International Orthopaedics (2019) 43:2807–2815
https://doi.org/10.1007/s00264-019-04337-7

ORIGINAL PAPER

Outcomes after locked plating of displaced patella fractures: a prospective case series

Alexander Ellwein[1,2] · Helmut Lill[2] · Rony-Orijit DeyHazra[2] · Tomas Smith[1] · Jan Christoph Katthagen[3]

Received: 19 November 2018 / Accepted: 12 April 2019 / Published online: 30 April 2019

Abstract

Purpose Tension band wiring remains a common treatment for patella fractures, but complication rates are high, with unsatisfactory results. The purpose of this observation study was to evaluate clinical results and complication rates of a novel patella locking plate fixation.

Methods Twenty patients (mean age, 59.2 ± 18 years) with displaced patella fractures were prospectively enrolled. Range of motion, knee scores (Tegner, Lysholm, Kujala), complications, and revision surgeries were assessed six weeks, six months, 12 months, and 24 months after surgery. Results were compared to the situation before trauma in regards to the time of follow-up using a paired sample *t* test.

Results According to the OTA classification, the fractures were classified as follows: one A1, four C1, six C2, and nine C3. Range of motion improved from 121° after six weeks to 140°, 141°, and 143° within the follow-up period. While the Tegner, Lysholm, and Kujala scores were 4.1/97/97, respectively, before trauma, they improved from 2.6/80/89 to 3.6/94/89, 3.7/95/94, and 4.1/97/97 within the follow-up period. Three patients had a complication (15%): one fracture dislocation, one reactive bursitis, and one renewed fracture. Four patients reported discomfort or anterior knee pain especially when kneeling on the implant.

Conclusions The patella locking plate is a safe and effective treatment for patella fractures, including comminuted fractures. Function can be restored within six months after surgery, and the complication rate is low. Nonetheless, the implant can cause discomfort or anterior knee pain especially when kneeling, which can necessitate an implant removal.

Keywords Patella fracture · Locking plate · Tension band wiring · Complication · SuturePlate

Introduction

Fractures of the patella account for approximately 3.5% of all lower extremity fractures [1], with an incidence of 1.2–6.1 per 100,000 inhabitants per year [2, 3], mostly as result of a direct, high-energy trauma. Fractures with a maximum dislocation of 2 mm, preserved extension capability of the knee and stable fracture situation are suitable for non-operative treatment [4–6]. For all other fractures, an operative treatment is indicated. During the healing period, which is assumed to be eight to 12 weeks, the knee performs about 100,000 cycles [4, 7]. Since forces on the patellofemoral joint equal body weight at 30° flexion, and increase to four to eight times body weight at 60° or 90° flexion, a fracture fixation is required, which adequately compensates for those forces during this time period [8–10].

Tension band wiring is a commonly used treatment for transverse fractures. In contrast to common opinion, extensor forces are not converted into compressive forces. Labitzke performed a force vector analysis, which showed gapping and distraction at the articular surface during active extension [11]. Newer biomechanical evaluations support these findings and consider tension band wiring more as a static than a dynamic fixation principle [12]. Furthermore, complication rates

✉ Alexander Ellwein
alexander.ellwein@diakovere.de

[1] Department for Orthopaedic Surgery, Medical School Hannover, DIAKOVERE Annastift, Anna-von-Borries-Straße 1-7, 30625 Hannover, Germany

[2] Department for Orthopaedic Surgery and Traumatology, DIAKOVERE Friederikenstift, Humboldtstr. 5, 30169 Hannover, Germany

[3] Department of Trauma, Hand and Reconstructive Surgery, University Hospital Münster, Albert-Schweitzer-Campus, building W1, 48149 Münster, Germany

are high, with 22–56% of cases resulting in revision rates of up to 55% owing to K-wire migration with perforation of the skin, loss of reduction, breakage of the implant, or soft tissue irritation [13–16].

Screw fixation is an alternative that offers higher biomechanical stability. While tension band wiring failed at 395 N in the biomechanical evaluation performed by Carpenter et al., screw fixation was stable up to 554 N [17]. The highest stability (732 N) was achieved by combining tension band wiring and screw fixation, using cannulated screws [17]. However, these types of fracture fixation are limited in the treatment of comminuted fractures, and full weight bearing is normally not allowed up to six weeks post-operatively.

The patella SuturePlate™ (Fa. Arthrex, Naples, FL, USA) is a novel locking plate, which addresses the aforementioned limitations. Its multiple screw holes supposedly offer adequate stabilization of multi-fragment fractures. Furthermore, biomechanical evaluations showed failure of the plate at 1052 N [18]. This is expected to allow immediate full weight bearing with accelerated rehabilitation and return to activity. The anatomical design and improved stability will reduce complication and revision rates.

So far, there is only one study presenting clinical results to this implant [19]. Due to its inhomogeneous study population with primary fracture treatment, revision surgeries and fracture treatment after total knee arthroplasty as well as various follow-up times (mean 38 months; range 7–75 months) despite a prospective study design, further clinical evaluations and complications analyses are necessary. Furthermore, to our knowledge, there is no prospective study evaluating clinical results after operatively treated patella fractures at diverse, defined follow-up times. This should give further knowledge regarding the process of rehabilitation.

Therefore, the purpose of this study was to prospectively evaluate clinical results at prescribed follow-up times as well as complications and revision surgeries for patients with patella fractures treated with this novel locking plate. The primary endpoint was set as the evaluation of the functional result of the knee regarding to its range of motion. This was statistically compared to the uninjured opposite side at different follow-up times. The secondary endpoint was defined as complication, which made a revision surgery necessary.

Materials and methods

This prospective observational study was performed at a level I trauma centre. The local ethics committee approved the study protocol. All work complied with the principles laid down in the Declaration of Helsinki. The study was registered at ClinicalTrial.gov (NCT02015975). All included patients provided written informed consent.

Between April 2013 and March 2016, all patients who presented at our department with a patella fracture were recorded (Fig. 1). Inclusion criteria for this study were as follows: aged 18 years or older, indication for surgery, and treatment with a patella SuturePlate™. Indication for surgery was fracture dislocation of more than 2 mm, loss of capability for knee extension, and comminuted and open fractures. Patients with pre-existing functional limitations of the knee, or who failed to attend follow-up appointments, were excluded from this study.

All fractures were classified according to the OTA classification [20], by reviewing the pre-operative radiographs. Subjective scores for activity and knee function (Tegner Activity Scale score, Lysholm score, Kujala score) were requested at the first visit after inclusion with regard to the situation before trauma. Peri-operative data were assessed by reviewing each patient's medical record, surgery protocol, and post-operative radiographs. All patients were invited to follow-up examinations six weeks, six months, 12 months, and 24 months after surgery. The functional outcome was evaluated in relation to range of motion and compared to range of motion on the uninjured side. The subjective scores were again requested and compared to the situation before trauma. Finally, pain situation, complaints, complications, and revision surgeries were evaluated. The radiological analysis and all follow-up examinations were performed by the principle investigator of the study (A.E.).

All data were analyzed by means of descriptive statistics. The functional outcome was statistically compared to the situation before trauma at each follow-up time point using a paired-sample t test. P values less than 0.05 were considered to be statistically significant. Statistical analyses were performed using SPSS for MAC software (IBM SPSS Statistics 22, Chicago, IL, USA).

Surgical technique

For surgery, the patient was placed in a supine position on the operating table. A tourniquet was used according to the preference of the surgeon. The fracture was approached by a central anterior skin incision just above the patella (Fig. 2). An arthrotomy was performed to relieve an intra-articular haemarthrosis and verify the fracture reposition. The fracture was reduced by the use of reposition forceps and K-wires. The anatomical reposition was guided by digital palpation of the retropatellar joint surface through the arthrotomy. If necessary, additional lag screws were inserted to stabilize the fracture. The locking plate was positioned onto the patella. Arrow- or star-shaped plates are available. Furthermore, the StarPlate® is available in three different sizes. Due to the shape of the plate and its position of the plate holes, the ArrowPlate® was predominantly used for transverse or distal pole fractures, and the StarPlate® was preferred for multi-fragment fractures. The

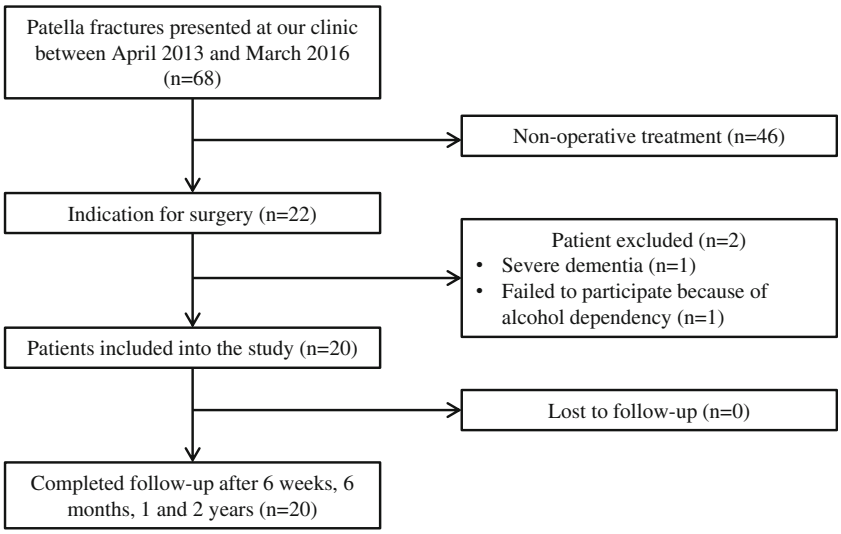

Fig. 1 Flowchart of participants through the study

plate was fixed to the patella using locking screws, which were inserted unicortically. Anatomical reduction and proper implant positioning were controlled by the use of biplanar fluoroscopic imaging.

All patients were mobilized, with full weight bearing starting on the first day after surgery. Depending on the complexity of the fracture, limitation of flexion at six weeks after surgery was possible, depending on the decision of the surgeon. Two days post-operative radiographs were obtained to verify implant position and fracture reposition.

Results

Between April 2013 and March 2016, 22 patients were operated at our department for a displaced patella fracture. Two patients were excluded: one because of severe dementia, and one who failed to participate at this study because of an alcohol dependency (Fig. 1). The mean age of the included 20 patients was 59.2 years (range 19–87) (Table 1). Nine of these patients were female. The fractures were classified according to the AO as one A1, four C1, six C2, and nine C3 fractures. One fracture was graded as a grade I open fracture according to the Oestern and Tscherne classification [21]. While one patient was a revision due to fracture dislocation after tension band wiring, the remaining 19 patients were primary treatments. Fifteen patients reported the trauma to have occurred during an activity of daily living, two during work, two as a result of a traffic accident (bicycle), and one during a sports activity. All described a direct impact on the patella because of a fall on the flexed knee (Table 2).

All patients were operated, on average, 2.5 ± 3.3 days (range 0–12) after trauma. The retropatellar joint surface was approached by a lateral arthrotomy in two cases, and a medial arthrotomy in 18 cases. Five patients were stabilized with an ArrowPlate® and 15 with a StarPlate®. Three patients required an additional lag screw, and one patient required two additional lag screws. The patient with the distal pole fracture (AO 34-A1) was additionally stabilized with a McLaughlin cerclage [22]. The mean time of surgery was 60 ± 21 minutes (range 31–115). The average skin incision was 9.5 ± 2.4 cm (range 6–15). While all patients were mobilized with full weight bearing, 14 patients received a brace with limitation of flexion to 30° for the first two weeks, 60° for another two

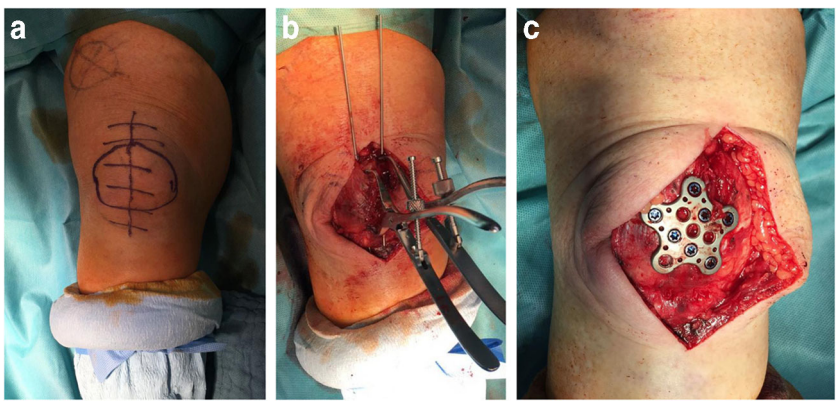

Fig. 2 An 82-year-old woman with a multi-fragmentary patella fracture AO type C2, right knee. **a** Pre-operative preparation with marking of the bony landmarks. **b** Open reduction and temporary fixation with K-wires and reduction forceps. **c** Fixation with a patella locking plate

Table 1 Characteristics of study population

Age [years]	
Mean and std. dev.	59.2 ± 18.2
Range	19–87
Sex (no. [%])	
Male	11 (55)
Female	9 (45)
Side of injury (no. [%])	
Left	12 (60)
Right	8 (40)
BMI [kg/m^2]	
Mean and std. dev.	24.9 ± 4.3
Range	19.5–33.6
Mechanism of injury (no. [%])	
Activity of daily living	15 (75)
Work	2 (10)
Traffic accident	2 (10)
Sports	1 (5)
OTA classification (no. [%])	
A1	1 (5)
C1	4 (20)
C2	6 (30)
C3	9 (45)
Time to surgery [days]	2.5 ± 3.3 (0–12)
Preinjury Tegner activity scale	
Mean and std. dev.	4.1 ± 1.4
Range	2–8
Preinjury Lysholm score	
Mean and std. dev.	97.3 ± 6.7
Range	71–100
Preinjury Kujala score	
Mean and std. dev.	96.6 ± 7.9
Range	73–100

weeks, and 90° for another two weeks (Fig. 3). The post-operative radiographs showed an anatomic fracture reposition in 16 patients and a persisting fracture step of less than 2 mm in four patients.

Regarding the functional outcome, the range of motion for extension–flexion improved from 121° after six weeks to 140° after 6 months, 141° after 12 months, and 143° after 24 months. This correlated with 84% ($p < 0.0001$), 98% ($p = 0.10$), 98%, and 99% range of motion compared to the uninjured knee. While the Tegner activity scale score was 4.1 before trauma, it improved from 2.6 after six weeks to 3.6, 3.7, and 4.1 within the follow-up period (Fig. 4). Moreover, the Lysholm score, which was 97 points before trauma, improved from 80 to 94, 95, and 97 points (Fig. 5), while the Kujala score, which was also 97 points before trauma, improved from 75 to 89, 94, and 97 points (Fig. 6). While all scores showed a significant difference in the period of time between trauma and six week follow-up (Tegner: $p < 0.0001$; Lysholm: $p < 0.0001$; Kujala: $p < 0.0001$), no more statistically significant differences were observed after six months compared to the situation before trauma for the Tegner activity scale score ($p = 0.11$) and Lysholm score ($p = 0.15$). Only the Kujala score did not reach values as before trauma after six months ($p = 0.017$). After 12 months, even the Kujala score showed no more statistically significant difference ($p = 0.22$). All scores persisted at a comparable level to before trauma hereinafter. The anterior knee pain under loading of the knee, assessed by the visual analog scale (VAS; 0 to 10), improved from 2.0 ± 1.8 (range 0–6) after six weeks to 1.4 ± 2.0 (range 0–8) after six months, 0.8 ± 1.4 (range 0–4) after 12 months, and 0.2 ± 0.5 (range 0–2) after 24 months. After two years, all patients were satisfied with their outcomes, though four patients reported some discomfort or pain when kneeling on the implant.

Overall, three complications were recorded (15%). An 84-year-old woman had a loss of reduction 13 days after surgery. Revision surgery was performed to remove the implant and stabilize the fracture using tension band wiring. Analysis of the post-operative radiographs revealed that two of the three screws fixing the distal fragment were positioned in the fracture gap. While the fracture healed adequately, after six months, a migration of one K-wire was observed. Since this wire perforated the skin hereinafter, the implant was removed after 13 months.

A 45-year-old man developed a prepatellar bursitis because of his kneeling work. The implant was removed after 60 days (bony consolidation was confirmed previously) with an additional resection of the bursa.

A 19-year-old man had a renewed trauma to the knee following a tumble after a jump off a three metre cliff with his skies nine months after surgery. The patella fractured right underneath the inferior border of the plate. The fracture was again stabilized with a locking palate, with the addition of a McLaughlin cerclage and an equatorial cerclage. To avoid another implant-related fracture, the plate was removed seven months later, as scheduled surgery.

Besides the aforementioned revision surgeries, a further three patients had their implant removed: the first patient had their implant removed after five months because of a persistent anterior knee pain, which disappeared completely after implant removal; the second patient complained of disturbing soft-tissue irritations, so the plate was removed eight months after surgery; and the third patient had their implant removed at the express request of the patient 18 months after surgery, even though there were no reported implant-associated problems.

Discussion

The purpose of this prospective observational study was to evaluate the clinical results and complication rates of this

Table 2 Baseline data of all included patients (ADL = activity of daily living; TBW = tension band wiring)

Case	Age [years]	Gender [m/f]	Classification (AO)	Cause of trauma	Implant	Operation time	Complication	Revision [months]	Implant removal [months]
1	84	F	C2	ADL	StarPlate	60	Loss of reduction	Tension band wiring (TBW)	Yes [13] (TBW)
2	59	m	C1	ADL	ArrowPlate	50			
3	87	f	C2	ADL	StarPlate	31			
4	45	m	C3	ADL	StarPlate + lag screw	115	prepatellar bursitis	Implant removal + resection of bursa	Yes [2]
5	56	f	C3	work	StarPlate	55			
6	53	m	C3	ADL	StarPlate + 2x lag screw	46			
7	62	f	C3	ADL	StarPlate	46			Yes [8]
8	73	m	A1	ADL	ArrowPlate + McLaughlin	74			
9	61	m	C1	ADL	StarPlate	99			
10	82	m	C3	ADL	StarPlate	74			
11	54	m	C2	ADL	StarPlate	38			
12	38	m	C3	traffic accident	StarPlate	50			
13	38	f	C1	ADL	ArrowPlate	71			
14	32	m	C2	ADL	ArrowPlate + lag screw	50			Yes [5]
15	74	f	C3	ADL	StarPlate	52			
16	75	m	C2	traffic accident	StarPlate	60			
17	19	m	C2	Sport	StarPlate + lag screw	75	Renewed fracture	Locking plate + cerclage	Yes [16]
18	56	f	C3	work	StarPlate	36			
19	64	f	C3	ADL	ArrowPlate	60			
20	72	f	C1	ADL	StarPlate	55			Yes [18]

novel patella locking plate. Overall, locked plating of displaced patella fractures with the SuturePlate™ revealed good clinical results, low complication rates, and high levels of patient satisfaction. Even six months after surgery, range of motion and subjective knee scores indicated full recovery. Immediate full weight bearing allowed early rehabilitation and return to activities of daily living. Nonetheless, the implant can cause discomfort or anterior knee pain, especially when the patient is kneeling.

In 1841, Johann Friedrich Dieffenbach performed the first documented surgery of a patella fracture [23]. Since then, multiple fixation techniques using compression bandages, percutaneous hooks, or silver wires were described [23]. Even at this early stage, three basic aspects had to be achieved while operating: healing of the wound without an infective complication, achievement of bony union, and good functional outcome [23]. Actually, tension band wiring is still one of the most commonly used techniques treating patella fractures. Nonetheless, complication rates are high (22–56%), especially with regard to a stable fixation [13–16]. Therefore, biomechanical evaluations showed significant benefits for fixation with locking plates [4, 18, 24–26].

Previous studies report traffic accidents as the main cause of patella fractures (78%) [4, 27]. Our own data, along with our clinical experience, did not confirm those findings. Patella fractures seem to result mostly from a fall on the flexed knee during an activity of daily living (75%), especially in the elderly. A population-based survey in China supports our findings [28]. With an overall incidence of 13.5/100,000 inhabitants per year, Zhu et al. identified a slip, trip, or fall as the most common cause for patella fractures (69.6%), while traffic accidents accounted only for 18.8% of the fractures. The highest incidence was seen for women older than 75 years and men between 64 and 74 years, which might correlate with the decrease of bone mass density in the elderly. Therefore, besides the high forces, which need to be neutralized during healing [8–10], a stable fixation in reduced bone quality is an issue. Besides age, alcohol consumption and previous history of fracture were identified as independent risk factors for patella fractures in adults [28].

Dy et al. performed a meta-analysis evaluating reoperation rates, infections, and nonunions after surgically treated patella fracture [29]. Twenty-four studies involving 737 patients showed a re-operation rate of 33.6%. While infection rates

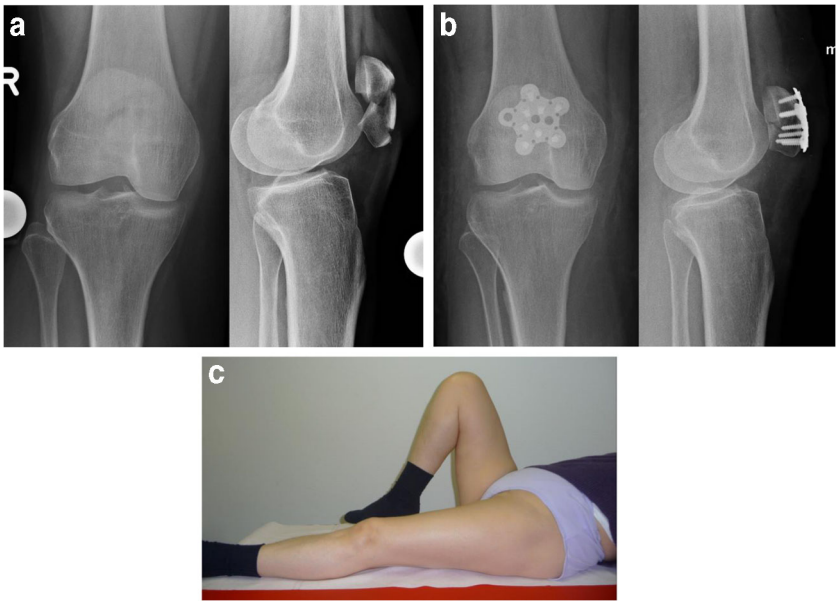

Fig. 3 A 56-year-old female with a patella fracture AO type-C3, right knee. **a** Pre-operative X-ray anteroposterior and lateral. **b** Post-operative X-ray in two planes after open reduction and fixation with a patella locking plate (StarPlate®, Arthrex GmbH, Munich, Germany). **c** Clinical result 6 months after surgery

(3.2%) and nonunion rates (1.3%) were low, re-operation rates were substantially high. Although tension band wiring remains one of the most commonly used techniques for treating patella fractures, and is recommended by the AO Foundation [30], complication rates remain at 22–56% [13–16], resulting in unsatisfactory long-term results [16, 31], especially for comminuted fractures [32]. Although our results showed lower complication rates (3 of 20; 15%), the comparability of these results is limited due to substantial differences in the number of assessed patients.

Wild et al. were among the first to report on locking plates for patella fractures [24–26, 33, 34]. These authors developed a bilateral, polyaxial plate, which was attached to the medial and lateral rim of the patella. Biomechanical evaluation showed significant superior strength and rigidity compared to modified anterior tension band wiring or cannulated lag screws with anterior tension wiring. While the mean tensile strength for tension band wiring was 625 N, cannulated lag screws with tension band failed at 1015 N and the patella locking plate at 2396 N. They also evaluated their clinical results in a prospective observational study involving 20 patients one year after surgery [35]. Range of motion was 125 ± 18° on average, and all reported scores showed good to excellent results (Lysholm score 89.5 ± 8.5; HSS 92 ± 12.5; Bostman 27.4 ± 3.8). Two patients (10%) had a complication: one superficial wound infection and one secondary fracture dislocation. Overall, five implants were removed (25%), although four of these had no implant-related problems. These findings are comparable to ours in regard to the functional outcome and complication rate. However, the authors did not recommend their implant for comminuted fractures since they discovered limitations in addressing all fragments. The

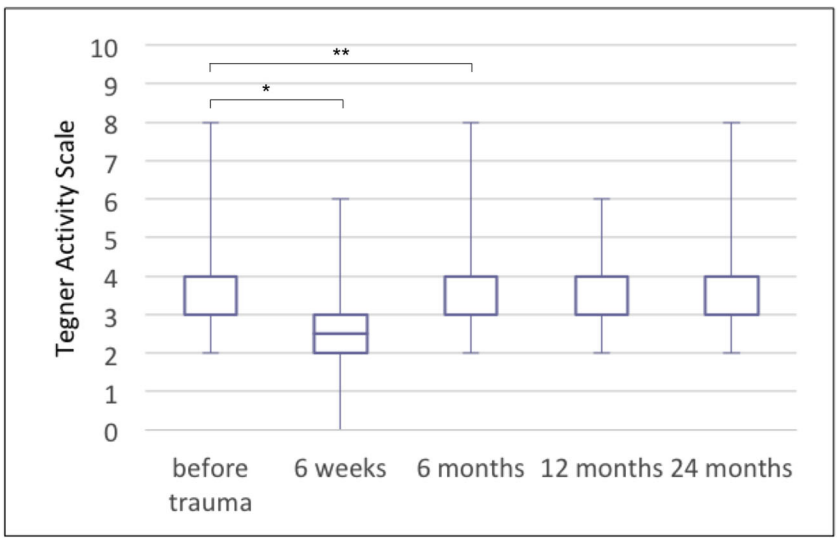

Fig. 4 Tegner activity scale scores [*statistically significant ($p < 0.0001$); **statistically not significant ($p = 0.11$)]

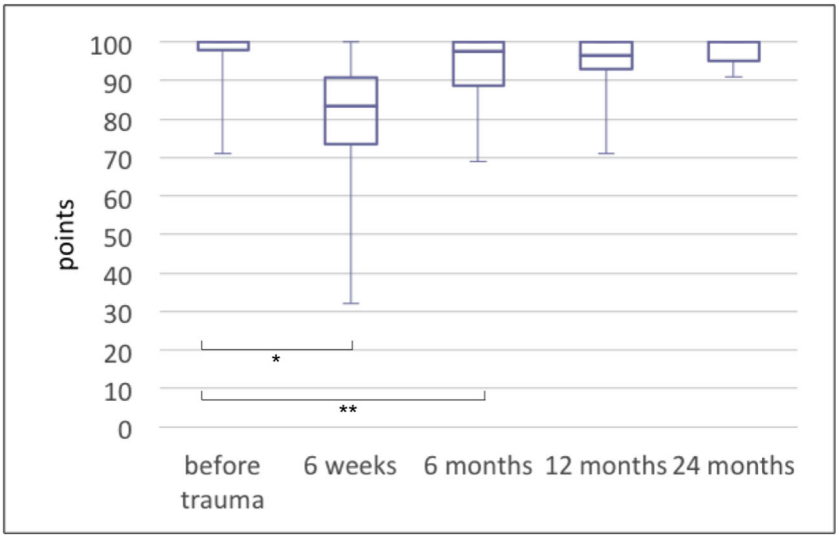

Fig. 5 Lysholm scores [*statistically significant ($p < 0.0001$); **statistically not significant ($p = 0.15$)]

multiple screw holes incorporated into the SuturePlate™ may offer an advantage in terms of allowing fixation of comminuted fractures and several fragments.

Morre et al. provided data on patients with complex patellar fractures treated with locking plates including different implants [36]. Nearly half of their patients (17 out of 36; 47%) required an additional screw osteosynthesis. In our data, we have also seen the need for additional screws in four cases (20%). The appreciably higher number of additional screws might be result of the used implants. Twenty-two of the 36 cases were treated with the variable angle 2.4/2.7 mm X-plate (Synthes, West Chester, PA). The SuturePlate™ with its multiple screw holes seems therefore to be beneficial over an X-shaped implant for stabilizing all fragments of comminuted fractures without additional screws. The functional outcome scoring of 20 evaluated patients showed good results after 132 weeks (range 12–269). The range of motion of 14 measured patients with an average of 1°–126° was comparable to our results. Although 20% of the patients reported hardware irritation and discomfort when kneeling was the most common symptom, none of those patients requested implant removal. Nonetheless, an anterior positioning of the implant seems to be a limitation.

Volgas et al. reviewed a mesh plate for comminuted patella fractures and nonunions [37]. Sixteen patients were retrospectively included with a mean follow-up of 10.5 months (range 3–12). Comparing the clinical results of the mesh plate and SuturePlate™, after 12 months, the SuturePlate™ showed better range of motion (109° vs. 141°) with less pain (2.75 vs. 0.8). The mesh plate was initially developed for treating calcaneus fractures. So far, there are no biomechanical studies evaluating its stability for patella fractures. This might be the reason why the authors did allow full weight bearing only in extension for the first six weeks. Wurm et al. proved stability of the SuturePlate™ up to 1052 N [18], which allows full weight bearing even in flexion and accelerates recovery.

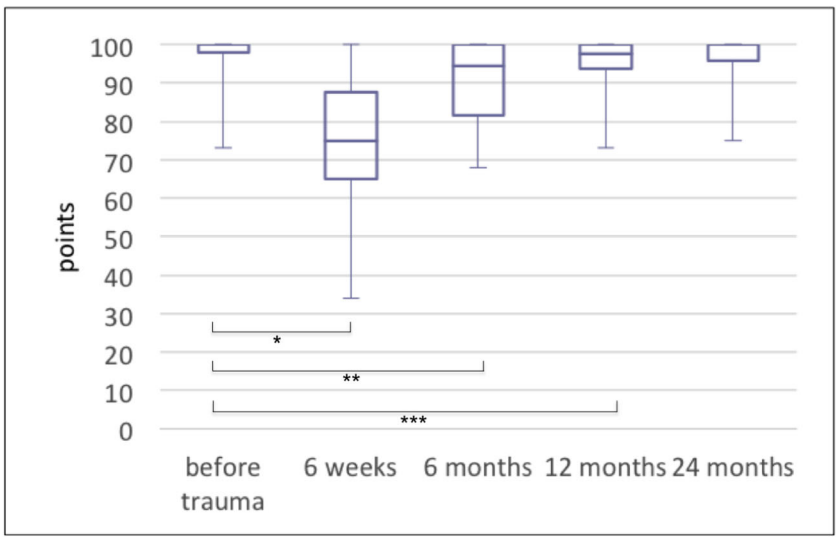

Fig. 6 Kujala scores [*statistically significant ($p < 0.0001$); **statistically significant ($p = 0.017$); ***statistically not significant ($p = 0.22$)]

Wurm et al. were the first to present clinical results to the SuturePlate™ [19]. Thirty-five of 67 (52%) patients were evaluated with a prospective follow-up of 38 ± 23 months (range 7–75). 23% ($n = 8$) were revision surgery and further two patients had a fracture after total knee arthroplasty. The mean flexion was 127° ± 21° with three patients having a flexion less than 100°. The complication rate was low with two in 35 (6%) cases. One implant failure was documented, and one patient suffered a fracture after a renewed fall. Although daily activities were not significantly restricted, half of the patients (51%) reported pain or discomfort while kneeling. While complication rates were comparable to our findings, the functional result was worse. The high number of revision surgeries might be a reason for the poorer range of motion. Besides the inhomogeneous study population, the irregular follow-up times and high dropout rate are limitations of this study.

Limitation of this implant remains the treatment of distal pole fractures. The implant design does not allow fixing small distal fragments adequately nor apply compression onto them. Osseous reattachment using suture anchors is a commonly used technique treating distal pole fractures. It is a simple technique showing comparable clinical and functional results to traditional treatments with reduced operation times [38]. Nonetheless, anchor pull out remains a cause of failure. As of late a modification of the SuturePlate™ (SuturePlate™ II, Fa. Arthrex, Naples, FL, USA) is available. The new design includes a hook at the distal end of the plate to address distal pole fractures. Additionally a compression screw to the distal pole can be applied through the hook. So far, there are no clinical and biomechanical studies available evaluating this implant.

Anterior knee pain and soft tissue irritation in conjunction with this implant remains an issue. While one patient reported severe anterior knee pain (VAS = 8), another patient developed a prepatellar bursitis and four patients reported discomfort or pain when kneeling on the implant. Therefore, three patients had their implant removed because of soft tissue irritation of anterior knee pain. Our data also shows that anterior knee pain can be a restriction especially within the first 12 months regarding to VAS and Kujala score.

For diagnostic purposes, we only performed plain X-rays pre- and post-operatively. In relation to our complication, where two screws were inserted into the fracture, a post-operative CT scan may have indicated incorrect implant positioning and prevented fracture dislocation. Furthermore, the literature shows that 88% of patella fractures affect the distal pole, yet only 44% of these fractures are recognized in plain X-rays [39]. Since a sole pre-operative X-ray also seems to underestimate the fracture, especially in regard to the number of fragments, routine pre- and post-operative CT scans need to be considered, especially since pre-operative CT scans led to a change in treatment strategy in 49% [39].

Regarding the post-operative mobilization, the locking plate fixation was sufficiently stable to allow full weight bearing. Although we limited flexion for the first six weeks in 14 patients (70%), our experiences and results encouraged us to dispense with this limitation. Therefore, we expect the rehabilitation to be even more comfortable with a faster return to full recovery.

Strength of this study is its prospective design with determined follow-up examinations after six weeks, six months, one year, and two years. This accurately allowed tracing the progress of the rehabilitation, especially since all patients attended all follow-up examinations. Furthermore, the study population is very homogeneous besides one secondary fracture treatment. Still, there are some limitations as the small sample size and a missing comparative group. Furthermore, specific scores evaluating the results after patella fractures are still missing. The inclusion of StarPlates® and ArrowPlates® is not seen as a limitation by the authors. The implant remains the same, and only the shape and size of the implant differs. The different shapes allows the surgeon to select an implant, which fits best the individual fracture pattern and stabilizes all fracture fragments.

In conclusion, the presented locking plate is a safe and effective implant for the treatment of patella fractures, including comminuted fractures. Complete function can be restored within six months after surgery with high patient satisfaction, while complications can be reduced compared to other implants. The high stability allows immediate full weight bearing, which allows for early rehabilitation and return to activities of daily living. However, the implant can cause discomfort or anterior knee pain, especially when kneeling, which may necessitate implant removal.

Compliance with ethical standards

The local ethics committee approved the study protocol. All work complied with the principles laid down in the Declaration of Helsinki. The study was registered at ClinicalTrial.gov (NCT02015975).

Conflict of interest H.L. is consultant for Arthrex GmbH. JC.K. is on the speakers' bureau of Arthrex GmbH. All other authors declare that they have no conflict of interest.

References

1. Dietz S-O, Hessmann M-H, Gercek E, Rommens P-M (2009) Patella fracture. Oper Orthop Traumatol 21:206–220
2. van Staa TP, Dennison EM, Leufkens HG, Cooper C (2001) Epidemiology of fractures in England and Wales. Bone 29:517–522
3. Yang N-P, Chan C-L, Yu I-L et al (2010) Estimated prevalence of orthopaedic fractures in Taiwan - a cross-sectional study based on nationwide insurance data. Injury 41:1266–1272
4. Wild M, Windolf J, Flohé S (2010) Fractures of the patella. Unfallchirurg 113:401–411 **quiz 412**

5. Braun W, Wiedemann M, Rüter A et al (1993) Indications and results of nonoperative treament of patellar fractures. Clin Orthop Relat Res (289):197–201
6. Boström A (1972) Fracture of the patella. A study of 422 patellar fractures. Acta Orthop Scand Suppl 143:1–80
7. Bostrom MP, Asnis SE, Ernberg JJ et al (1994) Fatigue testing of cerclage stainless steel wire fixation. J Orthop Trauma 8:422–428
8. Outerbridge R, Dunlop J (1975) The problem of chondromalacia patellae. Clin Orthop Relat Res 110:**177**–196
9. Kettelkamp D (1973) Clinical implications of knee biomechanics. Arch Surg 107:406–410
10. Oestern S, Varoga D, Lippross S et al (2011) Patella dislocation. Unfallchirurg 114:345–358
11. Labitzke R (1997) Proper and improper tension band fixation exemplified by patellar fracture. Chirurg 68:638–642
12. Zderic I, Stoffel K, Sommer C et al (2017) Biomechanical evaluation of the tension band wiring principle. A comparison between two different techniques for transverse patella fracture fixation. Injury 48:1749–1757
13. Smith ST, Cramer KE, Karges DE et al (1997) Early complications in the operative treatment of patella fractures. J Orthop Trauma 11: 183–187
14. Luna-Pizarro D, Amato D, Arellano F et al (2006) Comparison of a technique using a new percutaneous osteosynthesis device with conventional open surgery for displaced patella fractures in a randomized controlled trial. J Orthop Trauma 20:529–535
15. Mao N, Liu D, Ni H et al (2013) Comparison of the cable pin system with conventional open surgery for transverse patella fractures. Clin Orthop Relat Res 471:2361–2366
16. Levack B, Flannagan JP, Hobbs S (1985) Results of surgical treatment of patellar fractures. J Bone Joint Surg Br 67:416–419
17. Carpenter JE, Kasman RA, Patel N et al (1997) Biomechanical evaluation of current patella fracture fixation techniques. J Orthop Trauma 11:351–356
18. Wurm S, Augat P, Bühren V (2015) Biomechanical assessment of locked plating for the fixation of Patella fractures. J Orthop Trauma 29:e305–e308
19. Wurm S, Bühren V, Augat P (2018) Treating patella fractures with a locking patella plate - first clinical results. Injury 49(Suppl 1):S51–S55
20. Meinberg E, Agel J, Roberts CS et al (2018) Fracture and dislocation classification Compendium-2018. J Orthop Trauma 32:S1–S170
21. Oestern HJ, Tscherne H (1983) Pathophysiology and classification of soft tissue damage in fractures. Orthopade 12:2–8
22. McLaughlin H (1947) Repair of major tendon ruptures by buried removable suture. Am J Surg 74:758–764
23. Bartoníček J, Rammelt S (2015) Early history of operative treatment of patellar fractures. Int Orthop 39:2303–2308
24. Thelen S, Schneppendahl J, Baumgärtner R et al (2013) Cyclic long-term loading of a bilateral fixed-angle plate in comparison with tension band wiring with K-wires or cannulated screws in transverse patella fractures. Knee Surg Sport Traumatol Arthrosc 21:311–317
25. Thelen S, Schneppendahl J, Jopen E et al (2012) Biomechanical cadaver testing of a fixed-angle plate in comparison to tension wiring and screw fixation in transverse patella fractures. Injury 43: 1290–1295
26. Thelen S, Betsch M, Schneppendahl J et al (2013) Fixation of multifragmentary patella fractures using a bilateral fixed-angle plate. Orthopedics 36:e1437–e1443
27. Benli IT, Akalin S, Mumcu EF et al (1992) The computed tomographic evaluation of patellofemoral joint in patellar fractures treated with open reduction and internal fixation. Kobe J Med Sci 38: 233–243
28. Zhu Y, Liu S, Chen W et al (2018) Socioeconomic factors and individual lifestyles influencing the incidence of patella fractures: a national population-based survey in China. Int Orthop 43:687–695
29. Dy CJ, Little MTM, Berkes MB et al (2012) Meta-analysis of re-operation, nonunion, and infection after open reduction and internal fixation of patella fractures. J Trauma Acute Care Surg 73:928–932
30. Müller M, Allgöwer M, Schneider R, Willenegger H (1991) Manual of internal fixation: techniques recommended by the AO-ASIF. Springer, Heidelberg
31. Weber M, Janecki C, McLeod P et al (1980) Efficacy of various forms of fixation of transverse fractures of the patella. J Bone Joint Surg Am 62:215–220
32. Catalano JB, Iannacone WM, Marczyk S et al (1995) Open fractures of the patella: long-term functional outcome. J Trauma 39: 439–444
33. Wild M, Eichler C, Thelen S et al (2010) Fixed-angle plate osteosynthesis of the patella - an alternative to tension wiring? Clin Biomech (Bristol, Avon) 25:341–347
34. Wild M, Thelen S, Jungbluth P et al (2011) Fixed-angle plates in patella fractures - a pilot cadaver study. Eur J Med Res 16:41–46
35. Wild M, Fischer K, Hilsenbeck F et al (2016) Treating patella fractures with a fixed-angle patella plate — a prospective observational study. Injury 47:1737–1743
36. Moore TB, Sampathi BR, David P et al (2018) Fixed angle plate fixation of comminuted patellar fractures. Injury 49:1203–1207
37. Volgas D, Dreger TK (2017) The use of mesh plates for difficult fractures of the Patella. J Knee Surg 30:200–203
38. Kadar A, Sherman H, Drexler M et al (2016) Anchor suture fixation of distal pole fractures of patella: twenty seven cases and comparison to partial patellectomy. Int Orthop 40:149–154
39. Lazaro LE, Wellman DS, Pardee NC et al (2013) Effect of computerized tomography on classification and treatment plan for patellar fractures. J Orthop Trauma 27:336–344