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Comparison of the pre-shaped anatomical locking plate of 3.5 mm versus 4.5 mm for the treatment of tibial plateau fractures

Matthieu Ehlinger · Benjamin Adamczewski ·
Michel Rahmé · Philippe Adam · Francois Bonnomet

Abstract

Purpose Treatment of tibial plateau fractures is discussed. A retrospective comparative study of fractures treated with an anatomical locking plate of 4.5 mm or 3.5 mm. Our hypothesis is that the 3.5 mm plates give an equivalent hold of fractures with comparable results and better clinical tolerance.

Methods From May 2010 to October 2011, 18 patients were operated on using a 4.5-mm LCP™ anatomical plate (group A) and 20 patients received a 3.5-mm LCP™ anatomical plate (group B). Groups were comparable. One fracture was open.

Results For the Group A, 14 patients had a follow up of 35.3 months and for the Group B, 16 patients had a follow up of 27 months. Mobility was comparable in both groups. The Hospital for Special Surgery (HSS) score was 86.4 versus 80.6, the Lysholm score was 83.6 versus 77 for groups A and B respectively. Consolidation was 3.25 months versus 3.35 months and mean axis was 183.1° versus 181.6° for groups A and B. Mechanical axes during revision were statistically different to the controlateral axes. One secondary displacement was noted in group A and one secondary displacement in group B. Group A had eight patients reporting discomfort with the material versus three in group B ($p < 0.05$).

Conclusion The hypothesis is proven. In regards to the results, there is no significant difference between the two groups but the clinical tolerance was better in group B. More time is needed in the long term to better evaluate these severe fractures.

Keywords Proximal tibia · Fracture · Articular fracture · Locking plate

M. Ehlinger (✉) · B. Adamczewski · M. Rahmé · P. Adam ·
F. Bonnomet
Orthopedics, Hopital de Hautepierre, Strasbourg, France
e-mail: matthieu.ehlinger@chru-strasbourg.fr

Introduction

Tibial plateau fractures are rare, with a frequency of 1.2 % [1]. There is no consensus in the surgical management of simple fractures, whereas the "gold standard" treatment for complex fractures is plate osteosynthesis [2–10]. Nonetheless, there is no consensus on the type of assembling to be carried out for complex fractures: medial plate, double plate, standard or locking plate, 4.5-mm plates or 3.5-mm plates. Some authors recommend the use of a medial plate once the medial tibial plateau is affected [2–4], guaranteeing better axial resistance. Yoo et al. [5] and Jiang et al. [6] demonstrated that a standard double plate had a better mechanical resistance to that obtained by an unique locking plate, while Mueller et al. [7], Gosling et al. [8, 9] and Higgins et al. [10] proved experimentally and clinically the reliability of a unique lateral locking plate.

Pre-shaped plates theoretically facilitate reduction and improve clinical tolerance, but 4.5 mm plates are often voluminous and cumbersome. Recently Hasan et al. [11] compared the mechanical properties of 3.5-mm and 4.5-mm locking plates with a bicondylar tibial plateau model. No difference was noticed in cyclic loading or for elastic and plastic deformation, nevertheless, 4.5-mm plates are significantly more resistant in terms of axial loading but only for Schatzker V fractures [12]. The authors concluded in favour of 3.5-mm plates due to their comparable mechanical resistance and their clinical lower-profile. To our knowledge, no study has compared the results of tibial plateau fracture synthesis using a 3.5-mm locking pre-shaped anatomical plate or a 4.5-mm locking pre-shaped anatomical plate. The objective of this study was to demonstrate the radio-clinical results in the medium term of these two therapeutic modalities by specifically analyzing the solidness of the assembly and the clinical tolerance. Our hypothesis was based on data from literature that radioclinical results were comparable between 3.5-mm and 4.5-mm plates concerning post-reduction stability with time, but a better clinical tolerance for 3.5-mm plates.

Materials and methods

Fractures in this continuous retrospective series (from May 2010 to October 2011) were of traumatic cause. Fractures of open growth plates and pathologic fractures were excluded. Thirty-eight patients were included and distributed in two groups: group A (4.5-mm plates) (Fig. 1) and group B (3.5-mm plates) (Fig. 2). Both groups were comparable in terms of number of cases, age, sex and type of Schatzker fracture [12]. Both groups were consecutive. There were more road accidents in group B (13 versus 5). Fifteen patients were retired (group A=6, group B =9) and 23 were still in active service (group A= 12, group B=11). None of the fractures presented initially with vasculo-neurological complications and one fracture in group A was open stage II according to Gustilo [13] (Table 1).

Surgical procedure

Surgical delay was comparable in the two groups. In all cases, the surgeon was a senior physician, there were five different surgeons. The patients were always made to lie in the supine position on a standard table with a tourniquet in almost every case (group A= 18/18, group B=19/20). When a lateral plate was placed, the surgical approach was a classic lateral one with submeniscal

Fig. 1 Clinical example of a locking pre-shaped anatomical 4.5-mm plate, left side. **a**, **b** Lateral and AP pre-operative views, fracture type Schatzker II. **c**, **d** Fracture at consolidation (follow-up of 40 months)

athrotomy, and when a medial plate was placed, the surgical approach was a medial retro-ligamentary. The choice of the surgical approach and the kind of surgery was left to the preference of the operator on the basis of a systematic pre-operative CT scan. The plates used were anatomical locking plates LCP® (Depuy-Synthes, Etupes, France). For the 3.5-mm plates there was a lateral (ref. 02.124.20/21) or a medial (ref. 239.95/96) anatomic model, and for 4.5-mm plates (ref. 222.22) there was only a lateral anatomic one. Plates were always in titanium. In comparison with standard stainless plates, we choose anatomical locking plates because the screws had a better bony fixation, independent of bone quality, and because titanium gives elasticity to the assemblage that benefits consolidation. The choice of the plate (3.5 or 4.5 mm) was according to the surgeon's preference and independent of the type of fracture. In group A, the plates were always unique: 16 times in lateral and twice in medial. In group B, a unique lateral plate was used ten times, a unique medial plate four times and a double plate six times. In order to overcome the impossibility of compression by the locking screws, an additional initial screwing was done 14 times (seven times in each group). A graft was used 12 times (group A = six times with a bone substitute) (group B = 6: three times with a substitute and three times with a lyophilized bone). The average operating time was comparable for each group, 89.5 minutes in group A and 107 minutes in group B. A minimal postsurgical non-weight-bearing period of six weeks and immediate mobilization on an athromotor in a sector of 0–90° were prescribed in the immediate follow-up. Free mobilisation was allowed beyond six weeks. Total weight-bearing permission depended on radiologic imaging. It was 8.6 weeks (six to 16, med eight) in group A, and nine weeks (eight to 12, med eight) in group B (Table 2).

Evaluation

Evaluation was retrospective. We compared the immediate post-operative X-rays with those obtained at the consolidation time. An initial articular reduction default was considered as pathologic if it was greater than 2 mm [2–10]. Consolidation was considered as achieved when the whole fracture line had disappeared anteroposteriorly and laterally. Follow-up study was completed with a pangonometry. Deficiency in axis was considered as pathologic when pangonometry showed a global deformation superior to 5° compared to 180°. Signs of osteoarthritis were looked for over a long period of time. On review, clinical evaluation included a measure of mobility and functional evaluation using scores like Lysholm [15] and Hospital for Special Surgery (HSS) [16]. Patients were asked a satisfaction index ranging from (very good, good, worse). Observed complications were compiled.

Statistical analysis

For statistical results, a Student t-test was used with a positivity threshold of $p<0.05$ to compare for continuous variables
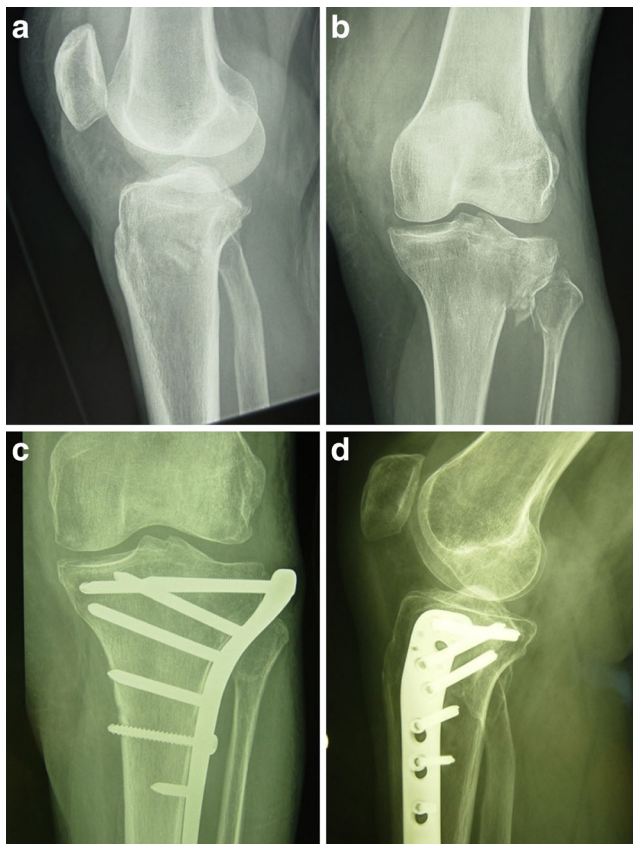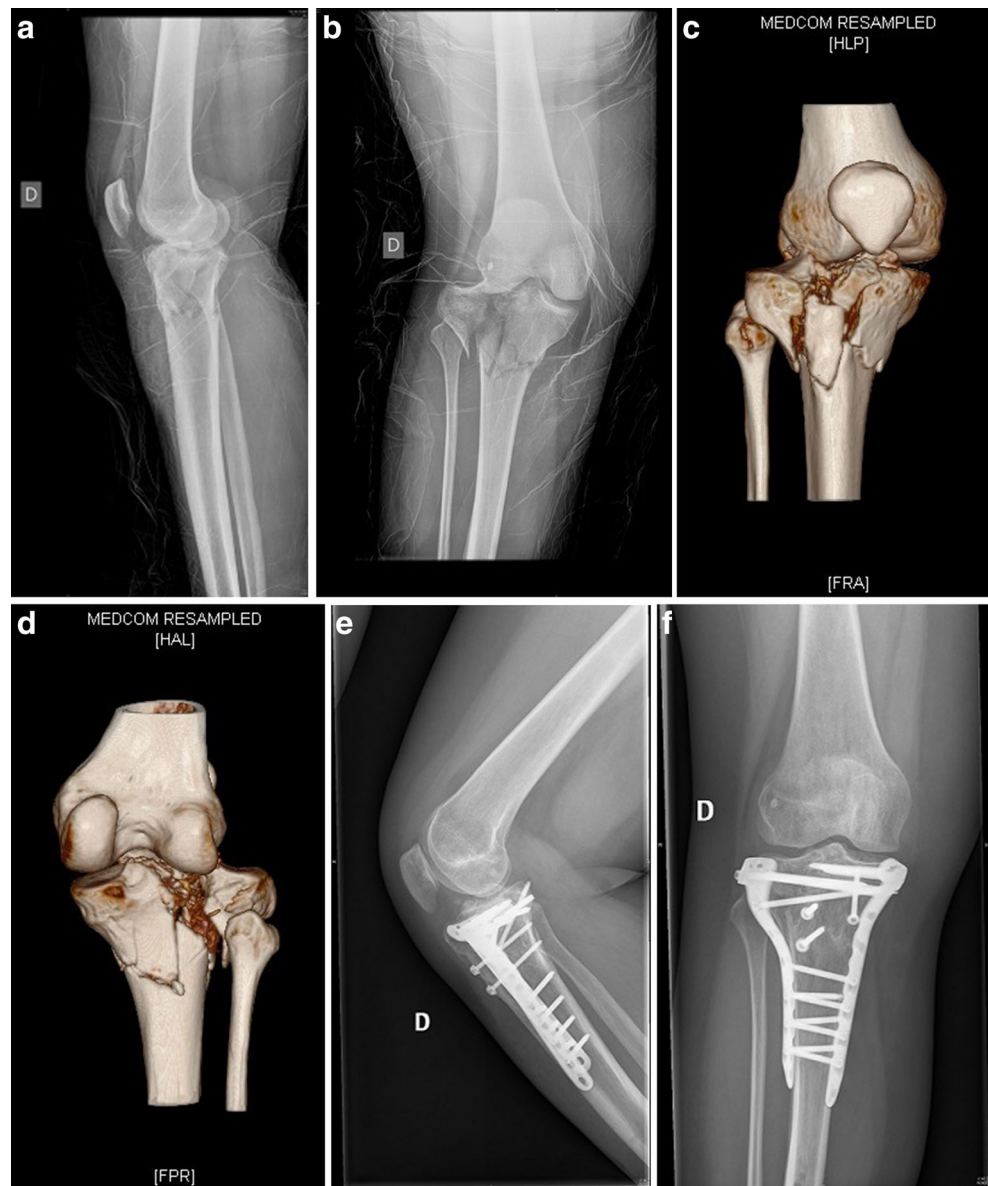
Fig. 2 Clinical example of a locking pre-shaped anatomical 3.5-mm plate, right side. **a, b** Lateral and AP pre-operative views, fracture Schatzker V. **c, d** Pre-operative tomodensitometry. **e, f** Fracture at consolidation (follow-up of 28 months)

(quantitative variables). A chi-squared test was used for categorical variables between the two groups with a positivity threshold of $p<0.05$.

Results

At the follow-up, one patient was lost in each group before estimating consolidation. In group A, 14 patients were reviewed (22 % were lost to follow-up) at a mean of 35.3 months (26–43, med 24), and 16 were reviewed in group B (20 % were lost to follow-up) at a mean of 27 months (19.5–38, med 27.5). The bigger mean of group A was due to the recent use of 3.5-mm plates in our usual practice.

Clinical results were presented in Table 3. Concerning group A, seven patients returned to the same level of their usual activity in an average time of four months (3–8) and two underwent professional rehabilitation. In group B, five returned to their same level of activity in an average time of 3.8 months (three to six) and three underwent rehabilitation. The remaining patients of the two groups were retired. No statistical difference was observed.

Radiologic results were presented in Table 4. In group A, a case of nonunion was reoperated at 5.5 months using an autologous decortications graft with a favorable outcome at three months post graft. During review, mechanical axis of lower limb in group A was 183.1° on average, for a contralateral mechanical axis of 179.5° ($p<0.02$). Four axial valgus deformity were greater than 5° (6°, 6.8°, and 14°) were observed. Four times more major modification of mechanical axis (>5°) were observed compared to the healthy side (8°, 8°, 9°, 11°), without evolving into osteoarthritis. During review,

Table 1 Series data

	Group A (4.5 mm)	Group B (3.5 mm)
Cases	18	20
Age (years)	51.9 (26–68, med 53)	51.7 (22–78, med 79)
Sex	Female: 8 Male : 10	Female: 10 Male: 10
Side	Right: 9 Left: 9	Right: 12 Left: 8
Type of trauma	Motor accident: 5 Domestic fall: 6 High energy: 4 Sports: 3	Motor accident: 13 Domestic fall: 5 High energy: 2
Schatzker [14]	Type I: 1 Type II: 6 Type III: 1 Type IV: 1 Type V: 6 Type VI: 3	Type I: 1 Type II: 6 Type III: 1 Type IV: 2 Type V: 8 Type VI: 2
Delay of operation (days)	2.8 (1–12, med 1.5)	3.7 (1–13, med 2.5)

mechanical axis of lower limb in group B was 181.6° on average for a contralateral mechanical axis of 178° ($p<0.002$), with an additional case of more than 5° valgus at 12°. Three times more major modification of mechanical axis (>5°) were observed compared with the healthy side with a difference of 10°, 12° and 12° respectively. Once, this led to an early case of osteoarthritis and twice the clinical results were disappointing with a HSS score of 58 and 45 respectively and a Lysholm score of 50 and 47 respectively. No statistical difference was noted between the two groups.

Several complications were noted. In group A, four complications were observed in three patients: one deep venous thrombosis, one spontaneous resolving algodystrophy, one immediate postoperative compartment syndrome requiring emergent fasciotomy with a favorable outcome in the end, and a spontaneous and complete regression of paraesthesia involving the common fibular nerve. In group B, three

complications were observed in three patients: one algodystrophy, one non-infectious dissension of scar tissue was treated locally with a satisfactory evolution and one *Enterobacter cloacae* arthritis developed on the 7th postoperative day and was treated in another establishment with no further information on its outcome.

Discomfort of osteosynthesis material was significantly ($p<0.05$) more common in group A ($n=8/14$, 57 %) with four hardware removals (28.6 %) on average at 19.5 months without any complication. In group B, material discomfort was observed three times (3/16, 18.7 %), leading to two removals (12.5 %). A third one was carried out in view of a programmed prosthetic knee replacement without any clinically reported discomfort.

Discussion

The most important finding of the present study was the comparable radio-clinical results between 3.5-mm and 4.5-mm locking pre-shaped anatomical plates and the better clinical tolerance of 3.5-mm plates.

Range of motion recuperation and functional recuperation were similar, responding more to the severity of the lesions rather than the type of material used. Radiologic results were equally comparable in terms of rate and time of consolidation but also of quality of articular reduction, which highlights the stability of the reduction for the two types of implants, thus confirming biomechanical data [11].

Our hypothesis was confirmed. Thus we are convinced of the benefits of the use of a 3.5-mm locking pre-shaped plate on functional recovery and stability of fracture.

There is no consensus in the literature concerning the strategy for surgical management of proximal tibial fractures: one or two plates? Standard or locking? Experimental data in literature are divergent. Based on an experimental point of view for medial fractures, the plate has to be medial with a console effect [2–4]. For more complex fractures, Yoo et al. [5]

Table 2 Surgical data

	Group A (4.5 mm)	Group B (3.5 mm)	p value
Delay of operation (days)	2.8 (1–12, med 1.5)	3.7 (1–13, med 2.5)	–
Tourniquet	15/18	19/20	–
One plate	16 lateral: (1 type I, 6 type II, 1 type III, 5 type V, 3 type VI) 2 medial: (1 type IV, 1 type V)	10 lateral: (1 type I, 6 type II, 1 type III, 2 type V) 4 medial: (2 type IV, 2 type VI)	–
Two plates	0	6 (6 types V)	–
Additional screw	7 (5 type V, 2 type VI)	7 (1 type II, 1 type IV, 4 type V, 1 type VI)	–
Graft	6 (3 type II, 1 type III, 2 type V)	6 (3 type II, 2 type V, 1 type VI)	–
Time of surgery (min)	89.5 (43–172, med 83.5)	107 (43–230, med 105.5)	$p=0.15$, NS
Full weight bearing (weeks)	8.6 (6–16, med 8)	9 (8–12, med 8)	$p=0.26$, NS

NS non-significant

Table 3 Clinical results

	Group A (4.5 mm)	Group B (3.5 mm)	p value
Cases	14	16	–
Follow up (month)	35.3 (26–43, med 24)	27 (19.5–38, med 27.5)	–
Flexion (°)	127.5 (100–140, med 130)	120 (80–140, med 120)	p=0.14, NS
Extension (°)	3 flessum (5, 5, 10)	3 flessum (5, 5, 10)	–
HSS [17]	86.4 (71–99, med 89)	80.6 (45–96, med 83.5)	p=0.17, NS
Lysholm [18]	83.6 (54–100, med 90)	77 (47–100, med 82.5)	p=0.28, NS
Satisfaction	Very good: 5	Very good: 4	–
	Good: 7	Good: 11	
	Worse: 2	Worse: 1	

NS non-significant

recommended the use of a double plate. They compared experimentally on synthetic bones: 3.5-mm lateral plates, medial double-plate LC-DCP, double plate with a third medial tube plate and a lateral LC-DCP, a lateral locking plate and a LISS plate. They concluded on the superiority of the association between 3.5-mm lateral plate and the 3.5-mm medial third tube plate when the assembly was exposed to axial stress. Jiang et al. [6] showed similar experimental results. Nonetheless, in other biomechanical studies, no difference was observed in resistance during compression when a unique lateral locking plate was used comparatively to an assembly with two plates [7, 8, 10].

Recent experimental studies have shown precisely the utilization of locking plates in these indications. For Estes et al. [19], there is no difference axially between the assembly "fully locked" and the "mixed type of assembly". For Cullen et al. [20], the use of poly-axial locking screws offered better rigidity and better resistance to rupture. Finally, Lindeque and Baldini [21] compared different locking systems, and concluded that the Synthes® and DePuy® systems had better resistance to wear in contrast to the Zimmer® system, but that the DePuy® system had a resistance to rupture better than the other two. Our radiologic results confirm these experimental data, even though a secondary displacement occurred in each group. Fracture stability was achieved irrespective of the type of plate, thus validating our hypothesis. Analysis of mechanical axes of lower limbs during review revealed metaphyseal abnormality, evaluation of the articular area was judged to be good. There is no particular type of fracture at risk with three type II, one type III, two type V and one type VI. The most important point during review was the significant difference in mechanical axis between the fractured side and the contralateral side for both implants, highlighting a lack of attention to detail during the restitution of the mechanical axis. The anatomic characteristics of the plates should reduce this risk, provided that they are used as a reduction mold with articular epiphyseal screw parallelism associated with cortical tibial plate parallelism.

Concerning radiologic and clinical results, Barei et al. [22] concluded that conventional osteosynthesis with two plates was a sure technique with satisfying results with no more complications. However, the use of two plates can expose difficulties when implanting a total knee arthroplasty, with the obligation to remove the plates through two incisions and a longer surgery time. Some authors proposed a multiplate reconstruction for severe bicondylar tibial plateau fracture, especially for young adults, with three to five plates [23]. In order to reduce cutaneous and septic complications a double mini-invasive surgical access was proposed. Oh et al. [24] reported 21 excellent clinical results out of 23 cases but 9.35 % of global malunion. These authors insisted on the absence of iatrogenia in this mini-invasive surgical technique.

Table 4 Radiological results

	Group A (4.5 mm)	Group B (3.5 mm)	p value
Consolidation	94 % (16/17)	100 % (19/19)	p=0.89, NS
Delay of consolidation (month)	3.25 (2.5–6, med 3)	3.35 (3–4, med 3)	p=0.35, NS
Postoperative immediate anatomical reduction	N=18 Anatomic: 15 >2 mm deformation: 3	N=20 Anatomic: 18 >2 mm deformation: 2	–
Loss of reduction at consolidation	1/17 (5.9 %)	1/19 (5.3 %)	–
HKA angle at revision (°)	N=14 183.1 (178–194, med 183)	N=16 181.6 (177.5–192, med 181)	p=0.49, NS
Arthrosis	2/14	1/16	–

N=cases, *NS* non-significant, *HKA angle* hip–knee–ankle angle

We do not have any experience in mini-invasive surgery for articular fractures, of which we remain convinced in the interest of direct control reduction. Despite this precaution, we observed defects in the mechanical axis during review, even though the articular area remained unaffected. To our knowledge only one clinical study (84 cases) compared standard double-plate osteosynthesis to lateral locking plate [18]. The results are statistically comparable in terms of reduction loss, material rupture, rate of infection, rate of consolidation and HSS functional score. Radiologic results were not in favor of the LISS locking system with an explanation for statistical difference for defects being due to the mini-invasive characteristics of the surgery. According to our experience, one lateral 4.5-mm locking plate is useful and gives very good radiological and clinical results, especially if there is a medial tibial plateau component [25]. In this series, the choice of plate was not done according to fracture type but to the surgeon's philosophy, and in case of two plates it was easier with 3.5-mm rather 4.5-mm plates. But we think that using locking plates changes our point of view about single or double plates. Publications showed satisfying radio-clinical results for the treatment of articular proximal tibial using locking plates [14, 17, 26–30], but to our knowledge none show comparative results for 3.5-mm plates. The rate of malunion ranged from 0 to 23 % and the rate of correction loss from 0 to 14 %. In our series, the observed rates were comparable. Clinical results seen in the literature are comparable to ours, emphasizing the severity of these lesions and the absolute necessity of a quality reduction [31, 32]. Mobility and functional scores that we reported were satisfying and identical irrespective of the type of plate. Thus, according to our experience, in the short term there were few repercussions on the existence of malunions.

To our knowledge, the clinical tolerance of locking plates was rarely studied, even though this was discusses by Hasan et al. [11]. The different studies showed at the most the number of material ablations, with different figures ranging from 5 to 11 % [14, 17, 25–36]. Concerning clinical tolerance, our hypothesis was confirmed with a better clinical tolerance for 3.5-mm plates, which has never been discussed in the literature.

Given the articular characteristics of these fractures, we do not recommend nailing in these cases. To our knowledge, there are no studies that compare nailing to locking plates for articular fractures of the tibial plateau. In a radiological and technical comparative study of centro-medullary nailing versus 4.5-mm locking anatomic plates in the treatment of proximal tibial extra-articular fractures, Lindvall et al. [37] demonstrated a higher rate of clinical intolerance for plates with three times more implant removal. The results of this series underline the difficulty in treating proximal tibial fractures with nailing with more malreduction. Indeed, apex anterior malreduction deformity occurred twice in the nailing group and additional surgical techniques were frequently used during reduction within the nailing group.

This study has several limitations. It was a retrospective study. The series was heterogeneous, with different surgeons and a non-standardized surgical procedure. The number of cases is low, but the two groups were comparable and it was a rare fracture. Follow-up time was limited to evaluate osteoarthritis evolution and there was a lot of cases lost to follow-up; but there were some young people in this series who left their first address. Nevertheless, this study allows confirmation of the hypothesis.

Conclusion

The objective of this study was to compare the radio-clinical results, in the medium term, of tibial plateau fractures treated by 3.5-mm or 4.5-mm locking plates, to analyze the solidness of the assembly and the clinical tolerance. Our hypothesis was that radio-clinical results were comparable between the two types of plates concerning post reduction stability with time, but with a better clinical tolerance for 3.5-mm plates. Our hypothesis was confirmed. In conclusion, we can recommend the use of 3.5-locking plates for all tibial plateau fractures. One or two plates were discussed case by case and according the surgeon's philosophy.

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