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Posterior tibial plateau fracture treatment with the new WAVE posterior proximal tibia plate: feasibility and first results

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ABSTRACT (238 words)

Introduction:

Operative management of posterior tibial plateau fractures (PTPF) remains challenging. The treatment goal is to restore the alignment and articular congruence, and providing sufficient stability which allows early mobilization. The purpose of this study was to assess the feasibility and safety of the newly developed WAVE posterior proximal tibia plate.

Methods:

Between October 2017 and June 2020, 30 adult patients with a tibial plateau fracture and posterior involvement were selected for treatment with a WAVE posterior proximal tibia plate. Patient reported outcome was assessed using the Knee injury and Osteoarthritis Outcome Score (KOOS) at time of injury (pre-injury) and at one-year follow-up. Radiological outcome was evaluated with CT-imaging.

Results:

Twenty-eight patients were eligible for treatment with the new implant (3 'one-column', 10 'two column' and 15 'three-column' fractures), whereas in 2 patients anatomical fit was insufficient. KOOS results showed fair outcome scores at one year, with a large negative impact compared to pre-injury levels, however, a trend towards better results compared to a previous PTPF reference cohort. Radiological follow-up showed insufficient posterolateral buttress in 2 cases and residual articular step-off (>2mm) in 7 patients, of which five were classified as three column fractures.

Conclusion:

Management of PTPF using the WAVE posterior proximal tibia plate is feasible and safe with satisfactory clinical and radiological results after one year. Nevertheless, there is a learning curve regarding optimal implant positioning in order to achieve the maximum benefit of the implant.

INTRODUCTION

Posterior tibial plateau fractures (PTPF) are increasingly recognized as an important prognostic factor [1–3]. In parallel, there is growing awareness to treat PTPF, since PTPF and subsequent sagittal malalignment predispose for significantly worse patient reported outcome scores [3]. Posterior column fractures are well depicted according to the three-column classification, introduced by Luo et al. in 2010 [4]. This classification has proven very helpful and reliable in the preoperative planning and treatment of tibial plateau fractures (TPF) [5]. According to the revised three-column classification approach, the posterior border of the lateral column lies medial instead of anterior of the fibular head (Figure 1) [6]. CT imaging has proven indispensable in classification and preoperative planning, with possible further beneficial effect of 3D imaging techniques [7]. Lateral column TPF extending into the posterolateral corner are mostly sufficiently treated via a single lateral (lazy-s) approach, whereas posterior column fractures (medial of the fibular head) should be treated via a posterior approach [1, 5, 6].

Various approaches have been described for reaching the posterior aspect of the tibia plateau, posterolateral, direct posterior and posteromedial, all with their benefits and drawbacks [1]. The posteromedial reversed L-shaped approach (PRLA) however, has been shown to be elegant and straightforward, and provides sufficient exposure of the entire posterior aspect of the proximal tibia [8, 9]. The WAVE posterior proximal tibia plate (7S-Medical, Oberkirch, Switzerland) is a newly designed implant in line with this approach with an identical inverted L-shaped configuration. The plate is designed in such a way that its horizontal arm provides both posteromedial and posterolateral buttress, due to its anatomical (epiphyseal) fit (Figure 2). Hence, PTPF that extend towards the medial border of the fibular head can therefore be treated via a single PRLA (Figure 3). This may avoid unnecessary complications associated with extensive (combined) posteromedial and posterolateral approaches. The PRLA is also known as the Burks and Schaffer approach (1990) for the treatment of posterior cruciate ligament avulsions [10]. Since the PRLA is straightforward, safe and easy to master, together with this new implant it could further lower the threshold for the operative management of PTPF.

The goal of this study was to assess the feasibility of the WAVE posterior proximal tibia plate for PTPF. To that end we aimed to investigate in a case series, its clinical applicability in terms of soft-tissue friendliness (i.e. required degree of soft tissue dissection), appropriate anatomical fit and thus the ability of fracture reduction and adequate fracture fixation.

PATIENTS AND METHODS

Patients

Between October 2017 and June 2020, 30 adult patients were treated with a WAVE posterior proximal tibia plate for a single posterior column, two column, or three column TPF at the Department of Trauma Surgery of the University Hospitals Leuven. In all patients the posterior column was involved. Patients in which both the posteromedial and posterolateral part of the posterior column were affected were eligible for a WAVE posterior proximal plate (Figure 1). Based on the trauma mechanism, either a flexion/(hyper-)extension and valgus/varus forces, TPF were classified as either posterior, lateral or medial column fractures, wherein a column fracture is defined as a disruption of the cortex combined with an articular depression of each respective column [4, 5]. All patients were both operated and postoperatively assessed during the entire follow-up by the same trauma surgeon (HH). All patients got a metal artefact reduction (MAR) CT immediately postoperative as well as during further follow-up. This study was completed in compliance with national legislation and the ethical guidelines of the University Hospitals Leuven.

Surgical technique

All patients were evaluated and treated according to the three-column concept [5]. All lateral plates used were VA-LCP lateral proximal tibia plates (DepuySynthes). All medial plates used were LCP medial proximal tibia plates (DepuySynthes). The PRLA is performed in prone position. Depending on whether or not the lateral and/or medial column require open reduction and fixation, the patients are turned into a supine position, subsequently. The inverse L-shaped configured skin incision starts at the center of the popliteus fossa, running 3-4 cm medial parallel to Langer' lines, and curves down parallel to the midline of the calf (Figure 4A). Attention should be paid to the saphenous nerve (medial), and sural nerve and the lesser saphenous vein (central). Subsequently, a full thickness fasciocutaneous flap is retracted laterally (Figure 4B). After blunt dissection, the medial head of the gastrocnemius muscle is retracted laterally and the popliteus muscle exposed (Figure 4C). Next, the posterior facet of the proximal tibia is exposed through a sharp longitudinal incision at the posteromedial margin of the popliteus muscle, followed by dissecting the popliteus muscle off the bone from medial towards lateral (Figure 4D-E) [12]. Homann retractors should be placed just cranial and caudal of the fibular head. A Homann retractor on top of the fibular head carries the risk for crushing the common peroneal nerve. Placement too caudal can cause damage to the anterior tibial artery that perforates the tibiofibular septum approximately 4 cm caudal of the proximal tibiofibular joint.

Regarding fracture dislocation, reduction of the posterior wall is performed either directly or by applying the WAVE posterior proximal tibia plate (i.e. buttress). If necessary, elevation of the depressed joint surface can be established through the fracture with the use of a plunger and bone graft (Figure 5A, 5B). A posterior arthrotomy is not necessarily required. The WAVE posterior proximal tibia plate is positioned, temporally fixed using K-wires, and after checking the correct height using fluoroscopy, it is pulled to the diaphyseal bone using a large fragment cortical screw (Figure 5C). Additional locking screws are inserted in the tibial shaft for controlled load transfer. Finally, small fragment subchondral locking (rafting) screws, diverging from posteromedial are inserted depending on whether a secondary reduction of the medial or extended lateral column is necessary (Figure 5D). A video summary of the surgical procedure and technique was composed in 2018 for future reference [13].

Outcome assessment

Functional outcome and general health status were assessed using the standardized Knee injury and Osteoarthritis Outcome Score (KOOS) [14]. This validated patient reported outcome measure consists of five subscales; symptoms, pain, activities of daily living, function in sport and recreation and knee related quality of life. Each subscale is presented as a normalized score (100 indicating no symptoms, 0 indicating extremely severe symptoms) and no summarized KOOS score can be constructed due to heterogeneity of the subscales [14]. All patients were asked at presentation to score their functioning before the accident. At approximately one year postoperatively, another KOOS score was obtained. Clinical follow-up in the outpatient clinic with assessment of articular stability and range of motion (using goniometer) was continued as long as deemed medically necessary.

Radiological assessment

CT-imaging using metal artefact reduction was performed in all patients for evaluation of quality of the reduction on postoperative day 1 or day 2. Reduction was assessed and marked as failed if the articular congruence (gap and/or step) exceeded 2mm. Plate positioning was assessed. In the sagittal plane the contour of the plate should match the contour of the proximal tibia metaphysis. In the coronal plane the horizontal arm should reach the superior medial border of the fibular head.

Statistical analysis

Statistical analysis was performed using IBM SPSS 26.0 (SPSS Inc. Chicago, IL). Postoperative KOOS outcome scores (at one year) were compared to a reference group using the Mann-Whitney U test for nonparametric continuous variables. Demographics are expressed as median and the respective interquartile range (IQR). A significance level of <0.05 was accepted for all tests.

RESULTS

A total of 30 consecutive patients that underwent application of the WAVE posterior proximal tibia plate via PRLA were initially included. Median age was 54 (IQR 44-61) years, concerning 19 male and 11 female patients. Ninety percent (n=27) suffered a low energy trauma, mainly bike accidents and falls. Regarding the trauma mechanism, 26 patients sustained a flexion trauma, of which 17 were classified as flexion-valgus, 2 as flexion (unspecified) and 7 as flexion-varus TPF. Three patients sustained an extension trauma and in 1 patient a hyperextension trauma was noted. One third of the patients was treated according to a delayed staged surgery protocol (external or staged internal fixation) at 7 (IQR 4-11) days. The remaining 20 patients got the definitive surgery after 3.5 (IQR 2-6) days. Two patients with a minimal contoured posterior proximal tibia metaphysis, in which no adequate buttress using the WAVE posterior proximal tibia plate could be obtained intra-operatively (Figure 6A), were treated with 2 conventional LCP (DepuySynthes) plates instead of a WAVE posterior proximal tibia plate. These patients were excluded from further follow-up in this study.

Trauma mechanism and implants

All 'one column' (posterior column) TPF (n=4) were treated with a single WAVE posterior proximal tibia plate. All 'two column' flexion-valgus TPF (n=5) and one 'two column' flexion-varus got dual plating (lateral *vs.* medial resp.), whereas 4 out 5 'two column' flexion-varus TPF got a single WAVE posterior proximal tibia plate only. One 'two column' extension-valgus fracture was treated with dual plating. Eight out of fifteen 'three column' TPF were treated according to the 3 column concept (i.e. triple plating). The remaining 7 'three column' TPF got dual plating (WAVE plate combined with lateral plate), concerning 6 flexion valgus and 1 extension valgus TPF.

Clinical outcome

Three patients were lost in follow-up, two of which after polytrauma with associated lower limb trauma. Figure 8 displays the KOOS scores (n=19) before and 12.2 (IQR 11.0-14.1) months after surgery, as well as the results of a reference cohort of PTPF [15]. Statistical analysis showed no significant difference between the study group and the reference group for any of the subscales (p=0.348, p=0.101, p=0.273, p=0.708, p=0.096; respectively symptoms, pain, activities of daily living, function in sport and recreation and knee related quality of life). During the last clinical follow-up of the remaining 25 patients, 11 patients showed a full range of motion of the knee, 9 patients showed a limited flexion deficit (135-110°) and 5 patients showed a slight extension deficit (5-10°). Seven patients had grade 2 (5-10mm) lateral instability, and a mechanical femoral-tibial axis valgization >5° compared to the contralateral side on full-leg x-ray. At 33 months after first surgery one of these patients underwent a

total knee arthroplasty.

Radiological outcome

Last postoperative CT evaluation of the implant position, alignment, and articular congruence at 6.5 (IQR 3.1-9.4) months, revealed an adequate position and axial epiphyseal fit of the WAVE posterior proximal tibia plate in 21 patients, providing sufficient epiphyseal buttress both posteromedial and posterolateral. In 6 patients the WAVE posterior proximal tibia plate was applied either too lateral or medial, where in 2 patients the lateral tip of the epiphyseal arm was detached from the bone and therefore did not provide posterolateral buttress (Figure 7). The median lateral and medial posterior proximal tibia angle were respectively 11 (IQR 9-13) and 7 (IQR 5-9) degrees. In seven patients a residual articular step-off (>2mm) in either the lateral or medial tibia plateau was shown, of which 5 were three column fractures treated with triple plating.

Complications

In total, nine patients suffered from perioperative complications. Two patients sustained a posttraumatic and 2 patients an impending postoperative compartment syndrome requiring fasciotomy with secondary closure. Two patients developed a fracture related infection, of which 1 after fasciotomy for postoperative compartment syndrome [16]. Furthermore, one patient suffered from popliteal artery intima dissection due to severe peripheral arterial occlusive disease, eventually leading to transfemoral amputation. One patient experienced transient peroneal nerve neuropraxia. One patient was diagnosed postoperatively with pes anserinus syndrome and one patient with complex regional pain syndrome. Finally, one patient required a redo procedure due to inadequate reduction of the depressed posterolateral tibial plateau.

DISCUSSION

The purpose of this study was to evaluate the feasibility the WAVE posterior proximal tibia plate for the treatment of PTPF. It was designed in line with the PRLA with an identical inverted L-shaped configuration, in order to treat posteromedial and posterolateral TPF simultaneously. Since the PRLA has been proposed as a straightforward and safe way to expose the entire posterior wall medial of the fibular head, we assume that this implant would simplify the operative management of TPF [8, 11].

As expected after TPF, a marked decrease in functional outcome and quality of life was noted at approximately one year postoperatively, compared to preoperative KOOS subscale scores. However, there was a clear tendency towards better results compared to a previous PTPF reference cohort with a median follow-up of 43.1 months (Figure 8) [15]. Furthermore, our results are in line with previously reported significant impact on sports and recreative activity [3, 8, 15, 17]. Prolonged follow-up showed concurrent increase in range of motion of the affected knee. In contrast, an extension deficit is associated with posterior knee surgery due to adhesions. Therefore, perioperative patient counseling and guidance is very important. In five patients a small extension deficit (5-10°) was seen. Since early mobilization (with plantar touch) can prevent major extension deficits, the authors recommend usage of varus-valgus stabilizing braces only in case of residual (ligamentous) instability, however with early full range of motion.

Radiological outcome, evaluated by residual articular gap or step >2mm showed a good quality of reduction in the vast majority of cases (21/28). This finding is promising, since previous PTPF studies have shown postoperative articular incongruence in up to 40% of cases [15]. Five (out of seven) cases with residual articular incongruence resulted from comminuted three column fractures. Evidently, in complex PTPF, anatomical restoration of the articular surface can be challenging as is true for all TPF.

TPF are generally associated with a relatively high complication rate (e.g. compartment syndrome, fracture related infection, neuropraxia), especially in cases with high energy trauma [2, 3]. However, complication rates for posteromedial approaches specifically, are low [8]. In our cohort, both postoperative compartment syndrome and fracture related infection were seen in two patients and one patient experienced transient peroneal nerve neuropraxia. These results are considered in line with the current literature [1-3, 8, 16]. However, one patient suffered from popliteal artery intima dissection eventually resulting in transfemoral amputation. It should therefore be noted that pre-existent peripheral arterial (occlusive) disease in the elderly is a risk factor when retracting the neurovascular bundle and it goes without saying that recognition of peripheral arterial disease in preoperative planning is crucial. Regarding infection, the PRLA has generally lower infection rates

compared to lateral and medial approaches [1, 8].

The PRLA is a straightforward surgical approach. The soft-tissue injury is limited and extensive manipulation of the popliteal neurovascular bundle, such as in the direct posterior approach by Trickey, is avoided. Sufficient exposure of the entire posterior wall medial of the fibular head is achieved (Figure 1 & 3) [9]. In fact, medial column fractures can also be addressed via the PRLA by elevating the pes anserinus. By installing the patient in 'floating position', tilting the table and flexing the knee, it is also possible to combine an (antero-) lateral approach and PRLA without the need for reinstalling the patient [11, 18]. However, this procedure has several disadvantages. Forced knee flexion necessary for the exposure of the extended lateral column tibial plateau fracture increases the axial pressure at the posterior column and the risk for loss of reduction intraoperatively. Recognition of anatomy and interpretation of fluoroscopy can be difficult as well. Furthermore, the procedure can be challenging with severe comminution of the lateral plateau and in a compromised host (i.e. obesity). In the current study, none of the patients were operated in floating position. The vast majority was treated in prone position first and then turned in supine according to the paradigm that we first treat the more simple (cortical) fractures in order to restore the alignment and then the more comminuted (articular) fractures, for which we need the other column(s) as a foundation. Therefore, operating associated highly comminuted medial metaphyseal fractures in supine position (anteromedial approach) first, should be considered. Finally, in this cohort all 'one-column' (isolated posterior) fractures and 4 out 5 flexion-varus 'two column' fractures (posterior and medial split) could be treated with a single implant (WAVE posterior proximal tibia plate), in prone position only, thereby simplifying the treatment for such fractures.

The WAVE posterior proximal tibia plate was specifically designed to provide buttress and articular support of the posteromedial and posterolateral part of de posterior tibial plateau, as well as fixation of the intercondylar eminence. However, in two cases, perioperative evaluation showed an inadequate sagittal fit of the WAVE posterior proximal tibia plate (Figure 6A), as a result of which it could not perform its buttress function and 2 other regular implants were used here. As presented in a principal component analysis by Quintens et al. there is large anatomical variation at the level of the tibial plateau [19]. A steeper type tibial tuberosity complex is associated with a less pronounced posterior proximal metaphysis. Despite the axial contour and length of the horizontal epiphyseal arm of the WAVE posterior proximal tibia plate being adequate in all patients, in 6 patients the plate was applied either too lateral or medial. In two of these cases postoperative CT imaging showed insufficient posterolateral buttress, wherein the lateral end of the arm was detached from the bone (Figure 7), due to suboptimal positioning of the WAVE posterior proximal tibia plate too far medial. As a

consequence, the combined 12° diaphyseal and 15° metaphyseal axial twist of WAVE posterior proximal tibia plate was not enough to compensate for this. This important insight will lead to better positioning in future patients.

The current study has some limitations. Firstly, for assessment of feasibility a study group of 30 patients is adequate. However, to assess for more generalized outcome and complications a larger cohort is needed. Secondly, since osteoarthritis is a long-term post-traumatic effect, this cannot be adequately evaluated during one-year follow-up. Moreover, the compared reference cohort has a longer follow-up period, therefore long-term osteoarthritis could be interfering with those results.

In conclusion, treatment of PTPF with the new WAVE posterior proximal tibia plate seems feasible. Our study shows satisfactory clinical and radiological results after one year. However, there is a learning curve regarding optimal implant positioning in order to gain adequate posterolateral buttress. With appropriate application of the WAVE plate, buttress of both the posteromedial and posterolateral tibia plateau can be accomplished. The proximal rafting screws diverging from posteromedial towards anterolateral, limit extended soft-tissue dissection, and allow for medial and lateral articular support as well as intercondylar eminence fixation. Furthermore, in far most cases of combined posteromedial and posterolateral TPF could adequately be treated with this single implant and single straight-forward approach. Early mobilization possibly with use of varus-valgus stabilizing braces should be promoted to reduce residual flexion and extension deficits. Nevertheless, further prospective cohort studies should investigate whether open reduction and internal fixation of posterior column fractures will improve long-term functional outcome.

COMPLIANCE WITH ETHICAL STANDARDS

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

Ethical approval Ethical approval for this study was granted by the Research Ethics Committee UHL/KU Leuven and registered as: S60860.
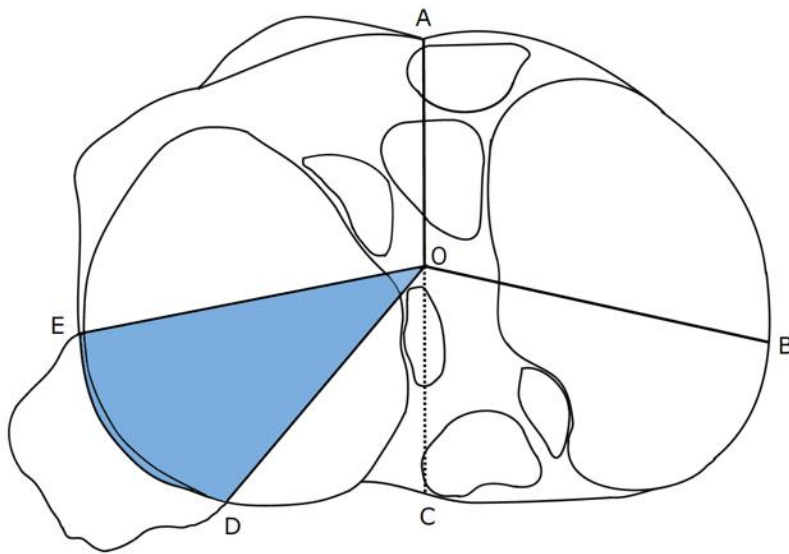
Figure 1: Revised three-column classification.

According to the revised three-column classification, lateral column fractures that extend into the posterolateral corner (blue area - OED), are defined as extended lateral column fractures (OAD). Fractures medial of the fibular head are referred to as posterior tibial plateau fractures (PTPF) (OBD) [6].
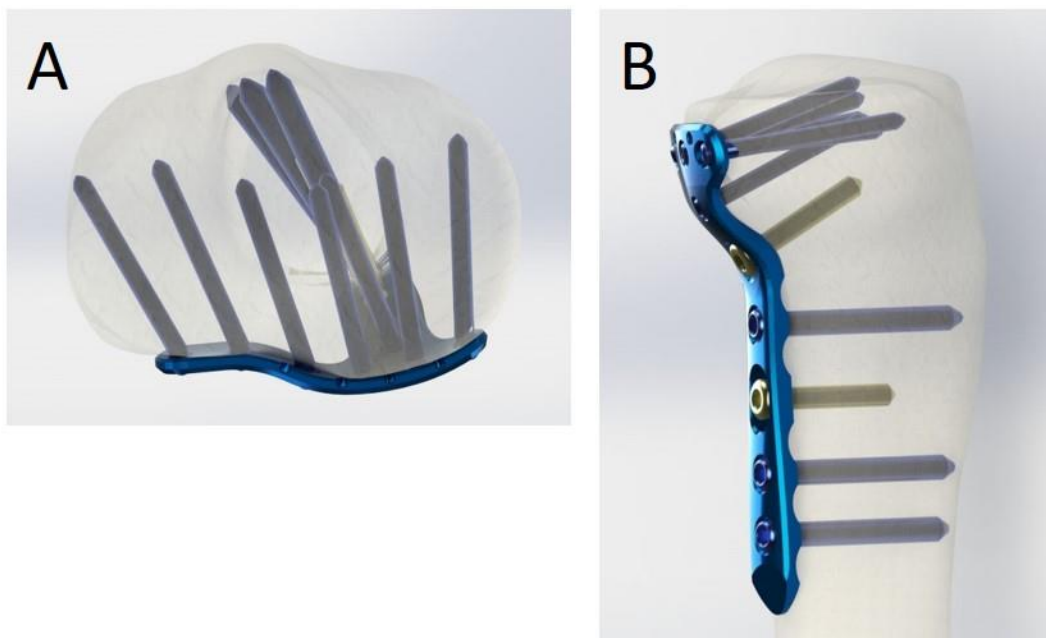

Figure 2: The WAVE posterior proximal tibia plate (7S-Medical, Oberkirch, Switzerland).

A. Axial view, B. lateral view.

This plate is designed with an 12° diaphyseal axial twist, an elongated large fragment screw hole for positioning of plate, and buttress and large fragment locking holes for load transfer; an additional 15°

metaphyseal axial twist with a large fragment screw hole to possibly achieve bone-plate compression; horizontal epiphyseal arm for posteromedial and posterolateral buttress with small fragment divergent locking screw holes for articular support.
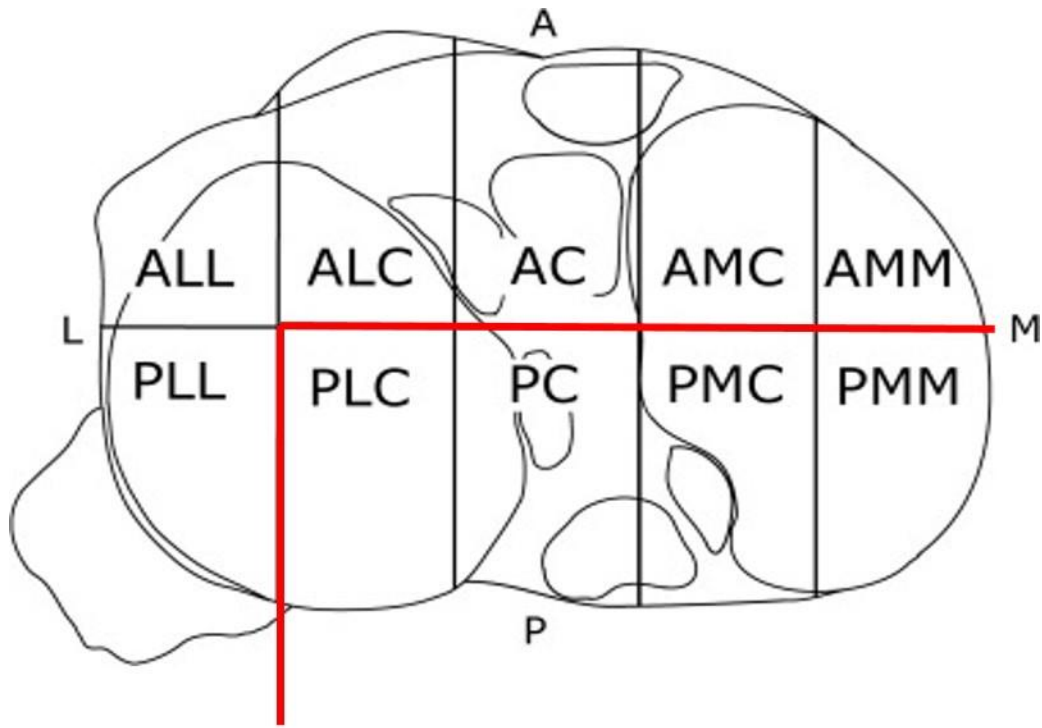

Figure 3: Ten segment classification as introduced by Krause et al. (2016).

Tibial plateau fractures affecting the posterior wall posteromediomedial (PMM), posteromediocentral (PMC), posterocentral (PC) and posterolaterocentral (PLC) can be addressed using a single posterior reversed L-shaped approach (PRLA) [20].
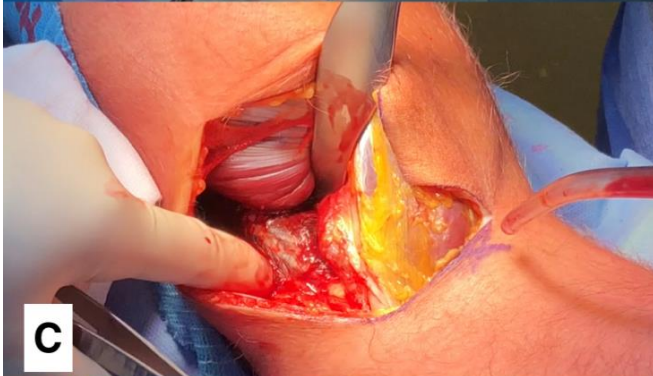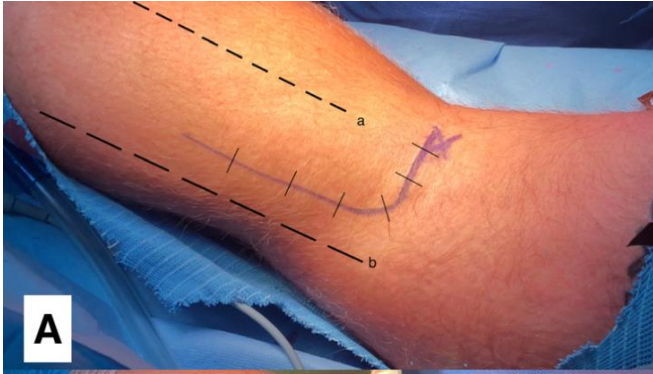
Figure 4: Posterior reversed L-shaped approach (PRLA)

A. Left knee, marking the reversed L-shaped skin incision, starting in the center of the popliteus fossa parallel to the Langer lines. It continues 3-4 cm to the medial corner of the popliteal fossa and then bends distally approximately 10-15 cm, parallel to the midline of the calf. Care should be given to avoid damage to the sural nerve and lesser saphenous vein (a) and the saphenous nerve (b). Note: it is useful to apply cross mark(s) in advance in order to be able to close the skin sufficiently after finishing the procedure.

B. A fasciocutaneous flap is lifted and retracted laterally. Attention should be paid to protect the saphenous nerve and vein. The interval between the popliteus muscle and gastrocnemius muscle is developed bluntly from distal to proximal with the medial caput of the gastrocnemius muscle and neurovascular bundle safe behind a retractor. Traction from the gastrocnemius muscle is released by flexing the knee

C. The tendon of the medial head of the gastrocnemius muscle is dissected further free (left intact though) and retracted laterally using a stump retractor to achieve good exposure of the posterior aspect of the popliteus muscle. The retractor can be placed carefully over the lateral edge of the popliteus muscle immediate caudal of the fibular head, in order to prevent vascular damage to the anterior tibial artery. The tibial neurovascular bundle lies between the medial and lateral caput of the gastrocnemius muscle.

D. The popliteus muscle is incised longitudinally at the posteromedial corner of the tibia from distal to proximal, and dissected from the posterior facet of the proximal tibia from medial to lateral.

E. The blunt retractor is replaced by two sharp ones flush over the bone and under the popliteus muscle, flush caudal and cranial of the fibular head to expose the posterior wall and fracture fragments.
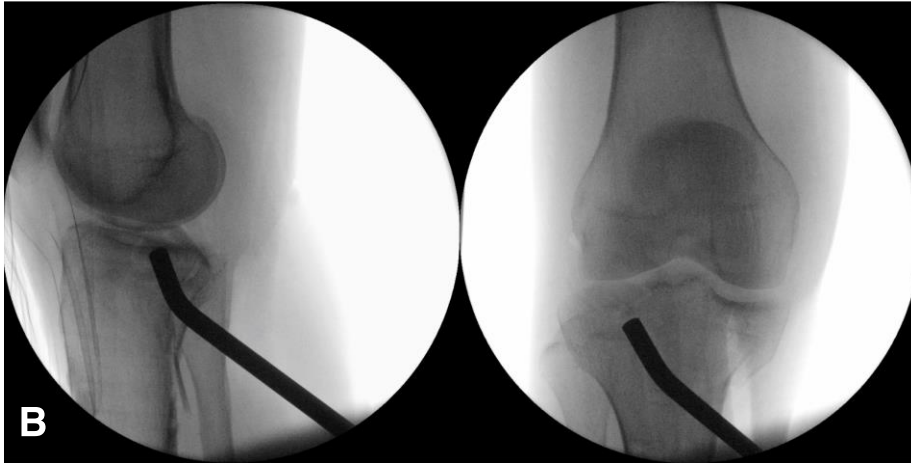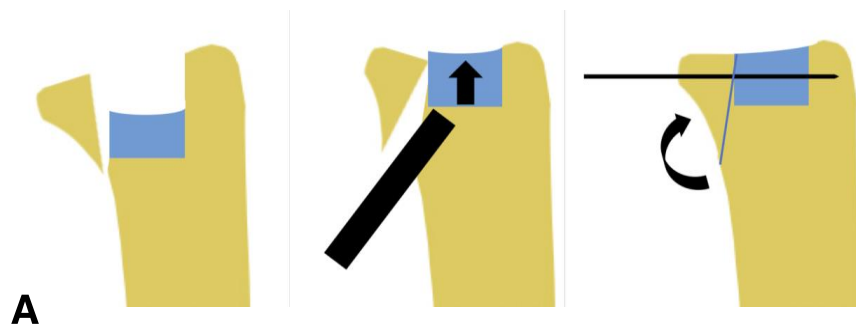
A

B

C

D

Figure 5: Indirect reduction technique and WAVE posterior proximal tibia plate application.

If buttress alone is not enough, first attempts can be made to reduce an associated articular depression by folding away the posterior fracture fragment (or opening the posterior cortex using a saw or drill) and inserting a plunger. (A, B) A posterior arthrotomy is not necessarily required. After reduction, posterior fracture fragment(s) are temporary fixated with K- wires and the reduction is verified using fluoroscopy. This buttress plate osteosynthesis starting with a large fragment cortical screw that will pull the plate to the bone and (further) reduce and restore the posterior wall. (C) Proximal locking screws (small fragment) are inserted in order to provide sufficient articular support. Depending on the need for further articular reconstruction of the existing extended lateral (or medial) column fractures, it can be decided not to use (all) the proximal locking screws. After application of the WAVE posterior proximal tibia plate fluoroscopy shows adequate reduction. (D) Articular congruence can be hard to evaluate intraoperative, therefore dry arthroscopy (i.e. fracturoscopy) or intraoperative CT might be beneficial here.

Figure 6: Steep proximal tibial contour and insufficient buttress.

2/30 Patients (both female) showed a less contoured posterior proximal tibia metaphysis, where the posterior proximal metaphyseal curvature of the WAVE posterior proximal tibia plate was larger than that of the patient. As a consequence, no epiphyseal buttress could be exerted using the WAVE posterior proximal plate.

Figure 7: Clinical case with insufficient posterolateral buttress.

This 41 year old male sustained a three column fracture after a car accident and was transferred to a tertiary hospital. Preoperative CT-scan showed articular comminution of the lateral column and a large posterior fragment with a (main) coronal fracture line. (A, B) Triple plating of this three-column tibial plateau fracture was performed using a PRLA, medial and lateral (Lazy S) approach, respectively. Although postoperative CT-scan at three months showed adequate reduction of the posterior column, insufficient posterolateral buttress of the WAVE posterior proximal tibia plate (epiphyseal arm), was detected (marked red). (C, D)
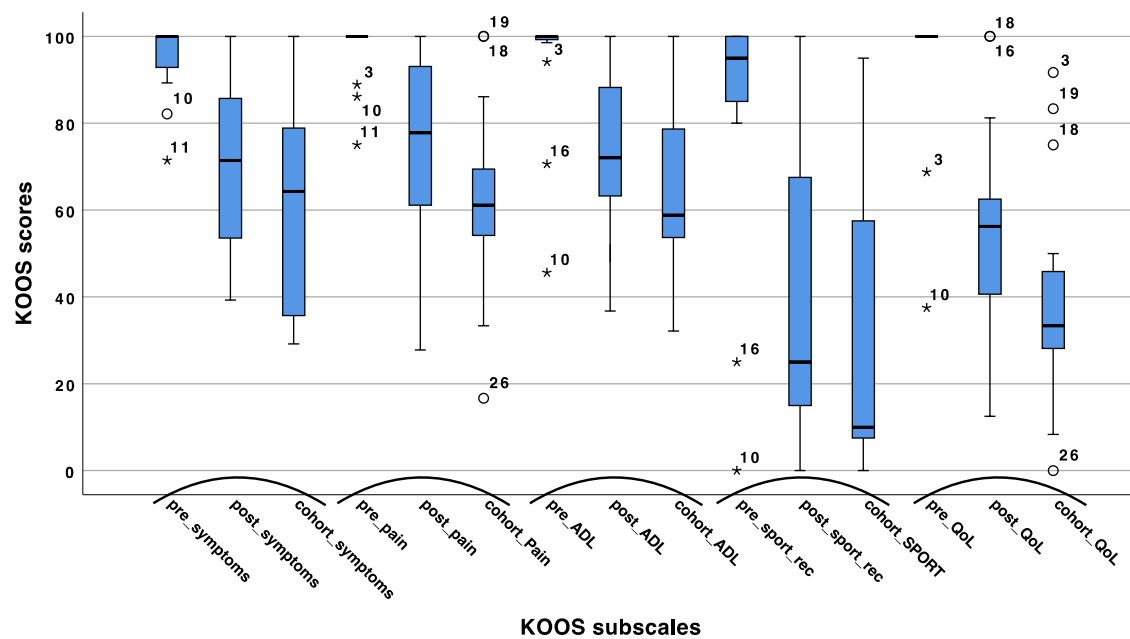
Figure 8: Boxplot KOOS subscale outcome scores.

Boxplot for all five KOOS subscale scores for pre-injury (noted as 'pre') and postoperative at approximately one year (noted as 'post') and reference cohort (noted as 'cohort'). [15] Median value is depicted by the horizontal black marking dividing the interquartile range (blue diagram). Outliers (value outside 1.5 to 3 times the interquartile range) are marked with 'o'. Extremes (value outside 3 times the interquartile range) are marked with '*'. Abbreviations: KOOS, Knee injury and Osteoarthritis Outcome Score; ADL, activities of daily living; Sports_Rec, Sports and recreation; QoL, quality of life.

KEY WORDS:

Tibial plateau fractures; posterior tibial plateau; new implant; posteromedial approach; WAVE; feasibility study

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