Similar Functional Results after HTO for Knees with Medial Osteoarthritis with Ruptured or Intact ACL - A prospective study with 10-year follow-up

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Abstract

Aim: To compare time-dependent functional improvement in patients with medial knee osteoarthritis (OA) with ruptured or intact anterior cruciate ligament (ACL) after treatment with high tibial osteotomy (HTO).

Patients and Methods: Forty-nine consecutive patients with medial knee OA were treated with opening wedge HTO stabilized with a Puddu plate and bone grafting. Seventeen patients had suffered anterior cruciate ligament (ACL) rupture mean 17.6 (1-38) years before the osteotomy. The mean age of these was 46 years (31-59 years), compared to 48 years (34-64 years) for the 32 patients (35 knees) with intact ACL. The patients were evaluated by the Knee Injury and Osteoarthritis Outcome Score (KOOS) preoperatively and at 6 months, 1, 2, 5 and 10 years postoperatively. The knee OA was graded radiologically.

Results: The angular correction, the preoperative KOOS and the OA gradings were similar in both groups. KOOS increased far beyond 10 points and clinically relevant compared to preoperative values during the two first postoperative years (P<0.001). This improvement was later sustained with similar KOOS in both groups during the 10-year period, except for higher KOOS subgroup Quality of Life (QoL) score for knees with intact ACL at the 5-year follow-up (P=0.014). The knee stability of the patients with ruptured ACL increased significantly after the HTO (P<0.001), and only two of them required a later ACL reconstruction. The 10-year survival was 84% for the 52 HTOs.

Conclusion: Patients with medial knee OA with ruptured or intact ACL improved with similar KOOS after HTO, but with higher QoL value for patients with intact ACL at the 5-year follow-up. The good functional result was sustained for 10 years for surviving osteotomies. The knee stability increased in patients with chronic ACL rupture, and most of these patients do not seem to require ACL reconstruction after the HTO.

Keywords: Varus knee; Opening wedge osteotomy; Bone transplantation; Knee stability; KOOS

Introduction

Rupture of the anterior cruciate ligament (ACL) increases the risk of knee osteoarthritis (OA) [1] and total knee arthroplasty (TKA) [2]. This may be related to increased instability with meniscal [3] and chondral lesions [4]. The increased risk of OA after ACL rupture is also present in ACL reconstructed knees, and this risk increases more than three times if the patients have additional meniscectomy [5]. The medial compartment of the knee carries on average 60-70% of the load during walking [6]. Medial meniscectomy aggravates varus alignment [7], resulting in increasing load and OA development [8,9]. Unloading the medial compartment by a corrective valgus high tibial osteotomy (HTO) will relieve the OA symptoms and destroyed hyaline cartilage may later be replaced by fibrocartilage [10]. HTO is also reported to improve knee stability [11,12]. As ACL rupture may induce or aggravate knee OA [13], the purpose of this study was to compare the time-dependent functional outcome of medial knee OA treated by opening wedge HTO for patients with chronic ACL rupture or intact ACL. The working hypothesis was that the functional outcome after HTO would be lower in patients with ruptured ACL than in those with intact ACL.

Patients and Methods

Forty-nine consecutive patients with medial knee OA were treated with opening wedge HTO in the period 2000-2008. Three patients had bilateral operations at different time points, including 52 knees in the study. Seventeen patients (17 knees) had additional ACL rupture and 32 patients (35 knees) had intact ACL. The demographic data of the two groups were similar (Table 1). The OA was mainly due to an open medial meniscal resection performed 20-30 years previously before the arthroscopic era, to

several successive arthroscopic meniscal resections, and to the added effect of a ruptured ACL in 17 of the 52 knees. The ACL rupture occurred mean 17.6 (CI 13.1-22.1) (range 1-38) years before the osteotomy. Only three of the 17 ACL injured knees had been ACL reconstructed, but with later graft failure and increasing

instability. Inclusion criteria were severe pain in an osteoarthritic knee with varus malalignment which had not responded to conservative treatment and where knee arthroplasty was not the first choice because of relatively young age. Exclusion criteria were patients with severe OA and pain needing a TKA.

Table 1: Demographic data of patients with high tibial osteotomy (HTO) and ruptured or intact anterior cruciate ligament (ACL).

Patients	HTO with ruptured ACL n=17	HTO with intact ACL n=32
Age (years)	46 (41.5-50.8) (31-59)	47 (45.1-50.5) (34-64)
Female	6 (35%)	13 (41%)
Male	11 (65%)	19 (59%)
BMI	27.8 (26.0-29.6) (20.5-35.1)	27.2 (25.9-28.4) (22.4-34.0)

n = number of patients. BMI = Body mass index. Mean with CI 95% and range. No significant difference between HTO patients with ruptured or intact ACL for age (P=0.540), sex distribution (P=0.955) and BMI (P=0.536).

Clinical Examination

All patients were subjected to a preoperative arthroscopy 6 weeks to 4 months before the HTO where the degree of OA of the medial knee compartment was recorded according to the International Cartilage Repair (ICRS) classification [14]. Any meniscal flaps and loose joint cartilage were removed. It was also considered if the joint surfaces of the lateral compartment could tolerate the increased weight load following a correcting osteotomy. Small cartilage changes with an intact lateral meniscus were accepted. The clinical examination included knee range of motion (ROM) measured with a goniometer, the Lachman stability test, and body weight and height for calculation of body mass index (BMI). The patients also filled in a questionnaire for calculation of the Knee Injury and Osteoarthritic Outcome Score (KOOS) the day before the HTO [15]. KOOS has five subscales: Pain, other Symptoms, Activities of Daily Living (ADL), Sport and Recreational function, and knee related Quality of Life (QoL), and is well recognized to evaluate knee function [16]. A score from 0-100 is calculated for each subscale, with 100 representing the best result. A score improvement of 10 is supposed to have clinical relevance [17].

Radiology

Radiological evaluation was made on weight-bearing radiographs with straight knees and on lateral knee radiographs. The radiographs were scored according to the Ahlbäck classification criteria [18] and the Kellgren-Lawrence grading scale [19]. Also, the tibiofemoral anatomical axis was recorded. The angular correction was calculated on standing (full leg length) hip, knee and ankle (HKA) radiographs according to Dugdale [20], aiming for the mechanical axis to pass just lateral to the intercondylar eminence corresponding to 62% of the width of the tibial plateau, measured from the medial side.

Osteotomy Failure

Failure was defined as conversion of the osteotomy to total knee arthroplasty (TKA). Data from TKA converted patients were

only included in the study until TKA surgery.

Surgical Technique

The patients were operated on a traction table with slight flexion of the knee to ease fluoroscopic guidance during the operation and secure rotational control of the leg. The osteotomy was performed as described by Puddu et al. [21]. The proximal part of the tibia was approached through a medial incision. The superficial medial collateral ligament was cut as part of an oblique osteotomy starting from the upper edge of pes anserinus and aiming for the fibular head. The height of the osteotomy cleft was calculated from the length of the osteotomy cut and the planned correcting angle, and the appropriate spacer plate chosen from a table provided by the plate manufacturer (Arthrex, Naples, FL, USA). Puddu plates of the first generation were used. The spacer plate was placed as far posteriorly as possible in order not to increase the tibial slope [9] (Figure 1). The osteotomy cleft was filled with bone from the iliac crest. All patients received antithrombotic prophylaxis with low molecular weight heparin (Fragmin®, Pfizer, New York. USA) for 10 days postoperatively. They were allowed partial weight-bearing (10 kg) postoperatively, and no braces were used. Increasing weight-bearing was allowed after 6 weeks and full weight-bearing a few weeks later depending on the radiological healing of the osteotomy. Healing was defined as ¾ of the osteotomy filled with new bone, and delayed healing as healing beyond 5 months postoperatively.

Follow-up

Standing weight-bearing radiographs of both knees were obtained at the 3-month, 5- and 10- year follow-ups, but only supine radiographs of the index knee at the 6-week follow-up. The patients filled in KOOS at the 6-month, 1-, 2-, 5- and 10-year follow-ups. Most of the follow-ups were performed by the first author, and no patients were lost to follow-up. The collection of data was approved by the Norwegian Social Science Data Services (project 22075), and the study was performed in accordance with the Helsinki Declaration with informed patient consent.
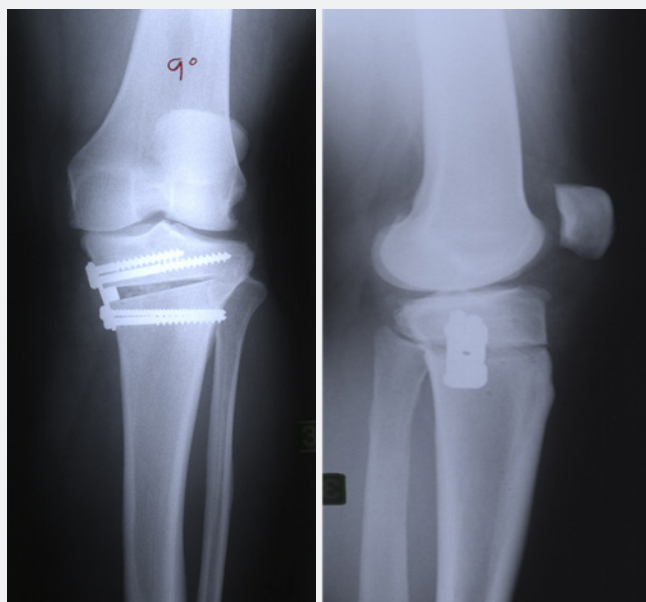
Figure 1: Medial opening wedge osteotomy in valgus of a knee with ruptured anterior cruciate ligament, frontal and side view 3 months postoperatively. The spacer plate is placed as far posteriorly as possible in order not to increase the posterior tibial slope.

Statistical Analysis

The results are presented as mean with CI 95% and range. Statistical differences were calculated by fitting separate linear mixed models for each of the KOOS subscores (Figures 2-6). Missing data were assumed to be missing at random. Treatment effects of patients with ACL rupture versus patients with intact ACL and the change from baseline to all other points in time were analyzed. The two-tailed T-test were used to calculate differences between the demographic data and for angular correction data (Tables 1 & 2). The Chi square test was used for categorical variables, and the two-tailed Fisher exact test when groups with small numbers were involved (Tables 3-6). The calculations were made with the SPSS software version 22 (IBM, Armonk, New York, USA) and Stata v16 (Stata 2015, College Station, Texas, USA). The level of statistical significance was set to $p < 0.05$.

Table 2: Angular correction and pre- and postoperative tibiofemoral axis angles for high tibial osteotomy (HTO) with ruptured or intact anterior cruciate ligament ACL).

Angles (degree)	HTO with ruptured ACL n = 17	HTO with intact ACL n = 35
Angular correction	7.1 (6.2-7.9) (4-11)	8.2 (7.5-8.9) (5-15)
Preop. tibiofemoral angle	0.2 varus (1.2 varus-0.9 valgus) (3 varus-3 valgus)	1.4 varus (2.3-0.4 varus) (7 varus-3 valgus)
Postop. tibiofemoral angle	6.9 valgus (6.0-7.8 valgus) (4-10 valgus)	6.8 valgus (6.2-7.4 valgus) (4-10 valgus)

n = Number of osteotomies. Mean with CI 95% and range. No significant difference between HTO patients with ruptured or intact ACL for angular correction (P=0.051), preoperative tibiofemoral angle (P=0.087) and postoperative tibiofemoral angle (P=0.869).

Table 3: Stability of knees with previous anterior cruciate ligament rupture subjected to high tibial osteotomy measured with the Lachman's test.

Time	Lachman test			
	0	1+	2+	3+
Preoperatively	0	3	10	4
2 years postop.	4	10	3	0
10 years postop.	6	7	2	1

n = 17. Significant difference between preoperative and 2-year and 10-year postoperative knee stability (P<0.001).

Table 4: Preoperative arthroscopic classification of OA according to the International Cartilage Repair Society for knees with ruptured or intact ACL

Grades	Knees with ruptured ACL n = 17	Knees with intact ACL n = 35
1	0	4
2	7	12
3	10	19

No significant difference between the two groups (P = 0.344).

Table 5: Ahlback [16] radiological OA grading of high tibial osteotomy (HTO) with ruptured or intact anterior cruciate ligament (ACL).

Time	HTO with ruptured ACL n = 17	HTO with intact ACL n = 35
	Grades 0-1/2-3	Grades 0-1/2-3
Preoperatively	11/6	28/7
5 years post-op.	10/7	24/8
10 years post-op.	8/8	17/7

n = Number of osteotomies. No significant difference between the two groups (preoperatively P=0.309, 5-year postop. P=0.399, 10-year post op. P=0.317). Neither significant difference between the preoperative and 10-year postop. gradings (HTO with ruptured ACL P=0.616 or intact ACL P=0.616). Radiographs of three knees are missing at the 10-year follow-up in addition to those converted to TKA and the knee from the person who died in the follow-up period.

Table 6: Kellgren-Lawrence [17] radiological OA grading of high tibial osteotomy (HTO) with ruptured or intact anterior cruciate ligament (ACL).

| Time	HTO with ruptured ACL n = 17	HTO with intact ACL n = 35
	Grades 1-2/3-4	Grades 1-2/3-4
Preoperatively	8/9	22/13
5 years post-op.	3/14	13/19
10 years post-op.	2/14	6/18

n = Number of osteotomies. No significant difference between the two groups (preoperatively P=0.434, 5-year postop. P=0.189, 10-year post op. P=0.439). The difference between the preoperative and 10-year postop. gradings was only significant for HTO with intact ACL (HTO with ruptured ACL P=0.057, intact ACL P=0.009), but this difference was even more significant when the two groups (HTO with ruptured or intact ACL) were combined (P<0.001). Radiographs of three knees are missing at the 10-year follow-up in addition to those converted to TKA and the knee from the person who died in the follow-up period.
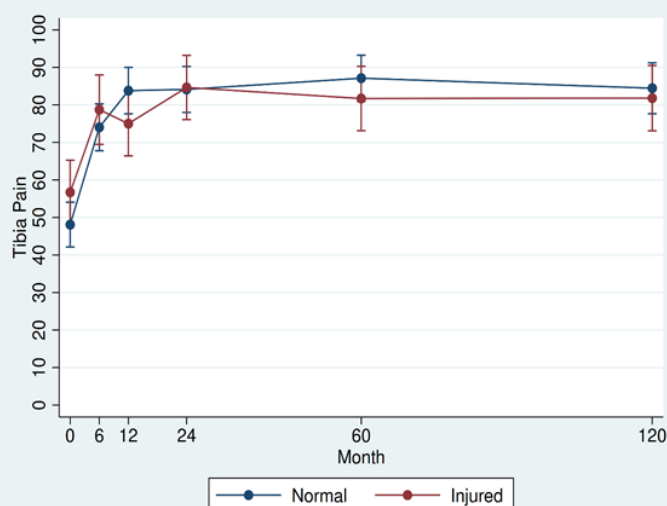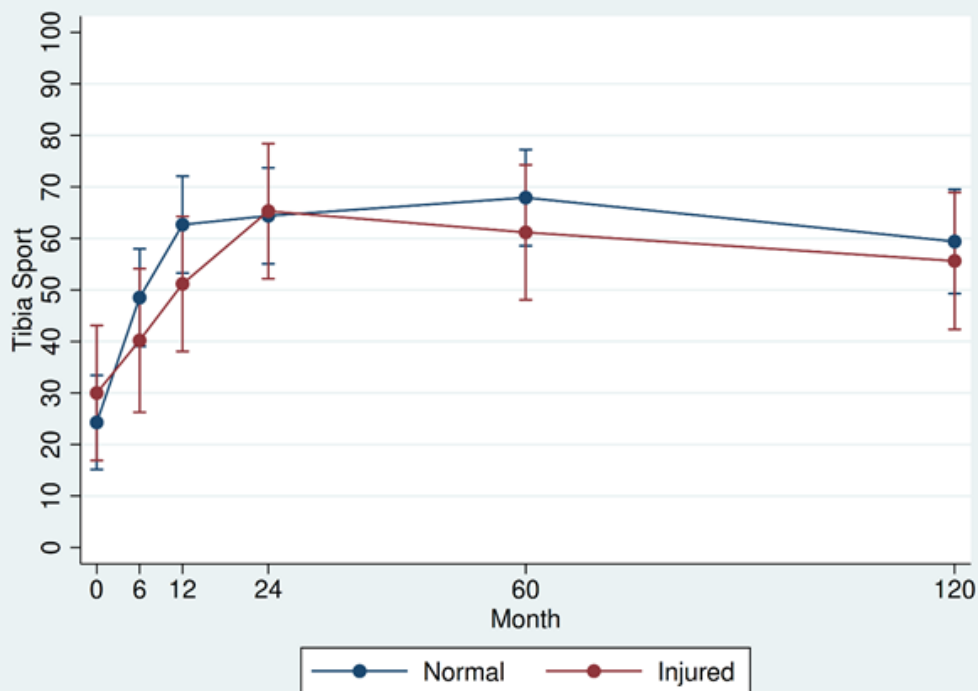

Figure 2: Improvement of the Knee Injury and Osteoarthritic Outcome Score (KOOS) subscale Pain for knees with high tibial osteotomy with ruptured (injured) (n=17) or intact (normal) (n=35) anterior cruciate ligament as a function of time after the operation. No significant differences were observed between the groups (P=0.103-0.923). Mean with 95% CI.
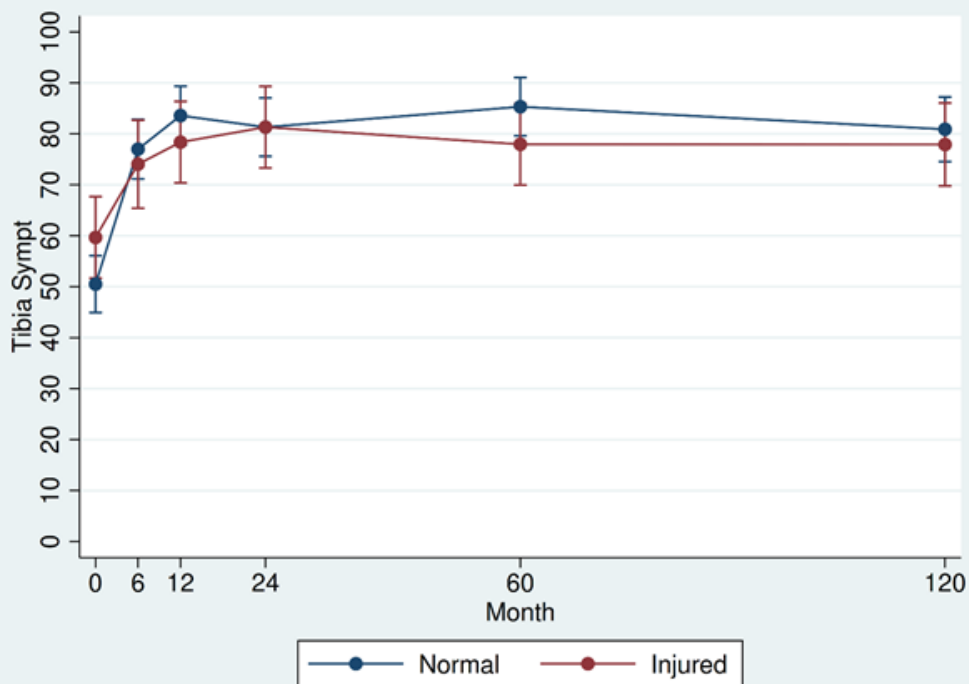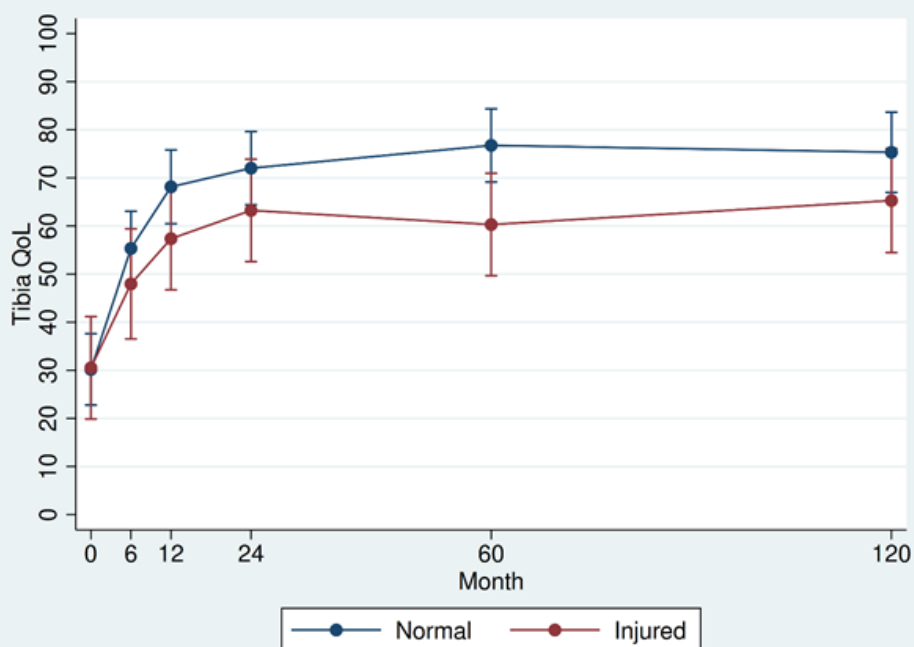
Figure 3: Improvement of the Knee Injury and Osteoarthritic Outcome Score (KOOS) subscale Symptoms for knees with high tibial osteotomy with ruptured (injured)(n=17) or intact (normal) (n=35) anterior cruciate ligament as a function of time after the operation. No significant differences were observed between the groups (P=0.142-0.999). Mean with 95% CI.
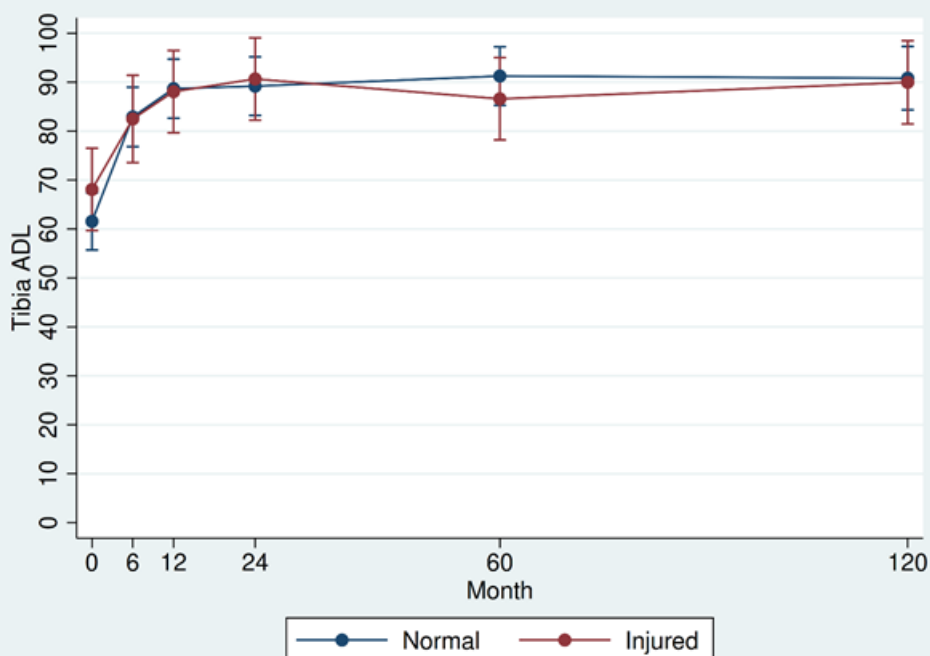
Figure 4: Improvement of the Knee Injury and Osteoarthritic Outcome Score (KOOS) subscale Activity of Daily Living (ADL) for knees with high tibial osteotomy with ruptured (injured) (n=17) or intact (normal) (n=35) anterior cruciate ligament as a function of time after the operation. No significant differences were observed between the groups (P=0.376-0.941). Mean with 95% CI.

Figure 5: Improvement of the Knee Injury and Osteoarthritic Outcome Score (KOOS) subscale Sport and Recreation for knees with high tibial osteotomy with ruptured (injured) (n=17) or intact (normal) (n=35) anterior cruciate ligament as a function of time after the operation. No significant differences were observed between the groups (P=0.162-0.912). Mean with 95% CI.

Figure 6: Improvement of the Knee Injury and Osteoarthritic Outcome Score (KOOS) subscale Quality of Life (QoL) for knees with high tibial osteotomy with ruptured (injured) (n=17) or intact (normal) (n=35) anterior cruciate ligament as a function of time after the operation. Higher scores were observed for patients with intact ACL at the 5-year follow-up (P=0.014). No significant differences were observed between the groups at other follow-up times (P=0.107-0.295). Mean with 95% CI.

Results

The mean angular correction measured from pre- and 3 months postoperative radiographs was 7.1° for knees with previous ACL rupture and 8.2° for those with intact ACL (Table 2). Also, the preoperative and 3 months postoperative tibiofemoral anatomical axis angles were similar for the two groups (Table 2). The angular correction was later sustained with mean tibiofemoral valgus angles of 6.3°/6.0° at the 5-year and 5.4°/5.5° at the 10-year follow-ups for HTOs with ruptured, respectively intact ACL. Fourteen of the 17 HTOs with ruptured ACL (82%) were healed at the 3-month and all at the 6-month follow-up. Of the 35 HTOs with intact ACL, 28 (80%) were healed at the 3-month and all but one with osteosynthetic failure at the 6-month follow-up. One patient in the group with intact ACL died in the follow-up period of causes unrelated to the knee surgery.

KOOS

Similar KOOS values were recorded preoperatively for both osteotomy groups. During the two first postoperative years, KOOS improved far beyond 10 points and clinically relevant in both groups compared to the preoperative values (P<0.001). Thereafter the KOOS values plateaued, remaining on that level throughout the 10-year follow-up period for surviving osteotomies Similar KOOS values were recorded at all follow-up times for patients with ruptured or intact ACL, except for higher QoL scoring for patients with intact than those with ruptured ACL at the 5-year follow-up (P=0.014) (Figures 2-6).

Knee stability

Most of the patients with ruptured ACL had fewer knee instability symptoms after the osteotomy. The knee stability measured by the Lachman's test was significantly increased (p<0.001) at the 2- and 10-year follow-ups compared to the preoperative recordings (Table 3). Only two of the 17 patients (12%) required an ACL reconstruction in the 10-year follow-up period. The first patient one year after the osteotomy due to a new knee injury and a previously failed ACL reconstruction, and the second 4 years after the osteotomy after a new knee injury. The knees with intact ACL were stable both pre- and post-osteotomy.

Arthroscopic cartilage evaluation

Many of the knees had pronounced OA in the medial compartment with degenerative meniscal ruptures and worn hyaline cartilage with loose flaps down to the subchondral bone plate. The ICRS evaluation of hyaline cartilage in the medial knee compartment was similar for knees with ruptured or intact ACL (Table 4).

Radiological Evaluation

The preoperative Ahlbäck scores were similar for knees with ruptured or intact ACL, and so were the scorings at the 5- and 10-year follow-ups (Table 3). Also, the Kellgren-Lawrence classification disclosed similar scorings for the two groups preoperatively and at the 5- and 10-year follow-ups, but a significant increase was observed between the preoperative and the 10-year postoperative scoring for knees with intact ACL. This difference was even more pronounced when the two groups (with ruptured or intact ACL) were combined (Table 4).

Body Mass Index

The mean preoperative BMI of the patients with ruptured or intact ACL was similar in both groups and about 27.5 (Table 1).

Range of motion

The preoperative ROM was similar in both groups and about 130°. After a small drop at the 3-month follow-up, the ROM was regained at the 6-month follow-up and later remained at the preoperative level.

Complications

The postoperative complications were similarly distributed among the two HTO groups (Table 7). The only osteosynthetic failure occurred in a patient with a body weight of 130 kg. He was reoperated with a Tomofix® plate (Synthes, Stratec Medical, Oberdorf, Switzerland) with autologous bone grafting. The osteotomy healed, but the OA deteriorated and the HTO was later converted to TKA.

Table 7: Postoperative complications after high tibial osteotomy (HTO) of knees with ruptured or intact anterior cruciate ligament (ACL).

Complication type	HTO with ruptured ACL n = 17	HTO with intact ACL n = 35
Delayed healing		1
Wound infection	1	1
Prolonged wound secretion		1
Deep venous thrombosis	1	1
Osteosynthetic failure		1

Survival

One of the 17 knees (6%) with ruptured ACL was converted to TKA 9.5 years postoperatively compared to 7 of 35 knees (21%) with intact ACL after mean 6.3 (CI 3.1-9.5, range 2.0- 9.8 years) (P=0.242), giving a 10-year survival of 84% for the HTOs. The angular correction was similar for the patients who ended up with TKA and those where the osteotomy survived.

Discussion

This study revealed that opening wedge HTO for medial knee OA resulted in good and similar functional results both for patients with ruptured and intact ACL. The age of the patients, the preoperative KOOS, the degree of preoperative OA, the BMI, the preoperative varus alignment and the angular correction were similar in both groups. The knee function evaluated by the five subgroups of KOOS was similar for the two groups in 24 out of 25 recordings, but with higher subgroup QoL scoring for patients with intact ACL at the 5-year follow-up (Figure 6). The working hypothesis was therefore only partly rejected.

The sagittal knee instability evaluated by the Lachman's test improved significantly after HTO in patients with chronic ACL rupture. This agrees with the findings of Mehl et al. [22] who reported the same improvement of instability in patients with ACL deficiency subjected to HTO alone or combined single-stage HTO and ACL reconstruction. At mean 5.8 years postoperatively no group differences were found in the KT-2000 examinations or Kellgren-Lawrence radiographic gradings. A systematic review has reported significant improvement of functional subjective outcome after simultaneous HTO and ACL reconstruction (ACLR), but due to the lack of comparative studies, it remains unclear if HTO with ACLR is superior to ACLR or HTO alone according to the authors [23]. The reason for the improvement in knee stability in ACL deficient knees after HTO is unclear. It may be related to better and more training of the stabilizing knee muscles after the post osteotomy pain relief when the medial knee compartment is unloaded, and later to a more fibrotic knee capsule by advancing osteoarthritis.

An increase in the posterior tibial slope will increase ACL tension and may lead to increased anterior tibial translation [9,24]. Opening wedge osteotomies may unintentionally lead to an increase of the posterior tibial slope depending on the location and the design of the osteotomy plate [9,25-27]. The spacer plates in this study were therefore placed far posteriorly in the osteotomy cleft (Figure 1). The preoperative arthroscopy displayed that most of the knees both in patients with ruptured and intact ACL had cartilage damage down to the subchondral bone plate. The HTO was performed to prevent or delay TKA in this middle-aged group of patients [28]. For the patients with additional ACL rupture and instability we were prepared to do a later ACL reconstruction, as some authors recommend doing these two operations during the same surgery [29,30]. But most of the patients with additional ACL rupture recovered so much after the correcting osteotomy (Figures 2-6), that a secondary stabilizing operation was only required in 2 of 17 patients (12%).

Both Ahlback [18] and Kellgren-Lawrence [19] radiological grading systems for OA were used in this study. In the Ahlback system, great importance is attached to obliteration of the joint space and any bone loss, whereas the Kellgren-Lawrence system also consider the presence of osteophytes in addition to narrowing of the joint space. Different descriptions of the Kellgren-Lawrence criteria for knee OA have been published, but we used the original description [31]. The degree of OA was similar in both groups of patients throughout the study, but with a significant increase of the Kellgren-Lawrence scoring at the 10-year follow-up compared to the preoperative scoring (Table 6). This may suggest that the Kellgren-Lawrence grading scale is more sensitive to OA changes over time than the Ahlbäck classification criteria. Kellgren-Lawrence is also the grading system recommended by the International Society of Arthroscopy and Orthopaedic Knee Surgery (ISAKOS).

The 10-year survival of the HTOs in this study was 84%. This agrees with the osteotomy survival reported by Jin et al. [32], but higher than reported by Keenan et al. [33]. The BMI was similar and about 26-28 both for patients with ruptured and intact ACL. Overweight is a risk factor for later conversion of HTO to TKA [34,35], but the number of patients with BMI>30 in this study was small.

All osteotomies healed in this study including the HTO with osteosynthetic failure, where the osteotomy healed after a reoperation. This is probably due to grafting of autologous bone from crista into the osteotomy cleft [36]. Nelissen et al. [37] used Vitoss superficial bone substitute in osteotomies stabilized with the Puddu plate and recorded pseudarthrosis in 11 of 49 patients (22%) and several other complications, claiming the spacer plate provided inadequate stability. The strength of this study is the prospective design with repetitive KOOS recordings enabling functional evaluation of the patients over time, that no patients were lost, and the long follow-up time. The limitations are that the tibial slope angle has not been measured as only short sagittal radiographs of the proximal tibia were available, that the anterior tibial translation was only evaluated by the Lachman test, and not by the instrumental KT-2000 test which is more accurate. Another weakness is the missing of postoperative HKA radiographs since the study started before such radiographs were available at our hospital. The preoperative HKA radiographs of the first included patients were therefore taken at another hospital, making it inconvenient for the patients to visit two hospitals for postoperative follow-ups. A later HTO study with pre- and postoperative HKA radiographs at our hospital disclosed an under correction of about 3° related to the planned correction with Dugdale's method [20], using the same opening wedge technique for HTO as in the present study [38].

Conclusion

The functional results after opening wedge HTO for knees with ruptured or intact ACL were good and similar for 10 years follow-ups, except for a higher KOOS QoL score for patients with intact ACL at the 5-year follow-up. HTO increased the knee stability in ACL deficient knees, and most of these patients do not seem to need an ACL reconstruction in addition to the HTO.

Funding statement

Acknowledgement

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