Can patients who have low-grade hip osteoarthritis expect the same outcome after total hip arthroplasty compared to those who have end-stage osteoarthritis? - A Matched Case-Control Study

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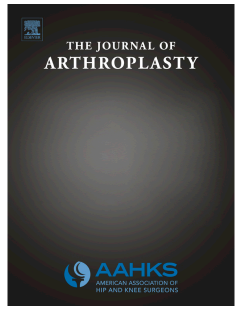

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Can Patients Who Have Low-Grade Hip Osteoarthritis Expect the Same Outcome After Total Hip Arthroplasty Compared to Those Who have End-Stage Osteoarthritis? – A Matched Case-Control Study

Abstract

Background

Total hip arthroplasty (THA) is an effective procedure for patients with end-stage hip osteoarthritis (OA). In addition, when hip preservation surgery is no longer indicated due to the presence of early or mild arthritic changes, THA can also be considered. Whether these patients can expect the same outcome after THA as patients who have end-stage OA remains unclear. The goal of this study was to compare the clinical outcomes after THA of patients who have low-grade OA versus a matched cohort with end-stage OA.

Methods

This is a retrospective, single-center, multi-surgeon case-control study in a high-volume referral center. Based on a cohort of 2,189 primary anterior approach THAs (1,815 patients), 50 low-grade OA cases were matched 1:1 by age, sex, and Body Mass Index (BMI) to 50 controls who have end-stage OA. Patient-reported outcomes (PROMS) were Hip Disability and Osteoarthritis Outcome Scores (HOOS) and Short Form-36 (SF-36).

Results

No significant differences in preoperative PROMs between low-grade and end-stage OA patients were found, except for SF-36 pain (33.0 versus 41.0; $P = 0.045$). In both groups a significant improvement of all PROMs was found postoperatively. However, all HOOS scores were significantly lower in the low-grade OA group compared to the end-stage OA group. In the group with low-grade OA, a significantly lower percentage of patients achieved the minimum clinically important difference (MCID) and substantial clinical benefit (SCB) after THA compared to the group with end-stage OA.

Conclusion

Patients who have low-grade OA can expect substantial clinical improvement after THA. However, the improvement is lower compared to patients who have end-stage OA. A thorough understanding of the factors that may lead to inferior clinical outcomes is imperative to improving the indications for THA in individuals who have low-grade OA.

Keywords:
Primary Hip Arthroplasty – Low-grade Osteoarthritis - Outcome – Direct Anterior Approach

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Introduction

Total Hip Arthroplasty (THA) has emerged as a successful surgical intervention for end-stage hip osteoarthritis (OA), relieving pain, improving function, and restoring patients' mobility.[1] A THA is primarily reserved for the elderly population with advanced disease, characterized by severe cartilage damage, significant joint space narrowing, and debilitating symptoms. However, due to successful long-term (>20 years) clinical results and implant survivorship, THA is also considered in younger patients, and this number is predicted to increase in the next decade.[2-5]

Hip pain in young and middle-aged patients is frequently caused by femoro-acetabular impingement (FAI), hip dysplasia, and labral pathology and can often be treated successfully with hip preservation surgery.[6 7] However, if signs of OA are present, the outcome is less predictable.[8] Even in early-stage hip OA, patients may experience significant pain, which can have a substantial impact on their daily activities and overall well-being.[9-11] As a result, THA is also being considered for those patients when hip preservation surgery is no longer indicated.

However, the relationship between the severity of radiological hip OA and the ability to predict the clinical outcome after THA is marked by inconsistent findings. While several studies found superior outcomes among patients who have high-grade OA versus those who have low-grade OA,[12-15] others found no correlation between radiological severity of OA and PROMs.[16] In addition, advanced age, women, obesity, deteriorated general health, and lower educational achievement can also aggravate clinical complaints.[17]

The primary goal of this study was to compare the clinical outcome, based on PROMs, and complication- and reoperation rates after THA among patients who have low-grade OA (Tönnis 1) compared to an age-, sex-, and Body Mass Index (BMI)-matched cohort of patients who have end-stage OA (Tönnis 3). Secondarily, we aimed to assess whether the different indications for THA had an influence on the clinical outcome.

Materials and Methods

Study Design and Patient Population

This is a retrospective, multi-surgeon, case-control study, conducted at a single high-volume tertiary referral center (Ziekenhuis Oost-Limburg, Genk, Belgium), utilizing prospectively recorded data from patients who underwent primary THA through an anterior approach on a standard table between January 1st, 2017, and December 31st, 2019. Only patients who have a minimum follow-up of 2 years were included in the analysis. The study received approval from the ethical committee, and all participants provided informed consent.

During the study period, a total of 2,189 primary THAs were performed on 1,879 patients. The exclusion criteria comprised: (1) individuals below 18 years of age (n = 4), (2) cases of death unrelated to the hip condition during follow-up (n = 33), (3) history of septic arthritis (n = 2), (4) post-traumatic cases (n = 118), (5) Leg-Calvé-Perthes (LCP) cases (n = 28), (6) slipped capital femoral epiphyses (SCFE) cases (n = 7), (7) utilization of a different surgical approach (n = 2), and (8) patients lost to follow-up (n = 7). Consequently, a total of 1,988 primary THAs performed were included, involving 1,698 patients. Cases with incomplete preoperative and 1-year postoperative PROMS (1,350 hips; 1,176 patients) were excluded. The remaining cohort of 617 hips (501 patients) consisted of 72 Tönnis 1 hips (62 patients) and 431 Tönnis 3 hips (340 patients).

Of these, 60 Tönnis 1 OA cases could be matched 1:1 by age (maximum difference of 5 years), sex and BMI (maximum difference of 2.5kg/m2) to 60 controls who have end-stage OA (Tönnis 3) using case-control matching in Statistical Package for the Social Sciences (SPSS) version 27 (IBM, New York, United States). The medical histories of these 120 cases were examined in detail, and cases with pertinent medical histories that may impact the outcomes of THA, such as previous hip surgery (n = 4), rheumatoid arthritis (RA) (n = 3), spinal fusion (n = 3), or degenerative spinal conditions (n = 4), were additionally excluded. Finally, 50 cases were included in both the Tönnis 1 and Tönnis 3 groups (Figure 1).

Patient demographics

The demographic and clinical data were similar for both matched cohorts. No significant differences were found in the indications for THA (Table 1).

Preoperative management

All patients had exhausted non-operative treatment, including a minimum of 6-months of physical therapy. In patients who have low-grade (Tönnis 1) or moderate (Tönnis 2) OA, an intra-articular hip infiltration procedure utilizing corticosteroids was performed. To optimize the physiotherapy program, all patients were assessed by a senior physiotherapist specializing in hip pathology who determined a personalized exercise program. After a period of 6 months, a multi-disciplinary team meeting between the patient, physiotherapist, and surgeon was organized to make a joint decision about THA. In the low-grade and moderate OA population, only patients who have a positive initial response to hip infiltration, where it proved to be insufficient in providing long, substantial symptom relief, were considered for a surgical intervention.

Surgical Procedure

All surgical procedures were conducted by two arthroplasty surgeons who have a minimum of 10 years' experience with and exclusively use the anterior approach for primary THA [18]. The anterior approach using the bikini incision was performed with the patient positioned supine on a standard operating table.[19-21] Uncemented acetabular cups were utilized in all patients (n = 109 DePuy Synthes Pinnacle (Raynam, Massachusetts, USA) (91.8%) and n= 11 Zimmer Biomet Trilogy (Warsaw, Indiana, USA) (9.2 %). There were two different femoral stems used, namely DePuy Synthes Corail (n = 109; 91.8%) and Zimmer Biomet Avenir (n = 11; 9.2 %). Most stems were uncemented (n = 116; 96.7%) and collared (n = 67; 55.8%). Capsular repair was consistently performed.[22] Following surgery, patients were allowed weightbearing as tolerated without any specific anterior or posterior hip precautions. No formal physiotherapy was initiated during the first 6 weeks postoperatively, and patients were recommended to avoid open-chain exercises.

Radiographic Assessment

Standing antero-posterior (AP) pelvic radiographs were analyzed using Orthoview (Materialise, Leuven, Belgium), and a calibration marker was used to correct for magnification error. The longitudinal rotation of the pelvis was verified as correct when the tip of the coccyx was in line with pubic symphysis. If the coccyx deviated > 1 centimeter from the symphyseal line, the X-ray was considered unacceptable for measurement purposes. The following measurements were obtained: (1) leg-length discrepancy is defined as the difference in leg length between the ipsilateral and contralateral hips measured by the distance between the inter-teardrop line and the most medial margin of the lesser trochanter,[23] (2) femoral offset is defined as the shortest distance from the center of the femoral head to a line parallel to the long axis of the femur; (3) acetabular offset is defined as the distance from the center of the femoral head to the medial teardrop, (4) cup inclination is defined as the angle between the long axis of the cup and a transverse line connecting the bottom edge of the acetabular teardrops,[24] and (5) acetabular cup anteversion defined as the inverse sine of the division between the distance of the short and long axis of the elliptical projection of the rim of the acetabular component.[25] Furthermore, the difference in diameter between the acetabular component and the native femoral head was calculated in millimeters and in a ratio between the two.[26]

Osteoarthritis was graded according to the Tönnis classification, which includes Grade 0 (absence of arthrosis), Grade 1 (slight narrowing of the joint space, slight lipping at the joint margin, and slight sclerosis of the femoral head or acetabulum), Grade 2 (presence of small bony cysts, further narrowing of the joint space, and moderate loss of femoral head sphericity), and Grade 3 (large cysts, severe narrowing of the joint space, severe femoral head deformity, and osteonecrosis).[27] There were two fellowship-trained arthroplasty surgeons (W.P. and J.V.) who independently assessed all X-rays, and in cases of differing grading, the X-rays were re-evaluated by both authors, who then jointly assigned a Tönnis grade. For patients who do not have radiographic evidence of end-stage osteoarthritis, additional imaging (CT arthrography or MRI) was obtained to assess for the presence of cartilage lesions, and to exclude other underlying sources of hip pain such as osteonecrosis, a stress fracture, or tumor pathology.

Clinical Assessment

Clinical, surgical, and hospitalization notes were examined for indication, past medical history, and postoperative complications. An automated artificial intelligence-supported algorithm (LynxCare, Leuven, Belgium) was used to screen all electronic medical records for key sentences, keywords, and clinical definitions. The accuracy of this algorithm has been described previously.[28] Missing data were completed by one of the authors (J.V.). If patients complained of low back pain or greater trochanter pain, this was noted in the electronic medical record. Lateral-sided thigh pain or altered sensation in this region was reported as lateral femoral cutaneous nerve (LFCN) complaints. At the time, we were not aware of the existence of Tensor Fascia Lata (TFL)-tendinopathy, and thus this diagnosis was not reported. Our diagnostic algorithm to detect psoas tendinopathy has been described previously.[29]

Patient-reported outcome measures

Patient-reported outcome measures (PROMs), including the Hip Disability and Osteoarthritis Outcome Score (HOOS)[30] and the 36-item Short Form Survey (SF-36)[31], were obtained 4 weeks before surgery and at least 12 months postoperatively. We assessed five different HOOS domains (symptoms, pain, activities daily life, sport and quality of life) and eight different SF-36 domains (physical functioning, role limitations due to physical health, role limitations due to emotional problems, vitality, emotional well-being, social functioning, pain and general health). To quantify the clinical improvement after THA, the percentage of patients who achieved the anchor-based Minimal Clinical Important Difference (MCID) and Substantial Clinical Benefit (SCB) per HOOS and SF-36 category was determined based on previously published reference values (Tables 5 and 6).[32 33]

Data Analyses

A power analysis was performed to determine the minimum number of subjects in each cohort. A sample size was calculated in SPSS v27 (IBM, New York, United States) based on a MCID of HOOS Pain of 9 and a mean postoperative HOOS Pain score of 92 ± 12 as a reference [33]. A minimum of 23 cases per group were necessary to achieve sufficient power ($1\text{-}ß = 0.80$, $\alpha = 0.05$). To increase power, we included 50 cases and 50 controls.

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 27 (IBM, New York, United States). A significance level of $P < 0.05$ was considered significant. The normal distribution was assessed using Q-Q plots and Kolmogorov-Smirnov tests. Non-normally distributed continuous data was compared between groups using Mann-Whitney *U*-tests, while normally distributed data was compared using independent-samples *t*-tests. A paired-samples *t*-tests were conducted to compare preoperative and postoperative values, and *Chi*-squared tests were used to compare categorical variables.

Results

Postoperative complications and complaints

The overall complication ratio was 0.3% for dislocation, 1.8% for periprosthetic fracture, and 0.2% for PJI [28]. For the cohorts in this study, the data is shown in Table 1. In the Tönnis-1 cohort, one patient had a traumatic postoperative dislocation that was treated by a closed reduction under general anesthesia. No other major complication (e.g., prosthetic joint infection (PJI) or periprosthetic fracture) was found.

Peri-articular muscle envelope complaints were significantly more common in the Tönnis 1 group compared to the Tönnis 3 group, respectively, in 9 versus 1 cases ($P = 0.008$). Both psoas tendinopathy and greater trochanter pain occurred more frequently in the Tönnis 1 group. Postoperative low back pain symptoms were also more often reported in the Tönnis 1 group compared to the Tönnis 3 group, although not statistically significant (respectively in 7 versus 2 cases ($P = 0.160$)) (Table 1).

Radiographic measurements

No significant difference was found in the femoral, acetabular, or global offset changes after THA. Furthermore, no significant differences were found in the other radiographic parameters between the two groups, apart from a significant lower native acetabular and global offset in the Tönnis 1 group (Table 2).

Patient reported outcome scores

Preoperatively, both cohorts scored equal in all PROMs, except for the SF-36 pain score, which was lower in the Tönnis 1 group (Tables 3 and 4, Figures 2 and 3). At one year postoperatively, all five HOOS domains showed significantly higher scores in the Tönnis 3 group compared to the Tönnis 1 group (Table 3, Figure 2). Also, in three SF-36 domains (physical functioning, role limitations due to physical health, and pain) higher scores were found in the Tönnis 3 group (Table 4, Figure 3).

A significantly higher percentage of Tönnis 3 patients reached the MCID HOOS ($P < 0.025$), except for 'HOOS Quality of Life' ($P = 0.110$) (Table 5). Also, a significantly higher percentage of Tönnis 3 patients achieved a SCB threshold in three HOOS domains (symptoms, pain and sport) with $P < 0.024$ (Table 5). Across the SF-36 domains, no significant difference in reaching a MCID threshold was seen (Table 6).

Subgroup analyses

For the primary OA subgroup, significantly lower postoperative mean HOOS scores were seen in the low-grade group compared to the end-stage OA group. Similarly, significantly lower postoperative mean HOOS and SF-36 scores were observed in the low-grade compared to the end-stage OA cohort in the subgroup of secondary OA to dysplasia. Due to the insufficient sample size, no conclusion could be made for the secondary OA-FAI subgroup (Table 7).

Discussion

Scheduled for THA, patients who have low-grade OA have similar PROMs as those who have high-grade OA. This indicates that symptoms affect their daily activities in a similar way. After THA, improvement in PROMs is smaller in patients who have low-grade OA than for patients who have end-stage OA, regardless of the indication for surgery. An arthroplasty achieves more frequently a minimal clinically important improvement and a substantial clinical benefit in patients who have end-stage OA compared to those who have low-grade OA. This is despite the use of PROMs, which are known for their large ceiling effect and high MCID, which makes detecting a difference in outcome difficult in young and high-demand patients.[34] This is important information for surgeons who are counseling and treating young patients who have hip pain.

Factors explaining the difference in THA outcome between low-grade and end-stage OA patients remain largely unclear.[35] Remarkably, patients who have low-grade OA reported more postoperative peri-articular muscle symptoms and low back pain compared to those who have end-stage OA. It is plausible that these complaints contribute to the observed disparity in THA outcomes. Radiographic analysis showed a successful restoration of native global, acetabular, and femoral offset, and anterior cup prominence was excluded in patients who had psoas complaints. Patients in the Tönnis 1 group showed a lower native acetabular offset, which reduces the leverage for medially located muscles such as the psoas. However, the underlying factors responsible for a higher occurrence of peri-articular muscle complaints in patients who had low-grade OA remain to be determined. A subgroup analysis suggests that Tönnis 1 patients have less favorable outcomes compared to Tönnis 3 patients, regardless of the underlying cause of OA. Other parameters, including level of activity[36], patient motivation and expectations, chronic pain perception, psychological status, societal roles, mental health issues, and social situations, are known to affect THA outcomes and should be considered as well.[37] Therefore, more research is required to determine the exact contribution of those factors to the lower THA outcome in low-grade OA patients.

The current study has some potential limitations. We recognize the rather low sample size of the patient cohort, which can partly be attributed to the fact that preoperative and postoperative PROMS were only completed in 30% of the total patient population. However, it is important to note that this bias affects both the Tönnis 1 cases and the Tönnis 3 controls equally, thereby not influencing the comparison between the two groups. Moreover, individuals who have low-grade OA constitute a small subgroup of THA patients and tend to be younger than those who have end-stage OA. Consequently, matching for age, sex, and BMI with suitable controls significantly reduces the sample size. However, studies with larger sample sizes are necessary to gain a deeper understanding of the driving factors explaining the differences in THA outcomes between low-grade and end-stage OA patients. Also, the prevalence of subjective adverse events such as low back pain was based on clinical notes and might have underestimated its true prevalence. We also did not use any PROMs to quantify low back pain, such as the Oswestry Disability Index. Additionally, a minimal follow-up of two years can be considered rather short. However, the investigated primary outcomes are not expected to change after the one-year follow-up term. Furthermore, both cemented and uncemented implants were included in the study, and this might have biased results.

Conclusion

Patients who have low-grade OA can expect substantial clinical improvement after THA. However, the improvement is lower compared to patients who have end-stage OA. The underlying factors responsible for this observation remain to be determined. A thorough understanding of the factors that may lead to inferior clinical outcomes is imperative to improving the indications for THA in individuals who have low-grade OA.

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Figures

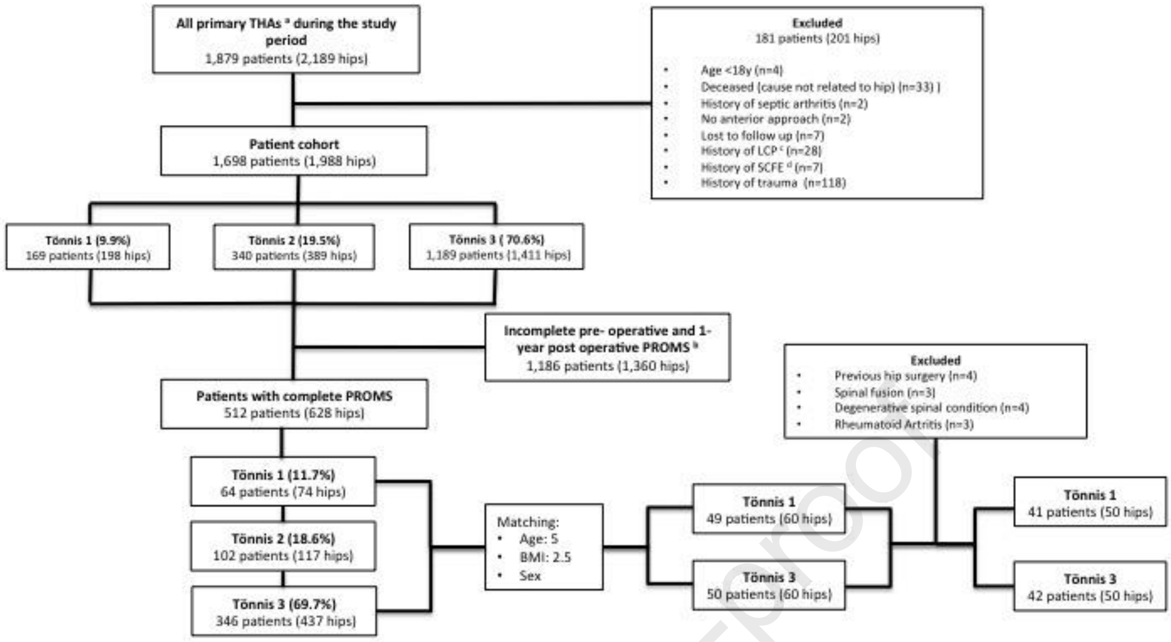

Figure 1. Flowchart of the cohort included in the study.

[a] *Total Hip Arthroplasty (THA)*
b Patient Reported Outcome Measures (PROMS)
c Leg-Calvé-Perthes (LCP)
d Slipped capital femoral epiphyses (SCFE)

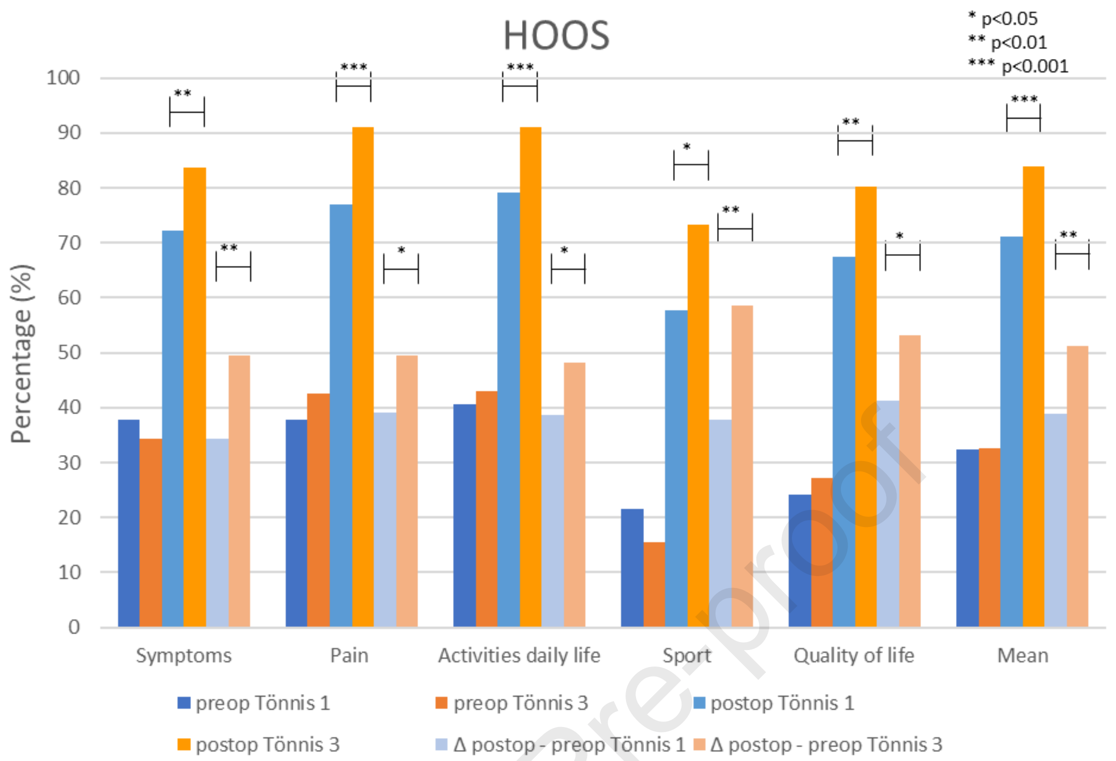

Figure 2: The mean preoperative and postoperative Hip Disability and Osteoarthritis Outcome Scores (HOOS) (%) per HOOS domain, shown for the low-grade osteoarthritis (OA) (Tönnis 1) and end-stage OA group (Tönnis 3).

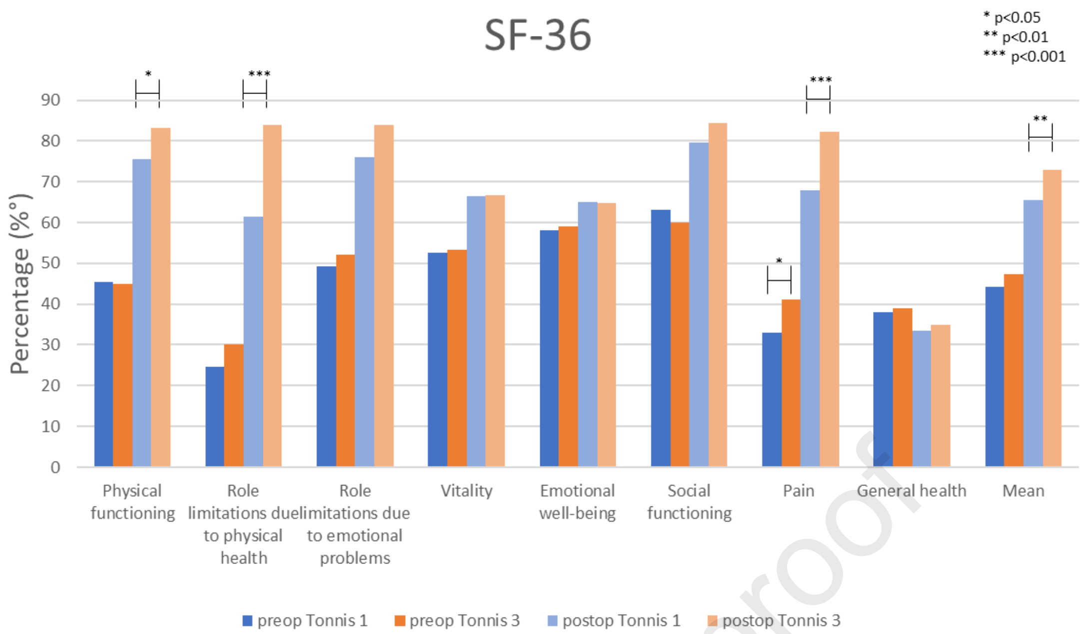

Figure 3: The mean preoperative and postoperative Short Form-36 score (SF-36) (%) per SF-36 domain, shown for the low-grade osteoarthritis (OA) (Tönnis 1) and end-stage OA group (Tönnis 3).

Tables

Table 1: Demographic and clinical data of cohort.

Parameters	Whole Cohort (n=100)	Tönnis 1 (n=50)	Tönnis 3 (n=50)	*P* value
Mean age [years ± Standard Deviation (SD) (range)]	56 ± 10 (36-78)	54 ± 10 (36-70)	57 ± 8 (38-78)	0.113 [f]
Sex				1.000 [g]
Men (n, %)	12 (12.0)	6 (12.0)	6 (12.0)	
Women (n, %)	88 (88.0)	44 (88.0)	44 (88.0)	
Mean BMI [kg/m2 ± SD (range)]	26.1 ± 4.38 (17.6-38.3)	26.3 ± 3.88 (20.6-34.8)	26.0 ± 4.87 (17.6-38.3)	0.521 [h]
Mean follow-up [years ±SD (range)]	2.8 ± 0.8 (2.00 -4.2)	2.7 ± 0.85 (2.00-3.8)	2.9 ± 0.77 (2.00-4.1)	0.438 [h]
Bilateral THA [a] (n, %)	17 (17.0)	9 (18.0)	8 (16.0)	0.642 [g]
Simultaneous bilateral THA (n, %)	7 (7.0)	4 (8)	3 (6.0)	0.382 [g]
Indication (%)				
Primary hip OA [b]	52 (52.0)	26 (52.0)	26 (52.0)	1.000 [g]
Secondary OA to Dysplasia [c]	41 (41.0)	21 (42.0)	20 (40.0)	0.839 [g]
Secondary OA to FAI [d]	7 (7.0)	3 (6.0)	4 (8.0)	0.693 [g]
Postoperative complaints/complications				
Dislocation (n,%)	1 (1.0)	1 (2.0)	0 (0.0)	1.000 [i]
Peri-Articular Muscle Envelope (%)	10 (10.0)	9 (18.0)	1 (2.0)	0.008 [g]
Psoas tendinopathy (n, %)	4 (4.0)	4 (8.0)	0 (0.0)	0.117 [i]
Greater Trochanter pain (n, %)	7 (7.0)	6 (12.0)	1 (2.0)	0.112 i
Low back pain (n, %)	9 (9.0)	7 (14.0)	2 (4.0)	0.160 [i]
LFCN complaints (n,%) [e]	2 (2.0)	2 (4.0)	0 (0.0)	0.495 [i]

[a] *Total hip Arthroplasty (THA)*
[b] *Osteoarthritis (OA)*
[c] *Secondary hip arthritis due to dysplasia as per Lateral Centre-Edge Angle (LCEA) ≤ 20°.*
[d] *Secondary hip arthritis due to Femoro-Acetabular Impingement (FAI) as per CAM (alpha angle ≥ 55°) or pincer (presence of retroversion and/or coxa profunda LCEA > 40°).*
[e] *Lateral Femoral Cutaneous Nerve (LFCN) Complaints*
[f] *Independent samples t-test.*
[g] *Chi-squared test.*
[h] *Mann Whitney U-test*
[i] *Fisher's exact test.*

Table 2: Radiographic assessment

Radiographic parameter	Whole Cohort (n=100)	Tönnis 1 (n=50)	Tönnis 3 (n=50)	*P* Value[a]
Leg length Difference (mm)	0.8 ± 2.0 (-6.0 - 5.0)	0.8 ± 1.9 (-3.0 - 5.0)	0.8 ± 2.2 (-6.0 - 5.0)	0.859
Cup anteversion (°)	23.0 ± 3.1 (13.4 - 32.8)	23.4 ± 3.0 (16.3 - 30.7)	22.4 ± 3.3 (13.4 - 32.8)	0.069
Cup inclination (°)	32.8 ± 5.3 (20.2 - 43.7)	33.7 ± 5.0 (20.2 - 43.7)	32.1 ± 4.9 (22.9 - 43.6)	0.066
Femoral offset (mm)				
Preoperative	58.0 ± 5.6 (40.0 - 76.0)	57.8 ± 4.0 (52.0 - 68.0)	58.1 ± 6.9 (40.0 - 76.0)	0.702
Postoperative	61.3 ± 5.8 (45.0 - 77.0)	61.2 ± 5.7 (52.0 - 77.0)	61.4 ± 6.0 (45.0 - 74.0)	0.341
Offset change	3.2 ± 4.9 (-7.0 - 17.0)	3.2 ± 4.8 (-3.0 - 17.0)	3.1 ± 5.1 (-7.0 - 14.0)	0.958
Acetabular offset (mm)				
Preoperative	33.8 ± 5.5 (22.0 - 59.0)	32.1 ± 5.6 (22.0 - 59.0)	35.5 ± 4.9 (26.0 - 45.0)	<0.001
Postoperative	31.1 ± 3.9 (24.0 - 44.0)	29.3 ± 3.1 (24.0 - 36.0)	33.0 ± 3.8 (26.0 - 44.0)	<0.001
Offset change	-2.2 ± 3.7 (-10.0 - 6.0)	-2.4 ± 3.3 (-10.0 - 3.0)	-2.0 ± 4.1 (-9.0 - 6.0)	0.697
Combined offset (mm)				
Preoperative	91.8 ± 8.2 (72.0 - 118.0)	90.0 ± 7.0 (79.0 - 118.0)	93.7 ± 8.9 (72.0 - 115.0)	0.027
Postoperative	92.4 ± 7.7 (79.0 - 113.0)	90.5 ± 7.4 (76.0 - 113.0)	94.5 ± 7.6 (79.0 - 113.0)	0.004
Offset change	0.9 ± 5.8 (-12.0 - 18.0)	0.8 ± 5.6 (-11.0 - 18.0)	1.0 ± 6.1 (-12.0 - 16.0)	0.430
Acetabular cup size (mm)	50.6 ± 2.9 (48.0 - 64.0)	50.4 ± 2.5 (48.0 - 60.0)	50.8 ± 3.1 (48.0 - 64.0)	0.719
Native femoral head size (mm)	46.5 ± 3.2 (40.0 - 59.0)	46.5 ± 3.3 (41.0 - 58.0)	46.4 ± 3.2 (40.0 - 59.0)	0.897
Difference between acetabular cup and native femoral head (mm)	4.2 ± 1.6 (-1.0 - 8.0)	4.0 ± 1.5 (1.0 - 8.0)	4.4 ± 1.7 (1.0 - 8.0)	0.122
Ratio acetabular cup/native femoral head	1.1 ± 0.04 (1.0 - 1.2)	1.1 ± 0.04 (1.0 - 1.2)	1.1 ± 0.04 (1.0 - 1.2)	0.158

Values presented as mean ± standard deviation (range).
[a] Mann Whitney U Test

482 **Table 3:** Hip Disability and Osteoarthritis Outcome Scores (HOOS) preoperatively and at 1 year postoperatively.
483

Patient reported outcome score	Timing	Tönnis 1 (n=60)	Tönnis 3 (n=60)	*P* value[a]
HOOS Symptoms	Preoperatively	37.7 ± 17.6 (5.0-85.0)	34.3 ± 18.9 (5.0-80.0)	0.267
	At 1y follow-up	72.1 ± 19.9 (15.0-100.0)	83.7 ± 16.8 (40.0-100.0)	0.001
	Difference between pre and postoperative score	34.4 ± 24.8 (-15.0-90.0)	49.4 ± 22.3 (-10.0 -90.0)	0.004
HOOS Pain	Preoperatively	37.8 ± 13.5 (0.0-67.5)	42.6 ± 18.2 (7.5-90.0)	0.151
	At 1y follow-up	77.0 ± 20.4 (17.5-100.0)	91.1 ± 13.9 (40.0-100.0)	<0.001
	Difference between pre and postoperative score	39.1 ± 23.2 (-15.0-85.0)	49.5 ± 20.2 (0.0-92.5)	0.046
HOOS Activities daily life	Preoperatively	40.6 ± 16.1 (7.3-70.6)	42.9 ± 18.2 (15.0 -92.0)	0.799
	At 1y follow-up	79.2 ± 21.1 (16.2-100.0)	91.1 ± 13.3 (36.8-100.0)	<.001
	Difference between pre and postoperative score	38.6 ± 23.7 (-16.2-83.8)	48.2 ± 19.5 (-7.35-79.4)	0.032
HOOS Sport	Preoperatively	21.6 ± 18.3 (0.0-75.0)	15.4 ± 15.6 (0.0-56.2)	0.072
	At 1y follow-up	57.8 ± 29.6 (0.0-100.0)	73.2 ± 25.1 (0.0-100.0)	0.015
	Difference between pre and postoperative score	37.8 ± 32.1 (-75.0-81.3)	58.5 ± 26.0 (0.0-100.0)	0.003
HOOS Quality of life	Preoperatively	24.2 ± 15.2 (0.0-56.3)	27.1 ± 17.6 (0.0-68.8)	0.373
	At 1y follow-up	67.5 ± 20.9 (12.5-100.0)	80.3 ± 20.1 (31.1-100.0)	0.002
	Difference between pre and postoperative score	41.2 ± 24.2 (-6.3-93.8)	53.1 ± 24.8 (6.3-100.0)	0.047
Mean HOOS	Preoperatively	32.4 ± 12.8 (8.1-60.3)	32.5 ± 14.6 (10.6-75.5)	0.909
	At 1y follow-up	71.1 ± 19.4 (12.2-98.8)	83.8 ± 15.8 (39.4-100.0)	<0.001
	Difference between pre and postoperative score	38.8 ± 22.7 (-19.6-77.3)	51.3 ± 18.0 (8.3-89.4)	0.007

484
485 Values presented as mean ± standard deviation (range).
486 [a] Mann Whitney U Test
487

Table 4: Short Form-36 Scores (SF -36) preoperatively and at 1 year postoperatively

	Tönnis 1 (n=50)		**Tönnis 3 (n= 50)**		***P*-value [a]**	***P*-value [b]**
SF-36	preoperative (n=50)	postoperative (n=50)	preoperative (n=50)	postoperative (n=50)		
Physical functioning	45.4 ± 16.9 (15.0-80.0)	75.5 ± 19.3 (15.0-100.0)	44.9 ± 21.5 (10.0-95.0)	83.3 ± 16.5 (20.0-100.0)	0.611	0.014
Role limitations due to physical health	24.5 ± 24.8 (0.0-100.0)	61.5 ± 38.5 (0.0-100.0)	30.0 ± 36.4 (0.0-100.0)	84.0 ± 31.0 (0.0-100.0)	0.068	<0.001
Role limitations due to emotional problems	49.3 ± 43.7 (0.0-100.0)	76.0 ± 39.3 (0.0-100.0)	52.0 ± 45.3 (0.0-100.0)	84.0 ± 33.2 (0.0-100.0)	0.693	0.250
Vitality	52.5 ± 16.0 (15.0-80.0)	66.4± 13.6 (35.0-90.0)	53.4 ± 21.2 (5.0-90.0)	66.7 ± 18.0 (5.0-100.0)	0.912	0.779
Emotional well-being	58.1 ± 12.2 (28.0-80.0)	65.0 ± 10.0 (36.0-80.0)	59.0 ± 12.2 (36.0-76.0)	64.7± 9.9 (44.0-80.0)	0.698	0.747
Social functioning	63.0 ± 19.7 (12.5-100.0)	79.5 ± 21.1 (12.5-100.0)	60.0 ± 24.7 (12.5-100.0)	84.3 ± 19.4 (12.5-100.0)	0.549	0.186
Pain	33.0 ± 14.6 (0.0-67.5)	67.9 ± 22.7 (10.0-100.0)	41.0 ± 21.6 (0.0-90.0)	82.3 ± 23.3 (10.0-100.0)	0.045	<0.001
General health	38.1 ± 14.5 (10.0-65.0)	33.5 ± 15.9 (10.0-65.0)	39.0 ± 16.3 (15.0-80.0)	35.0 ± 16.6 (10.0-70.0)	0.714	0.690
Mean	44.2 ± 12.6 (19.3-74.0)	65.6 ± 15.1 (35.4-84.0)	47.4 ± 16.6 (21.3-81.7)	73.0 ± 14.4 (19.6-86.3)	0.420	0.003

Values presented as mean ± standard deviation (range).
a Mann-Whitney U test comparing preoperative subscores between Tönnis 1 and Tönnis 3 patients.
b Mann-Whitney U test comparing postoperative subscores between Tönnis 1 and Tönnis 3 patients .

Table 5: Percentage of patients achieving Minimal Clinical Important Difference (MCID) and Substantial Clinical Benefit (SCB) across the different Hip Disability and Osteoarthritis Outcome Scores (HOOS) domains.

HOOS	**Clinical change**	**Reference value** [33]	**Tönnis 1 (n (%))**	**Tönnis 3 (n (%))**	***P*-value** [b]
HOOS Symptoms	MCID	20	39 (78.0)	47 (94.0)	0.021
	SCB	25	33 (66.0)	45 (90.0)	0.004
HOOS Pain	MCID	36	25 (50.0)	36 (72.0)	0.024
	SCB	36	25 (50.0)	36 (72.0)	0.024
HOOS Activities daily life	MCID	14	41 (82.0)	48 (96.0)	0.025
	SCB	24	39 (78.0)	45 (90.0)	0.102
HOOS Quality of life	MCID	13	42 (84.0)	47 (94.0)	0.110
	SCB	27	36 (72.0)	41 (82.0)	0.235
HOOS Sport	MCID	26[38]	32 (64.0)	43 (86.0)	0.011
	SCB	N/A[a]	-	-	-

a no reference value available
b *Chi* Square test

502 **Table 6:** Percentage of patients achieving Minimal Clinical Important Difference (MCID) and Substantial Clinical Benefit
503 (SCB) across the different Short Form-36 (SF-36) domains.
504

SF-36	Clinical change	Reference value [32]	Tönnis 1 (n (%))	Tönnis 3 (n (%))	P-value [b]
Physical functioning	MCID	8.29	43 (86.0)	44 (88.0)	0.766
	SCB	[a]			
Role limitations due to physical health	MCID	11.0	36 (72.0)	39 (78.0)	0.488
	SCB	[a]			
Role limitations due to emotional problems	MCID	20.83	21 (42.0)	22 (44.0)	0.840
	SCB	[a]			
Vitality	MCID	14.51	25 (50.0)	24 (48.0)	0.841
	SCB	[a]			
Emotional well-being	MCID	16.15	6 (12.0)	6 (12.0)	1.000
	SCB	[a]			
Social functioning	MCID	17.97	25 (50.0)	26 (52.0)	0.841
	SCB	[a]			
Pain	MCID	18.34	37 (74.0)	44 (88.0)	0.074
	SCB	[a]			
General health	MCID	-6.37	28 (56.0)	29 (58.0)	0.840
	SCB	[a]			

505

506 a no reference value available
507 b *Chi* square test

Table 7: Mean Hip Disability and Osteoarthritis Outcome Scores (HOOS) and Short Form-36 score (SF-36) preoperatively and at 1-year follow up per diagnostic subgroup

Patient reported outcome score	Timing	Tönnis 1	Tönnis 3	P-value [c]
Primary OA [a]		n=26	n=26	
Mean HOOS	Preoperatively	32.7 ± 11.1 (15.5-54.3)	34.6 ± 13.6 (10.6-64.0)	0.596
	At 1y follow-up	72.2 ± 17.0 (12.2-98.8)	83.5 ± 15.9 (39.4-100.0)	0.005
	Difference between pre and postoperative score	39.5 ± 17.4 (0.0-67.4)	49.0 ± 18.0 (8.3-89.4)	0.062
Mean SF-36 score	Preoperatively	45.9 ± 11.0 (25.1-66.8)	49.3 ± 16.5 (21.3-79.8)	0.540
	At 1y follow-up	68.7 ± 12.6 (37.8-83.6)	73.5 ± 12.0 (40.4-85.6)	0.164
	Difference between pre and postoperative score	22.7 ± 14.7 (0.0-47.9)	24.3 ± 16.5 (2.1-58.5)	0.742
Secondary OA to dysplasia		n=21	n=20	
Mean HOOS	Preoperatively	32.1 ± 16.8 (8.8-60.3)	30.9 ± 16.8 (10.8-75.5)	0.375
	At 1y follow-up	69.6 ± 22.7 (19.5-93.7)	88.7 ± 12.1 (45.6-100.0)	<0.001
	Difference between pre and postoperative score	37.5 ± 26.8 (0.0-77.3)	57.7 ± 17.3 (22.5-81.3)	0.009
Mean SF-36 score	Preoperatively	42.7 ± 15.1 (19.3-74.0)	48.1 ± 17.2 (23.1-81.7)	0.256
	At 1y follow-up	62.9 ± 16.9 (35.4-83.8)	75.8 ± 13.0 (37.4-86.3)	0.003
	Difference between pre and postoperative score	20.2 ± 14.9 (0.0-42.1)	27.7 ± 16.1 (0.0-57.6)	0.155
Secondary OA to FAI [b]		n=3	n=4	
Mean HOOS	Preoperatively	32.5 ± 23.5 (9.5-56.4)	26.4 ± 7.6 (17.0-35.6)	1.000
	At 1y follow-up	74.1 ± 20.5 (51.8-92.2)	61.2 ± 14.3 (41.7-76.0)	0.400
	Difference between pre and postoperative score	41.5 ± 40.1 (0.0-68.7)	34.8 ± 6.9 (24.7-40.4)	0.629
Mean SF-36 score	Preoperatively	40.7 ± 7.6 (34.2-49.0)	32.1 ± 7.2 (21.4-37.3)	0.400
	At 1y follow-up	59.7 ± 23.0 (38.2-84.0)	55.9 ± 25.9 (19.6-74.5)	1.000
	Difference between pre and postoperative score	18.9 ± 30.3 (0.0-49.8)	23.8 ± 20.0 (0.0-39.6)	1.000

Values presented as mean ± standard deviation (range).
[a] Osteoarthritis (OA)
[b] Femoro-Acetabular Impingement (FAI)
[c] Mann Whitney U Test