Original Article

Outcome of angular stable locking plate fixation of tibial plateau fractures Midterm results in 101 patients

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ABSTRACT

Background: Articular reconstruction and stable fixation of tibial plateau fractures and its various subtypes continue to represent a surgical challenge. Only few trials have studied results following angular stable plate fixation. The present study aimed to investigate the clinical, radiological, functional and quality of life results following tibial plateau fractures using angular stable plate fixation.

Materials and Methods: 101 patients were retrospectively studied using functional (ROM; KSS; VAS), radiographic (osteoarthritis score, loss of reduction) and quality of life (WOMAC; Lysholm) scores. There were 46 males and 55 females. The average of patients was 51 years (range 22-77 years). Study groups were assigned according to the AO fracture classification.

Results: Mean followup was 57 ± 30 months. Fracture type distribution revealed a significantly ($P < 0.001$) increased number of type B- (62.4%) compared to C-fractures. Functional assessment showed a significantly better total KSS (84.1 ± 15.6 vs. 74.7 ± 18.0; $P = 0.01$) as well as ROM (active: 124°±17° vs. 116°±15°, $P = 0.014$; passive: 126°±18° vs. 118 ± 14°, $P = 0.017$) in the B-fracture group. VAS was found to be markedly higher ($P = 0.0039$) following type C-fractures. Rating osteoarthritis secondary to a tibial plateau fracture as a function of injury severity (r = 0.485; $P < 0.001$) and relating the loss of reduction to the grade of evolving osteoarthritis (r = 0.643; $P < 0.001$) a positive correlation was found. Quality of life showed significantly improved results for Lysholm score ($P = 0.004$) following B-fractures with low overall values for the WOMAC score.

Conclusion: Presented data provide sufficient evidence that anatomic restoration of tibial plateau fractures with angular stable plate fixation result in decreased loss of reduction and declined incidence of posttraumatic osteoarthritis, thereby providing acceptable mid to long term outcome.

Key words: Angular stable locking plate, osteosynthesis, clinical results, radiologic results, tibia plateau fracture
MeSH terms: Bone fracture, tibial fracture, fracture fixation, internal, bone plates

INTRODUCTION

Fractures to the articular surface of the proximal tibia are serious injuries with a broad range of subtypes. Due to the complex anatomy including large cartilaginous surfaces, insertions of ligaments, meniscal structures and the high level of force transmission that the tibial joint surface is subjected during axial loading, its reconstruction continues to represent a major surgical challenge.[1] Among the factors known to determine the outcome, the degree of comminution, as well as the severity of accompanying soft-tissue damage, are the most important determinants.[2-4] Typical mechanisms include a combination of axial loading and angular forces, which result in a split/depression of the tibial plateau along with metaphyseal impaction and comminution.[4-6] Due to the specific anatomy of the knee joint and the high axial and varus/valgus forces that any biomechanically effective osteosynthesis has to sustain, the appropriate fracture treatment is still controversial.[6-9] Different surgical approaches have been described, and the techniques for fracture reduction and fixation have been tremendously improved recently.[10-12] Dislocated plateau fractures require an open reduction with intraarticular exposure of the fracture zone, subchondral bone grafting and screw/plate fixation.[10] Despite all reconstructive efforts osteoarthritis following tibial plateau fractures is reported to evolve in 23-44%,[8,13-16] underscoring the prognostic and socio-economic importance of these injuries. Consequently, there is an unmet clinical need for the development of effective fixation techniques and implants that minimize loss of reduction and decrease surgery-associated soft tissue trauma. Increasing the appreciation of the

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causative factors known to reduce the risk for secondary articular incongruence and implant failure has led to the development of new fixation techniques that exactly address these points and act as internal fixators.[10,13,14,17-23] Subsequent efforts resulted in the introduction of anatomically preshaped angular-stable plates that allow minimal invasive insertion and fixation of reduced articular fragments, thereby refraining from additional medial or lateral plate fixation.[17,24,25] In particular in osteoporotic bone these biomechanical advantages of angular-stable implants have been shown to significantly improve the outcome.[10,26] Although many existing reports describe treatment results after tibial plateau fractures (mostly with conventional plating),[7] very few studies have investigated results of tibial plateau fracture fixation using angular-stable implants. The drawbacks of more recent studies are small patient numbers[6,10] and missing data for functional outcome or information about the used implant type.[8]

Therefore, the present study aimed to investigate the clinical, radiological and functional results as well as disease specific quality of life following tibial plateau fractures using angular stable plate fixation.

MATERIALS AND METHODS

176 patients underwent open/closed reduction, followed by reconstructive angular stable plate fixation for tibial plateau fracture between January 1999 and June 2011. The records followed the department's standard protocol (clinical as well as radiographic followup at 1 and 6 week(s) as well as 3 and 6 month after surgery). The followup was 57.4% (15 died; not able to complete due to health problems not related to the tibial plateau fracture = 23; unreachable = 37). All patients with an incomplete followup were excluded. 101 patients were included for statistical analysis (46 male, 55 female, mean age 51 years [range 22-77 years]). The mean followup was 57.3 ± 30.4 months [range 19-154 months] [Table 1]. Throughout the entire study period angular stable implants of only one manufacturer were used (less invasive stabilizing system, 3.5 mm locking compression plate [LCP] proximal tibia, 3.5/4.5 mm L-/T-shaped LCP, Synthes GmbH, Umkirch, Germany). Surgical, functional and radiographic data including fracture pattern, type of surgical approach local and systemic complications, additional use of bone graft for defect filling, degree of soft-tissue damage, presence of compartment syndrome including the rate of performed emergency fasciotomies, were quantitatively assessed.

Operative procedure
Surgery was performed under general anesthesia on a standard radiolucent fracture table. In the case of severe soft-tissue damage or accompanying multiple injuries, a temporary knee-spanning external fixation preceded definitive surgery. In patients with G3 closed soft-tissue damage[27] primary emergency fasciotomy was performed, allowing the elevated intramuscular pressure to decline [Table 2].

Timing of surgery, as well as surgical approach, was dependent on the severity of concomitant soft-tissue damage and underlying fracture type [Figure 1]. Most type-C-fractures that have been associated with a typical

Table 1: Patients demographics

Variable	*n*=101
Gender	
Male	46
Female	55
Mean age in years (range)	51 (22-77)
Followup in month (range)	57.3 (19-154)
Injury mechanism	
Motorcycle accident	23
Car/truck accident	7
Bicycle accident	3
Pedestrian accident	13
Skiing accident	13
Simple fall	35
Sport accident	5
Attempted suicide	2
Classification	
B1	6
B2	10
B3	47
C1	8
C2	3
C3	27
Closed soft-tissue damage (Tscherne and Oestern[28])	
G1	40
G2	51
G3	7

Table 2: Need for primary stabilization and/or fasciotomy

Procedure	Yes	No	Percent of fractures
Need for external fixator			
B1	1	5	1
B2	0	10	0
B3	3	47	3
C1	3	3	3
C2	0	3	0
C3	21	6	21
Fasciotomy			
B1	1	5	1
B2	0	10	0
B3	0	47	0
C1	1	7	1
C2	0	3	0
C3	5	22	5

posteromedial fragment requiring articular reduction and buttressing were addressed with a posteromedial approach first before the lateral pathology was addressed. In such cases, two plates were used to stabilize the fracture. Exposure of the posterolateral quadrant was reached by a posterolateral approach via osteotomy of the fibula head according to the description by Lobenhoffer *et al.*[28] A strict posterior approach according to Trickey[29] was performed in fracture types with dislocated eminential insertion of the posterior cruciate ligament or posterior tibial rim avulsions.

Following anatomical reduction, stabilization of the articular surface or dislocated metaphyseal cortical fragments was done by using multidirectional lag screw fixation according to AO/ASIF (Association for the Study of Internal Fixation) principles. In the presence of articular impressions with resulting metaphyseal defect zones after reduction, defect filling was done by the use of homo/autologous bone graft. For angular stable fixation either 3.5 mm or 4.5 mm mono - or bicortical locking head screws, were used. Prophylactic

antibiotics for 24 h (Unacid® (Sultamicillin) (3 × 3 g i.v.) and Sobelin® (clindamycin) (2 × 600 mg i.v.) in case of penicillin allergy) and mechanical/pharmacological prophylaxis (intermitting pneumatic compression/body weight adapted low molecular heparin (Fraxiparin®)) against deep venous thrombosis were given routinely. Rehabilitation started at day 2 after surgery, after drain removal, with continuous passive motion and walking with partial weight bearing (15 kg) for 6-12 weeks depending on fracture type, bone quality and radiographic followup. Flexion was limited to 60° for the first 3 weeks and to 90° for another 3 weeks. Stepwise increase in weight bearing was recommended, allowing full weight bearing usually not before 6-8 weeks after surgery.

Radiographic assessment

Radiographic evaluation was done by two independent observers (trauma surgeon/radiologist) with longtime experience in diagnostic evaluation of radiographs. Radiographic studies were performed at the same institution throughout the study in order to achieve the same picture quality and magnification. Union was defined according
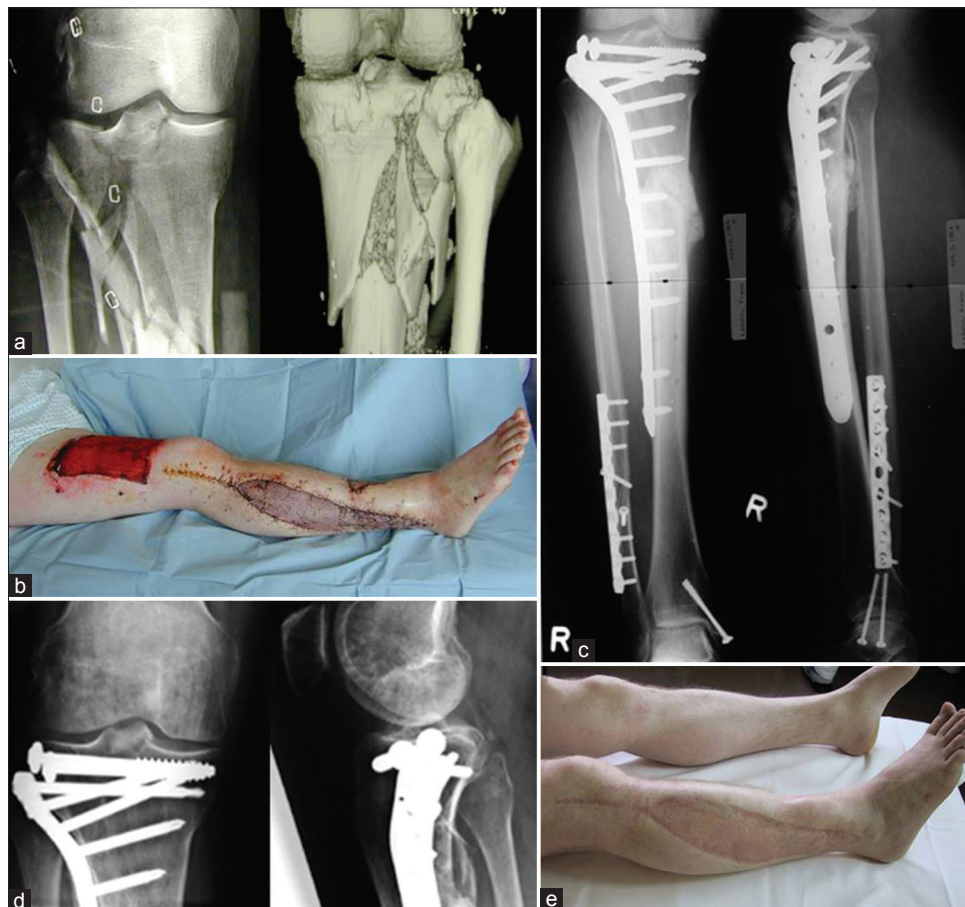

Figure 1: (a) Plain radiograph anteroposterior and 3D CT reconstructed of proximal tibia of a 46 year old male after a high velocity car accident with a type-C-fracture of the tibial plateau (b) Clinical photograph after primary dermatofasciotomy and secondary soft-tissue coverage (c) Plain radiographs anteroposterior and lateral views at 12 weeks following fixation showing union with implant in site (d and e) clinical and radiographic followup 12 month postoperative showing maintained proximal tibial alignment without any collapse and well covered soft tissue

to accepted criteria.[10] While blinded to the followup data of the outcome assessments they evaluated the quality of reduction on the early postoperative biplanar radiographs, the presence of secondary loss of reduction (loss of the postoperative condylar height of > 2 mm in the last followup radiographs, [Figure 2]) as well as the presence of osteoarthritis in the radiographs at the last followup. Posttraumatic osteoarthritis (pO) was assessed and graded according to the classification of Kellgren and Lawrence [Figure 3].[30]

Knee function and outcome assessment

The knee society score (KSS)[31] and a visual analog scale (VAS) for pain ([0-10], 0 = no pain; 10 = worst imaginable pain) for the rest/loaded condition were obtained from all patients during the last consultation. Functional outcome was evaluated using the KSS and total KSS (mean of the sum of the knee score and functional score). A total score of <60 was graded to be poor, 60-70 as fair, 71-85 as good and 86-100 as excellent.[8] For quality of life assessment the Western Ontario and McMaster Universities (WOMAC)[32,33] and Lysholm *et al.*[34-36] scores were recorded.

Data analysis

All data were recorded and analyzed using IBM® SPSS® Statistics Release 20.0 (IBM Corporation, 1 New Orchard Road, Armonk, New York 10504-1722, United States). The assumption of normality and homogeneity of variance was tested using the Kolmogorov–Smirnov test. The statistical analysis was performed using the Mann–Whitney U-test for comparison of unmatched nonparametric samples as well as the *t*-test for testing numeric samples. For one-sample testing, the one-sample bionominal test was used. Regarding correlations the Pearson or the Spearman

coefficient were used about the data scales. Differences were considered significant for *P* < 0.05.
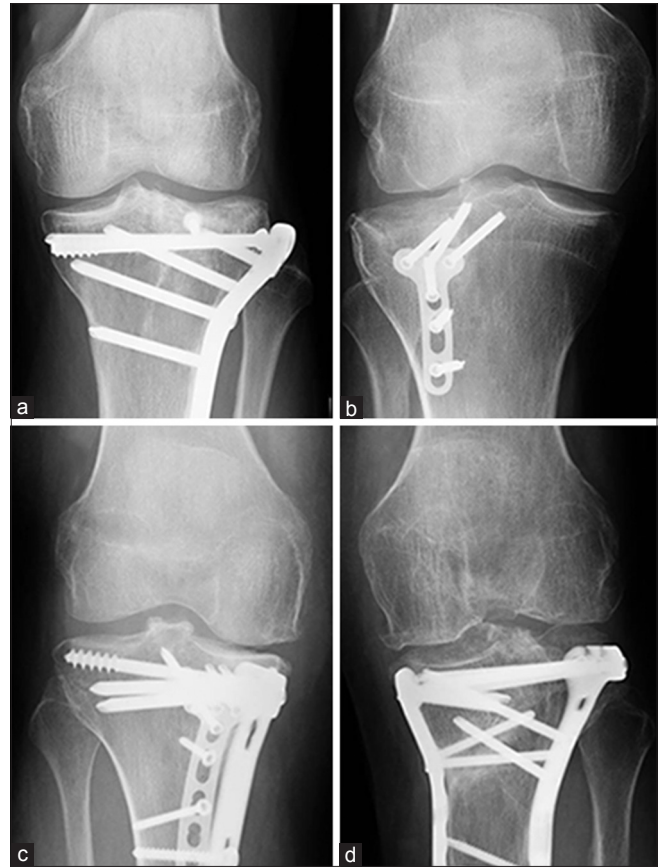

Figure 3: Followup X-rays were assessed for osteoarthritis according to the classification of Kellgren and Lawrence (a) Grade I: Subchondral sclerosis, no osteophytes, normal joint space; (b) Grade II: Little osteophytes, small changes in joint space, beginning irregularity of the joint surface; (c) Grade III: Osteophytes, decrease of joint space, irregularities of the joint surface; (d) Grade IV: Obvious destruction of the joint surface, osteophytes and distinct decrease of the joint space)
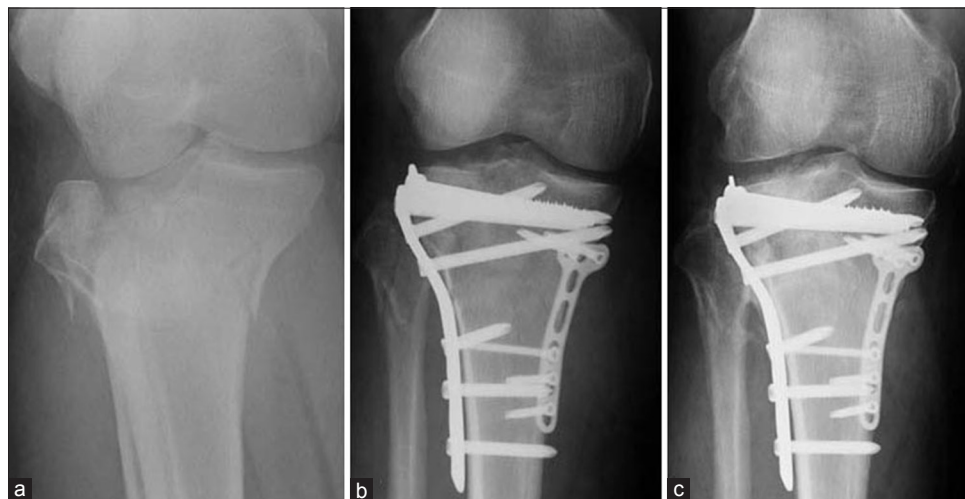

Figure 2: (a) Anteroposterior radiograph of the knee joint showing proximal tibia fracture (b) Immediate postoperative radiograph showing well reconstructed joint space and lifted depressed fragment (c) Final followup radiograph showing a loss of reduction of more than 2 mm in the condylar height compared to the initial postoperative radiograph

RESULTS

The mean hospitalization was 19.5 ± 19 days [range 3-125 days]. Fracture type distribution revealed a significantly (*P* < 0.001) increased number of type-B-fractures (62.4%) when compared to type-C-fractures (37.6%). Grouped by age most fractures were found to occur in the middle age group with a significant dominance of B-fractures (*P* = 0.045, [Figure 4]). Patient characteristics and the mechanisms of trauma are summarized in Table 1. Due to multiple injuries or severe soft tissue damage in 27.7% of all patients temporary external fixation was performed before the final surgery. Dermatofasciotomy was performed during initial surgical intervention in seven patients [Table 2]. Analysis of the different types of performed surgical approaches showed that the standard anterior-lateral approach was most frequently used (*n* = 81) [Table 3]. The soft-tissue damage correlated positively (*r* = 0.322, *P* = 0.001, [Figure 5]) with the osteoarthritis score, indicating a significant functional relation. In 69.3% of all patients, mostly B3-fractures,
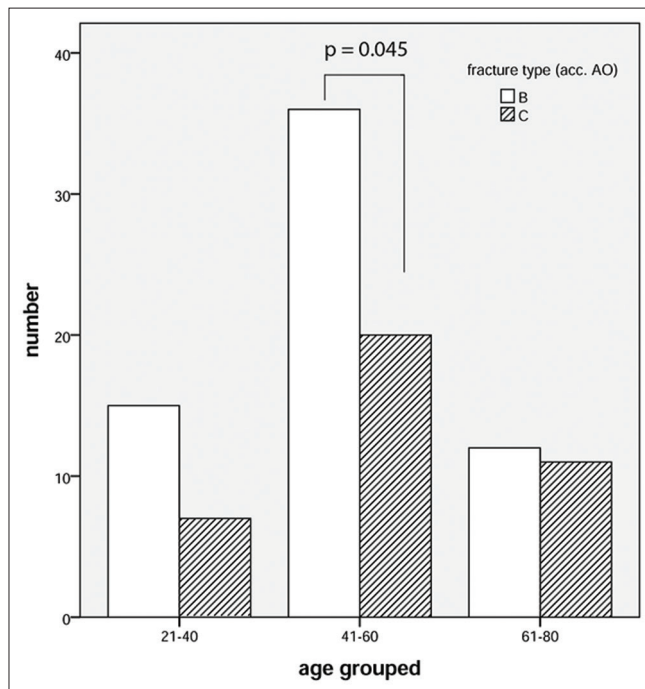
defect filling was necessary. Type of the bone substitute used for defect reconstruction did not influence final outcome.

Radiographic assessment

The overwhelming majority of the 63 B-fractures (46.5%) have been found to be B3-fractures. 38 fractures were classified as bicondylar type-C with type-C3-fractures in most cases [Table 1].

Quantitative analysis of secondary loss of reduction more than 2 mm when compared to postoperative radiographs was found in 22 (21.8%), while loss of reduction did not exceed 2 mm in 12 (11.9%) with an unchanged reduction in 67 (66.3%) patients. As expected, type B-fractures [Figure 6] were found to show significantly less loss of reduction compared to multifragmentary type C-fractures (0.43 ± 0.79 vs. 1.10 ± 1.28; *P* < 0.001). Further statistical analyses demonstrated a positive correlation [Figure 7] between loss of reduction and osteoarthritis score (*r* = 0.643; *P* < 0.001). Interestingly, results of the total KSS and the osteoarthritis score of patients who sustained a loss of reduction revealed no difference between patients with and without initial anatomic reduction.
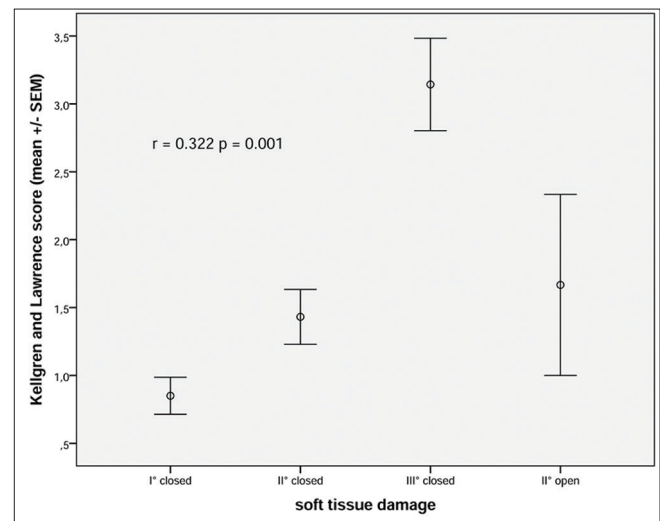

Figure 4: Fracture type distribution grouped by age, displaying peak of fracture incidence during the most active period of life

Figure 5: The risk for posttraumatic osteoarthritis markedly rises as the severity of the soft-tissue damage increases. (A significant and positive correlation between those parameters could be shown)
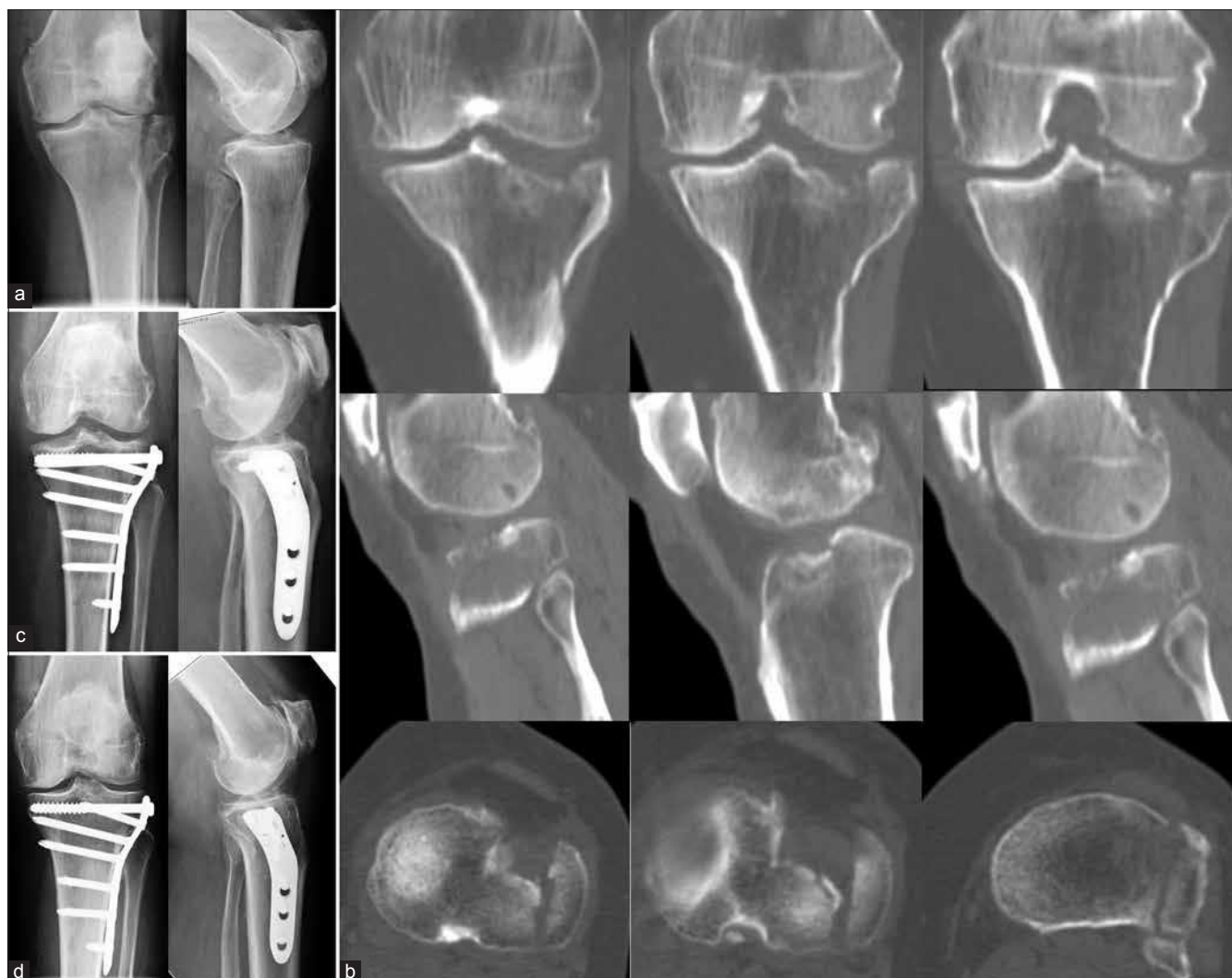
Table 3: Surgical approaches

Approach	Anterior-lateral (%)	Medial (%)	Posterior-lateral (%)	Posterior-medial (%)	Combined medial and lateral (%)	Dorsal (%)
B1	5 (83.3)	0 (0)	0 (0)	0 (0)	1 (16.7)	0 (0)
B2	10 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
B3	41 (87.2)	0 (0)	6 (12.8)	0 (0)	0 (0)	0 (1.7)
C1	6 (75)	1 (12.5)	0 (0)	0 (0)	1 (12.5)	0 (9.1)
C2	3 (100)	0 (0)	0 (0)	0 0)	0 (0)	0 (0)
C3	16 (59.3)	1 (3.7)	1 (3.7)	1 (3.7)	0 (0)	8 (29.6)

Figure 6: 79 year old female after simple fall (a) The preoperative X-ray of knee joint anteroposterior and lateral views showing a type B fracture of the lateral tibia plateau (b) Diagnostic CT-scan showing a type B3 fracture (c) Postoperative x-ray of anteroposterior and lateral views showing angular stable plating in combination with autologous bone grafting (d) Followup x-rays anteroposterior and lateral views at 54 years showing maintained reduction of tibial plateau, joint space, no collapse and implant *in situ*

In two patients, a total knee arthroplasty was performed due to severe OA. Analysis of evolving OA showed a mean score of 1.33 ± 1.32. However, 62.4% of all patients showed either no radiographic sign of OA or only grade I. Further analysis of the influence of different fracture types on incidence of OA displayed a significantly ($P < 0.001$) increased OA rate (2.21 ± 1.36 vs. 0.79 ± 0.97) following type-C-fractures. Rating the degree of pO following a tibial plateau fracture as a function of injury severity showed a positive correlation ($r = 0.485$; $P < 0.001$, [Figure 8]). Investigating the relationship between postoperative malalignment and OA revealed that valgus malalignment resulted in a significantly higher osteoarthritis score (2.82 ± 1.24 vs. 1.02 ± 1.12; $P < 0.001$) as opposed to varus malalignment that did not differ significantly (1.9 ± 1.45 vs. 1.26 ± 1.3; $P = 0,211$).

Functional assessment

The results of the total KSS was 80.6 ± 17.1 (KSS knee 80.5 ± 18.7, KSS functional 80.6 ± 19.6). Regarding the defined categories the total KSS was found to be excellent in 42.6%, good in 30.7%, fair in 8.9% and poor in 16.8%. A significant better total KSS in the B-fracture group than in the C-fracture group (84.08 ± 15.58 vs. 74.74 ± 18; $P = 0.01$, [Figure 9]) was observed and confirmed in the subscores (knee score: 83.87 ± 16.29 vs. 75 ± 21.27; $P = 0.031$, functional score: 84.29 ± 17.64 vs. 74.47 ± 21.24; $P = 0.019$).

The range of motion (ROM) was measured in degrees (active, passive). Consistently to the KSS results, significant better results for active ROM in type-B-fracture patients than those who sustained a type-C-fracture were found ($124° \pm 17°$ vs. $116° \pm 15°$; $P = 0.014$, [Figure 10]). Notably, the passive

ROM showed similar results (126° ±18° vs. 118 ± 14°; $P = 0.017$, [Figure 10]). The VAS results demonstrated low scores: 1.52 ± 1.59 (rest) and 2.78 ± 2.23 (loaded). In a subgroup analysis significant higher rest pain scores following type-C-fractures were found when compared to B-fractures (1.95 ± 1.59 vs. 1.27 ± 1.54; $P = 0.0039$). Regarding the obtained life quality scores significant better results for the B-fracture group regarding the Lysholm (75 ± 23 vs. 60 ± 25; $P = 0.004$) were observed. Considering the WOMAC the series resulted in low scores (pain: 9.5 ± 15.3 vs. 10.7 ± 11.2; stiffness: 13.3 ± 18.5 vs. 19.8 ± 17.7; daily activity: 11.9 ± 17.3 vs. 23.8 ± 21.9) without significant differences regarding the study groups.

The overall complication rate in the series was 15.8% ($n = 16$). In 7.9% ($n = 8$) of the patients, a deep venous thrombosis was diagnosed. Deep infections were seen in six (6%) patients. They were successfully treated either with local wound care/antibiotics or surgical debridement/antibiotics. One patient had a prolonged course (125 days) due to a deep joint infection after open fracture, which could be managed by programmed and serial revision surgeries and long term intravenous-antibiotics. No implants had to be removed due to persistent infection. In 2% ($n = 2$) mechanical complications (loose screws) were
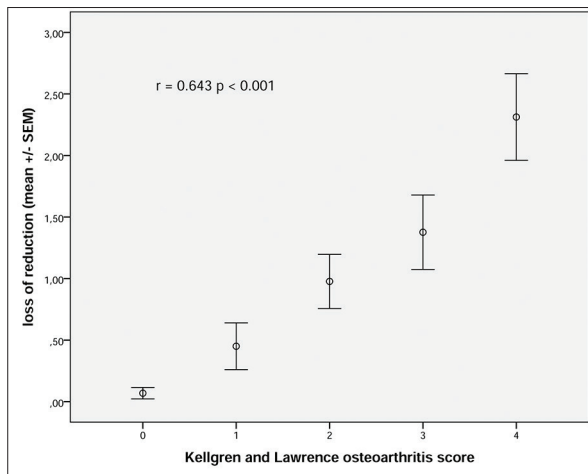

Figure 7: The higher the results of Kellgren and Lawrence (osteoarthriris) score the higher the amount of loss of reduction. This observation is underscored by the positive and significant correlative relationship indicating the tremendously prognostic importance of anatomic reduction and stable fixation
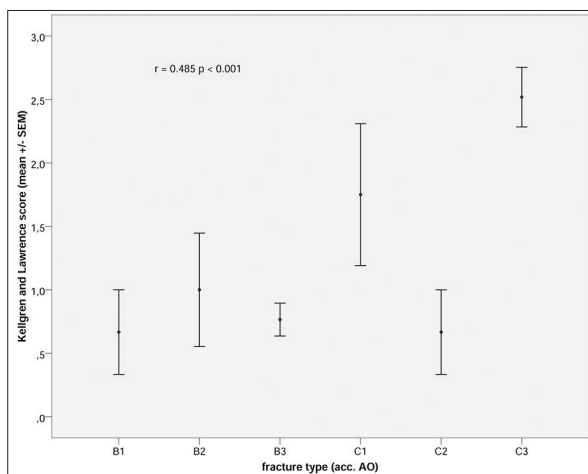

Figure 9: A significant difference between the studied groups could be shown regarding the total knee score (as defined in the text) with C-type fractures resulting in lower score values

Figure 8: The severity of the fracture type correlates positively with the results of Kellgren and Lawrence (osteoarthritis) score. This functional relationship is most likely reflecting that severe fracture types are either more difficult to reduce, and end up in decreased quality of primary anatomic reduction, or are more susceptible to early, secondary loss of the initial reduction–ultimately leading to a higher risk of posttraumatic osteoarthritis
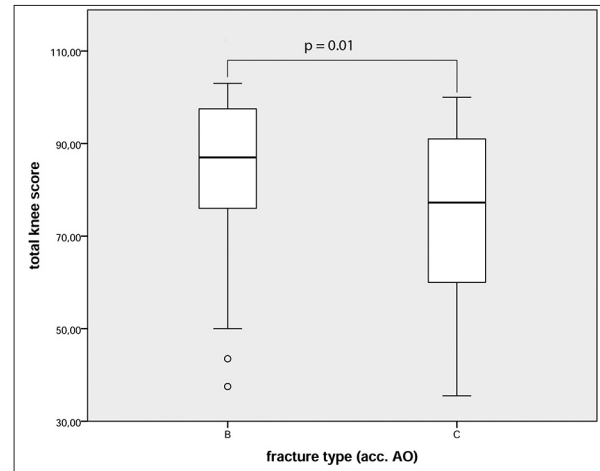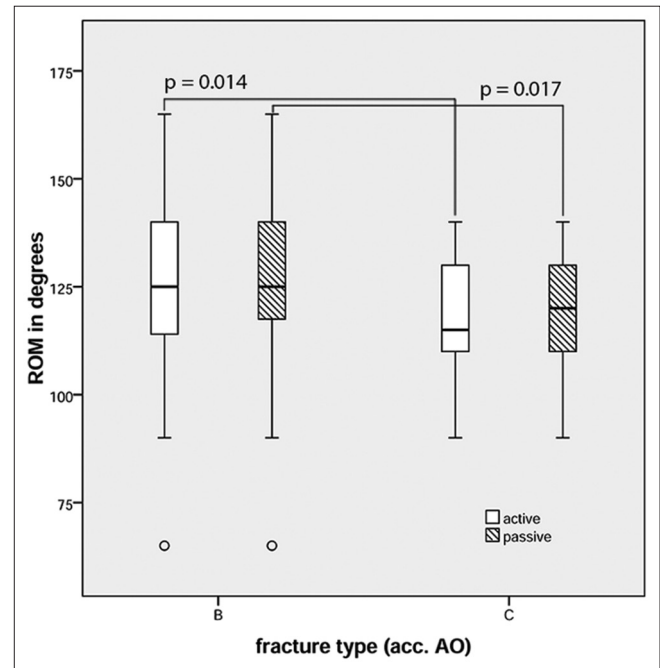

Figure 10: The findings of functional assessment demonstrate a significant better range of motion (active and passive) in the B-type fracture group and are in line with corresponding functional and radiographic results

revised, and screws either replaced or removed. Statistical analysis showed a significant higher infection rate in the C-fracture group ($P = 0.027$).

DISCUSSION

The present study provides sufficient evidence that the treatment of tibial plateau fractures using angular-stable plate fixation results in 73.3% excellent to good functional outcome. These findings are underscored by the encouraging results of the quality of life assessment. Since a positive correlation between injury severity, incidence of OA and function could be demonstrated, increasing injury severity appears to remain the most predictive factor for poor outcome. These findings are underlined by a positive correlation between the loss of reduction and the severity of resulting OA. The current study reinforces the results of previous investigations showing that particularly the degree of intraarticular comminution in tibial plateau fractures seems to result in high risk for poor outcome.[37,38]

Treatment strategies and specific indications for surgery of tibial plateau fractures continue to be a controversy.[10] Different treatment options have been established in the last decades.[4,6-8,10,21] Nonoperative treatment options are restricted to undisplaced fractures that allow early partial weight bearing and functional exercise.[11] Various clinical and experimental studies have clearly pointed out that the extent of anatomic reduction and degree of the articular congruency, determines the final outcome.[7,39] In addition to anatomic reduction, preservation of surrounding soft-tissue has shown to improve functional outcome and reduce periosteal microvascular dysfunction. Therefore, implant systems and techniques that allow minimal invasive application are expected to provide preconditions for undisturbed fracture healing. Prior to the availability of angular-stable systems, loss of articular reduction was prevented by either additional medial/lateral plating or external fixation. However, these methods require additional surgical exposure or transcutaneous pin placement.

The fact that the current body of literature is confusing regarding the outcome of surgically treated tibial fractures is most likely due to the heterogeneous inclusion criteria, different classification systems and fixation techniques or even missing functional outcome data.[37] There is little controversy about the fact that open anatomic reduction followed by stable internal fixation remains the gold standard for intraarticular fractures.[22] However, if high-energy fractures are selected for independent analysis, previous studies report unsatisfactory results in 20-50%.[40] To decrease the risk for loss of reduction, some authors have advocated the use of external fixators as a standalone

procedure or in combination with minimal invasive screw fixation.[6,22,39,41] But for high-energy trauma with comminuted intraarticular fractures this methods tolerate a significantly reduced range of knee motion varying from 85° to 107°.[39,42,43] Therefore, these discouraging results of tibial plateau fractures have been questioned by different authors. Experimental and clinical evidence[24,44-46] suggests that the external fixation as the definitive fixation method causes soft-tissue problems and is associated with an increased loss of reduction while conventional plate fixation causes marked damage to the vascular periosteal supply, profoundly delaying and impairing fracture healing.[18,19,47]

Outcome studies of tibial plateau fractures treated with angular-stable implants are currently rare. Relevant investigations that analyze these implants and their results are missing. Most of the studies on angular-stable plate fixations for tibial plateau fractures are not comparable due to the use of different scoring systems and fracture classifications. Until date, there are no studies available, which report radiographic and corresponding functional midterm results of intraarticular tibial fractures depending on the underlying fracture type. In the present study a mean loss of reduction rate in 21.8% using angular-stable implants was seen, whereas majority of reviewed studies shows up to 80% of reduction loss.[45,48,49]

Singh *et al.* reported outcome results of 22 patients treated with a combination of lateral angular-stable plating and medial external fixation of bicondylar fractures with a good ROM. Similarly, Stannard *et al.* have demonstrated outcome data with a mean followup of 21 months and were able to show a mean knee ROM of 128°. In this series, the authors did not report on the incidence of secondary loss of reduction or pO. Regarding postoperative complications they noted an infection rate of 6% and hardware problems in 18% of the patients. In the present study, a significantly better ROM in type-B-fractures compared to type-C-fractures was found. These results are comparable to previously published data.[40,50] In the current analysis initial and mild signs of osteoarthritis were found in 62.4% with a mean osteoarthritis score of 1.33 ± 1.32 which is a comparatively satisfactory to a good outcome. These data are further unique in view of the fact that up to now no other study has related individual quality of initial articular reduction, of the radiographic result to the functional and osteoarthritis outcome. In the contrary to other data[51] the present data are indicative of a significantly higher osteoarthritis score in patients with a postoperative valgus malalignment. This is supported by the positive correlation between loss of reduction and osteoarthritis score as the majority of tibial plateau fractures affect the lateral plateau. While radiographic changes are reported with a variance of 17-83%,[8] functional outcome data using the KSS were presented by Manidakis *et al.* with

69% good, 24% fair and 7% poor results. Other authors report good/excellent scores in up to 65-89%,[49,51,52] which are confirmed by the current data. The complication rate of the present study is comparable to previously reported data (3-32%).[46,48] Type C-fractures were found to result in a worse outcome regarding the incidence, the severity of osteoarthritis and the functional scores.

The limitations of the study. First, is that it is of a retrospective character with known restrictions. Moreover, mean followup period was <10 years which rather represents midterm results.

We conclude that anatomic restoration of tibial plateau fractures and consecutive angular-stable fixation results in minimized rate of implant failure, effective decrease on loss of reduction and declined incidence of posttraumatic arthritis, thereby providing acceptable midterm functional outcome.

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