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The Hyperextension Tibial Plateau Fracture Pattern: A Predictor of Poor Outcome

Leah J. Gonzalez BS[1], Ariana Lott BA[1], Sanjit Konda MD[1,2], Kenneth A. Egol MD[1,2]

Investigation performed at NYU Hospital for Joint Diseases, New York, NY[1] and Jamaica Hospital Medical Center, Jamaica, NY[2]

Address correspondence to:
Kenneth A Egol MD
301 East 17th Street
New York, NY 10003
Kenneth.Egol@nyumc.org

Authors:
Leah J. Gonzalez, BS
301 East 17th Street, Suite 1402
New York, NY 10003
201.841.5640
Leah.gonzalez@nyumc.org

Ariana Lott, BA
301 East 17th Street, Suite 1402
New York, NY 10003
310.948.9096
arianalott@gmail.com

Sanjit R. Konda, MD
301 East 17th Street, Suite 1402
New York, NY 10003
212.598.6460
Sanjit.konda@nyumc.org

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Abstract

Objectives: To assess the outcome of patients with hyperextension bicondylar tibial plateau fractures (HEBTP) to those with other complex tibial plateau fractures

Design: Retrospective cohort design

Setting: Academic Medical Center

Patients: A total of 84 patients were included in the study. There were 69 patients with 69 knees (82%) that had sustained non-hyperextension bicondylar tibial plateau fractures and 15 patients with 15 knees (18%) that had hyperextension bicondylar tibial plateau fractures (HEBTP)

Intervention: Surgical repair of bicondylar tibial plateau fracture

Main Outcome Measures: Clinical and functional outcomes included knee range of motion, post-operative alignment, NRS pain scores and Short Musculoskeletal Functional Assessment (SMFA) scores at long-term follow-up. Complications were recorded for both cohorts including infection and post-traumatic osteoarthritis.

Results: There was no difference in knee range of motion at one-year follow-up between hyperextension and non-hypertension patients. Patients with hyperextension mechanisms did however have higher functional (SFMA) scores and a trend of higher pain scores, indicating worsened functional outcomes, and were more likely than their non-hyperextension mechanism counterparts to have associated soft tissue damage and to develop post-traumatic osteoarthritis.

Conclusions: Non-HEBTP and HEBTP fracture patients have similar outcomes in terms of range of motion at approximately 1 year of follow up, however, differ significantly in terms of functional recovery and the types of complications associated with their injuries.

Key words: Tibial Plateau Fractures; Hyperextension; Trauma; Poor outcome

Level of evidence: Prognostic Level III Study

Introduction:

Tibial plateau fractures are the most common fracture about the knee. They occur secondary to axial load with a secondary varus, valgus, or purely anterior force. Typically, these injuries are classified by either the Schatzker,[1] AO/OTA,[2] or Moore classification systems.[3] Fractures classified as Schatzker V and VI, or bicondylar tibial plateau fractures, are considered the most severe of these and usually occur as a result of high energy mechanisms. Within these bicondylar tibial plateau fractures, there is a subset of injuries that occur secondary to a hyperextension mechanism and are referred to as hyperextension bicondylar tibial plateau (HEBTP) fractures. HEBTP injuries have been defined radiographically by Firoozabadi as the (1) loss of the normal posterior slope of the tibial plateau, (2) tension failure of the posterior cortex, and (3) compression of the anterior cortex due to axial load on a hyperextended knee.[4] (Figure 1A) While the Firoozabadi study further refined their cohort to include only the varus deformity subset from medial articular injury, we extended our study to include varus, as well as valgus (Figure 1B) and pure hyperextension injuries with no coronal plane deformity, broadening our study to all BTPs that are a result of a hyperextension mechanism. Currently, there is very little in the literature that examines this subset of injuries as well as no classification system that isolates this subset of BTPs from the others. No study has yet concretely defined the differences in outcomes the patients of this population experience.

The purpose of this study was to compare clinical and functional outcomes of patients who had sustained hyperextension bicondylar tibial plateau fractures (HEBTP) to those with other complex tibial plateau fractures without hyperextension mechanisms and determine whether or not this rare entity is an indicator of worse clinical and functional outcomes.

Methods:

This study was institutional review board approved. Between November 2008 until July of 2016 a total of 351 patients who sustained 357 tibial plateau fractures were evaluated and treated by one of 3 fellowship trained orthopaedic traumatologists. The following were required for inclusion in this analysis: Schatzker V or VI fracture pattern, having complete imaging, and at least one-year of follow up. Sagittal pre-operative CT scans were examined in all included cases to identify which patients had sustained a hyperextension mechanism of injury. Based upon the previously described pattern by Firoozabadi et al, we identified the HEBTP fractures using the following modified radiographic finding criteria: (1) Loss of the normal posterior slope of the tibial plateau (10 degrees), (2) tension failure of the posterior cortex, and (3) compression of the anterior cortex.[4] Of the 351 patients (357 knees) treated for a tibial plateau fracture, 110 patients with 115 knees (32%) sustained a bicondylar pattern. Of these 110 patients, 84 patients with 84 knees (76%) had complete data and accessible CT scans and at least one-year of follow up. (Figure 2) Critical review of each patient's CT scan by two fellowship trained orthopaedic traumatologists (SK and KE) had consensus agreement that among 69 patients, 69 knees (82%), had sustained non-hyperextension BTP fractures, and 15 patients, with 15 knees (18%), had sustained hyperextension tibial plateau fractures. Of these 15 HEBTP injury patients, 2 had a valgus deformity, 9 had a varus deformity, and 4 had a pure hyperextension injury with no coronal plane deformity. One patient sustained one open fracture in the HEBTP population (7%) and 5 patients sustained 5 open fractures in the non-HEBTP population (7%). These injuries were graded according to the system of Gustillo et al[5]. Five of the six open fractures were Type 3A. The remaining open fracture was in a non-hyperextension patient and required an advancement flap with a split thickness skin graft and thus classified as Type 3B.

The use of an initial temporary joint spanning external fixator was at the discretion of the treating or referring surgeon. Twenty (24%) patients underwent initial joint spanning external fixation to temporize the knee until definitive surgery could be performed. Of those undergoing external fixation 5 were hyperextension injury patients (33% of the hyperextension group) and 15 were of the non-hyperextension mechanism group (22% of the other complex mechanism group). The mean time between surgeries for those undergoing delayed repair was 8 days.

All patients underwent definitive surgical repair of their fractures utilizing standard surgical approaches (dual incision vs single incision) and fixation with pre-contoured proximal tibial locking or non-locking plates and screws. The use of bone void filler for metaphyseal bone loss was at the discretion of the treating surgeon, however, a calcium phosphate substitute was used in all cases in which it was deemed necessary. The hyperextension fractures in general were repaired with more anteriorly applied plates rather than lateral and posteromedial. (Figure 3) If the tibial tubercle was involved, additional fixation was utilized with anterior to posterior directed lag screws placed. Internal associated soft tissue injury was identified at the time of surgery by clinical examination and direct visualization, and was recorded. Post-operative protocol was similar in all cases, with knee immobilization for 7-10 days to allow wound healing followed by early range of knee motion and non-weight bearing for 10-12 weeks until healing allowed for advancement. If the tubercle fragment was separate, and independent fixation utilized for repair, knee flexion was delayed 3-4 weeks. All patients were provided VTE prophylaxis for 4 weeks. All patients were provided a prescription for outpatient physiotherapy with a standard regimen of active and gentle passive knee range-of-motion for the first 6 weeks followed by graduated knee strengthening for the following 6 weeks. At the initiation of full-

weight bearing at 10-12 weeks post-operatively, patients were allowed graduated impact activities as tolerated.

For both groups, HEBTP and non-HEBTP, patient demographics and mean follow-up time were collected. Age-adjusted Charlson Comorbidity score was calculated for each patient using each patient's age and past medical history.[6] Clinical and functional outcomes were recorded at each post-operative visit and one-year post-injury including knee extension, knee flexion, post-operative alignment, pain at follow up (scale of 0-10), pain quality at follow up (continuous, intermittent, or none), and follow up, as well as change in, short musculoskeletal functional assessment (SFMA) score. Complications were monitored including infection, neuropathy, post-traumatic osteoarthritis, reoperation rate, and other complications. Other complications included, but were not limited to, urinary tract infections, deep vein thrombi, and pulmonary emboli. Associated soft-tissue injuries (open fractures, ligamentous or tendinous injury) were also monitored. Radiographs of the injured extremity at 1 year were analyzed to determine incidence of post-traumatic osteoarthritis. Fisher's exact and Chi-square tests were used to test for normality amongst the HEBTP and non-HEBTP groups for all variables. Independent t-tests, as well as Fisher's exact and Chi-square tests, were utilized to compare clinical and functional outcomes between HEBTP and non-HEBTP cases. SPSS (Version 22) was used for all calculations.

Results:

The mean follow-up time was 18 months (range: 12-60 months) for hyperextension injury patients and 25 months (range: 12-86 months) for non-hyperextension patients (p=0.240). Amongst the patient demographic criteria investigated, there was no difference between the two

groups with regard to demographic factors (Table 1). The most common mechanism of injury in both groups was similar: a low velocity fall, followed closely by pedestrian struck accidents. There was a greater incidence of associated internal soft tissue damage at time of injury in the HEBTP group. Assessment of associated soft tissue damage including, but not limited to, LCL, MCL tears, and meniscal damage was made at the time of surgery. Twenty-seven percent (n=4) of the hyperextension injury group had associated soft tissue damage compared to 4% (n=3) of the non-hyperextension injury group (p=0.011).

Clinical and functional outcomes of the non-HEBTP and the HEBTP groups are compared in Table 2. With regard to knee range of motion, there was no difference between the groups, with hyperextension patients achieving a mean range of knee motion of 2.0°-113.0° and non-hyperextension patients achieving a mean range of knee motion of 1.2°-118.8°. Radiographically, post-operative anatomic tibial alignment in the coronal plane was not different between the 2 groups (p=0.479). The mean loss of alignment in the sagittal plane was not statistically different between the two groups with a mean post-operative posterior slope change of 4.0 degrees anteriorly from normal anatomic alignment (7-10 degrees posterior) in the HEBTP population.

Patient reported pain between the two groups was not different initially at the time of injury or at 6 months follow up (p=0.911), however, the HEBTP group trended towards greater pain than the non-HEBTP group at final follow up, 4.0±2.3 and 2.8±2.7 on the NRS respectively although this trend did not reach statistical significance (p=0.113). There was no difference between the two groups in pain quality at follow up (continuous, intermittent, or none). Pain scores were compared between patients with open fractures and those with closed fractures to ensure that this did not confound results. The pain scores between the open and closed fracture

groups were not significantly different, 3.4 and 2.9 respectively (p=0.697). Additionally, to ensure differences in operative treatment did not confound results, the follow up SFMA scores and pain scores were compared between those patients receiving external fixation in addition to open reduction internal fixation (ORIF) and those receiving only ORIF. Patients receiving only ORIF had a mean follow up SFMA score of 20.08 and those receiving the external fixator with ORIF were not different with a mean score of 27.88 (p=0.200). Similarly, the mean follow up pain score of the ORIF only group was 3.0 and in the combination group it was 2.9 (p=0.859). With all of the above taken into account, we did find that HEBTP fracture patients had higher follow up SFMA scores (indicating poorer function), with a mean of 33.6±22.4, compared to the non-HEBTP group, with a mean of 19.6±18 (p=0.013).

Complications were categorized into infection, neuropathy, post traumatic osteoarthritis, and other complications (Table 2). Infection, neuropathy, and other complications did not differ between the two patient groups. Early radiographic post-traumatic osteoarthritis at latest follow up was more common in the HEBTP patient population, with 33% of this subset effected at a mean of 17 months after surgery, while non-HEBTP patients had only 10% effected at a mean of 27 months after surgery (p=0.047).

Discussion:

This study examined the clinical and functional outcomes of patients with hyperextension bicondylar tibial plateau fractures as compared to other patients with bicondylar tibial plateau fractures. We found that patients injured by a hyperextension mechanism were more likely to have associated soft tissue damage, record worse functional outcomes at the 1-year follow up mark, as measured by the standardized total SFMA scoring system, and develop early post-

traumatic osteoarthritis as compared to fractures caused by non-hyperextension mechanisms. These HEBTP patients additionally trended towards worse pain at 1 year out from surgery. We postulate that this more extensive damage is due to the energy imparted to these structures at the time of injury. Based on this assumption and the direction of the acting forces, one might also expect neurovascular injury to be seen more commonly in HEBTP fracture patients, but that was not identified in this study.

Hyperextension knee injuries were first described in the literature by Chiba et al, in 2001, in a case presentation describing patients with posterolateral knee injuries considered to be varus and hyperextension in mechanism. Of the 12 patients reviewed in this presentation, 11 had serious ligamentous injuries.[7] In our study of 15 patients with hyperextension type injuries, 27% had soft tissue associated injuries identified, including ligamentous and meniscal damage, while only 4% of the other complex mechanism of injury group sustained associated soft tissue injuries (p=0.011). This finding suggests, as was similarly noted by Chiba et al, that more attention should be paid to the possibility of soft tissue injury in this subset of patients to assist in the treatment and rehabilitation process of these injuries.

Since then, other studies including an MRI review study of 16 knees by Bennet et al in 2003 and a case study review by Yoo et al in 2009, have also confirmed cases of hyperextension type knee injuries associated with ligamentous damage.[8,9] In our study, we used direct observation at the time of surgery to assess injury to soft tissue structures rather than MRI, and thus we may be underestimating the true incidence of these injuries. In 2008, Barei et al. conducted a retrospective chart and radiographic review that examined bicondylar tibial plateau fractures specifically looking at the posteromedial fragment in this injury to better classify its frequency and morphologic characteristics. Similarly, this study concluded that some of the

more complex of the BTP fracture patterns were not adequately described by current classification systems and further went on to note that current fixation techniques and implants may not be adequate in stabilizing this injury pattern after surgery.[10] In the case of hyperextension patients, the anterior articular surface needs to be addressed. These areas are more accessible to surgeons and tend to follow standard fixation protocols. Plate configuration may need to be adjusted however, to buttress the appropriate fragments.

In a study in 2005 by Egol et al, external fixation was examined as a means to reduce soft tissue complications and improve outcomes for high energy proximal tibia fractures. The results of this study demonstrated the additional time for the soft tissue envelope to recover before definitive fixation is placed did accomplish this goal. The authors recommend this technique for all high energy intra-articular and extra-articular proximal tibia fractures.[11,12] In our study, we saw that 33% of hyperextension pattern patients were managed initially with external fixation, while 22% of the non-HEBTP group was managed this way. This preference for external fixation in hyperextension patterned injury patients makes complete biomechanical sense as the anterior frame counteracts the injury force in addition to temporizing the increased soft tissue damage seen in our cohort and in this group in general. However, the aims of this study did not set out to assess the effects of this treatment strategy and thus no conclusions regarding its use can be made with regard to these specific patterns of injury versus other high energy patterns.

A paper published by Firoozabadi et al, was the first study to directly address the hyperextension subtype. This retrospective cohort study that defined this fracture pattern precisely, generally looked at hyperextension pattern associated injuries, and suggested treatment strategies for this subset of bicondylar tibial plateau fractures. They also concluded that current classification systems are inadequate for isolating the constellation of issues brought about by

this subset of injury and that rates of surrounding tissue damage are higher in this special population.[4] Our study builds upon this literature and includes all hyperextension injuries, not just those with a secondary varus mechanism, by reporting clinical and functional outcomes of these patterns in comparison to another group of bicondylar tibial plateau fracture patients without hyperextension injuries.

When surgeons are presented with injury patterns that portend poor clinical results it is incumbent upon them to understand and discuss these outcomes directly with patients. Furthermore, once identified, early intervention strategies should be employed for patients at risk for complications and poor clinical results. In the case of tibial plateau fractures, it is possible that different therapy strategies should be employed early to maximize functional recovery. The tibial tubercle and patellar tendon were involved in some cases and required supplementary stabilization with additional fixation (screws). The post-operative protocol was altered in these cases to delay knee flexion and hold in extension for 3-4 weeks prior to starting physical therapy. Although an anteriorly placed external fixator acts to directly counteract the deforming forces of the injury, we cannot empirically advocate for its use in every case. This paper does not assess the efficacy of this approach. The authors do believe that there is very little to lose from this strategy.

There were several limitations to this study, most relating to its retrospective design. Primarily, the study was likely underpowered due to the fact that HEBTP fractures are a less common injury mechanism and our collection was restricted to our academic center. Additionally, with regard to pain reporting, we did not control for pre-operative narcotic use, although as baseline data was collected at the first office visit before definitive surgery, most patients did not have access to narcotics before that time. The only documented pre-operative

narcotic use in our cohort was in one patient of the non-hyperextension group. We did, however, control for pain differences between groups based on open versus closed injuries, and initial internal versus initial external fixation. These factors did not play a statistically significant role in pain scoring based on our data, however, our cohort size may be too small to say so definitively. As stated earlier, imaging was limited to plain radiography and CT scan. MRI could have helped identify more soft tissue injury, but it remains unclear whether unidentified soft tissue injuries are clinically significant.[13] However, some of the poor functional outcomes could be attributed to inadequate treatment of these undiagnosed problems. Finally, while we found no difference in anatomic tibial alignment, we cannot comment about the mechanical alignment as full length and contralateral limb radiographs were not obtained as a control.

In conclusion, the hyperextension bicondylar tibial plateau fracture is a subset of significantly complex fractures about the knee. These injuries result in worse functional outcomes and poorer radiographic results than non-hyperextension bicondylar injuries. This report adds to the evidence regarding this unusual fracture pattern. Physicians who care for these injuries now can counsel patients regarding potential outcomes and more realistic expectations regarding their prognoses.

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Figure Legends:

Figure 1A: Pre-operative radiographs for a 28 year old female patient who fell from standing sustaining a varus hyperextension bicondylar tibial plateau fracture.
Figure 1B: Pre-operative radiographs for a 68 year old male patient who was struck as a pedestrian sustaining a valgus hyperextension bicondylar tibial plateau fracture.

Figure 2A: Sagittal CT of same HEBTP patient.
Figure 2B: 3D CT reconstruction of same HEBTP patient.

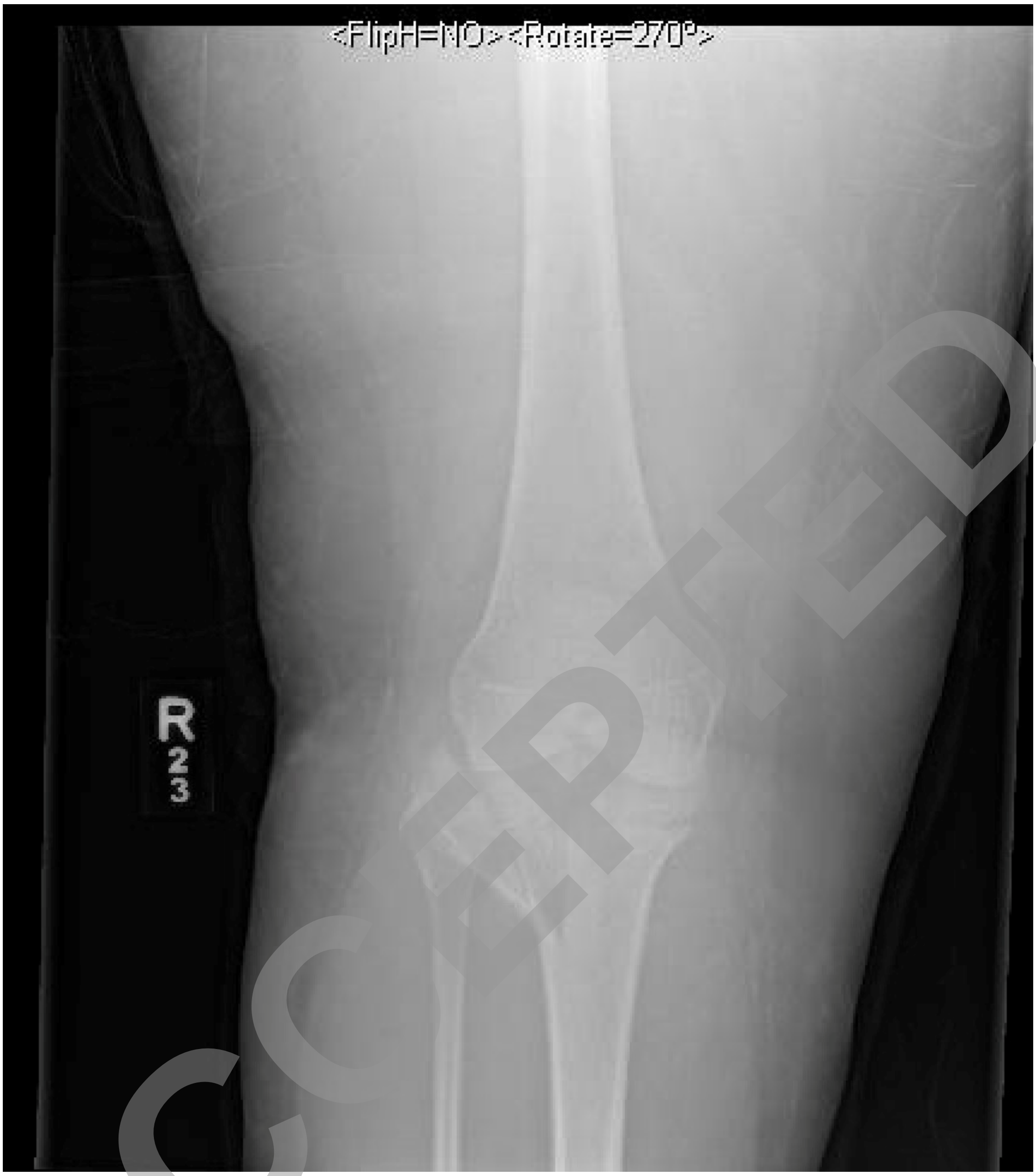
Figure 3A: AP and lateral post-operative images of HEBTP fracture fixation. Note the anteromedial and anterolateral plate placement.
Figure 3B: AP and lateral films of 1 month post-operative HEBTP fracture fixation.

Table 1: Patients demographics comparing hyperextension and non-hyperextension BTP fracture patients.

Table 2: Clinical outcomes, functional results, and complications, comparing hyperextension and non-hyperextension BTP fracture patients. Bold indicates significance with $p<0.05$.

	HEBTP	**Non-HEBTP**	**P-Value**	**Overall**
Age at Injury (Mean±SD)	51.65±13.1	49.44±14.0	0.582	
Gender N (%)	Male: 7 (46.7) Female: 8 (53.3)	Male: 41 (59.4) Female:28 (40.6)	0.600	Male: 48 (57.1) Female: 36 (42.9)
Race N (%)	Black: 6 (40.0) White: 4 (26.7) Hispanic: 3 (20.0) Other: 2 (13.3)	Black: 20 (29.0) White: 21 (30.4) Hispanic: 12 (17.4) Other: 16 (23.2)	0.835	Black: 26 (31.0) White: 25 (29.8) Hispanic: 15 (17.9) Other: 18 (21.4)
BMI	28.2±6.9	27.0±5.5	0.500	
Smoking Status (Yes) N (%)	2 (13.3)	17 (24.6)	0.494	19 (22.6)
Alcohol Use (Chronic) N (%)	0 (0.0)	3 (4.3)	0.609	3 (3.6)
Worker's-Compensation Status (Yes) N (%)	0 (0.0)	2 (2.9)	1.00	2 (2.4)
Age-Adjusted Charlson Comorbidity Score (Mean±SD)	1.53±1.5	1.24±1.5	0.500	
Follow Up time (Mean±SD)	18.3±14.6	24.7±19.6	0.240	

	HEBTP	Non-HEBTP	P-value
Extension(º) (Mean±SD)	2.00±5.6	1.15±3.4	0.455
Flexion(º) (Mean±SD)	113.00±13.3	118.81±17.2	0.636
Post Op Alignment (º) (Mean±SD)	87.07±1.7	87.48±2.2	0.479
Pain at Follow up (Mean±SD)	4.00±2.3	2.77±2.7	0.113
Pain at 6 months Follow up (Mean)	3.56	3.68	0.911
Pain Quality at Follow up:			
None N (%)	1 (6.7)	15 (26.3)	0.172
Intermittent N (%)	12 (80.0)	37 (64.9)	
Continuous N (%)	2 (13.3)	5 (8.8)	
Follow Up Standardized Total SFMA (Mean±SD)	**33.6±22.4**	**19.6±17.9**	**0.013**
Change in Standardized Total SFMA (Mean±SD)	**29.5±20.9**	**17.4±16.7**	**0.021**
Infection N (%)	3 (20.0)	7 (10.1)	0.391
Neuropathy N (%)	1 (6.7)	1 (1.4)	0.350
Post-Traumatic Osteoarthritis N (%)	**5 (33.3)**	**7 (10.1)**	**0.047**
Other complications N (%)	4 (25)	11 (15.9)	0.470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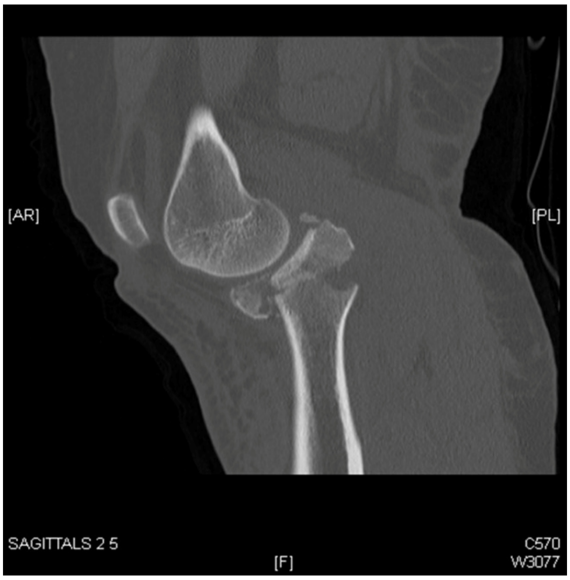
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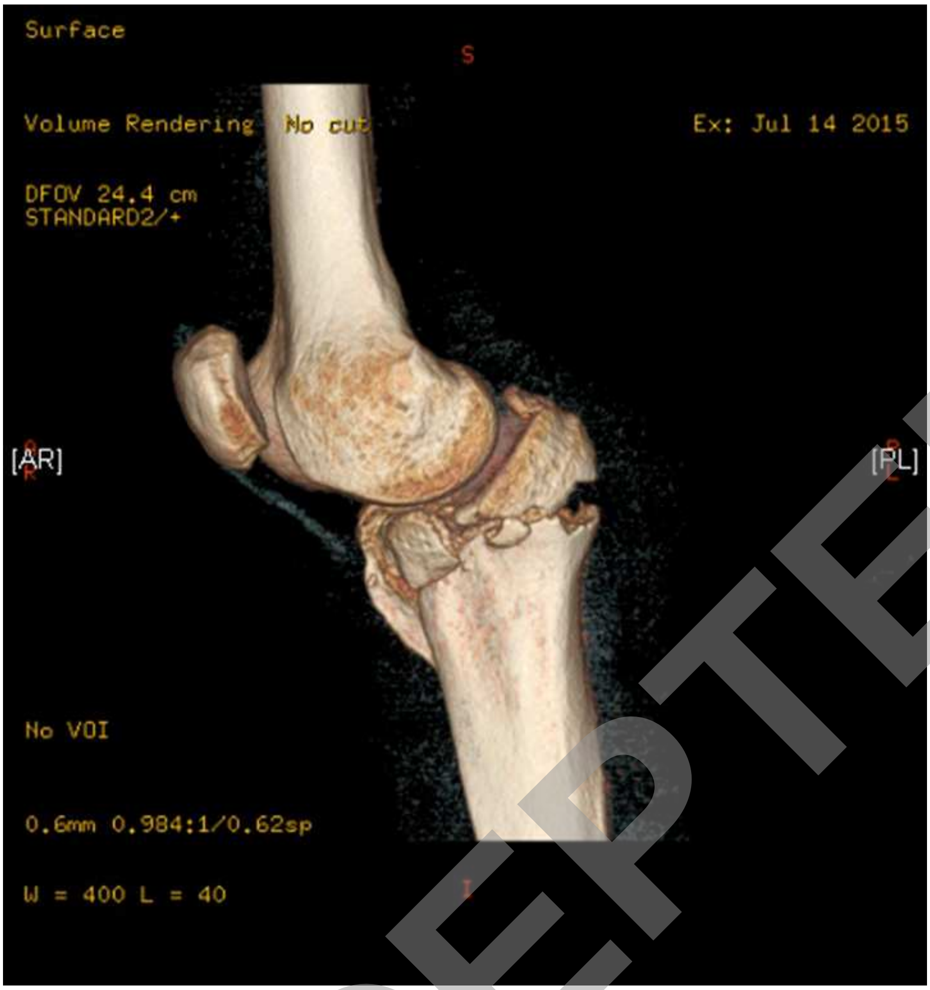
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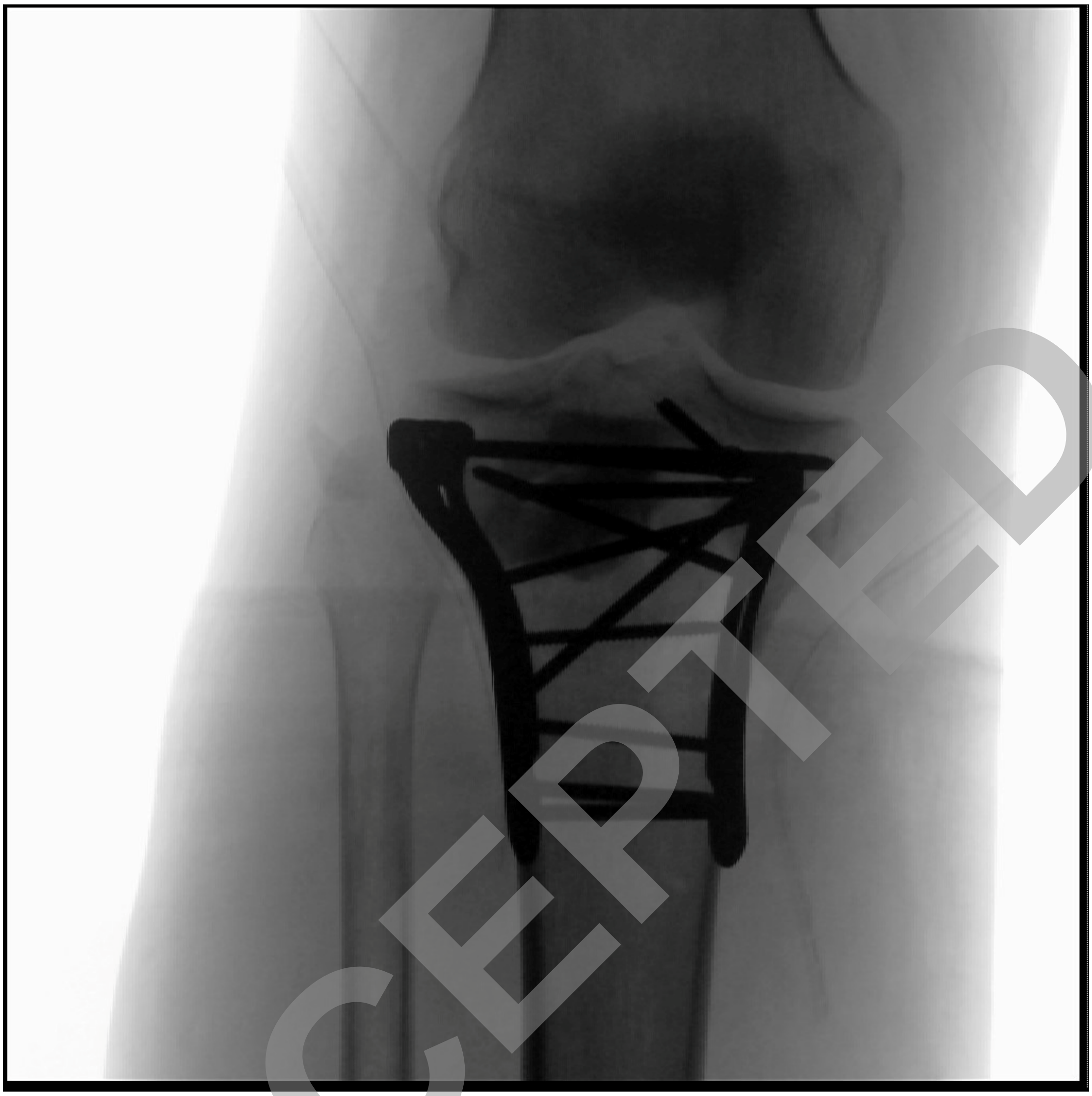

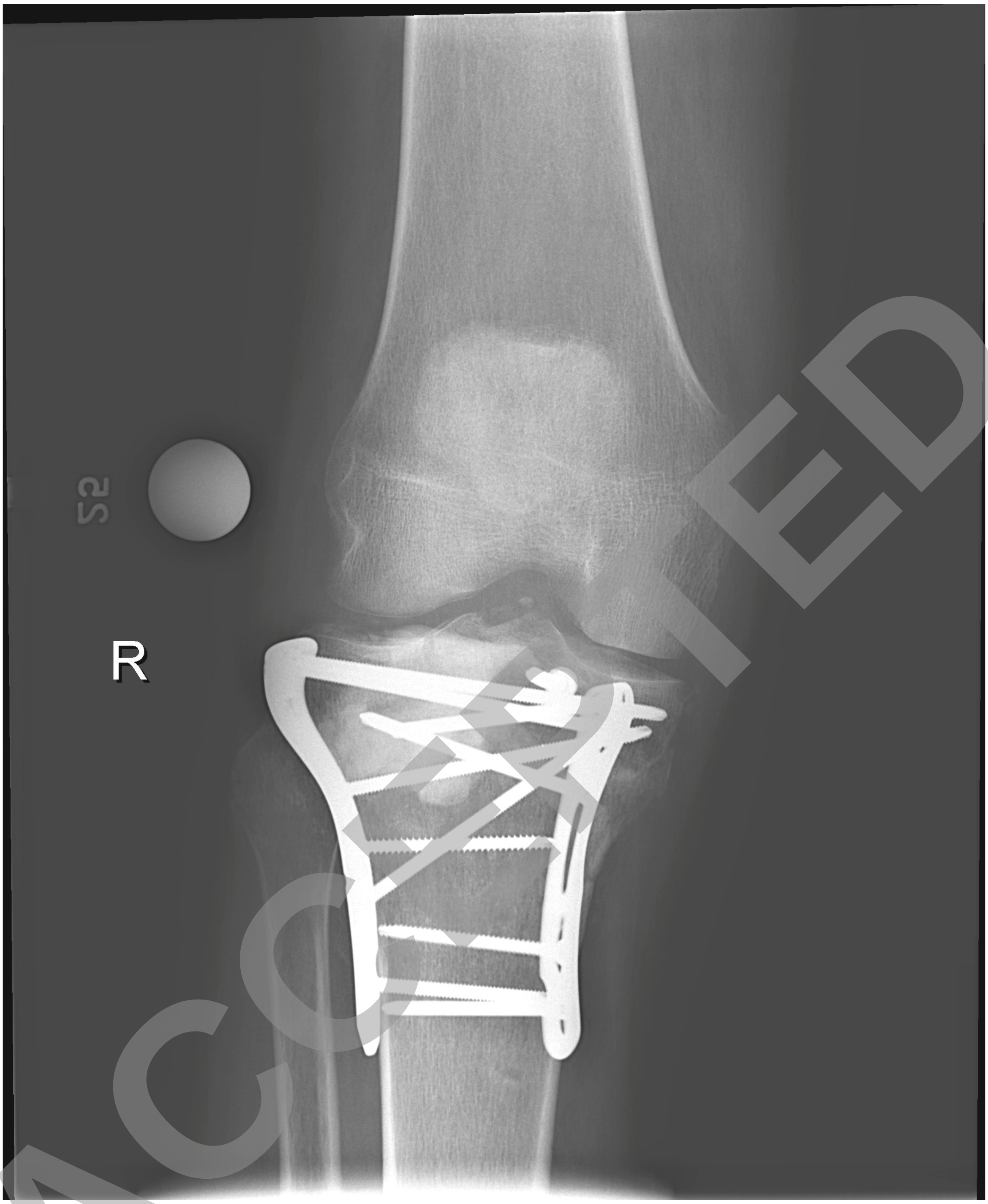
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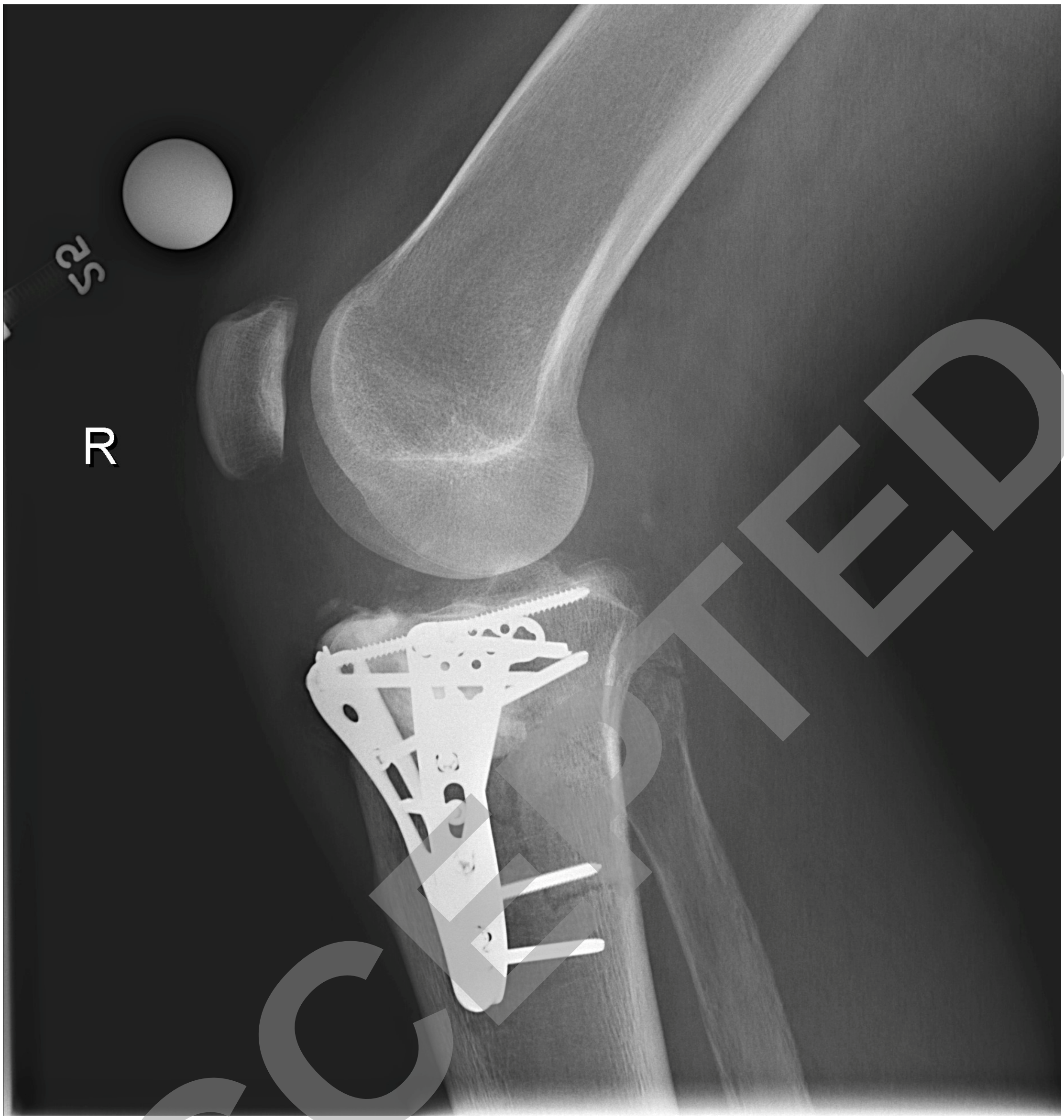
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