Subchondral drilling for chondral flaps reduces the risk of total hip arthroplasty in femoroacetabular impingement surgery at minimum five years follow-up

Short title: Treatment of acetabular chondral flaps in FAI surgery

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The authors certify that an institutional review board approved this study and investigations were conducted in conformity with ethical principles of research.

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Abstract

Introduction: The best treatment of acetabular chondral flaps during surgery for femoroacetabular impingement (FAI) is unknown. We asked if subchondral drilling improves clinical and radiographic outcome and if there are factors predicting failure.

Methods: We treated 79 patients with symptomatic FAI and acetabular chondral flaps with surgical hip dislocation between January 2000 and December 2007. Exclusion of all patients with previous hip pathology or trauma resulted in 62 patients (80 hips). The chondral flap was slightly debrided in 43 patients/ 51 hips (control group). In 28 patients/ 29 hips (study group), additional osseous drilling was performed. 4 patients (5 hips, 6%) were lost to follow-up. Mean follow-up was 9 years (5–13 years). The groups did not differ in demographic data, radiographic parameters or follow-up. Clinical outcome was assessed with the Merle d'Aubigné score, modified Harris Hip Score and University of California Los Angeles activity score and progression of osteoarthritis with the Tönnis grade.

Results: No patient underwent conversion to total hip arthroplasty (THA) in the drilling group compared to 7 patients (8 hips, 16%) in the control group ($p = 0.005$); in the remaining hips, clinical scores and progression of Tönnis grade did not differ. Increased acetabular coverage, age and body mass index were univariate predictive factors for conversion to THA. No drilling was as an independent predictive factor for conversion to THA (hazard ratio 58.07, $p = 0.009$).

Conclusion: Subchondral drilling under acetabular chondral flaps during surgical treatment of FAI is an effective procedure to reduce the rate of conversion to THA.

Keywords

Chondral flap, femoroacetabular impingement, hip

Introduction

Symptomatic femoroacetabular impingement (FAI) is frequently associated with chondral damage along the anterior-superior acetabular rim.[1] This lesion is caused by the aspherical part of the femoral head which is pushed into the acetabulum in flexion and internal rotation of the femur, causing high shearing forces on the acetabular cartilage and eventually leads to cleavage lesions with debonding of the cartilage from the subchondral bone.[1,2] In the initial stage, the cartilage is mobile (wave sign) but macroscopically still intact.[3] In a later stage, the cartilage ruptures from the acetabular rim and a chondral flap develops. The aim of impingement surgery is the removal of the aspherical part of the femoral head-neck junction to restore an impingement free range of motion of the hip. This eliminates the cause of the chondral lesions and the detached but otherwise intact cartilage flap can potentially regenerate.[1] Mid- to long-term follow-up studies of surgical treatment of FAI showed that outcome (clinical scores, progression of osteoarthritis and conversion to THA) is affected by the age at surgery, the presence of osteoarthritis or insufficient offset correction.[4,5] The need for a specific treatment of chondral defects is recognized and various forms of therapies are currently in use. Techniques to stimulate the healing potential for limited sized chondral defects (typically <2–4 cm^2) are debridement with drilling of the subchondral bone to access bone marrow cells,[6] abrasion of the chondral defect to induce a fibrous scar or resection with microfracture techniques.[7-9] Pridie and Gordon[6] described growth of fibrocartilage in debrided areas of cartilage defects after drilling of subchondral bone. In the early 1980s, Steadman et al.[10] introduced a procedure that combined surgery with a specific rehabilitation programme. With special awls, holes (“microfractures”) are introduced in a perpendicular fashion into the subchondral bone. This allows bone marrow to fill the previously debrided cartilage defect and form a stable clot containing fibrin and pluripotential stem cells that differentiate into a fibrocartilaginous repair tissue.[11] Given the good outcomes in degenerative and traumatic cartilage defects of the knee,[12,13] microfracturing or Pridie drilling has been used as an adjunct for the treatment of acetabular chondral defects during FAI surgery. Philippon et al.[14] showed that adequate filling of acetabular cartilage defects could be achieved. This was confirmed by Karthikeyan et al.,[15] who performed second-look arthroscopy 17 months after initial treatment and observed coverage of 96% ± 1% of the former cartilage defect with macroscopically sound repair tissue in 95% of patients. A systematic review of patients undergoing hip arthroscopy (HAS) for treatment of FAI with additional debridement and microfracturing of chondral lesions showed positive outcomes in 11 of 12 studies with improved clinical scores at a mean follow-up of 2.5 years (range 0.3–5).[16] To the best of our knowledge there are, however, no mid- to long-term comparative studies analysing the effect of microfracturing/drilling or cartilage debridement only for the treatment of acetabular chondral flaps in FAI surgery.

We therefore asked, if subchondral drilling under chondral flaps in FAI surgery improves clinical and radiographic outcome at mean 9 years follow-up and if there are factors that predict failure.

Patients and methods

In this case-control study, we identified in our patient management system (Qualicare Client Version 8.0.7, Qualidoc – The Medical Data Company, Berne, Switzerland) all consecutive patients with symptomatic FAI who were treated with surgical hip dislocation from January 2000 to December 2007 and that had intraoperatively visually confirmed acetabular chondral debonding or cleavage (chondral flaps) according to the classification of Beck et al.[17] Included were all patients in which the chondral flap was retained and where a complete set of preoperative radiographs was available. This resulted in 79 patients (98 hips, 65 males). Excluded were 17 patients (18 hips) with a known history of slipped capital femoral epiphysis (2 hips), Perthes' disease (2 hips) and all patients with previous surgery: periacetabular osteotomy (4 hips), previous FAI surgery (4 hips), additional intertrochanteric osteotomy (4 hips), and previous trauma (2 hips). This resulted in 62 patients (80 hips, 57 males) that were included in the study. During the study period, no evidence of the best treatment of chondral flaps was available. The standard treatment at our institution was retaining the flap with either minimal debridement on the edges without further treatment (control group) or minimal debridement with additional subchondral drilling to induce bleeding under the flap (study group). 28 patients (29 hips; 36%) were allocated to the drilling group and 43 patients (51 hips; 64%) to the control group. 9 patients had hips treated in both groups. Totally, 4 patients (5%) were lost to follow-up (3 hips in the study group and 2 hips in the control group). 9 patients (9 hips, 3 in the study group) refused radiographic follow-up but declared that they did not have a conversion to THA.

The diagnosis of FAI was based on patient history, clinical examination, conventional anterior-posterior pelvis and cross-table lateral hip radiographs and magnetic resonance (MR) arthrography.[18] Pincer-type FAI was defined as a lateral centre-edge angle (LCE) of >33° or an acetabular index (AI) of <3°,[19,20] cam-type FAI as an alpha angle of >50°.[21] Mixed-type FAI was defined if criteria for both types were present.

Standard treatment method of symptomatic FAI during the study period was surgical hip dislocation. Due to our limited experience at the time, hip arthroscopy was only performed in selected cases (limited cam-type FAI without signs of chondral or labral lesions in the MR). Contraindications for surgical treatment of FAI were advanced osteoarthritis (Tönnis grade 2 or higher) and/or evidence of migration of the femoral head into a cartilage defect in (MR) arthrography.

All surgeries were performed by senior members of the hip team. The technique of surgical hip dislocation has been described previously.[22] Once the femoral head is dislocated, the femoral and acetabular cartilage can be inspected and palpated. The size of the acetabular cartilage flaps was routinely quantified and documented in the OR report by measuring the maximal depth in centimeters and its extent on the clock face. The diameter of the acetabulum was not measured (Figure 1).

[**Figure 1.** Measurement of the chondral flap and approximation of the surface size: The size of the cartilage flap was quantified intraoperatively by measuring the maximal depth in centimetres (arrow) and its extent on the clock face (dotted lines). The resulting area was normalised to the size of the most common acetabular component in total hip arthroplasty (50 mm). Thus, 1 hour on the clock face corresponded to 1.31 cm.]

Osteochondroplasty on the femoral neck was performed depending on the bony pathomorphology. The labrum was detached and the acetabular rim trimmed according to the preoperative planning. In all cases, frayed borders of the chondral flaps were slightly debrided. Additional subchondral drilling of the acetabular defect was performed according to the optional treatment protocol that was the same in all patients. A 1.5-mm drill bit was used to evenly apply holes in the exposed subchondral bone with a distance of 3–4 mm and a depth that the subchondral cortex was penetrated and bleeding was confirmed. The chondral flap was then put back in place. The femoral head was reduced, and the greater trochanter fixed with 2 or 3 cortical screws.

The postoperative protocol did not differ between the 2 groups and consisted of partial weight-bearing (foot-flat) for 6 weeks. At 6 weeks, a clinical and radiological examination at our outpatient clinic took place. If the trochanteric fragment was healed, full weight-bearing was allowed, and physical therapy was initiated.
Mean follow-up was 8 years (range 6–11 years) in the drilling group and 9 years (range 5–13 years) in the control group (p = 0.280). At last follow-up, a standardised clinical examination by an orthopaedic resident (not a treating surgeon) was performed to obtain range of motion of the hip, measure muscular forces and evaluate gait pattern. Patients filled out a questionnaire to obtain clinical outcome scores (Merle d'Aubigné (MdA), modified Harris Hips Score (mHHS) and University of California Los Angeles activity score (UCLA). In addition, standardised plain radiographs were obtained (conventional anterior-posterior pelvis and cross-table lateral hip.[18] The size of the chondral flaps was determined using maximal depth and extent on the clock face as indicated in the OR report. The resulting absolute area of

the lesion is dependent on the size of the acetabulum. Since the pre-operative radiographs were not calibrated, we assumed a mean acetabular diameter of 50 mm, corresponding to the size of the most commonly implanted acetabular component of a local total hip prosthesis manufacturer during the study period. This resulted in a distance of 1.31 cm per hour on the clock face ($5\frac{\pi}{12}$). Both groups were comparable with no significant differences of demographic data, size of chondral flap, pre-operative radiographic parameters and amount of surgical correction (Tables 1–3).

Kolmogorov-Smirnov test was used to determine normal distribution. Comparison of normally distributed continuous variables was performed using unpaired t-test, for comparison of not normally distributed continuous variables Mann-Whitney U-test was used. Comparison of binominal data was done by chi-square test. Univariate predictors for conversion to THA were identified using cox regression analysis. The identified factors were further analysed to find multivariate predicting factors. For all statistical analysis WinSTAT (Version 2012.1, © Robert K. Fitch, Bad Krozingen, Germany, 2012) in Microsoft Office Professional Plus 2010 (Version 14.0.7128.5000, Microsoft Corporation, Redmond/WA, USA, 2010) was used. Statistical significance was defined as a *p*-value of ≤ 0.05.

Table 1. Demographic data of the study and the control group. There was no statistical difference between the 2 groups.

	Drilling Study Group	**Control Group**	***p*-value**
Number of patients	28 (29 hips)	43 (51 hips)	-
Number of male patients	24 (83%)	33 (65%)	0.480
Age (years)	33.4 (19–52)	31.5 (16–53)	0.342
Follow-up (years)	8.29 (6–11)	9.2 (5–13)	0.280
Weight (kg)	79.3 (57–120)	76.9 (55–117)	0.462
Height (m)	1.77 (1.67–1.90)	1.77 (1.58–1.95)	0.889
Body mass index (BMI, kg/m^2)	25.4 (20–39)	24.7 (20–34)	0.465

Note: Continuous variables expressed as mean (range); *p*-value calculated with the Mann-Whitney U-test for continuous variables and chi-square test for binominal variables.

Table 2. Preoperative radiographic parameters of the study and the control group. There was no statistical difference between the 2 groups.

	Study Group	**Control Group**	***p*-value**
Tönnis Grade 0	21 (72%)	37 (73%)	0.943
Tönnis Grade 1	8 (28%)	14 (27%)	0.991
LCE (°)	29.2 (20–34)	33.5 (24–56)	0.076
AI (°)	6.5 (1–12)	5.0 (-11–17)	0.322
Cross-over sign (positive)	12 (41%)	15 (29%)	0.611
Ischial spine sign (positive)	9 (31%)	15 (29%)	0.829
Alpha angle (°)	66.7 (44–88)	60.1 (30–79)	0.258
Size of cartilage flap (cm^2)*	4.87 (1.9–11.8)	5.03 (0.7–15.8)	0.844

Note: Continuous variables expressed as mean (range); *p*-value calculated with the Mann-Whitney U-test for continuous variables and chi-square test for binominal variables.

*Calculated on data derived from the OR-report.

Table 3. Postoperative radiographic parameters and achieved correction in the study and the control group. There was no statistical difference between the 2 groups.

	Study Group	**Control Group**	***p*-value**
Postoperative radiographic parameters			
LCE (°)	26.7 (20–34)	29.0 (15–43)	0.149
AI (°)	7.1 (0–16)	5.9 (-4–17)	0.152
Cross-over sign (positive)	6 (21%)	11 (22%)	0.713
Ischial spine sign (positive)	9 (31%)	15 (29%)	0.935
Alpha angle (°)	37.9 (25–50)	38.8 (29–52)	0.575
Amount of correction			
LCE (°)	2.8 (0–10)	5.2 (0–18)	0.122
AI (°)	1.4 (0–8)	1.6 (0–15)	0.953
Alpha angle (°)	29.1 (3–49)	20.7 (0–41)	0.075

Note: Continuous variables expressed as mean (range); *p*-value calculated with the Mann-Whitney U-test for continuous variables and chi-square test for binominal variables.

Results

In the drilling group no patient underwent conversion to THA, whereas 3 male and 4 female patients (8 hips, 16%) underwent conversion to THA in the control group (p = 0.005). Conversion to THA occurred at mean 6.1 years (range 1–9 years) after surgery. Clinical outcome scores of the surviving hips (MdA, mHHS, UCLA) and progression of joint degeneration on radiographs (Tönnis score) did not differ between the 2 groups (Table 4).

Table 4. Clinical outcome parameters of the study and the control group.

	Study Group	Control Group	*p*-value
Conversion to THA (hips)	0 (0%)	8 (16%)*	0.005
Tönnis progression (hips) †	5 (22%)	17 (33%)‡	0.187
Merle d'Aubigné score§	16.5 (12–18)	16.3 (11–18)	0.541
Modified Harris Hip Score§	86.6 (51–100)	85.7 (54–100)	0.541
UCLA activity score§	5.9 (1–10)	5.0 (1–10)	0.296

THA, total hip arthroplasty.

Note: Continuous variables expressed as mean (range); *p*-value calculated with the Mann-Whitney U-test for continuous variables and chi-square test for binominal variables.

*Conversion to THA at 1.1, 1.5, 5.0, 7.0, 8.3, 8.5, 8.7, and 9.0 years (mean 6.1, range 1–9 years) after surgery; †Only hips with available radiography at last follow-up; ‡Hips with conversion to THA were defined as Tönnis progression; §Only considering the surviving hips.

Several parameters could be identified as univariate negative predictive factors for conversion to THA: No treatment of acetabular chondral flaps, increasing overcoverage of the femoral head (LCE and AI) and patient age at surgery. Surprisingly, pre-operative Tönnis grade and size of the cartilage defect had no adverse effect on the outcome. Multivariate Cox-regression analysis identified no treatment of acetabular chondral flaps as the sole independent factor to predict failure (hazard ratio 58.07, $p = 0.009$) (Table 5).

Table 5. Hazard ratios and the corresponding *p*-values deriving from univariate and multivariate cox-regression analysis identifying predictive factors for conversion to THA.

Variable	**Univariate analysis**		**Multivariate analysis**	
	Hazard ratio	***p*-value**	**Hazard ratio**	***p*-value**
No-intervention	36.51 (2.78–479)	**0.006**	58.07 (2.81–1.197)	**0.009**
Age (years)	1.14 (1.05–1.23)	**0.002**	0.95 (0.73–1.24)	0.690
BMI (kg/m^2)	1.15 (1.00–1.32)	0.052	1.29 (0.77–2.16)	0.325
Preoperative LCE angle (°)	1.23 (1.10–1.37)	**<0.001**	0.74 (0.38–1.48)	0.405
Preoperative AI (°)	0.83 (0.70–0.99)	**0.039**	0.77 (0.27–2.19)	0.627
Preoperative Tönnis grade	1.58 (0.46–5.43)	0.464	9.39 (0.00–305.376)	0.673
Size of cartilage defect > 2 cm^2	0.63 (0.85–1.16)	0.535	0.57 (0.00–563.102)	0.936

Values expressed as hazard ratio (95% confidence interval).

Discussion

The results of this study suggest that subchondral drilling is a successful method to treat chondral delamination of the acetabulum in FAI. The presence of acetabular cartilage flaps indicates an advanced stage of damage. 16% of the patients in the control group, where the cause of the impingement was removed but no specific treatment for the chondral flap was performed, progressed to end stage osteoarthritis and conversion to THA between 1 and 9 years after surgery.

We hypothesise that the advantages of subchondral drilling are twofold. First, once the impingement as the cause of the cartilage lesion is removed,[2,23] the delaminated acetabular cartilage is no longer affected from shearing forces and can potentially heal if stabilised. Good clinical results were reported by attaching the flap to the subchondral bone with fibrin glue.[24,25] However, biomechanical testing has shown that gluing on its own provides insufficient fixation of the chondral flaps.[26] A more physiological clot produced by subchondral drilling might sufficiently stabilse the cartilage flap. Second, previous studies found evidence that even though the chondral flaps appear normal macroscopically, the biochemical properties and percentage of live chondrocytes are significantly reduced and variable stages of matrix and chondrocyte damage are present.[1,27] Similar to the AMIC technique,[28] bone marrow stem cells released by the drilling can migrate into the cartilage flap, using the flap as scaffold and revitalising the affected cartilage.

This study has several limitations. First, the lack of randomsation into the 2 treatment groups can cause selection bias. The surgeons performing the surgeries were all senior members of the hip team with vast and comparable experience in hip surgery.

Surgical hip dislocation was performed in a standardsed manner and the setting was identical for both groups. At time of surgery, there was no scientific evidence of the best treatment of chondral flaps and the lack of pilot information made it impossible to conduct a randomsed study. Secondly, the preoperative mean LCE is higher in the control group (p = 0.07). In mixed impingement, different chondral lesions can occur, depending on which impinging mechanism is more important.[2] In this study however, the inclusion criteria was a well-defined chondral flap of the acetabulum typical for cam-type impingement and we conclude that the pincer morphology, even though present in some patients, was not the cause of the lesions. In addition, the postoperative values showed a similar and normalsed mean LCE in both groups (p = 0.149). 1 patient in the control group was resected to a value that could be defined as “over-resected” (LCE of 15°). He however showed a good clinical result at last follow-up and did not progress to THA. Thirdly, the size of the chondral flaps was approximated, as the diameter of the acetabulum was not routinely measured at time of surgery. For all patients, we based the diameter of the acetabulum on the average acetabular size of patients with final stage osteoarthritis during the study period. Since demographic data, in particular age, sex and height, did not differ between the 2 groups, it is unlikely that averaging the size of the acetabulum lead to a systematic error. To exclude that better results of the drilling group were only due to the fact that the true size of the flaps were consistently overestimated, we conducted a best-/worst-case scenario analysis. We assumed that all patients in the study group had a small acetabulum (48mm) and the patients in the control group had a large acetabulum (52mm). This would result in a generally underestimated flap size in the drilling group and a generally overestimated flap size in the control group. Statistical analysis of this scenario however showed no significant difference of the flap sizes (p = 0.782).

Our results with good clinical outcomes in patients undergoing additional drilling compare well with the literature. Procedures that aim to repair articular defects with chondral tissue are autografting (osteochondral autograft transplantation system, OATS),[29] autologous chondrocyte implantation (ACI),[30] or autologous matrix-induced chondrogenesis (AMIC).[28] The disadvantage of OATS is possible donor site morbidity.[31] AMIC allows the treatment of larger size full thickness defects of the cartilage but requires a 2-stage procedure and is relatively expensive, since fabricated tissue is needed.[28] Allografting has shown poor results and is not routinely used.[32] A systematic review by Benthien et al.[33] showed no significant superiority of OATS, ACI, and AMIC procedures compared with microfracturing. MacDonald et al.[16] reviewed 12 original studies on microfracturing as an adjunct to hip arthroscopy involving a total of 267 patients. Mean follow-up was 29.5 months (range 4–60 months). 11 of the 12 studies reported overall positive results. The most commonly used outcome score was the modified Harris Hip Score (mHHS) with a mean outcome of 76.5 (range 39.6–96) points out of 100. Even though most studies report on a short follow-up, microfracturing for treatment of limited acetabular chondral lesions in FAI surgery show consistently good results.[34]

To the best of our knowledge this is the largest study with the longest follow-up on treatment of acetabular chondral flaps including a control group with the same kind and size of cartilage lesions. In open FAI surgery, osseous drilling of the acetabulum is easily performed in a single stage procedure without prior preparation. In hip arthroscopy, which has become the treatment of choice for the majority of FAI patients, the technique of osseous drilling is also readily applicable.

Conclusion

Subchondral drilling is a simple, inexpensive and effective procedure to improve outcome in patients with acetabular chondral flaps during surgical correction of FAI. Compared to simple debridement, the rate of conversion to THA at mean 9 years follow-up is significantly reduced (p = 0.005). No treatment of chondral flaps in FAI surgery is an independent risk factor for conversion to THA (58-fold risk, p = 0.009).

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