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TRAUMA SURGERY

Long-term outcome after surgical treatment of intra-articular tibial plateau fractures in skiers

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Abstract

Introduction Tibial plateau fractures occur frequently during downhill skiing. There is a lack of information about the outcome and development of posttraumatic osteoarthritis after internal fixation of such fractures at long-term follow-up in skiers.

Materials and methods A population of 83 skiers was followed up in a case series after internal fixation of intra-articular tibial plateau fractures AO-OTA 41 B1-B3 and C1-C3. Functional outcomes Visual Analog Scale, Tegner Activity Scale, Modified Lysholm Score, Hospital for Special Surgery (HSS) Knee Score and X-ray images of the affected knees (preoperative, postoperative and at time of follow-up) were obtained. Radiological evaluation focused on severity of osteoarthritis according to the Kellgren and Lawrence score of the lateral, medial and retropatellar knee compartments separately. Subgroup analyses for fracture type and age were performed separately.

Results Patients age was 49.8 ± 12.9 years (range 19–74 years) at the time of surgery, with a mean follow-up period of 10.3 ± 1.9 years (range 6–14 years). All tibial plateau fractures affected the lateral compartment, while the medial compartment was affected in addition as part of bicondylar fractures in two cases. Both the Tegener Activity Scale and Lysholm Score decreased significantly during the follow-up period and their median values dropped from 6 (range 3–7) to 5 (range 2–7) and from 100 (range 90–100) to 95 (range 58–100), respectively (both $p < .01$). The median clinical knee function at the time of follow-up revealed an HSS Knee Score of 96.5 points (range 74–100). Among the whole patient population, the radiological evaluation at follow-up revealed a significantly higher grade of osteoarthritis in all compartments of the knee joint compared to the time of the operation ($p < .01$). The grade of osteoarthritis in the lateral compartment was significantly higher than that in the medial and retropatellar compartments ($p < .01$).

Conclusions In addition to physiologic aging, progression of radiologic signs of osteoarthritis following internal fixation of intra-articular tibial plateau fractures in an athletic population of skiers is most severe in the lateral knee compartment corresponding to fracture location. However, the long-term functional outcomes seem to be very satisfactory.

Keywords Tibia · Fracture · Skiers · Osteoarthritis · Outcome

Introduction

Fractures of the tibial plateau represented about 1% of all knee injuries in skiers in the 1980s [1]. A significant increase in their incidence has been observed since then, due to new trends and newly developed equipment, leading to increased forces and moments transmitted to the knee joint during skiing [2].

Various surgical procedures and approaches [3] have been proposed so far to achieve accurate anatomical reduction with absolute stability (and rigid fixation) of the articular surface and fulfill the basic requirement for early rehabilitation and range of motion exercises to allow cartilage

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lubrication [4, 5]. However, despite all reconstructive efforts, osteoarthritis (OA) following tibial plateau fractures is reported with an incidence rate ranging from 23 to 44% [6–11].

After tibial plateau fractures with an average follow-up period of 7.8 years, the majority of patients (88%) were able to return to an active lifestyle with a shift from higher- to lower-impact activities [12]. A large percentage of them (more than 45%) had to give up downhill skiing. Fracture type and extent of the cartilage injury were identified as the most important factors influencing the physical activity and clinical results.

Osteochondral trauma, including intra-articular fractures, represents the most important single factor for acquired biomechanical disorders and initiation of OA in the knee joint [13]. Moreover, the extent of cartilage injury sustained after the trauma has been identified as the most important prognostic factor [14]. Several studies have evaluated clinical and radiological outcomes after osteosynthesis of tibial plateau fractures so far [7–11, 15, 16]; however, none of them has considered a long-term follow-up investigation of tibial plateau fractures following skiing accidents with special regard to the radiologic development of posttraumatic OA.

Therefore, the aim of the present study was to assess the grade of OA preoperatively and at the time of follow-up after surgically treated tibial plateau fractures in an athletic population of skiers. Moreover, knee function and clinical outcomes were investigated. We hypothesized that the majority of investigated skiers develop a progression of radiologic signs of osteoarthritis within the fractured knee compartment; however, they resume an active life style after internal fixation of tibial plateau fractures.

Materials and methods

Exclusion and inclusion criteria

A total of 172 international alpine skiers with intra-articular tibial plateau fractures, classified as AO/OTA 41 B1-B3, C1-C3, were operatively treated between January 2000 and December 2006 in a level III trauma center located in a skiing resort with approximately 100 km of slopes. All non-german-speaking patients under the age of 18 years at the time of the injury, and patients with multiple fractures were excluded. Consequently, all patients were over the age of 18 years and the tibial plateau fracture was their most severe injury. Out of them, all 108 patients residing in Switzerland, Germany and Austria were considered for the study. Two patients were lost to follow-up because of untraceable changes in contact data and seven patients passed away in the meantime without relation to the initial injury, and 16 patients refused participation. The remaining 83 patients were included in the present study (recall rate 83.8%, Fig. 1).

Surgical technique and postoperative rehabilitation

All fractures were surgically treated by internal fixation according to the AO/OTA principles by senior trauma surgeons. According to the AO/OTA classification, the main fracture types were B3 ($n=36$, 43.4%), B2 ($n=15$, 18.1%) and C3 ($n=13$, 15.7%). Fracture types C2 ($n=8$, 9.6%), B1 ($n=8$, 9.6%) and C1 ($n=3$, 3.6%) were less frequent (Fig. 2).

Thirty-seven unicondylar fractures were fixed with screws and anti-sliding washers. Additional support of the fracture area was required for 46 patients and they were consequently treated by open reduction and internal plate fixation. Buttressing was performed in 28 cases with a Less Invasive Stabilization System plate and in 18 cases with a Locking Compression Plate (both: DePuy Synthes, Zuchwil, Switzerland). Additional buttressing of the medial condyle was done in one case with bicondylar fracture using a one-third tubular plate plate (DePuy Synthes, Zuchwil, Switzerland). Arthroscopically assisted minimally invasive osteosynthesis was performed 13 patients. All depressed fragments of the joint surface were elevated with a bone impactor introduced through the fracture or through a small cortical window. Continuous passive motion was started on the first postoperative day and weightbearing was restricted to 15 kg during a period of 6 weeks after surgery for all patients.

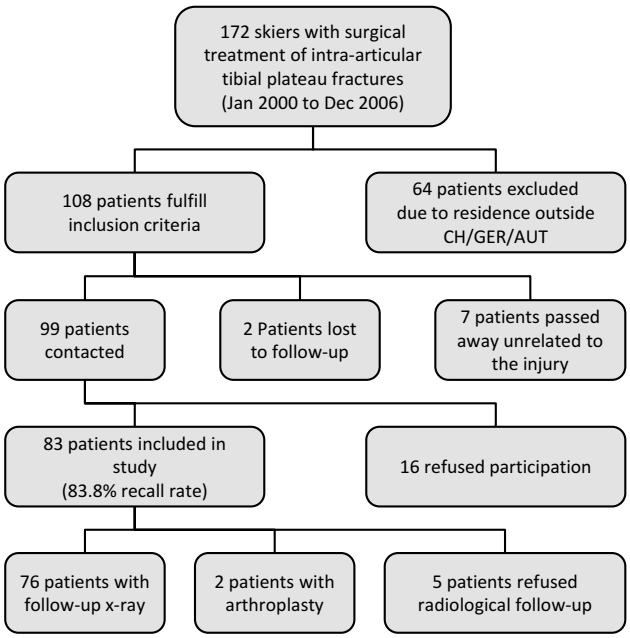

Fig. 1 Patient flow diagram. *CH* Switzerland, *GER* Germany, *AUT* Austria

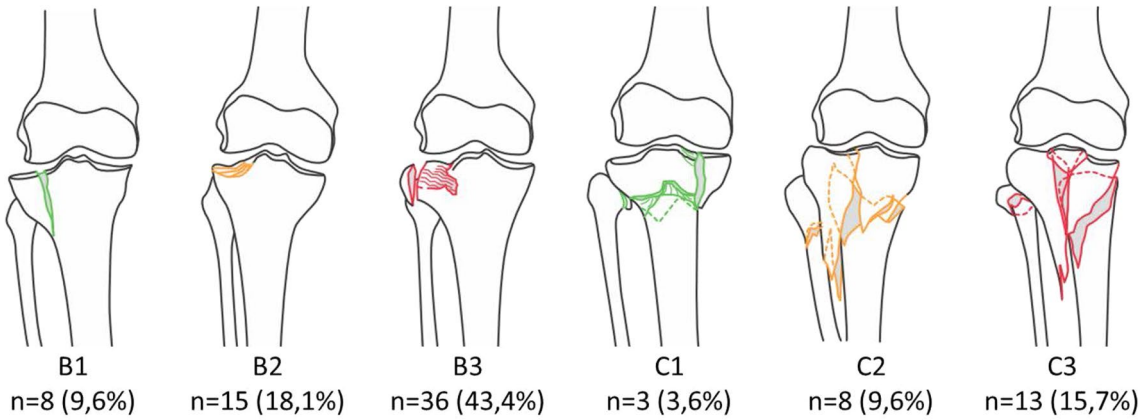

Fig. 2 Distribution of affected knee joints according to the AO-OTA classification

Radiographic assessment

Anteroposterior and lateral X-ray images of the affected knee joint were taken at the time of follow-up. The pre- and postoperative X-ray images were obtained from the database system of the hospital. OA was graded according to the classification of Kellgren and Lawrence [12] for each knee compartment separately (medial, lateral, retropatellar) by three observers (all orthopedic trauma surgeons) from the X-rays at the times of the operation and follow-up. An example of a radiographic course of one patient is shown in Fig. 3.

Knee function and outcome assessment

All eligible patients were seen for a follow-up visit in the outpatient clinic. At presentation, the clinical outcome was assessed during a clinical exam of the affected knee joint with the Visual Analog Scale (VAS) for pain (0 representing "no pain" and 10 representing "maximal imaginable pain"),

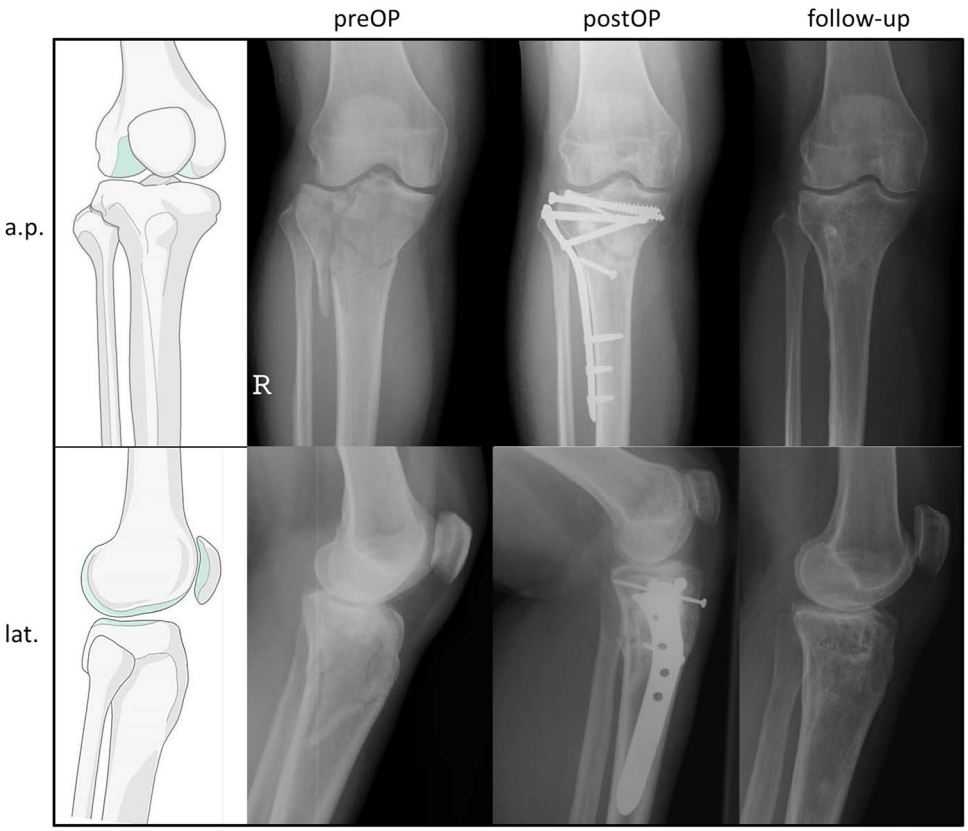

Fig. 3 Example of the radiographic course of a 38-year-old male with an AO 41.B1 fracture and 9-year follow-up

the modified Lysholm score [17] and the Hospital for Special Surgery (HSS) knee score [18]. The patients' level of sports activity was determined with the Tegner activity scale [19]. All scores were also assessed retrospectively for the time before the operation. Moreover, additional surgeries at the affected knee, such as implant removal, knee arthroscopy or joint replacement, were registered.

Statistical analysis

Statistical analysis was performed using SPSS software package (Version 23, IBM SPSS Inc., Chicago, IL, USA). All data were tested for normality of distribution using the Shapiro Wilk test. Wilcoxon Signed-Rank test was used to analyze nonparametric data. Subgroup analyses were performed based on age (four groups regarding the age at time of trauma: < 40 years, 41–50 years, 50–60 years, > 60 years) and fracture type using the Independent-Samples Kruskal–Wallis and Independent-Samples Mann–Whitney Test. Level of significance was set to $p = .05$ for all statistical tests.

Results

Demographics

From all 83 patients included in the current study, five patients were asymptomatic and did not undergo X-ray imaging; however, their clinical data were available for evaluation. The age of all participating patients was 49.8 ± 12.9 years (mean ± standard deviation, range 19–74 years) at the time of surgery. The follow-up period was 10.3 ± 1.9 years (range 6–14 years).

The study cohort comprised 44 women (53.0%) and 39 men (47.0%), with 43 right and 40 left knees involved (Table 1). At the time of the operation, 21 patients were < 40 years (25.3%), 17 patients were 41–50 years (20.5%), 26 patients were 51–60 years (31.3%) and 19 were > 60 years (22.9%).

Radiologic signs of posttraumatic osteoarthritis

The radiographs of the affected knee joints at the time of the operation demonstrated no signs of OA according to the Kellgren and Lawrence Classification for the lateral, medial and the retropatellar knee compartments, without a significant difference between fracture types ($p \geq .16$, Table 2).

Two patients with a B3 and a C3 fracture underwent total knee arthroplasty and could not be evaluated for osteoarthritis at follow-up. During the follow-up period after B3 and C3 fractures, the OA grading of all three compartments increased significantly in comparison to the preoperative state ($p \leq .04$). Moreover, at the time of follow-up, we found a significantly higher OA grading in the lateral compartment in comparison to both the medial and retropatellar compartments in B3 and C3 fractures ($p = .01$).

With reference to the B1 and C1 fracture types, the grading of OA according to the Kellgren and Lawrence Classification revealed no significant difference between the time of follow-up and operation for all three compartments separately, as well as no significant difference between all three compartments at the time of follow-up ($p \geq .16$). However, there was a significantly increased grading of OA between the two time points in the lateral compartment after B2 fractures ($p = .02$), as well as in the lateral and retropatellar compartments after C2 fractures ($p \leq .04$). In addition, the OA grading at the time of follow-up after B2 and C2 fractures revealed a significantly more severe OA in the lateral compartment than in the medial and retropatellar compartments ($p \leq .04$).

Among the whole patient population, considering all 6 fracture types together, the radiological evaluation of the affected knee joints at follow-up revealed a significantly higher grade of OA in all compartments of the knee joint compared to the time of the operationf ($p < .01$). In addition, the grade of OA in the lateral compartment was significantly higher than in the medial and retropatellar compartments ($p < .01$).

All age groups showed a significant increase of radiologic grading of OA in all three compartments at the time of follow-up ($p < .05$). The lateral compartment was affected more

Table 1 Patient demographics

Demographics	Value
No. of patients	83
No. of follow-up X-rays	76
Male, *n* (%)	39 (47.0)
Female, *n* (%)	44 (53.0)
BMI at the time of follow-up mean ± STD (range)	24.9 ± 3.5 (19–32)
Follow-up, mean ± STD (range), years	10.3 ± 1.9 (6–14)
Age at the time of surgery, mean ± STD (range), years	49.8 ± 12.9 (19–74)
Age at the time of follow-up, mean ± STD (range), years	60.7 ± 12.6 (33–86)

Table 2 Radiologic evaluated arthrosis at the time of accident and the time of follow-up according to the AO/OTA classification

	accident	p*	p*	p*	follow-up	p*	p*	p*	P-value
AO B1 (n=6)									
KL medial	0 (0-0)	0.99			0 (0-2)	0.66			0.32
KL lateral	0 (0-0)			0.32	0 (0-2)			0.99	0.18
KL retropatellar	0 (0-1)		0.32		0 (0-1)		0.56		0.31
AO B2 (n=14)									
KL medial	0 (0-2)	0.41			0 (0-2)	**0.04**			0.05
KL lateral	0 (0-1)			0.99	0 (0-3)			0.26	**0.02**
KL retropatellar	0 (0-1)		0.32		0 (0-1)		**0.01**		0.16
AO B3 (n=34)									
KL medial	0 (0-1)	0.65			0 (0-2)	**0.01**			**<0.01**
KL lateral	0 (0-2)			0.21	0 (0-4)			0.18	**<0.01**
KL retropatellar	0 (0-1)		0.44		0 (0-1)		**0.01**		**<0.01**
AO C1 (n=3)									
KL medial	0 (0-1)	0.99			0 (0-3)	0.56			0.18
KL lateral	0 (0-1)			0.32	0 (0-2)			0.18	0.16
KL retropatellar	0 (0-0)		0.32		0 (0-2)		0.16		0.32
AO C2 (n=8)									
KL medial	0 (0-1)	0.32			1 (0-3)	**0.04**			0.1
KL lateral	0 (0-1)			0.16	2 (0-3)			0.18	**0.01**
KL retropatellar	0 (0-0)		0.32		0.5 (0-1)		**0.01**		**0.04**
AO C3 (n=11)									
KL medial	0 (0-3)	0.99			1 (0-3)	**0.01**			**0.01**
KL lateral	0 (0-3)			0.16	2 (0-3)			0.26	**0.01**
KL retropatellar	0 (0-2)		0.16		0 (0-2)		**0.01**		**0.04**
Sum (n=76)									
KL medial	0 (0-3)	0.59			0 (0-3)	**<0.01**			**<0.01**
KL lateral	0 (0-3)			0.99	1 (0-4)			0.36	**<0.01**
KL retropatellar	0 (0-2)		0.68		0 (0-2)		**<0.01**		**<0.01**

Significant values (0.05) are given in bold

Data expressed as median (range)

KL Kellgren and Lawrence

**P* Value between the compartments at the same point of time

than the medial and retropatellar compartment ($p < .04$). No significant difference was found in the development of OA between the different age groups ($p \geq .14$).

Clinical outcome

During the follow-up period, the median VAS score for pain (range 0–8) did not change (Table 3). However, the number of patients expressing no pain (VAS 0) decreased significantly from 70 patients (84.3%) preoperatively to 46 patients (55.4%) at the time of follow-up ($p < .01$).

The Tegner Activity Scale, representing the activity level, significantly dropped from a median of 6 (range 3–7) preoperatively to 5 (range 2–7) at the time of follow-up ($p < .01$). The median Lysholm score decreased significantly from 100 (range 90–100) to 95 (range 58–100) ($p < .01$). The HSS knee score could be evaluated only for the follow-up as it includes a physical examination and was 96.5 points (range 74–100).

Additional surgeries at the involved knee were performed in 60 patients (72.3%): 55 (66.3%) hardware removals, 5 (6.0%) knee arthroscopies, 2 (2.4%) joint replacements in patients with preexisting OA. There was the need for one (1.2%) open revision due to one early deep infection, one (1.2%) delayed deep infection and two

Table 3 Specific results at the time of the operation and at the time of follow-up according to the AO-OTA classification

	Preoperative	Follow-up	Absolute change	*P* value
AO B1 ($n=8$)				
VAS	0 (0–3)	0 (0–1)	0	0.28
Tegner Activity Scale	6 (5–6)	5 (3–6)	−1	0.11
Lysholm Score	100 (95–100)	100 (90–100)	0	0.10
HSS-Knee Score	–	98 (95–100)	–	–
AO B2 ($n=15$)				
VAS	0 (0-4.5)	0 (0–3)	0	0.23
Tegner Activity Scale	6 (4–6)	4 (3–6)	−2	**0.01**
Lysholm Score	100 (95–100)	95 (77–100)	−5	**<0.01**
HSS-Knee Score	–	97.5 (85–100)	–	–
AO B3 ($n=36$)				
VAS	0 (0–7)	0 (0–7)	0	**0.01**
Tegner Activity Scale	6 (3–7)	5 (2–6)	−1	**<0.01**
Lysholm Score	100 (90–100)	95 (58–100)	−5	**<0.01**
HSS-Knee Score	–	96 (74–100)	–	–
AO C1 ($n=3$)				
VAS	0 (0–0)	0 (0–0)	0	0.99
Tegner Activity Scale	6 (3–6)	4 (3–6)	−2	0.32
Lysholm Score	100 (100–100)	100 (100–100)	0	0.99
HSS-Knee Score	–	90.5 (88–93)	–	–
AO C2 ($n=8$)				
VAS	0 (0–0)	0 (0–2)	0	0.11
Tegner Activity Scale	6 (3–7)	6 (3–7)	0	0.32
Lysholm Score	100 (100–100)	96 (85–100)	−4	**0.03**
HSS-Knee Score	–	98 (93–99)	–	–
AO C3 ($n=13$)				
VAS	0 (0–8)	0 (0-3.5)	0	0.11
Tegner Activity Scale	6 (3–6)	6 (3–6)	0	**0.04**
Lysholm Score	100 (100–100)	91 (75–100)	−9	**<0.01**
HSS-Knee Score	–	93 (80–100)	–	–
Sum ($n=83$)				
VAS	0 (0–8)	0 (0–7)	0	**<0.01**
Tegner Activity Scale	6 (3–7)	5 (2–7)	−1	**<0.01**
Lysholm Score	100 (90–100)	95 (58–100)	−5	**<0.01**
HSS-Knee Score	–	96.5 (74–100)	–	–

Significant values (0.05) are given in bold

Data expressed as median (range)

VAS Visual Analoge Scale

(2.4%) superficial wound infections that needed superficial revision without initial hardware removal.

Considering the AO/OTA classification, no significant deterioration was observed between the time of the operation and follow-up for VAS, Tegner Activity Scale or Lysholm score in patients with B1 and C1 fractures ($p \geq .10$). Significant deterioration was observed in patients with C2 fractures only with regard to the Lysholm Score ($p = .03$), and in patients with B2 and C3 fractures for both Lysholm Score and Tegner Activity Scale (both $p \leq .04$), while VAS score for pain was unaffected ($p \geq .11$). Patients with the most frequent B3 fractures revealed significant deterioration regarding all three scores ($p \leq .01$).

In the age group < 40 years, a significant change in the distribution of the VAS Score was found, although the median remained unchanged at 0 ($p < .01$). The median Tegner activity also remained at the same level with a median of 6 ($p > .33$). In all other age groups (i.e.: 41–50 years, 51–60 years and > 60 years), there was no significant change in the median VAS which remained 0 at the time

of the operation and follow-up ($p > .10$). The median Tegner Activity decreased in those three groups significantly with a change of the median in the groups 41–50 years and 51–60 years from 6 to 5 and the highest change in the group > 60 years form 6 to 3 ($p < .01$). Regarding the Lysholm Score, we observed a deterioration in all four age groups although the median did not decrease 5 points in all age groups ($p < .01$).

Discussion

The present study focused on the radiological long-term evaluation of OA development and the functional outcomes after surgically treated intra-articular tibial plateau fractures in skiers.

Due to the injury mechanism, 96% of the unicondylar fractures during skiing affect the lateral tibial plateau and corresponding cartilage [20]. Our patient cohort revealed similar pattern and the lateral tibial plateau had to be surgically addressed in all cases, whereas only 2.4% of the cases needed additional buttressing of the medial condyle. This corresponds well with the predominant development of OA in the lateral compartment after a follow-up of 10.3 ± 1.9 years in our patients. In contrast, in the general population without particular knee injury, OA predominantly affects the medial or the retropatellar compartment, while OA of the lateral compartment is rare [21].

The severity of trauma is known to be the most important prognostic factor for development of OA [22]. In the current study, severe fractures type B2 and B3, as well as C2 and C3 according to the AO/OTA classification system, were more likely to develop radiological signs of OA, while patients with type B1 split fractures or type C1 simple metaphyseal fractures did not demonstrate radiographic signs of OA at the time of follow-up.

Chronic overload is known to lead to subchondral stiffening as a result of OA [23]. Obesity is a central factor for knee joint overload, with a sixfold increased incidence of OA of the knee joints with a body mass index (BMI) > 30 kg/m^2 [24]. However, this factor is unlikely to be the cause for OA in our patient collective of skiers with BMI of 24.9 ± 3.5 kg/m^2 at the time of follow-up.

The overall functional outcomes did not worsen in patients with type B1 and C1 fractures, while there was a slight deterioration with regard to the other fracture types. Kraus et al. [25] reported a Lysholm score of 76.6 points at the time of their survey (mean 52.8 months). This compares reasonably with our value for the Lysholm score of 95 points.

Nevertheless, the median Tegner Activity score > 5 and the median Lysholm score > 90 represent good long-term outcomes and are well comparable to individuals of the same age without previous knee trauma [26]. Rademakers et al. [11] reported in a similar sized population a mean HSS score of 84.8 points (range 19–100 points) with a long-term follow-up of 14 years (range 5–27 years). This is considerably lower than the value of 96.5% measured in our study.

Moreover, a median HSS Knee Score of > 90 indicates good knee function for all fracture types [27]. The functional outcome and the return rate to lower impact sports are known to be very high in an athletic population [25, 28]. This is different to tibial plateau fractures after high energy trauma, where the outcome is known to be worse [15, 16]. We also assume that the good functional outcome in our population might also be influenced by their high rehabilitation motivation and socioeconomic status, which is known to affect the outcome in lower extremity fractures [29].

Two patients aged over 65 years at the time of follow-up with severe fractures type B3 and C3 had an arthroplasty in the meantime. This rate of arthroplasties (2.4%) is rather low compared to previous reports. Dreumel et al. [30] reported that a total knee arthroplasty was eventually required after a median term of 1 year (range 0.63–3.81 years) in 7.3% of patients. Timmers et al. [31] reported an arthroplasty rate of 22% after a mean follow-up of approximately 6 years. Wasserstein et al. [32] defined the risk for arthroplasty in a large cohort at 5.3% and 7.3% after 5 and 10 years, respectively. Kalmet et al. [33] reported an overall arthroplasty rate of 11%. As a possible explanation for the low arthroplasty rate of 2.4% in our study, we assume again a high rehabilitation motivation due to the socioeconomic status and the normal BMI in the athletic population of skiers.

While there was no difference in the radiographic assessment of OA between the age groups, a decrease of the Tegner Activity in the higher age groups could be observed. This effect might also be caused by the patients' general age which was for example > 70 years at the time of follow-up in the highest age group (i.e., > 60 years at the time of the operation). In this age group, the median Tegner Activity at the time of follow-up was 3, which is a similar score compared to patients with normal knees [26]. Nevertheless, short-term outcomes do not seem to be influenced by age or bone density [34].

The present study is subjected to the following limitations. First, it is retrospective and a recall bias might have influenced the outcome scores. Second, magnet resonance imaging (MRI) or computed tomography (CT) scans might have offered better evaluation of the cartilage damage and malalignment than the used plain radiographs [35]; however, this would have exceeded the feasibility of the study. CT and MRI images were not performed routinely and were not stored digitally for some of the patients in the period 2000–2004. Therefore, concomitant intra-articular injuries (cartilage, ligamentous and meniscal lesions) could not be

assessed separately. Furthermore, a considerable number of the patients had to be excluded due to language reasons.

Finally, the methods of fracture fixation and treating traumatologists differed. However, this limitation represents the clinical reality in the setting of acute trauma care.

The strengths of this study are the long follow-up period and the unique cohort of skiers after surgical treatment of tibial plateau fractures.

Conclusion

Development of OA after operatively treated intra-articular tibial plateau fractures of skiers predominately affects the lateral compartment of the knee joint. More severe fractures result in a higher radiologically detectable degree of OA in the lateral compartment. Despite progressive radiological grading of OA at long-term follow-up, the functional outcomes seem to be very satisfactory.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was approved by the institutional review board.

Informed consent Informed consent was obtained from all individual participants included in the study in accordance with the declaration of Helsinki.

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