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Medial unicompartmental knee replacement is a viable treatment option after failed high tibial osteotomy: a systematic review

Claudio Legnani[1], Andrea Parente[2], Franco Parente[2] and Alberto Ventura[1]

[1]IRCCS Istituto Ortopedico Galeazzi, Sports Traumatology and Minimally Invasive Articular Surgery Center, Milan Italy
[2]IRCCS Istituto Ortopedico Galeazzi, Hip and Knee Arthroplasty Surgery Center, Milan, Italy

Correspondence should be addressed to C Legnani
Email
claudio.legnani@grupposandonato.it

- *Purpose:* It is debatable whether or not previous high tibial osteotomy (HTO) has negative effects on the results of subsequent medial unicompartmental knee replacement (UKR). The purpose of this study is to report, through a systematic review of the literature, the outcomes of medial UKR after failed HTO. It was hypothesized that this procedure would be safe and effective in providing satisfactory postoperative functional outcomes.
- *Methods:* A systematic review was performed by searching Pubmed/MEDLINE, Embase and CINAHL. Only studies in English pertaining to all levels of evidence reporting on subjects undergoing UKR following HTO were considered. Review articles and expert opinion or editorial pieces were excluded. Outcomes of interest included indications, surgical technique and associated procedures, type of prosthesis, clinical and functional outcomes, rate of complications, revision surgery and failure rate.
- *Results:* Overall, six studies met all the inclusion criteria for this review. All were published between 2006 and 2021. The search resulted in one prospective comparative study, four retrospective comparative cohort studies, and one retrospective cohort study. Average follow-up periods ranged from 1 to 13 years. From these studies, 115 patients (117 knees) were identified. Overall, most studies reported satisfying postoperative clinical and functional outcomes. Implant survivorship ranged from 66 to 97.6%. In 15 patients, revision surgery was performed due to persistent pain.
- *Conclusions:* Medial UKR performed after failed HTO appears as a feasible procedure providing satisfying outcomes and limited complications in most cases. Further prospective comparative studies reporting long-term outcomes are needed, as high-level studies on this topic are lacking.

Keywords

- high tibial osteotomy
- knee
- unicompartmental knee replacement

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Introduction

The treatment of medial unicompartmental knee osteoarthritis (OA) following failed high tibial osteotomy (HTO) is an issue of debate (1, 2). Although prior HTO has traditionally been considered as a contraindication for medial unicompartmental knee replacement (UKR) (3), according to recent reports, the outcomes of a UKR may not be affected by previous osteotomies around the knee (4, 5, 6, 7, 8, 9, 10).

Performing UKR after HTO could be challenging since several factors can contribute to make this procedure technically demanding: soft tissue scarring, anatomic tibial abnormalities and poor bone-stock, presence of hardware and residual ligamental laxity (5, 7).

For these reasons, authors are more likely to implant total knee replacement (TKR) following HTO (11, 12, 13, 14, 15, 16), while still limited experience exists on the use of UKR in this specific scenario.

However, since in the presence of a failed HTO residual varus may be observed, frequently OA may be limited to the medial compartment, thus allowing to perform UKR which carries advantages of shorter operative time and quicker recovery, reduced pain and blood loss compared to TKR (17, 18).

The aim of the current study is to report, through a systematic review of the literature, on UKR following failed HTO, highlighting indications, results and possible complications of this therapeutic approach. It was hypothesized that this procedure would be safe and effective in providing satisfactory postoperative functional outcomes.

Materials and methods

Types of studies

In the present review, only studies in English pertaining to all levels of evidence reporting on subjects who underwent UKR after prior failed HTO were considered. Date limits were set from 1990 to 2021 to allow a review of the recent data. Review articles and expert opinion or editorial pieces were excluded.

Search strategy

Searches were carried out using the following string on Pubmed/MEDLINE, Excerpta Medica Database (EMBASE) and Cumulative Index to Nursing and Allied Health Literature (CINAHL): ((high tibial osteotomy) OR (HTO)) AND ((unicompartmental knee replacement) OR (unicompartmental knee prosthesis) OR (unicompartmental knee arthroplasty) OR (unicondylar knee arthroplasty) OR (unicondylar knee prosthesis) OR (unicondylar knee replacement)). The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used (19). The abstracts of all hits were reviewed and duplicates were sorted out. The full texts of the selected articles obtained were evaluated for eligibility. References were hand screened for relevant citations to identify any articles not included in the primary search.

Data extraction

Study characteristics such as year of publication, study population, level of evidence, mean age, male/female ratio, follow-up duration and prosthesis design were extracted and collected by two reviewers and checked by a third. An electronic database was created. Outcomes of interest included indications, surgical technique and associated procedures, type of prosthesis, clinical and functional outcomes, rate of complications, revision surgery and failure rate.

Results

Search results

Overall, the search query yielded 727 results. After duplicates were sorted out, 439 articles were screened for eligibility on the basis of title and abstract. Overall, eight studies whose full-text articles were assessed for eligibility met all the inclusion criteria for this review. One article reported redundant data and one article did not report clinical outcomes and were therefore excluded, thus leaving six studies to be included in the present review (Fig. 1). All were published between 2001 and 2021. The search resulted in one prospective comparative study (3), four retrospective comparative cohort studies (4, 5, 6, 7) and one retrospective cohort study (8). The average follow-up periods ranged from 1 to 13 years. From these studies, 115 patients (117 knees) were identified. In all cases, medial UKR was performed after failed HTO. Table 1 provides an overview of the characteristics of the studies considered.

Indications

The indication for conversion from HTO to UKR is based on the number of knee compartments involved. The decision to undertake UKR rather than TKR after failed HTO should be restricted to selected patients with radiological and symptomatic progression of OA limited to the medial compartment. Other inclusion criteria used to choose conversion to UKR were integrity of the anterior cruciate ligament, varus knee deformity less than 10° and tibial slope less than 10° (5, 7).

Surgical technique and hardware removal

Among 115 patients (117 knees), only 23 patients of a single retrospective study underwent a one-stage procedure without hardware removal. Only in one study, an UKR was implanted in 9 patients retaining a TomoFix locking plate

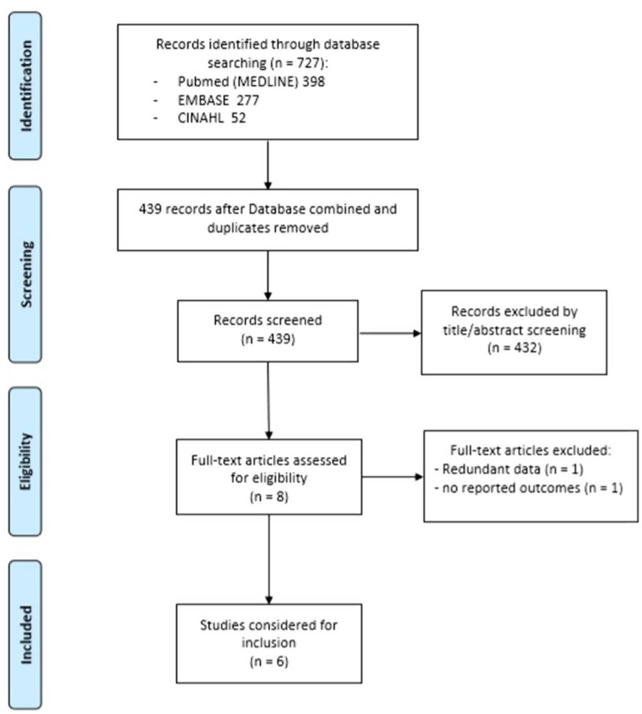

Figure 1
PRISMA flow diagram showing the number of studies identified, screened and included in the present review.

Table 1 Characteristics of included studies.

Reference	Year	Patients, *n*	LOE	Study type	Age, years*	Male/female ratio	Follow-up*	Prosthesis type	Survival rate (%)	Complications (rate)
Rees *et al.* (3)	2001	18	II	PCS	68 ± 8.0	N/a	5.4 years (3.6–7.1)	Mobile-bearing medial UKR	66	Five revisions (27.7%) to TKR due to persistent pain, in one case associated to progression of OA on the lateral compartment. Mean time to failure 2.9 years (range: 1.9–3.9)
Vorlat *et al.* (4)	2006	8	III	RCS	N/a	N/a	66.4 months (12–153)	Mobile-bearing medial UKR	35.7	Two (25%) revisions to a TKR; two (25%) augmentations due to progression of OA on the lateral compartment
Valenzuela *et al.* (5)	2009	20 (22 knees)	III	RCS	64.8 (48–80)	13:7	77.6 months (24–180)	Fixed-bearing medial UKR	N/a	One mechanical axis overcorrection creating lateral OA and subsequent conversion to TKR; one osseous loose body; one tibial plateau fracture
Heyse *et al.* (6)	2012	18	III	RCS	53.7 ± 5.8	N/a	10.0 ± 4.6 years	Fixed-bearing medial UKR	92	Two (11%) revisions to a TKR at a mean of 9.3 years
Schlumberger *et al.* (8)	2021	27	III	RAS	59.5 (32.8–72.7)	N/a	4.3 years (2.1–9.9)	Mobile-bearing medial UKR	93	Two revisions to a TKR; one revision due to hematoma; one revision due to newly lateral meniscus tear; one superficial wound infection
Parente *et al.* (10)	2021	24	III	RCS	64.6 (48–77)	12:12	8.1 years (5–13)	Fixed-bearing medial UKR	97.6	One symptomatic patellofemoral OA leading to implantation of patellofemoral prosthesis

*Presented as mean ± S.D. or range.
HTO, high tibial osteotomy; LOE, level of evidence; PCS, prospective comparative study; RAS, retrospective case series; RCS, retrospective comparative study; TKR, total knee replacement; UKR, unicompartmental knee replacement.

(Synthes, Stratec Medical, Oberdorf, Switzerland) and 15 patients retaining Puddu plates (Arthrex, Naples, FL, USA), respectively (7). In the Tomofix group, only one or two proximal locking screws were removed to place the UKR tibial plate if needed (7). In all the other studies considered in this review, UKR was performed in the absence of any hardware. This occurred either after closing-wedge HTO as reported by Valenzuela *et al.* (5) or open-wedge HTO (Schlumberger *et al.* (8)). However, most studies do not report information about the presence of retained hardware (3, 4, 5, 6, 8); it can be concluded that in most cases, patients underwent a two-stage procedure with hardware removal followed by UKR.

Prosthesis design

Three studies report on the implantation of mobile-bearing design prostheses using Oxford Knee Phase II and III (Zimmer-Biomet, Warsaw, IN, USA) UKR. The remaining three studies adopted fixed-bearing implants: Miller–Galante metal-backed fixed-bearing prosthesis (Zimmer) was implanted in 22 knees, Allegretto fixed-bearing prosthesis in 11 patients, Zimmer Unicondylar Knee System (ZUK, Zimmer) in 13 patients and Genesis Unicondylar implant (Smith & Nephew, Memphis, TN, USA) in 18 patients. No case–control studies comparing the results of fixed vs mobile inlays were reported.

Functional outcomes

Patient-reported outcome scores (PROMs) were Oxford Knee Score Knee Society Score (KSS), UCLA (University of California at Los Angeles) score and Western Ontario and McMaster (WOMAC) index of OA. Most frequently reported outcome was KSS in four studies: average postoperative KSS objective score ranged from 82.9 to 91.7, while KSS functional score ranged from 82.9 to 94.1. Two studies did not provide information on PROMs (4, 6). An overview of postoperative outcome score is reported in Table 2.

Complication rates, survivorship and revision surgery

Overall, the following major complications were reported: 1 tibial plateau fracture, 15 revisions due to persistent pain. In three cases, due to pain persistence and symptomatic lateral OA, implantation of additional lateral UKR was performed, while in another case additional patellofemoral (PF) prosthesis was implanted due to progression of OA on the PF compartment. Survivorship of the implant ranged from 66 to 97.6%. The highest failure rate (27.7%) was reported by Rees *et al.* (3). One study reported complications arising from external meniscus tear. One case of superficial wound infection was reported and one osseous body removal was performed.

Table 2 Summary of functional and clinical outcomes utilized in included studies.

Reference/outcome measures	Year	Pre-operative score		Postoperative score	
		Mean ± S.D.	Range	Mean ± S.D.	Range
Rees *et al.* (3)	2001	N/a		N/a	
Vorlat *et al.* (4)	2006	N/a		N/a	
Valenzuela *et al.* (5)	2009				
OKS		22.3 ± 5.0	13–30	43.7 ± 4.4	33–49
KSS Objective		54.7 ± 13.1	35–87	88.8 ± 11.2	54–100
KSS Functional		49.8 ± 10.9	20–70	84.9 ± 15.1	50–100
Heyse *et al.* (6)	2012				
KSS Objective		N/a		91.7 ± 4.9	
KSS Functional		N/a		94.1 ± 5.2	
Schlumberger *et al.* (8)	2020				
OKS		N/a		42.7 ± 6.0	25.0–48.0
KSS Objective		N/a		82.9 ±10.1	54.0–100.0
KSS Functional		N/a		93.3 ± 9.7	70.0–100.0
WOMAC index of osteoarthritis		N/a		*7.9 ±15.6	0.0–67.1
Parente *et al.* (10)	2021				
KSS Objective		45.4 ± 5.7		84.6 ± 6.6	
KSS Functional		50.7 ± 10.5		82.9 ± 7.8	
UCLA score		3.6 ± 0.5		5.4 ± 0.6	
WOMAC index of osteoarthritis		**47.5 ± 5.9		**79.9 ± 6.8	

*Lower scores indicate better results; **Higher scores indicate better results.
KSS, Knee Society Score; OKS, Oxford Knee Score; UCLA, University of California at Los Angeles; WOMAC, Western Ontario and McMaster.

Discussion

Based on the results present in the literature, UKR following HTO appears a safe and effective procedure in the treatment of unicompartmental OA following failed HTO in selected patients: satisfying outcomes and limited complications were reported, although these data should be interpreted with caution because of the low-quality evidence of the studies included.

Medial OA following HTO is still an issue of debate, as evidence lacks on how to treat unicompartmental OA after failed HTO (3, 4, 5, 6, 7, 8, 9, 10). Previous HTO has long been considered a contraindication to UKR due to potential difficulties such as the presence of soft tissue scarring, altered tibial slope and patella height and poor bone stock. These challenges have led the surgeon to prefer TKR in this scenario, although the outcomes vary among authors (11, 12, 13, 14, 15, 16, 20). A recent meta-analysis demonstrated that patients who underwent conversion of HTO to TKR reported longer operative time and higher infection rate compared to primary TKR while having a similar survival rate (21).

According to our systematic review, concerning indications, authors agree that UKR following HTO should be reserved for knees with OA progression limited to the medial compartment, ACL integrity, varus knee deformity and tibial slope less than 10°. In fact, the presence of excessive tibial slope can produce an increased load on the ACL due to anteroposterior translation. In addition, since the previous HTO may affect soft tissue tension, UKR should therefore be limited to patients with minimal deformities (6, 7, 8, 9, 10). In fact, the previous HTO may lead to an increased necessity to perform ligament release compared to primary UKR, in which the implant fills the gap left by worn cartilage. The presence of medial collateral ligament (MCL) or pes anserinus contracture brought by residual varus deformity should be taken into account when performing ligament balancing, as excessive soft tissue release should be avoided in UKR.

In the presence of retained hardware, a two-stage procedure could be adopted to avoid bone weakening and potential fractures in the setting of a concurrent hardware removal before UKR. Therefore, most authors prefer a two-stage procedure with hardware removal followed by UKR, since hardware in the medial compartment following open-wedge HTO may interfere with prosthesis implant. Also, ligament balancing may be required following extra medial dissection which could be necessary to remove osteotomy hardware (22).

In order to benefit from shorter hospitalization, reduced complications and costs without the need for two surgical procedures, single-stage UKR without hardware removal has been proposed (10). Drawbacks include a more technically demanding procedure, potential undersizing or misplacement of the tibial base plate. To allow implant positioning without interfering with retained hardware, the use of a prosthetic design whose tibial component has no keel or pegs is therefore recommended (10). On the other hand, in case of hardware removal and UKR performed in the same sitting, the surgeon could be forced to cope with poor tibial bone stock thus bringing to tibial implant loosening at early follow-up, and medial ligamentous imbalance with a high risk of overcorrection and/or instability (7).

Mobile-bearing prosthesis design possesses the advantages of reduced wear and loosening rates although are associated with an increased risk of inlay dislocation (23); fixed-bearing implants have been proposed with the goal to ease implant placement and allow optimal ligament tension (24).

Rees *et al.* (3) demonstrated a 27.7% failure rate at a mean follow-up of 5.8 years for UKR after failed HTO group. According to the authors, the main problem for failure was an overcorrection of the lower limb's mechanical axis: while previous HTO corrected varus deformity extra-articularly, UKR corrects varus alignment within the joint bringing to an overall overcorrection of the lower limb. This results in a valgus mechanical axis overloading lateral compartment and causing progredient OA. Vorlat *et al.* (4) pointed out only a 35.7% survivorship at 10 years follow-up for the Oxford knee group with the previous HTO. They addressed the high challenging and unforgiving Oxford surgical technique as the reason for failure. Since the presence of a mobile bearing this kind of implant needs great medial compartment stability.

In fact, superficial fibers of the MCL are commonly released following medial HTO to reduce the pressure in the medial compartment, thus leading to increased medial laxity (25, 26). In this setting, the use of a mobile-bearing prosthesis design may necessitate to use a thicker inlay to avoid bearing dislocation thus resulting in valgus overcorrection (27). For this reason, some authors suggest the use of a fixed-bearing prosthesis, which allows the possibility to cope with residual medial laxity without resulting in postoperative valgus alignment (7, 8). Schlumberger *et al.* (8) reported a 7% revision rate at a mean follow-up of 4.3 years for UKR after the HTO group using Oxford UKR, with only one case of failure due to overcorrection. Despite this result, they agree with previous studies on the major risk of overcorrection with medial mobile-bearing design. Managing medial laxity avoiding at the same time inlay dislocation and limb's overcorrection can be too much challenging for surgeons.

Valenzuela *et al.* (5) reported good to excellent results at knee scores in 22 UKR after HTO with 3 failures at 77 months follow-up, only one caused by overcorrection resulting in valgus alignment. According to Parente *et al.* (7) among 24 patients who underwent UKR after HTO only one case needed revision surgery for femoro-patellar OA at an average follow-up of 8.1 years. No significant statistical difference was found in terms of revision rate and knee functional scores between UKR after HTO and primary UKR (7). Both studies report good to excellent results, and UKR after HTO was considered a safe and effective procedure (7, 8).

Performing UKR after HTO with a fixed-bearing design seems to be a less challenging and difficult procedure for surgeons leading to the best results for patients in terms of functional recovery and better survivorship at long-term follow-up (28).

Overall, most studies reported satisfying postoperative clinical and functional outcomes, as reported by PROMs, thus supporting the finding that UKR appears a viable treatment option following HTO, although in two studies no information regarding postoperative outcomes was reported. Implant survivorship ranged from 66 to 97.6%. The majority of implant failures requiring revision to TKR were due to symptomatic lateral OA. According to Rees *et al*, lateral wear may occur as a consequence of overcorrection of the varus deformity brought by medial UKR, which follows the correction made by the previous HTO. This could result in a valgus alignment with overloading of the lateral compartment and ultimately implant failure. For these reasons, authors agree that higher degrees of mechanical valgus axis should be avoided.

Since HTO can lead to modifications in patella height, there are concerns that OA progression may affect the PF compartment, which could lead to anterior knee pain and ultimately revision surgery. Patellar tendon shortening and a decreased distance from the tubercle to the joint may be observed after closing-wedge osteotomy (29). Valenzuela *et al.* (5) reported a higher incidence patella infra in knees postclosing-wedge correction HTO (6/22, 27%). Despite this, the average patellar position was still within normal limits after surgery. In the study by Parente *et al.* (7), revision surgery with additional patellofemoral prosthesis was performed in one patient due to the progression of OA on the patellofemoral compartment. However, according to the authors, postoperative mean C-D index did not significantly change from pre-operative values. One case of progredient patellofemoral degeneration associated with tibial loosening has been reported also by Schlumberger *et al.* (8). According to the authors, revision surgery was not related to prior HTO, performed over 8 years before.

The main limitation of this systematic review was the considerable lack of high-level studies reporting on UKR following HTO. Further comparative studies are required in order to drive the surgeons to determine the most appropriate therapeutic approach for patients suffering from medial OA following failed HTO. There is potential for this method of treatment to become more mainstream, but further research is warranted, thus physicians' practice and expertise still represent the most useful tool in clinical practice.

Conclusions

Although technically demanding, UKR following HTO appears a safe and effective procedure providing satisfying outcomes and limited complications in selected patients with medial OA after failed HTO. The literature on this subject is limited and further comparative studies reporting long-term outcomes are needed, as high-level studies on this topic are lacking.

ICMJE Conflict of Interest Statement

Please check that the information provided in the ICMJE Conflict of interest statement and Funding Statement sections are accurate.

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