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# Higher activity level after opening wedge high tibial osteotomy compared to medial unicompartimental knee arthroplasty in a selected cohort of advanced age: A propensity score-matched analysis

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ABSTRACT

*Background:* High tibial osteotomy (HTO) and medial unicompartmental knee arthroplasty (mUKA) are accepted treatment for medial knee osteoarthritis (OA). Patients often present meeting indications for both procedures. The purpose of this study was to compare results after MOWHTO and UKA in a matched population of patients older than 50 years.
*Method:* A retrospective analysis searching for patients older than 50 years meeting indication both for UKA and MOWHTO was performed. A propensity score matching (PSM) based on demographics and clinical data was performed. Tegner activity scale (TAS), Lysholm knee score (LKS) and numeric rating scale for pain (NRS) were recorded prospectively prior to surgery, at 6 months and after a minimum of 4 years.
*Results:* 64 UKA and 71 MOWHTO were found. Mean follow up was similar (54,05 ± 4,80 and 52,62 ± 3,91). A significant improvement was found in both groups for all outcomes at 6 months and at final follow up. PSM yielded 29 pairs. Patients treated with MOWHTO showed superior TAS scores at 6 months (3,41 ± 0,50 vs 3,10 ± 0,56; $p < 0,05$) and at final follow up (3,83 ± 0,80 vs 3,27 ± 0,59; $p < 0,005$). NRS and LKS were comparable between groups.
*Conclusions:* MOWHTO performed using an open wedge technique, with locking plate and a fast rehabilitation protocol guaranteed higher level of activity than UKA in patients older than 50 years. Difference is significant already at 6 months and last longer than 4 years.
Level of evidence: III.


## 1. Introduction

High tibial osteotomy (HTO) and medial unicompartmental knee arthroplasty (mUKA) are both well accepted treatment for painful medial unicompartmental knee osteoarthritis (OA) [1,2].

*Abbreviations*: HTO, High Tibial Osteotomy; UKA, Unicompartmental Knee Arthroplasty; OA, Osteoarthritis.

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Ideally, HTO should be proposed in active patients, up to 60 years old, nearly full range of motion (ROM) and extraarticular tibial deformity producing a varus malalignment [3].

On the other hand, strict historical indications for mUKA are isolated anteromedial osteoarthritis (AMOA) and medial femoral condyle avascular osteonecrosis (AVN) [4,5]. Nevertheless, in clinical practice mUKA indications are often expanded to include patients affected by medial compartment OA with consistent joint space narrowing, functional ligaments, partially reducible mild varus deformity up to 15°, even with coexistent extraarticular deformity [6].

In addition, young age is being considered no longer a limitation for UKA as some authors have reported superior outcomes after UKA compared to HTO even in patients younger than 55 years [7,8]. On the other hand, other authors have proposed HTO as a valuable option in older active patients [9].

Moreover, the notional dichotomy between extraarticular and intraarticular deformity is often useless in clinical practice, as many patients present with combined intra and extraarticular deformity that produces a varus malalignment [10].

This results in a significative overlap of indications between the two techniques, with a consistent number of patients meeting indication criteria both for UKA and HTO, [11] mainly in the setting of middle aged patients, with consistent joint space narrowing, intermediate level of activity and moderate varus deformity of mixed intra and extraarticular origin.

In this setting, surgeon's opinion and preferences may play a role, given that arthroplasty surgeons tend to prefer UKAs and knee/sport surgeons prefer HTOs.

Choice is made even more controversial given that most of the studies comparing HTO and UKA have different design, with variable inclusion criteria and consider different surgical techniques and postoperative protocols for HTO [12].

Thus, aim of the present study was to determine functional scores, pain scores and activity level after medial opening-wedge HTO (MOWHTO) or mUKA in patients older than 50 years with advanced isolate medial knee OA and mild to moderate varus deformity of mixed origin. It was hypothesised that in these patients, MOWHTO performed with locking plate may guarantee superior results in terms of activity level and knee function as compared with mUKA.

## 2. Materials and methods

Our hospital database was queried for patients older than 50 years old who underwent either mUKA or MOWHTO between January 2017 and December 2018. All patients gave informed consent to the treatment of personal data for research purpose.

Indications for MOWHTO were: medial compartment OA (Kellgren & Lawrence (KL) </= III) [13] associated with good status of patellofemoral (PF) and lateral tibio-femoral compartments (including mild asymptomatic OA), varus alignment confirmed by a Hip-Knee-Ankle angle (HKA) > 5° with a Medial proximal tibial angle (MPTA) < 84°, a stable knee or stabilizable knee with additional concomitant procedures, full extension and at least 120° of flexion.

Indications for UKA were the following: symptomatic medial compartment OA associated with good status of PF and lateral tibio-femoral compartments (including mild asymptomatic OA), stable knee, full extension and at least 120° of flexion, HKA < 15° with completely or partially reduceable varus and a joint lane convergence angle (JLCA > 2°).

Patients meeting indications for both MOWHTO and UKA patients were left free to choose, after adequate counselling on advantages and disadvantages of each technique. All patients performed preoperative MRI for evaluation of the status of PF and lateral tibio-femoral compartments.

To create comparable groups for the retrospective analysis, patients with KL grade I OA in the MOWHTO group were excluded, as well as patients with KL grade IV OA in the UKA group. This is consistent with previous studies comparing HTO and UKA [14]. To reduce confounders, patients in which MOWHTO was performed as an additional procedure in meniscal, cartilage or ligaments reconstruction were excluded, as they followed a different and personalized postoperative rehabilitation protocol.

Inclusion criteria for the retrospective analysis were: (1) age at surgery > 50 years, (2) KL II or III isolated medial compartment OA, (3) isolate treatment with either primary MOWHTO or mUKA, (4) availability of preoperative Tegner activity scale (TAS), Lysholm knee score (LKS) and Numeric Rating Scale (NRS) for pain. Regarding alignment criteria, in a similar manner our group previously published for lateral DFO versus UKA, [15] only patients with a HKA between 5° and 10°, originating from a MPTA </= 84° and a JLCA > 2°, thus meeting indications both for MOWHTO and mUKA, were included in the retrospective analysis.

Exclusion criteria were the following: (1) concomitant ligament injury/reconstructive surgery, (2) concomitant cartilage reconstructive surgery, concomitant meniscal repair or meniscal allograft transplantation, (3) concomitant surgery or conditions interfering with postoperative rehabilitation program, (4) KL I or IV grade OA, (5) absence of preoperative or postoperative information.

### 2.1. Data collection

Patient's age, sex, BMI, preoperative TAS, LKS and NRS were collected.[16] Even though LKS was originally adopted for ligament injury, it has been validated also in chondral disorders [17] and it is one of the most used functional scores among studies comparing UKA with HTO [12].

OA grade was determined according to Kellgren - Lawrence classification using preoperative weight-bearing radiographs [13].

Long standing radiographs were used to evaluate coronal alignment. HKA, medial proximal tibial angle (MPTA) and joint line convergence angle (JLCA) were calculated.

Complications reported as commonly related to these procedures were noted, including infection, deep vein thrombosis (DVT) and peroneal palsy. Failure of the procedure was considered: persisting pain (NRS > 6) for longer than 6 months after surgery, continuative knee-related pain (NRS > 6) forcing the patient to seek medical attention at all time during follow up; functional impairment requiring revision surgery (apart from implant removal without complications after MOWHTO).

Activity level, function and pain were measured, respectively, with TAS, LKS and NRS. Questionnaires completed at 6 months during routine follow up were collected, and the same questionnaires were submitted again to patients at last follow up, after a minimum of 4 years. Patients lacking postoperative information were excluded. To further increase consideration of patients' reported outcomes, at last follow up patients were also asked a Yes or No "anchor" questions: "Has this surgery consistently improved the quality of your life?".

Survival was defined as conversion to total knee arthroplasty (TKA) for both groups. In addition, conversion to UKA was also considered if patients were in the MOWHTO group.

### 2.2. Surgical technique

All the HTO procedures were performed in the same centre by two high volume surgeons performing more than 100 HTO per year.

In all patients, a knee arthroscopy was performed to assess patellofemoral and lateral compartment status and to rule out or treat associated intraarticular lesions. Moreover, during the diagnostic phase of the arthroscopy, medial femorotibial compartment chondral degeneration was assessed according to International Cartilage Reaserch Society score (ICRS).

As routinary at our centre, a medial opening - wedge HTO was performed in all cases, using the same angular plate for stabilization (*NCT- NewClip Technics, 44,115 Haute-Goulaine, France*). In all patients, a cancellous bone mobilization procedure was performed after plate fixation and no bone substitute was implanted. Briefly, a small osteotome was used to penetrate the cancellous metaphyseal bone, that was thereafter elevated, obtaining a partial obliteration of the osteotomy space. Plate removal was not routinarily indicated, and performed only if the patient reported local discomfort as an outpatient surgical procedure. The number of patients requiring implant removal was collected. Figure 1).

All the mUKA procedures were performed in the same centre by two high volume surgeons performing at least 200 knee replacement procedures per year.

UKA was performed using a cemented, fixed bearing component (*Sled, Waldemar Link GmbH & Co. KG, 22,339 Hamburg, Germany*).

The postoperative protocol for MOWHTO included 2 weeks of toe-touch weight-bearing followed by a transition to full wight-bearing as tolerated with knee brace and with progressive dismission of crutches. Range of motion (ROM) was restricted to 0-90° for the first 2 weeks then free. Rehabilitation program started after 2 weeks, with open chain strengthening and mobility exercises with complete ROM. Weight bearing exercises were progressively introduced after 6–8 weeks.

For mUKA a standard protocol was adopted, with immediate weight bearing as tolerated, full ROM and rehabilitation from the day after surgery.

### 2.3. Propensity score matching

A priori power analysis, performed using *G-power 3.1,* indicated that a total sample size of 54 patients was necessary to obtain a 0.95 power level with an effect size of 0.5 using a *T test* for matched pairs. All continuous variables are expressed as mean ± standard deviation (SD). For comparison of the 2 groups, to generate propensity score matching (PSM), logistic regression was used based on the following baseline covariates: age, sex, BMI, laterality, preoperative TAS, LKS and NRS. A caliper width of 0.1 with interval of confidence of 95 % and 0.001 tolerance were used (*XLSTAT ver.2022.3.1.1320, Addinsoft Inc., 244 Fifth Avenue, Suite E100, New York, N.Y.*).

PSM yielded a total of 58 patients (29 pairs). T test for matched pairs was used to compare TAS, LKS and NRS between groups both at 6 months and at last follow up. Chi-squared test was used to evaluate differences between categorical variables.

## 3. Results

Between January 2017 and December 2018, a total of 288 UKA and 332 MOWHTO were performed.

All the charts were reviewed and a total of 64 UKA and 71 MOWHTO were found to meet inclusion criteria, with a mean follow up of 54,05 ± 4,80 and 52,62 ± 3,91, respectively ($p > 0,05$). Selection process is deeply described in Figure 2.

In the UKA group, TAS significantly increased as compared with preoperative level (2.23 ± 0.66) at 6 months (2.84 ± 0.59) and at final follow up (3.22 ± 0.70). In the MOWHTO group, preoperative TAS values (2.86 ± 0.57) significantly improved at 6 months (3.42 ± 0.52) and at final follow up (4.03 ± 0.69).

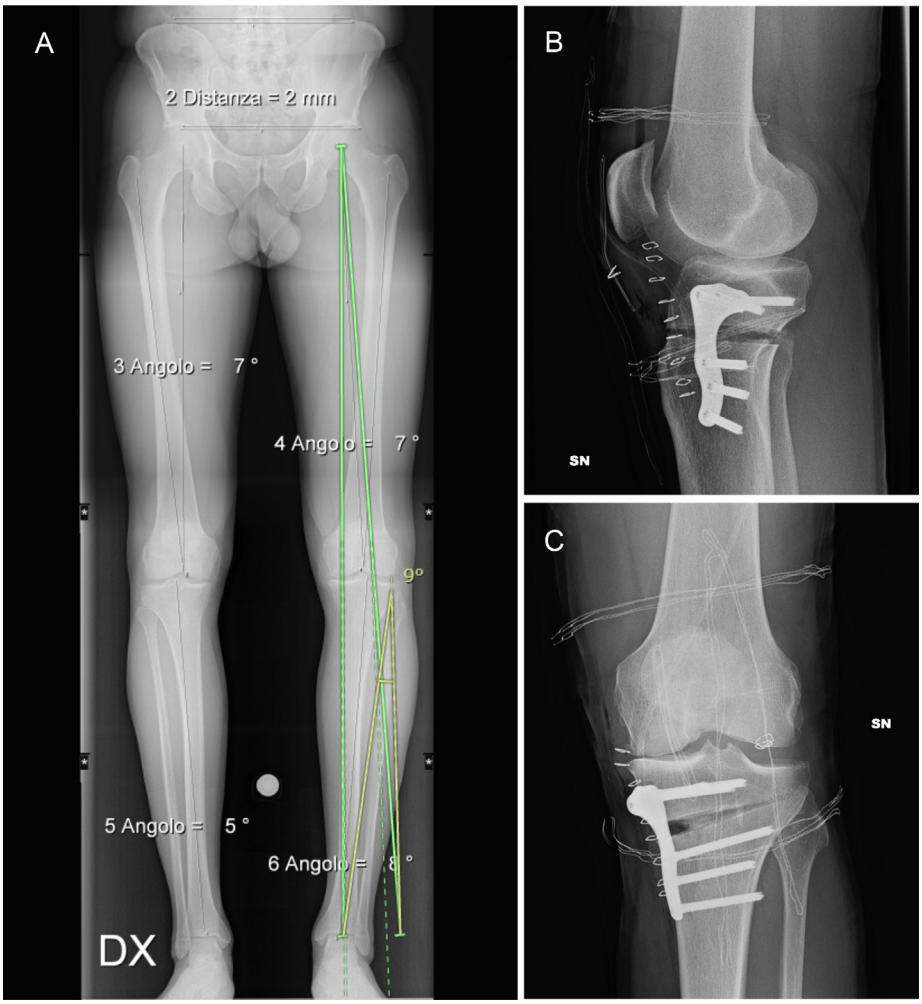


**Figure 1. Preoperative and postoperative evaluation of HTO** A) Mechanical axis evaluation performed using standard long-leg X-rays. Preoperative planning for HTO is performed using Miniaci's method. B-C) Postoperative images showing the locking plate. The osteotomy gap is left without bone grafting, but partially filled with the mobilized cancellous bone from the near metaphysis.

LKS significantly increased from baseline to 6 months levels and to final follow up both after UKA and MOWHTO. A consistent decrease in pain levels after surgery was observed in both groups. Patients in both groups continued to improve their functional scores and level of activity from 6 months to last follow up, with a significant increase both in TAS ($p < 0.001$) and LKS ($p < 0.05$). Pain reported levels were substantially stable during follow up, with no significant differences. (Table 1).

No major postoperative complications were reported, either during the perioperative period and at last follow up. Only one patient in the UKA group complained moderate persisting knee pain 28 months after surgery, without signs of radiographic migration or signs of PJI. No cases of DVT nor peroneal palsy were reported in either group. No UKA showed signs of radiographic migration during follow up. No suspected or diagnosed infections were reported.

Regarding the anchor question, 100 % of patients treated with HTO and 97.4 % of the patients treated with UKA answered "yes", with only 1 patient in the UKA group complaining about a negative result.

No patients in MOWHTO group required revision surgery to either TKA or UKA during the follow up, with a 100 % rate of survival at final follow up. Only 1 patient in the UKA group was not satisfied with surgery, but still refused conversion to TKA.

Arthroscopically assessed medial cartilage wear prior to MOWHTO, according to ICRS revealed grade IV lesions in 28 patients (40 %), grade III in 32 patients (45 %) and grade II in 11 patients (15 %).

At last follow up, 23 patients out of 71 (32 %) required plate removal due to implant intolerance. All the procedures were performed as outpatient surgery and without complications.

PSM yielded 29 pairs of patients, matched for age, sex, BMI, KL, and preoperative TAS, LKS and NRS. (Table 2).

After matching of the two groups, postoperative values of TAS, LKS and NRS were compared.

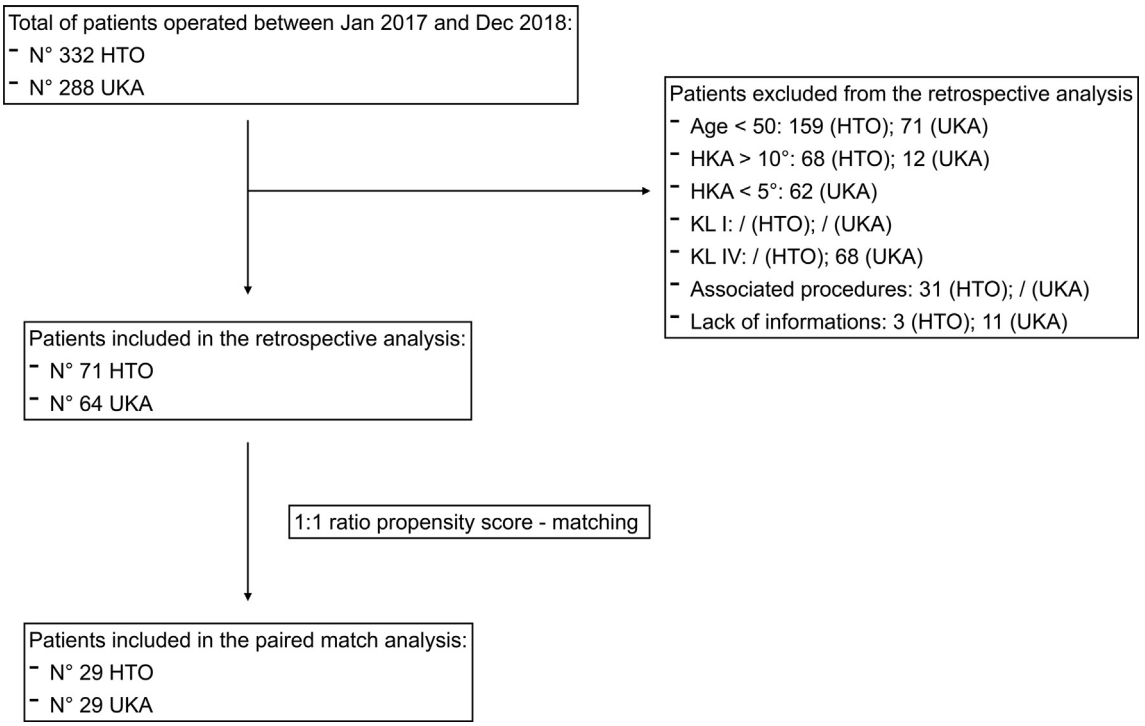


**Figure 2. Patients' selection process and propensity score – match** The chart reports inclusion and exclusion criteria for patients' selection and patients included in the propensity score – matching. *UKA: Unicompartmental knee Arthroplasty; HTO: High tibial osteotomy; HKA: Hip-Knee-Ankle angle;*

**Table 1**
Data from the retrospective analysis.

| | | PRE | 6 MONTHS (*p*) | LAST FU (*p*) |
|---|---|---|---|---|
| HTO | TAS | 2,85 ± 0,57 | 3,42 ± 0,53 *(<0.001)* | 4,03 ± 0,69 *(<0.001)* |
| | LKS | 63,19 ± 9,56 | 91,48 ± 3,43 *(<0.001)* | 96,18 ± 4,31 *(<0.01)* |
| | NRS | 8,35 ± 0,93 | 1,65 ± 0,99 *(<0.001)* | 1,13 ± 1,13 *(n.s.)* |
| UKA | TAS | 2,23 ± 0,66 | 2,84 ± 0,59 *(<0.001)* | 3,21 ± 0,70 *(<0.05)* |
| | LKS | 59,73 ± 7,73 | 92,35 ± 5,13 *(<0.001)* | 96,61 ± 4,74 *(<0.05)* |
| | NRS | 8,69 ± 0,92 | 1,63 ± 1,15 *(<0.001)* | 1,06 ± 1,35 *(n.s.)* |

Baseline and postoperative LKS, TAS and NRS from HTO and UKA groups, as included in the retrospective analysis according to inclusion and exclusion criteria.
*UKA: Unicompartmental knee Arthroplasty; HTO: High tibial osteotomy; LKS: Lysholm Knee Score; TAS: Tegner activity scale; NRS: Numeric rating scale for pain; FU: Follow up.*

**Table 2**
Patients demographics after PSM.

| | HTO (29) | UKA (29) | p |
|---|---|---|---|
| AGE | 58,03 ± 5,08 | 58,13 ± 6,31 | n.s. |
| BMI | 28 ± 1,67 | 27,86 ± 2,05 | n.s. |
| KL | 2,48 ± 0,51 | 2,45 ± 0,50 | n.s. |
| SEX | 18F (62 %) | 19F (65,5%) | n.s. |
| LATERALITY | 13 D (45 %) | 18 D (62 %) | n.s. |
| TAS pre | 2,48 ± 0,57 | 2,41 ± 0,57 | n.s. |
| LKS pre | 61,07 ± 8,99 | 59,76 ± 8,95 | n.s. |
| NRS pre | 8,72 ± 0,96 | 8,72 ± 0,92 | n.s. |

Patients demographics after paired matching confirms that groups are comparable. *PSM: propensity score matching;KL: Kellgren – Lawrence; BMI: body mass index.*

**Table 3**
Comparison of outcomes after propensity score matching.

| | HTO (29) | UKA (29) | p |
|---|---|---|---|
| TAS 6 M | 3,41 ± 0,50 | 3,10 ± 0,56 | < 0,05 |
| TAS LFU | 3,83 ± 0,80 | 3,27 ± 0,59 | < 0,005 |
| LKS 6 M | 92,93 ± 3,02 | 95,28 ± 5,98 | n.s. |
| LKS LFU | 94,38 ± 3,83 | 96,48 ± 6,02 | n.s. |
| NRS 6 M | 1,72 ± 1,07 | 1,41 ± 1,52 | n.s. |
| NRS LFU | 1,59 ± 1,15 | 1,21 ± 1,61 | n.s. |

TAS score was significantly higher in the HTO group both at 6 months and at last follow up. LKS and NRS did not differ between groups.
*LFU: Last Follow up; 6 M: 6 months; UKA: Unicompartmental knee Arthroplasty; HTO: High tibial osteotomy; TAS: Tegner activity score; LKS: Lysholm knee score; NRS: Numeric rating scale for pain; n.s: Non-significant.*

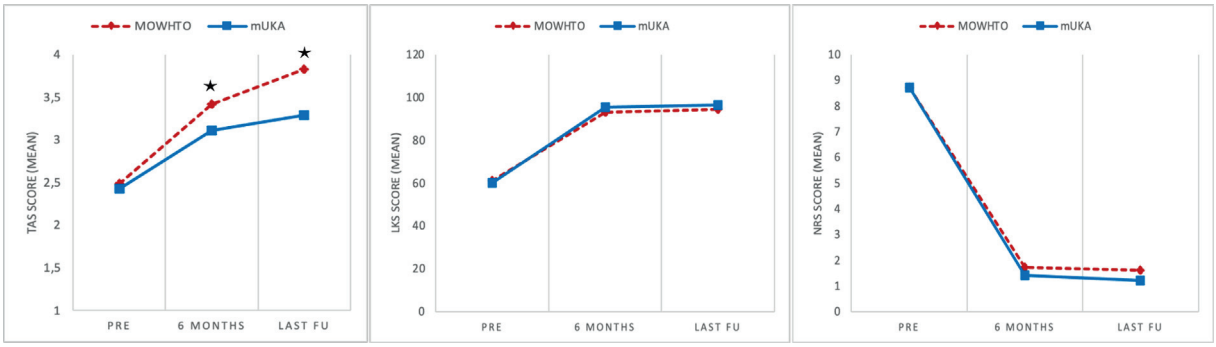


**Figure 3. Evolution of mean TAS, LKS, NRS scores during follow up after propensity score matching** The paired match analysis, revealed that TAS score was significantly superior in the MOWHTO group as compared to mUKA group both at 6 months ($p < 0,05$) and at last follow up ($p < 0,005$). LKS and NRS were similar between groups.*PRE: preoperative; FU: follow up; mUKA: medial Unicompartmental knee Arthroplasty; MOWHTO: Medial Opening Wedge High tibial osteotomy; TAS: Tegner activity score; LKS: Lysholm knee score.: Statistically significant.*

Postoperative activity level (TAS) was significantly higher in the MOWHTO group as compared with the UKA group at final follow up ($p < 0.005$) and after 6 months, when the difference between groups was less pronounced, but still statistically significant ($p < 0.05$). (Table 3).

LKS and NRS did not differ significantly between groups both at 6 months and at final follow up. (Figure 3).

## 4. Discussion

The most important finding demonstrated by the present study was that MOWHTO performed with locking plates and a fast rehabilitation protocol leads to higher activity level than UKA in a selected population where there is indication overlap between these two procedures. Noteworthy, this difference is already noticeable at 6 months after surgery and lasts for longer than 4 years.

Moreover, this study found that patients up to 68 years old, even with consistent articular degeneration (KL III and ICRS 3/4) can benefit for several years from an articular-sparing procedure such as MOWHTO, with excellent results.

Originally, UKA was mainly indicated for patients older than 60 years with isolated medial OA [18]. Nevertheless, the increasing quality of materials along with a more precise surgical technique have expanded the indication to younger patients [19].

Some studies have reported superior results after UKA than HTO in terms of activity level and early postoperative outcomes [7,8,20]. Krych et al [7] reported higher activity and durability after UKA in patients between 18 and 55 years old,. Nevertheless, these results might be biased by the slow postoperative rehabilitation protocol and the inclusion of LCWHTO in the HTO group [21].

On the contrary, the present study is in line with more recent findings from Jacquet et al. [14] who demonstrated that MOWHTO allows higher level of activity in patients expecting to return to impact sports. Similarly, Bastard et al. [22] found that all patients treated with HTO had returned to sport within 1 year from surgery.

These difference among studies may be in part explained by the fact that a considerable number of studies included HTO performed with different techniques and implants, often followed by conservative rehabilitation protocols [12,7]. In addition, the UKA groups often display significantly lower preoperative activity level that may bias the postoperative outcomes.

To minimize selection bias, we performed a paired matching for all preoperative data including not only demographics (age, sex, BMI), but also preoperative level of activity (TAS), functional score (LKS) and reported pain levels (NRS).

Given the strict inclusion and exclusion criteria for the retrospective analysis, we found a high proportion of matching between groups, thus reaching the sample size indicated by the a priori power analysis.

After application of propensity score matching, similar postoperative functional scores (LKS) and pain reported levels (NRS) between groups indicated that both procedures are effective for the treatment of medial OA, and this is in line with previous studies [12,23]. Nevertheless, the higher activity level already reached 6 months after surgery was somehow surprising, given that most of the study reported long recovery time after MOWHTO [20,11,8].

HTOs are often discouraged also for the reported complications, such as common peroneal nerve palsy (CPNp), DVT, nonunion and implant intolerance [24,12]. Yet, CPNp is a concern only in the lateral closing wedge technique, DVT is mainly associated with the long period of immobilization characterizing outdated rehabilitation protocols, and nonunion have been considerably reduced since the introduction of locking plates [25]. At our centre, we always perform MOWHTO using locking plate and allowing a fast rehabilitation protocol with early weight bearing. This combination improves outcomes [25], dramatically reducing complications and increasing patients' satisfaction.

In fact, we found no cases of DVT, nonunion or CPNp in all patients undergoing MOWHTO with our technique. On the contrary, 32 % of the patients required implant removal due to intolerance. All these procedures were undertaken as outpatient surgery and no patient reported complications.

It is well established that the load shift following HTO has a chondroprotective effect and can lead to regeneration of articular cartilage in a consistent number of patients [26,27]. Indeed, HTO has demonstrated to effectively delay TKA, with 10 years survivorship rates higher than 90 % and demonstrated survivorship up to 35 years, in some casuistries [28].

Moreover, when HTO fails, surgeons still have the possibility to revise it to a UKA or a TKA, with excellent long-term survivorship and clinical outcomes.[29,30].

While survivorship of TKA is not affected by prior HTO [31], it has to be considered that conversion to TKA after UKA is more likely to require revision components (8–58 %) and higher level of constrain (up to 27 %) [32], with increasing evidence suggesting reduced survival when compared to TKA after HTO [33,34].

To the best of our knowledge, this is the first study to compare outcomes after MOWHTO and UKA in a selected population of advanced age, where there is a concrete overlap of indications between the two procedures. The retrospective design is the main limitation of this study. Given that we included in the analysis a selected a population where the choice between HTO and UKA is controversial, risk of selection bias was a concrete concern. Nevertheless, data were prospectively collected and a propensity score – matching was performed to minimize confounders. Lastly, the study was designed starting from a *a priori* power analysis aiming for a 0.95 power level.

## 5. Conclusion

In conclusion, our study demonstrated that MOWHTO performed with locking plate and accelerated rehabilitation program is safe and effective also in advanced age patients with moderate medial OA and consistent articular damage. Patients reached higher activity level after MOWHTO than after UKA, with comparable functional scores and pain relief. Although excellent results and high rates of patients reported satisfaction were reached both after UKA and MOWHTO, it should be reasonable to consider the less demolitive surgical act as the first line of therapy.

## Availability of data and material

The datasets generated and/or analysed during the current study are not publicly available due to respect of privacy policies but are available from the corresponding author on reasonable request and after obtaining patients' consent.

## Ethics approval and consent to participate

The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. All patients have given their written informed consent and the study protocol was approved by the institute's ethics committee on human research of our institute.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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