Orthop Relat Res. 1992; 284:156-60.

21. Takahara M, Ogino T, Takagi M, Tsuchida H, Orui H, Nambu T. Natural progression of osteochondritis dissecans of the humeral capitellum: initial observations. Radiology. 2000;216:207-12.

22. Dipaola JD, Nelson DW, Colville MR. Characterizing osteochondral lesions by magnetic resonance imaging. Arthroscopy. 1991;7:101-4.

23. Nelson DW, DiPaola J, Colville M, Schmidgall J. Osteochondritis dissecans of the talus and knee: prospective comparison of MR and arthroscopic classifications. J Comput Assist Tomogr. 1990;14:804-8.

24. Yamamoto Y, Ishibashi Y, Tsuda E, Sato H, Toh S. Osteochondral autograft transplantation for osteochondritis dissecans of the elbow in juvenile baseball players: minimum 2-year follow-up. Am J Sports Med. 2006;34:714-20.

25. Yadao MA, Field LD, Savoie FH. Osteochondritis dissecans of the elbow. Instr Course Lect. 2004;53:599-606.

26. Stubbs MJ, Field LD, Savoie FH. Osteochondritis dissecans of the elbow. Clin Sports Med. 2001;20:1-9.

27. Kuwahata Y, Inoue G. Osteochondritis dissecans of the elbow managed by Herbert screw fixation. Orthopedics. 1998;21:449-51.

28. Ruch DS, Cory JW, Poehling GG. The arthroscopic management of osteochondritis dissecans of the adolescent elbow. Arthroscopy. 1998;14: 797-803.

29. Kiyoshige Y, Takagi M, Yuasa K, Hamasaki M. Closed-Wedge osteotomy for osteochondritis dissecans of the capitellum. A 7- to 12-year follow-up. Am J Sports Med. 2000;28:534-7.

30. Brownlow HC, O'Connor-Read LM, Perko M. Arthroscopic treatment of osteochondritis dissecans of the capitellum. Knee Surg Sports Traumatol Arthrosc. 2006;14:198-202.

31. Hangody L, Kish G, Karpati Z, Szerb I, Udvarhelyi I. Arthroscopic autogenous osteochondral mosaicplasty for the treatment of femoral condylar articular defects. A preliminary report. Knee Surg Sports Traumatol Arthrosc. 1997;5:262-7.

32. Baltzer AW, Arnold JP. Bone-cartilage transplantation from the ipsilateral knee for chondral lesions of the talus. Arthroscopy. 2005;21:159-66.

33. Ueblacker P, Burkart A, Imhoff AB. Retrograde cartilage transplantation on the proximal and distal tibia. Arthroscopy. 2004;20:73-8.

34. Scheibel M, Bartl C, Magosch P, Lichtenberg S, Habermeyer P. Osteochondral autologous transplantation for the treatment of full-thickness articular cartilage defects of the shoulder. J Bone Joint Surg Br. 2004;86:991-7.

35. Imhoff AB, Ottl GM, Burkart A, Traub S. [Autologous osteochondral transplantation on various joints]. Orthopade. 1999;28:33-44. German.

36. Agneskirchner JD, Brucker P, Burkart A, Imhoff AB. Large osteochondral defects of the femoral condyle: press-fit transplantation of the posterior femoral condyle (MEGA-OATS). Knee Surg Sports Traumatol Arthrosc. 2002;10:160-8.

37. Ahmad CS, Cohen ZA, Levine WN, Ateshian GA, Mow VC. Biomechanical and topographic considerations for autologous osteochondral grafting in the knee. Am J Sports Med. 2001;29:201-6.

38. Link TM, Mischung J, Wortler K, Burkart A, Rummeny EJ, Imhoff AB. Normal and pathological MR findings in osteochondral autografts with longitudinal follow-up. Eur Radiol. 2006;16:88-96.

39. Broberg MA, Morrey BF. Results of treatment of fracture-dislocations of the elbow. Clin Orthop Relat Res. 1987;216:109-19.

40. Morrey BF, An KN, Chao EYS. Functional evaluation of the elbow. In: Morrey BF, editor. The elbow and its disorders. 3rd ed. Philadelphia: WB Saunders; 1985. p 73 -91.

41. King GJ, Richards RR, Zuckerman JD, Blasier R, Dillman C, Friedman RJ, Gartsman GM, Iannotti JP, Murnahan JP, Mow VC, Woo SL. A standardized method for assessment of elbow function. Research Committee, American Shoulder and Elbow Surgeons. J Shoulder Elbow Surg. 1999;8:351-4.

42. Hangody L, Fules P. 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. 2003;85 Suppl 2:25-32.

43. Nakagawa Y, Matsusue Y, Ikeda N, Asada Y, Nakamura T. Osteochondral grafting and arthroplasty for end-stage osteochondritis dissecans of the capitellum. A case report and review of the literature. Am J Sports Med. 2001;29:650-5.

44. Tsuda E, Ishibashi Y, Sato H, Yamamoto Y, Toh S. Osteochondral autograft transplantation for osteochondritis dissecans of the capitellum in nonthrowing athletes. Arthroscopy. 2005;21:1270.