

1 **INCONCLUSIVE AND CONTRADICTORY EVIDENCE FOR OUTCOMES FOLLOWING HIP ARTHROSCOPY IN**
2 **PATIENTS WITH FEMOROACETABULAR IMPINGEMENT AND TÖNNIS GRADE 2 OSTEOARTHRITIS OR**
3 **GREATER: A SYSTEMATIC REVIEW**

4 **Running Title: Hip Arthroscopy in Tönnis Grade 2 or greater OA**

5
6 **ABSTRACT**

7 **Purpose:** To investigate whether hip arthroscopy (HA) is effective in patients with femoroacetabular
8 impingement (FAI) and concomitant Tönnis Grade 2 or greater hip osteoarthritis (OA). We hypothesised that
9 HA would result in high rates of conversion to total hip arthroplasty (THA).

10 **Methods:** The review was registered in the International Prospective Register for Systematic Reviews and
11 Meta-analysis (PROSPERO): CRD42020210936. It followed the PRISMA guidelines and included multiple
12 databases: MEDLINE, EMBASE, Web of Science Core Collection, Cochrane library. All studies in English or
13 German from inception to 1st of December 2020 that investigated outcomes of HA in patients with Tönnis
14 grade 2 or greater were considered eligible. The risk of bias was assessed using the MINORS tool. Data
15 heterogeneity was explored using the I² test in a random-effects-model.

16 **Results:** Eleven studies met the eligibility criteria. The MINORS score averaged 68 % (range 46 to 81%). A
17 total of 616 hips, consisting of 247 hips of interest (Tönnis Grade 2 or greater) and 369 controls, were
18 included. The weighted estimated follow-up averaged 29.1 months (range 12 – 84 months). Data on PROMs
19 could be extracted for 6/11 studies, and for 8/11 on conversion to THA. Four studies reported an overall
20 improvement in PROMs after HA and two highlighted a failure of improvement in PROMs. Failure of HA with
21 conversion to THA was observed from 0-9% in 4 studies, as opposed to proportions as high as 35-70% in the
22 other 4 studies. There was a high level of heterogeneity with a calculated I² value of 89%.

23 **Conclusion:** There is currently contradictory and insufficient evidence regarding the efficacy of HA for hips
24 with FAI and concomitant OA Tönnis 2 or greater. This is in the context of data with low-evidence, consisting
25 of retrospective case series with a high risk of bias and high heterogeneity ($I^2 \sim 90\%$).

26 **Level of Evidence:** Level IV (Systematic Review of Level III and IV studies).

27 **Keywords:** hip arthroscopy; femoroacetabular impingement; FAI; Hip Osteoarthritis; hip preservation

28

INTRODUCTION

Femoroacetabular impingement (FAI) represents an abnormal hip morphology and has become an important cause of hip pain in young adults in recent times.¹ It may lead to early development of hip osteoarthritis (OA) in view of the abnormal stresses being placed on the joint.² Initial treatment focuses on conservative measures which include activity-modification and physiotherapy.³ In cases where the conservative treatment is unsuccessful, joint-preservation surgery can be considered: mainly hip arthroscopy (HA) or in specific cases, surgical hip dislocation or a periacetabular osteotomy (PAO).⁴ The aim of such surgery is to reshape the hip joint to prevent further impingement⁵, address labral and articular cartilage damage and finally resolve any concomitant extra-articular causes if present.⁶ There is evidence to support that intra-articular damage in the form of labral tears should be addressed with a repair or reconstruction for optimal outcomes.⁷⁻⁹ Furthermore, along with debridement and microfracture, there are different biological regenerative techniques being continuously developed for addressing articular cartilage injury in patients with FAI.¹⁰⁻¹²

High quality RCTs,^{13,14} have shown that HA is effective in achieving improved hip-related quality of life in patients with FAI and a maximum concomitant joint degeneration of Tönnis Grade 1 Hip OA. Outcomes for FAI and concomitant moderate- to advanced hip OA (Tönnis Grade 2 or greater), for both hip arthroscopy and other conservative regimens or preservation techniques, is still a matter of debate and the literature is at best sparse in this arena.^{15,16} Nakano et al suggested judicious patient selection prior to any surgical intervention, especially exercising caution in the presence of OA and obesity.¹⁷ As such, it is still unclear whether patients with FAI and concomitant Tönnis Grade II or above OA would benefit from HA.

This study aims to investigate whether HA is effective in patients with FAI and concomitant Tönnis Grade 2 or greater hip OA. We hypothesised that HA would result in high rates of conversion to THA.

METHODS

Strategy of the Systematic Search

The systematic review followed The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines¹⁸. It was registered in the International Prospective Register for Systematic Reviews and Meta-analysis (PROSPERO) under the registration number: CRD42020210936. The study protocol was published after peer-review.¹⁹ The following databases: MEDLINE, EMBASE, Web of Science Core Collection, and the Cochrane library were searched from database inception to December 1st 2020. Articles published in English or German language were included. The search included studies reporting on patients that underwent HA for the treatment of FAI and concomitant Tönnis Grade 2 or greater hip OA. A total of 9 combinations using the following key-words combined with the Boolean term AND, were used: ("hip arthroscopy", "FAI", "femoroacetabular impingement") AND ("outcome", "failure", "results"). This search strategy was adapted as appropriate for all databases.

Selection Process and Data Extraction

Two authors ((OA and SK) performed blind and independent study selection by applying the eligibility criteria (**Table 1**). In cases where consensus could not be reached, the senior author (VK) was consulted. Review articles, surgical techniques, oral presentations, experimental or animal studies, as well as studies mixing and overlapping patient populations were excluded. Furthermore, studies including participants with active inflammatory disease, neurologic conditions, previous ipsilateral surgeries of the hip or osteonecrosis were also excluded. Where data were not available, authors were contacted by email.

Risk of Bias Assessment

The risk of bias assessment was performed using the Methodological index for non-randomized studies (MINORS) criteria²⁰ for each type of study design. MINORS criteria assess eight critical aspects of study design for non-comparative clinical studies and an additional four aspects of study design for comparative clinical studies. Each item is scored zero if information is not reported, one if information is reported but inadequate, and two if information is reported and adequate. Therefore, the maximum possible score is 16 for comparative studies and 24 for non-comparative studies. Furthermore, an additional assessment of reporting quality on biological augmentation techniques, mainly with MSCs (mesenchymal stem cells) was performed using the recently introduced MIBO tool²¹ (Minimum Information for Studies Evaluating Biologics in Orthopaedics). A scoring system was then used per study such as studies that answered yes to a question from the checklist scored 2, not clear scored 1 and no scored 0. Each score was then converted into a percentage.

Data synthesis and statistical analysis

The statistical analysis was performed using SPSS (IBM SPSS Statistics, Version 24.0; Chicago, Illinois) and R Software. Two authors (OA, SK) blindly and independently extracted clinical scores, diseases stages, radiographic outcome and comparative results from the included studies and performed comparisons. Author (VK) was consulted in instances of discrepancy. In these cases, a confidence interval of $p < 0.05$ was considered statistically significant. A random-effects-model of meta-analysis was used. The methodological inconsistency and heterogeneity were quantified using a I^2 test, with a p-value of $p = 0.10$. Values more than 40% were considered significant for moderate heterogeneity and over 75% were considered to be highly heterogenous.²² This evaluated whether observed differences in results are compatible with chance alone. Subgroup analysis will be performed based on the scores achieved on risk of bias assessment. Studies will be separately analysed in two groups: those that achieved more than 50% using MINORS and those that achieved 50% or less.

RESULTS

Study Selection

The database search yielded 14457 citations. 6309 studies remained after removal of duplicates (**Fig. 1**). 6010 studies were excluded at title and abstract stage. 299 full text papers were assessed for eligibility against the inclusion and exclusion criteria. Of these, 11 studies were eligible and included for final analysis. The included studies, as classified by the study authors, were all retrospective designs²³: 4 case-control studies with comparators (level III evidence),^{15,24–26} 2 retrospective cohort studies (level III evidence)^{27,28} and 5 retrospective case series (level IV evidence).^{29–32}

Risk of Bias Assessment

As expected and per study protocol,¹⁹ the risk of bias assessment was performed individually for each study using the MINORS tool (**Table 2**). The average score was 68 % (range 46 to 81%). The main limitations were lack of appropriate sample size, loss of follow-up, lack of blinded outcome assessment and inhomogeneous comparators that also lacked detailed demographic description. No studies used biologic augmentation with bone marrow stem cells (BMSc). Mardones³¹ injected platelet rich plasma (PRP) at the head-neck junction of the femoral head. Description of details of reporting for the augmentation technique was performed using the MIBO tool (**Suppl. Table 1**).

Demographics, Indications and Surgical Techniques

A total of 616 hips, consisting of 247 of hips of interest (Tönnis Grade 2 or greater) and 369 controls, were included (**Table 3**). From the hips of interest, 221 of hips were classified with Tönnis 2, 8 hips with Tönnis 3, whilst one study reported outcomes cumulatively (18 Tönnis 2 and 3) and did not allow stratification based on disease stage.²⁶ All comparators across case-control studies^{15,25,26,33} consisted of hips undergoing the same main intervention (HA), but with milder degenerative changes (Tönnis 0 or 1).

Six studies reported the number of patients that were evaluated^{15,25,26,29,30,33} It may be noted, that patients were significantly younger in two studies with an average of 27 (range 15-49)¹⁵ and 39 (range 13-63)³³, respectively, when compared to the rest of study populations (with averages exceeding 40 years)^{20,21,24,25}.

Regarding primary aetiology and surgical indication, all patients had FAI. Some studies^{25,27,28} may have included patients that had concomitant borderline hip dysplasia, defined as an Wiberg's lateral center edge angle (LCE-angle) between 18° and 25°.

For purposes of biologic augmentation and cartilage regeneration, in 7/11 studies microfractures were performed for full-thickness cartilage defects/Outerbridge 4 lesions, mostly on the acetabular side (**Table 3**). Nakashima²⁶ performed labral reconstruction using iliotibial band autograft in 29% of cases. Mardones et al²⁶. used augmentation with cell therapy, injecting platelet rich plasma (PRP) at the head-neck junction of the femoral head.

All studies reported on a minimum follow-up of 12 months after HA. For calculation of a cumulative average follow-up, data of minimum follow-up was considered as average in cases where this information was missing (**Table 3**). As such, the weighted follow-up averaged 29.1 months (range 12 – 84 months).

Patient-reported and Radiographic Outcomes

Data on PROMs could be extracted for six studies^{15,24-27,30} due to lack of stratification based on disease stage and mixed patient populations (**Table 4**). The most common tool of assessment was the modified Harris Hip Score (mHHS). Additionally, various scoring systems were inconsistently used across studies (**Table 4**): Return to Sports (%), Visual Analogue Scale (VAS), Hip Outcome Score - Activities of Daily Living (HOS-ADL), Hip Outcome Score Sports Specific Subscale (HOS-SSS), Non-arthritic Hip Score (NAHS), Lower Extremity Functional Scale (LEFS).

When looking at preoperative values and PROMs at the last follow-up, four studies reported an improvement across all measures of PROMs domains'.^{15,24,25,30} Two studies clearly outline a negative

development with deteriorating PROMs.^{26,27} In the cohort of Nakashima et al²⁶, hips with Tönnis 2 and 3 scores were worse compared to control group for both mHHS (p=0.011) and NAHS (p=0.047).

Although some studies reported on radiographic outcomes with changes in the alpha angle or radiographic OA progression^{31,32}, no outcomes could be extracted for the hips with Tönnis 2 or greater due to lack of data stratification. Two studies reported no complications.^{24,34} In other studies neither information was reported nor could it get extracted.

Revisions and Conversion to Total Hip Arthroplasty

8/11 studies reported the incidence of reoperations (**Table 5**). The reoperations were either of a revision HA or a conversion to primary THA. Byrd²⁴ reported on a total revision rate of 6% (2/33) with two revision HA and no conversions to THA at the last follow-up. These were the same studies that included patients with an average age below 40. In contrast, in the study by Chandrasekaran et al²⁵, 54% (20/33) of hips with Tönnis 2 and 3 underwent a reoperation with 5 revision HA and 15 conversions to THA. Inconsistent rates of conversion could be observed across studies (**Table 5**) with conversion rates of 0%,^{15,24,34} 9%,³¹ 35%,²⁵ and 70%^{26,28,35}. This was next explored using a random-model meta-analysis with calculation of effect sizes and heterogeneity (**Fig. 2**).

Quantitative Analysis of Heterogeneity

Due to the lack of sufficient detail in the reported evidence and the amount of methodological heterogeneity (e.g., different study designs, lack of control groups and retrospective data analysis), an attempt to perform a meta-analysis to estimate a pooled summary effect could be misconceived and improper for clinical extrapolation. As such, we performed a quantitative analysis of heterogeneity. Our purpose was to quantify the heterogeneity and discuss ways to reduce it for future studies.

We agreed to not perform the planned subgroup analysis based on the score achieved on risk of bias assessment (MINORs <50% vs >50%) due to lack of sufficient studies that would lead to improper study stratification.

The single tool among PROMs that was common for all studies was the mHHS. However, there was a lack in reporting the change from the pre- to postoperative scoring, which would offer the most important information on the impact of the surgical procedure. From the 6 studies that have reported on this data,^{15,24–27,30} three did not use standard deviations/standard error or confidence intervals for the values of Δ mHHS^{26,27,30}. This did not allow a further analysis of heterogeneity.

An analysis was performed using the data from studies reporting on the proportion of hips that were converted to a THA (**Fig. 2**). A random model for meta-analysis was used and the calculated I^2 was 89%, which represents a high level of heterogeneity.

DISCUSSION

We found inconclusive and contradictory evidence regarding the efficacy of HA for hips with FAI and concomitant OA Tönnis 2 or greater. This patient population has shown to benefit from HA in some studies where the need for THA could be avoided in all cases,^{15,24} whilst at the same time, high rates of conversion to THA (up to 50-70%) were reported in other studies^{26,28,29}. Unfortunately, the current data does not permit a definitive answer regarding the efficacy of HA as an intervention for FAI and Tönnis 2 OA or greater. There is a lack of sufficient reporting, a high risk of bias and high heterogeneity across studies. Nevertheless, the current study suggests that the procedural success of arthroscopic management of FAI seems to be less dependent on the technical aspects of performing the procedure and more substantially dependent on patient selection and pathology.³⁶

It is well known that hip arthroscopy is beneficial to patients with FAI and early OA, as reported by two large scale multicentre randomized controlled trials.^{13,14} Previously, poor predictors have been reported for HA: less than 2 mm of joint space and Tönnis grade 3 changes.^{16,}

However, in this patient cohort with FAI and Tönnis Grade 2 or greater of OA, contradictory outcomes are still being reported.^{15,37} Domb and colleagues³⁷ have reported a 23% conversion rate to THA in a systematic review amongst patients with hip OA compared with 8.3% amongst patients without OA. Supporting these findings, same authors reported a 41% conversion rate to THA in their patient cohort with grade 2 Tönnis changes compared with a 11% conversion rate to THA at 2 years among patients with grade 0 and 1 Tönnis OA.²⁵ Opposed to these results, Byrd et al. stated no differences in terms of conversion to THA between patients with FAI and Tönnis grade 0 and 1 of OA versus grade 2 changes.³³ A latter study from the same group, reported successful clinical outcomes even in the presence of Tönnis grade 2 radiographic features.¹⁵

No substantial differences in the management of chondral lesions could be noted between studies. Apart from microfracture for Outerbridge 4 lesions (full-thickness) and labral reconstruction using different grafts, no chondral regeneration or culture techniques were employed. Mardones³¹ was the single to use PRP injections at the head-neck junction but did not describe sufficient details of the augmentation technique

(harvesting, preparation, preservation, delivery and other). In the context of lack of outcome data, no statement can be made on the potential benefit of this type of augmentation. Further research in this area is warranted, as various techniques (autologous matrix-induced chondrogenesis, osteochondral autograft transplantation and other) are emerging and have an increasing popularity, although without any evidence on the clinical benefits, yet.¹⁰

Several authors have included some patients with concomitant dysplasia or borderline hip dysplasia.^{25,28} This may have influenced the clinical outcomes and poses a potential source of bias. Another source of potential methodological inconsistency could be the differences that were observed in the mean age across studies. Whilst Byrd et al. performed HA in patients with a mean age of 27-39 years^{15,24}, other studies included mainly patients over the age of 40 years. This could explain the positive outcomes in the intervention groups that were reported for both conversion to THA and for PROMs when compared to controls (**Table 3, Table 4**). For the other two comparative studies that were included,^{25,26} both the rates of conversion to THA and the subjective PROMs of hips with FAI and Tönnis grade 2 or greater were detrimental when compared to the controls (Tönnis 0 or 1). The patients in these cohorts were however, significantly older (mean age 46 and 56).

Another factor that would explain these contradictory outcomes with be the difference in the length of follow-up (**Table 3**). Byrd et al^{15,24} that reported beneficial outcomes had a minimum follow-up of 1 year, whilst the rest of the authors had the minimum line at 2 years postoperatively. It is however also presumed that in most cases where there is already too much joint degeneration, a rapid decline occurs postoperatively.³⁸

LIMITATIONS

The limitations of the current systematic review are directly linked to the individual limitations of the included studies. Using the MINORs critical appraisal tool, there was a clear lack of prospective data collection and high rates of loss to follow-up; and also, a lack of an appropriate a-priori prospective statistical

calculation of the required sample size (**Table 2**). We could not perform an appropriate heterogeneity analysis for all measures of PROMs due to the lack of data regarding standard deviations and/or standard errors. Another issue that needs to be considered is the lack of consistency of using the Tönnis grading system of hip OA preoperatively. We needed to exclude a considerable number of studies due to different preoperative hip OA classifications (such as Kellgren-Lawrence) or because some authors only used intraoperative grading scales (Outerbridge). Also, the Tönnis grading system has certain limitations with Kappa values being previously published: interobserver reliability (0.74) and intraobserver reliability (0.73).³⁹ The strengths of our systematic review are represented by rigorous methodology and selection criteria. The methodology used international guidance and followed the PRISMA guidelines.¹⁸ A standardized tool (MINORs) for risk of bias assessment was used for all studies, which were non-randomized and were appropriately critically appraised. Appropriate risk of bias assessment allowed objective evaluation of the evidence level and highlighted all the weaknesses and sources of bias and heterogeneity.

CONCLUSION

There is currently contradictory and insufficient evidence regarding the efficacy of HA for hips with FAI and concomitant OA Tönnis 2 or greater. This is in the context of low-evidence data mainly consisting of retrospective case series (level IV) with high risk of bias and high heterogeneity ($I^2 \sim 90\%$).

FIGURE LEGENDS

Figure 1. Flowchart of the systematic search using the PRISMA guidelines.

Figure 2. Forest plot depicting the odds ratio of patients that received HA for FAI and concomitant Tönnis Grade 2 or greater hip OA to ultimately undergo a THA. Confidence intervals (95%) are given and the heterogeneity was quantified using a I^2 test.

TABLES

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none">• Studies in English or German language that investigated hip arthroscopy alone as the only intervention without open surgery• Studies that included patients with femoroacetabular impingement and Tönnis grade of osteoarthritis 2 or greater• Clinical and/or radiographic outcome was reported• Minimum follow-up of 6 months• Sample size equal or greater to 10 hips	<ul style="list-style-type: none">• Articles not written in English or German• Review articles, surgical techniques, oral presentations, experimental or animal studies, studies mixing and overlapping patient populations• Intervention included adjunct open procedure• Patient population with inflammatory or septic arthritis• Patient population with previous surgery on the ipsilateral hip• Patient population with osteonecrosis or post-avascular necrosis sequelae (Perthes) or slipped capital femoral epiphysis

258 **Table 2.** Individual risk of bias assessment using the MINORS tool (Methodological index for non-randomized studies)

	Adequate statistical analyses	Baseline equivalence of groups	Contemporary groups	An adequate control group	Prospective calculation of the study size	Loss to follow up less than 5%	Follow-up period appropriate to the aim of the study	Unbiased assessment of the study endpoint	Endpoints appropriate to the aim of the study	Prospective collection data	Inclusion of consecutive patients	A clearly stated aim	Total (%)
Byrd 2018 (JHPS) ¹⁵	0	1	1	1	0	1	1	1	2	0	1	2	11/24 (46%)
Byrd 2018 (Arthroscopy) ²⁴	1	1	2	1	0	2	2	1	2	1	2	2	17/24 (71%)
Chandrasekaran 2016 ²⁵	2	1	2	1	2	0	2	1	2	2	2	2	19/24 (79%)
Comba 2016 ²⁹	NA	NA	NA	NA	0	2	2	1	2	1	2	2	12/16 (75%)
Dall'Oca 2016 ³⁰	NA	NA	NA	NA	0	1	1	1	2	1	1	2	8/16 (50%)
Giordano 2019 ²⁸	NA	NA	NA	NA	0	1	2	1	2	2	1	2	11/16 (69%)
Hevesi 2017 ²⁷	NA	NA	NA	NA	2	0	2	1	2	2	1	2	12/16 (75%)
Horisberger 2009 ³²	NA	NA	NA	NA	0	2	1	2	2	2	2	2	13/16 (81%)
Mardones 2016 ³¹	NA	NA	NA	NA	0	1	1	1	2	0	1	2	8/16 (50%)
Nakashima 2019 ²⁶	2	1	2	1	0	1	2	1	2	1	1	2	16/24 (67%)
Tjong 2017 ³⁴	NA	NA	NA	NA	0	2	2	2	2	2	1	2	13/16 (81%)
NA – not applicable.													

260 **Table 3.** Demographics, indications and surgical techniques

First Author	Journal	Year	Level of Evidence	Nr. Patients	Nr. Hips	Tönnis Staging	Indications	Augmentation	Age	Gender	Follow-up
Byrd ¹⁵	<i>JHPS</i>	2018	III	45	48	48 T2	FAI	NR	27 (15 - 49)	30 M, 15 F	Minimum 1 year
			Control Group	150	150	37 T0; 113 T1	FAI	NR	30 (11 - 60)	116 M; 36 F	Minimum 1 year
Byrd ²⁴	<i>Arthroscopy</i>	2018	III	33	33	29 T2; 4 T3	FAI	Microfracture (Outerbridge 4 Acetabulum)	39 (13 - 63)	23 M, 10 F	Minimum 2 years
			Control Group	66	66	17 T0; 49 T1	FAI	Microfracture (Outerbridge 4 Acetabulum)	T0 - 33 (17 - 48); T1 - 34 (16 - 76)	T0 - 6M, 9 F; T1 - 36 M 13 F	Minimum 2 years
Chandrasekaran ²⁵	<i>JBJS Am</i>	2016	III	37	37	37 T2	FAI, several concomitant BHD	Acetabular Microfracture 5/37 (T2); Femoral Head Microfracture 2/37 (T2)	46 (20 - 63)	22 M, 15 F	30 (20 - 62) months
			Control Group	74	74	37 T0; 37 T1	FAI, several concomitant BHD	Labral Reconstruction - 1/37 (T0); Acetabular Microfracture - 5/37 (T0), 3/37 (T1); Femoral Head Microfracture - 1/37 (T1)	45 (20 - 63) - T0; 46 (17 - 67) - T1	22 M, 15 F (both for T0 and T1 - matched)	32 (22 - 64)
Comba ²⁹	<i>Muscle, Ligaments and Tendons J</i>	2016	IV	15	15	11 T2; 4 T3	FAI	Microfracture for Outerbridge 4 (n=3)	42 (31 - 56)	12 M, 3 F	84 months
Dall'Oca ³⁰	<i>Acta Biomed</i>	2016	IV	13	13	13 T2	FAI	Microfracture for Outerbridge 4	cannot extract (unstratified data)	cannot extract (unstratified data)	12 months
Giordano ²⁸	<i>AJSM</i>	2019	III	not reported	10	10 T2	FAI including Dysplasia (n=3) and BHD (n=1)	NR	cannot extract (unstratified data)	cannot extract (unstratified data)	75 ± 13 months
Hevesi ²⁷	<i>AJSM</i>	2017	III	not reported	11	11 T2	FAI and labral tears	NR	cannot extract (unstratified data)	cannot extract (unstratified data)	5 years
Horisberger ³²	<i>CORR</i>	2009	IV	not reported	28	28 T2	FAI	Microfracture for Outerbridge 4	cannot extract (unstratified data)	cannot extract (unstratified data)	1.3 years
Mardones ³¹	<i>Muscle, Ligaments and Tendons J</i>	2016	IV	not reported	11	11 T2	FAI	Microfracture for chondral lesion; Platelet Rich Plasma (PRP) was	cannot extract (unstratified data)	cannot extract (unstratified data)	2 years

								positioned at the head- neck junction			
Nakashima ²⁶	<i>Clin J Sport Med</i>	2019	III	18	18	18 (T2 and T3)	FAI	Microfracture for Outerbridge IV of acetabular rim (n=6, 33%); labral reconstruction using iliotibial band autograft (n=4, 29%)	56 (37 - 78)	9 M 9 F	30 ± 8 (24-43) months
			Control Group	79	79	T0 and T1	FAI	Microfracture for Outerbridge IV of acetabular rim (n=8, 10%); labral reconstruction using iliotibial band autograft (n=17, 22%)	51 (35 - 76)	34 M 45 F	35 ± 13 (24-62) months
Tjong ³⁴	<i>Arthroscopy</i>	2017	IV	not reported	23	23 T2	FAI	NR	cannot extract (unstratified data)	cannot extract (unstratified data)	Minimum 28 months
<i>Total/Average</i>			6 level III; 5 level IV		616 (369 controls)	221 T2; 8 T3; 16 T2 and T3					29.1 months weighted (range 12 – 84 months)

Nr. – number; T0, T1, T2, T3 - Tönnis grading of hip osteoarthritis; M – male; F – female; FAI – femoroacetabular impingement; BHD – borderline hip dysplasia; NR – not reported

Author	Nr. Hips	Follow-up	PROs assessed	PROMs preop	PROMs postop	Evolution at last follow-up
Byrd 2018 (JHPS) 15	48	Minimum 1 year	mHHS, Return to Sports	71.6	88.0	mHHS: +16.4 (95% CI: 11.4–21.5); Return to sports: 85%
Controls	150	Minimum 1 year	mHHS, Return to Sports	69.0 (T0); 73.9 (T1)	92.1 (T0); 94.5 (T1)	mHHS: +23.1 (T0, 95% CI: 16.9–29.3); +20.6 (T1, 95% CI: 17.9–23.4); Return to sports: 95% (T0); 92% (T1)
Byrd 2018 (Arthroscopy) ²⁴	33	Minimum 2 years	mHHS	66.9 (T2); 60.3 (T3)	81.8 (T2); 79.0 (T3)	mHHS: +14.9 (T2, 95% CI: 8.6–21.2); +18.8 (T3, range 9–33)
Controls	66	Minimum 2 years	mHHS	66.1 (T0); 63.5 (T1)	86.8 (T0); 85.7 (T1)	mHHS: +20.6 (T0, 95% CI: 12.5–28.8); +22.1 (T1, 95% CI: 16.9–27.4)
Chandrasekaran 2016 ²⁵	37	30 (20 – 62) months	mHHS HOS-ADL HOS-SSS NAHS VAS	57.5 ± 15.3 59.2 ± 22.6 37.9 ± 27.4 51.6 ± 18.9 6.42 ± 1.59	76.0 ± 20.4 77.5 ± 21.1 61.6 ± 31.7 74.7 ± 20.1 3.59 ± 2.71	mHHS: +18.5 HOS-ADL: +18.3 HOS-SSS: +23.7 NAHS: +23.1 VAS: -2.83
Controls	74	32 (22 – 64) months	mHHS HOS-ADL HOS-SSS NAHS VAS	59.0 ± 13.6 (T0); 56.7 ± 15.4 (T1); 57.1 ± 19.6 (T0); 59.2 ± 21.3 (T1); 39.2 ± 23.9 (T0); 39.2 ± 26.9(T1); 52.6 ± 17.5 (T0); 53.4 ± 18.1 (T1); 6.29 ± 1.85(T0); 6.27 ± 2.13 (T1)	74.5 ± 18.9 (T0); 80.5 ± 18.6 (T1); 76.1 ± 22.3 (T0); 79.8 ± 21.9 (T1); 61.8 ± 31.5 (T0); 65.6 ± 34.3 (T1); 73.3 ± 20.2 (T0); 78.1 ± 18.4 (T1); 3.67 ± 2.47 (T0); 3.54 ± 2.74 (T1)	mHHS: +15.5 (T0); 23.8 (T1); HOS-ADL: +19.0 (T0); +20.6 (T1); HOS-SSS: +22.6 (T0); +26.4 (T1); NAHS: +20.7 (T0); +24.7 (T1); VAS: -2.62 (T0); -2.73 (T1)
Comba 2016 ²⁹	15	84 months	WOMAC, mHHS	cannot extract (unstratified data)	cannot extract (unstratified data)	cannot extract (unstratified data)
Dall’Oca 2016 ³⁰	13	12 months	mHHS; LEFS	mHHS: 57; LEFS: 44.6	mHHS: 85.1; LEFS: 62.5	mHHS: 57 to 85.1; LEFS 44.6 to 62.5
Giordano 2019 ²⁸	10	75 ± 13 months	mHHS; HOS-SS; NAHS	cannot extract (unstratified data)	cannot extract (unstratified data)	cannot extract (unstratified data)
Hevesi 2017 ²⁷	11	5 years	mHHS; HOS-SSS; VAS	mHHS: 72.7; HOS-SSS: 68.8	mHHS: 71.0; HOS-SSS: 49.5	VAS: -3.7; mHHS: -1.7; HOS-SSS: -19.3
Horisberger 2009 32	28	1.3 years	NAHS, VAS, ROM	cannot extract (unstratified data)	cannot extract (unstratified data)	cannot extract (unstratified data)
Mardones 2016 ³¹	11	2 years	mHHS; VAS	cannot extract (unstratified data)	cannot extract (unstratified data)	cannot extract (unstratified data)
Nakashima 2019 ²⁶	18	30 ± 8 (24–43) months	mHHS; NAHS	mHHS: 74.6 ± 11.3; NAHS: 65.1 ± 13.1	mHHS: 74.2 ± 18.5; NAHS: 71.0 ± 22.3	compared to control group worse mHHS (p=0.011) and worse NAHS (p=0.047)
Controls	79	35 ± 13 (24–62) months	mHHS; NAHS	mHHS: 66.2 ± 18.2; NAHS: 56.6 ± 19.2	mHHS: 89.7 ± 14.4; NAHS: 84.2 ± 14.8	mHHS: +33.5 (p<0.001); NAHS: +27.6 (p<0.001)

Tjong 2017 ³⁴	23	Minimum 28 months	mHHS; iHOT-12; HOS-SSS	NR	mHHS: 71.5; iHOT-12: 58.8; HOS-SSS: 59.9	-
<i>Total/Average</i>	<i>616 (369 controls)</i>	<i>29.1 months weighted (range 12 – 84 months)</i>	<i>mHHS</i>			

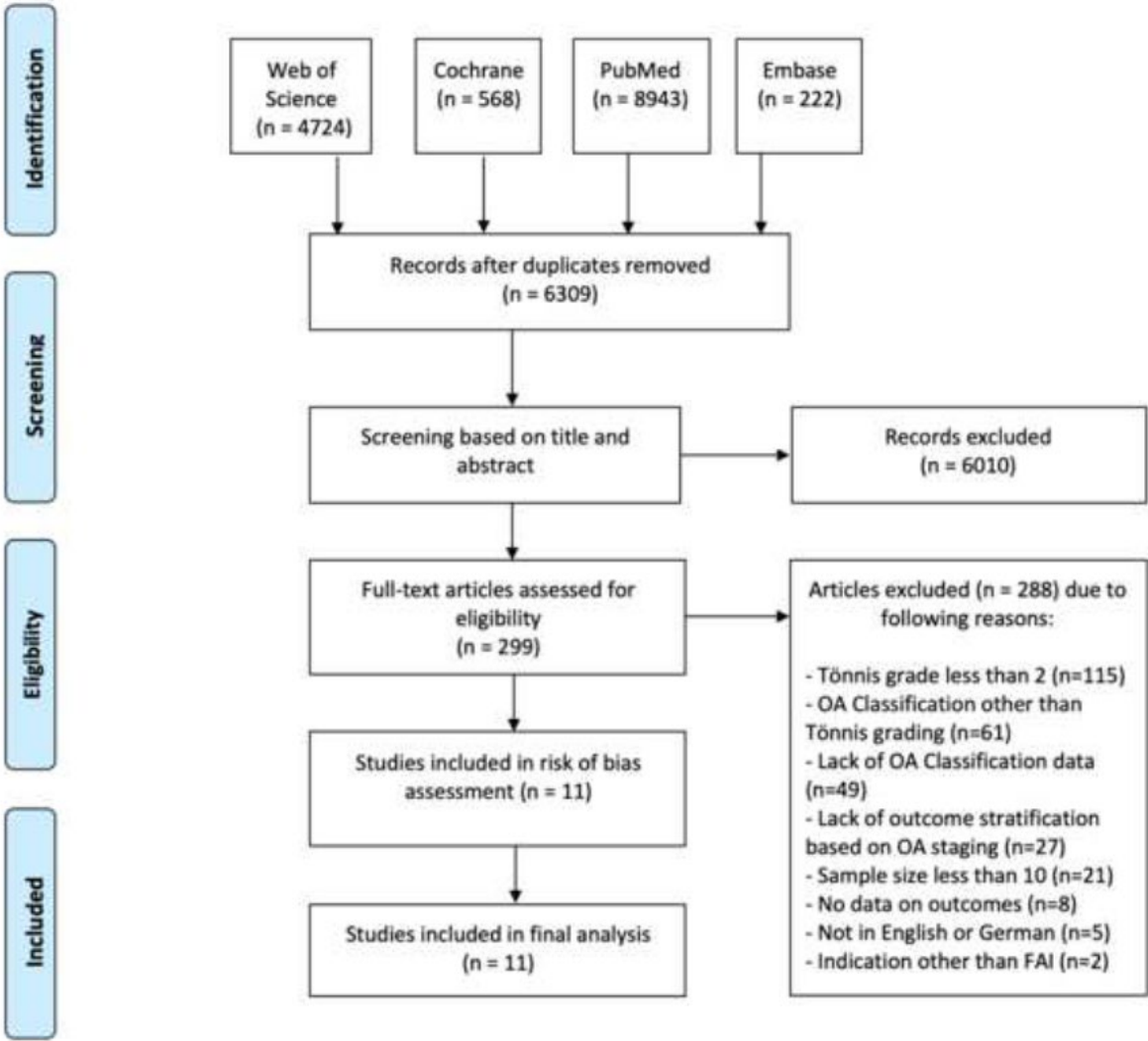
Nr. – number; PROMs – patient-reported outcomes; T0, T1, T2 and T3: Tönnis grades of osteoarthritis; CI – confidence intervals; mHHS – modified Harris Hip Score; VAS - Visual Analogue Scale; HOS-ADL - Hip Outcome Score - Activities of Daily Living; HOS-SSS - Hip Outcome Score Sports Specific Subscale; NAHS - Non-arthritic Hip Score; LEFS - Lower Extremity Functional Scale; NR – not reported

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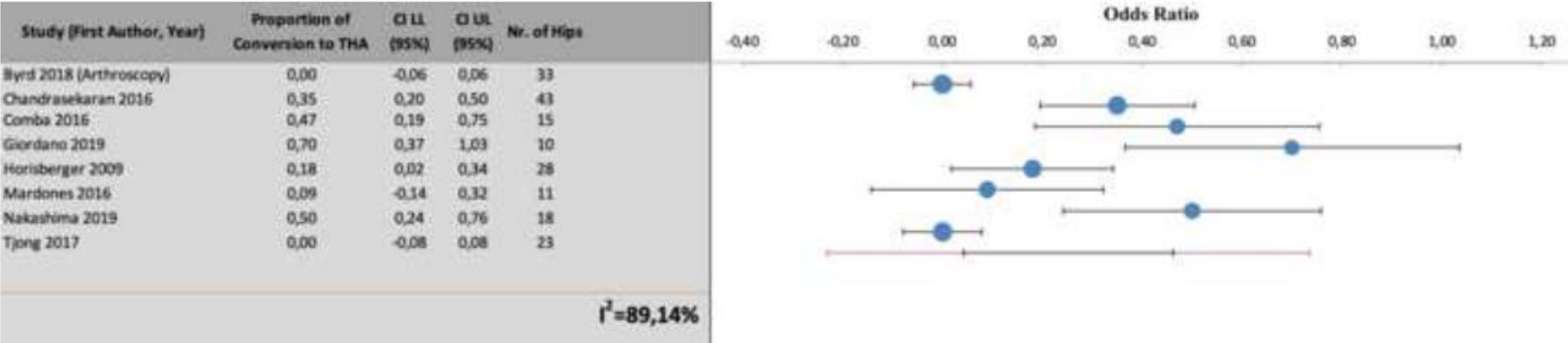
264 **Table 5.** Revisions and conversion to total hip arthroplasty

Author	Nr. Hips	Follow-up	Radiographic Outcome	Revisions	Conversion to THA (%)	Time to THA Conversion (months)
Byrd 2018 (JHPS) ¹⁵	48	Minimum 1 year	NR	NR	NR	NR
Controls	150	Minimum 1 year	NR	NR	NR	NR
Byrd 2018 (Arthroscopy) ²⁴	33	Minimum 2 years	NR	2/33 (HAS Revision)	0/33 (0%)	NR
Controls	66	Minimum 2 years	NR	4/66 (HAS Revision)	0/66 (0%)	NR
Chandrasekaran 2016 ²⁵	37	30 (20 - 62) months	NR	5/37 HAS and 15/37 THA	15/43 (35%)	29 (17 -44)
Controls	74	32 (22 - 64) months	NR	<u>HAS Revision:</u> 3/37 (T0) and 2/37 (T1); <u>THA Conversion:</u> 3/37 (T0); 5/37 (T1)	3/37 (8%, T0); 5/37 (14%, T1)	38 (T0); 42 (26 - 58) (T1)
Comba 2016 ²⁹	15	84 months	cannot extract (unstratified data)	7/15 THA	7/15 (47%)	NR
Dall'Oca 2016 ³⁰	13	12 months	cannot extract (unstratified data)	NR	NR	NR
Giordano 2019 ²⁸	10	75 ± 13 months	cannot extract (unstratified data)	7/10 THA	7/10 (70%)	cannot extract (unstratified data)
Hevesi 2017 ²⁷	11	5 years	NR	cannot extract (unstratified data)	cannot extract (unstratified data)	cannot extract (unstratified data)
Horisberger 2009 ³²	28	1.3 years	alpha angle - cannot extract (unstratified data)	5/28 THA	5/28 (18%)	NR
Mardones 2016 ³¹	11	2 years	Radiographic OA progression - cannot extract (unstratified data)	cannot extract (unstratified data)	1/11 (9%)	cannot extract (unstratified data)
Nakashima 2019 ²⁶	18	30 ± 8 (24-43) months	NR	9/18 THA	9/18 (50%)	6 conversions in the first 2 years
Controls	79	35 ± 13 (24-62) months	NR	4/79 THA	4/79 (5%)	2 conversions in the first 2 years
Tjong 2017	23	Minimum 28 months	NR	0	0/23 (0%)	NR
<i>Total/Average</i>	<i>616 (369 controls)</i>	<i>29.1 months weighted (range 12 – 84 months)</i>				

Nr. – number; PROMs – patient-reported outcomes; HAS – hip arthroscopy; THA – total hip arthroplasty; T0, T1, T2 and T3: Tönnis grades of osteoarthritis; NR – not reported



267 **Figure 2**



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