Review article

How Important are Posterior Tibial Plateau Fractures? A review of the incidence, fragment characteristics, and mechanisms of injury

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Posterior tibial plateau fracture is a common feature found in complex tibial plateau fractures. However, the fracture characteristics of posteromedial and posterolateral fragments are different. Various mechanisms of tibial plateau injuries result in diverse fracture types which require appropriate treatment strategies. To emphasize the importance and diversity of posterior tibial plateau fractures, the incidence and characteristics of those fractures is reviewed. In addition, integration of knowledge of mechanisms of injury and fracture characteristics with the selection of surgical procedures is discussed. **Chiang Mai Medical Journal 2019;58(2):113-21.**

Keywords: Posteromedial tibial plateau fracture, posterolateral tibial plateau fracture, tibial plateau fracture

Introduction

Since the three-column concept was proposed by Luo et al. in 2010 (1), interest in posterior tibial plateau fractures has increased. Crucial factors, including the incidence of column involvement, fracture characteristics, and mechanisms of injury have been used to establish tibial plateau classification systems. Current 3D- and CT-based classifications, e.g., three-column (1), four-column (2, 3), and ten segment classifications (4), are characterized by the specific articular surface area involved. Many authors have endeavored to link the mechanism of injury with the classification to further facilitate selection of surgical applications. The aim of tibial plateau fixation is to neutralize or buttress specific fragments. Poor mechanical fixation of a tibial plateau fracture with coronal fracture involvement, in particular, a posteromedial fragment, can cause loss of reduction (5, 6). Treatment failure of a tibial plateau fracture in which posterolateral involvement results in fragment depression can lead to knee instability (7). Understanding the mechanism of injury together with fracture characteristics can improve treatment outcomes and help surgeons to choose the proper treatment strategy. Here, we review the current literature to document the incidence of posterior tibial plateau fracture. We also consider fracture mechanisms that might suggest the cause of the fracture characteristics and provide clues with surgical relevance.

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Incidence of posterior fragments in tibial plateau fractures.

Posteromedial and posterolateral fragments have commonly been found to be associated with bicondylar tibial plateau fractures resulting from a high energy mechanism of injury. The incidence of posteromedial fragments in bicondylar tibial plateau fracture cases reported in the literature varies from approximately one-third to two-thirds. The largest case series, by Yang et al. (8), included 525 tibial plateau cases with an incidence of posterior tibial plateau fractures of 28.8%, of which 35.1% involved the posterolateral column, 45.7% the posteromedial column and 19.2% both the posterolateral and posteromedial columns. Zhai et al. retrospectively reviewed 115 cases of Schatzker type IV fractures, reporting that 47.83% of the total had posterior articular depression (9).

Most studies have reported that posterolateral fragments occuring in bicondylar fractures (Schatzker type V and VI) are related to high energy injury mechanisms, while isolated tibial plateau fractures, which are related to low energy injury mechanisms, are less common. The reported incidence of posterolateral fragments varies and involves different inclusion criteria; therefore, it is difficult to compare rates over a diverse range of clinical settings. The incidence of posterolateral tibial plateau fractures has been estimated to reach 44.2% (OTA type B and C) (Sohn et al.) (10) and 44.32% (Zhu et al.) (11, 12) of bicondylar cases (Table 1). Posterolateral fragments can consist of a single split fragment, a single depressed fragment or a complex fracture; however, the incidence of a single split or depressed fragment is low (13). In the case of bicondylar tibial plateau fractures with posterolateral involvement, fragment-specific surgical approach and fixation strategies are needed to deal with this complex condition. In the case of isolated posterolateral tibial plateau fractures, however, a direct posterolateral approach to minimize soft tissue dissection is required (14-17). The incidence and morphology of posterior fragments is shown in table 1-3 (18-21).

Mechanism of injury in posteromedial and posterolateral fractures

Understanding the mechanisms of tibial plateau injuries can help explain fracture characteristics. Many classification systems, e.g., Schatzker (22), three-column (1, 23), four-column and nine segment classification (24), use the mechanism of injury of each fracture pattern as a guide to treatment. In fact, there are many other factors which are related to fracture mechanisms such as force intensity, force direction and knee position. These factors can result in differences in the tibio-femoral contact area (25-28), and thus potentially influence the variety of tibial plateau fracture characteristics (29). These posteromedial fracture mechanisms may be explained by indirect evidence. Immerman et al. (27) prepared maps showing the relationship between knee flexion angle and tibio-femoral contact area on the tibial plateau. Those relationships may also suggest stress concentration locations. In theory, the stress concentration area is associated with material failure, i.e., bone fracture. The indirect clues described in Immerman's study, however, do not allow extrapolation from the degrees of knee flexion or the intensity and moment of loading to fragment size and fragment morphology (Figure 1).

Posterolateral tibial plateau fractures are commonly found in bicondylar tibial plateau fractures resulting from a high-energy mechanism of injury; the less common isolated posterolateral tibial plateau fractures are associated with a low-energy mechanism. There have been few biomechanical studies regarding mechanisms of injury to that fragment. Zhu et al. (11) in biomechanical studies on cadavers found that 30°and 60° of knee flexion with axial loading results in posterolateral split fractures, while 90° of knee flexion is more commonly associated with posterolateral depression fractures. Chang et al. (14) and Waldrop et al. (7) noted further that most isolated posterolateral tibial plateau fractures are associated with a low energy of axial compression and with valgus moment, although in that study the location of the fracture varied by knee flexion angle (29) (Figure 2).

Table 1. Incidence of posteromedial fragments

	Barei et al. 2008 (18)	Higgins et al. 2009(19)	Yang et al. 2013 (8)	Molenaars et al. 2016(20)	Sohn et al. 2014 (11)	Xiang et al. 2013(21)	Zhu et al. 2014(12)
Period of observation	2002-2003	2002-2007	2008-2009	2000-2013	2005-2011	2008-2012	2008-2012
Total tibial plateau cases	-	-	525	127	190 OTA type B=103 (54.2%) C=87 (45.7%)	242	-
Bicondylar cases	57	111	149 (Schatzker V and VI)	48 (Schatzker V and VI)	-	-	370
Posterior plateau cases	-	-	151	-	-	-	-
Posterolateral fragment	-	-	35.1% of posterior plateau fracture cases	-	44.2% (84 cases) of type B and C B=35.9% (37 cases) C=54% (47 cases)	15% of tibial plateau fracture cases (36 cases)	17.57% of PL-S (65 cases) and 26.76% PL –D bicondylar cases (99 cases)
Posteromedial fragment	73.7% of bicondylar case (42 cases)	58.6% of bicondylar case (65 cases)	45.7% of posterior plateau fracture cases	87% of Schatzker IV (13 in 15 cases) and 87.5% of bicondylar cases (42 cases)	-	-	
Posterolateral and Posteromedial fragment	-	-	19.2% of posterior plateau fracture cases	-	-	-	

PL-S,= posterolateral split; PL-D, posterolateral depression

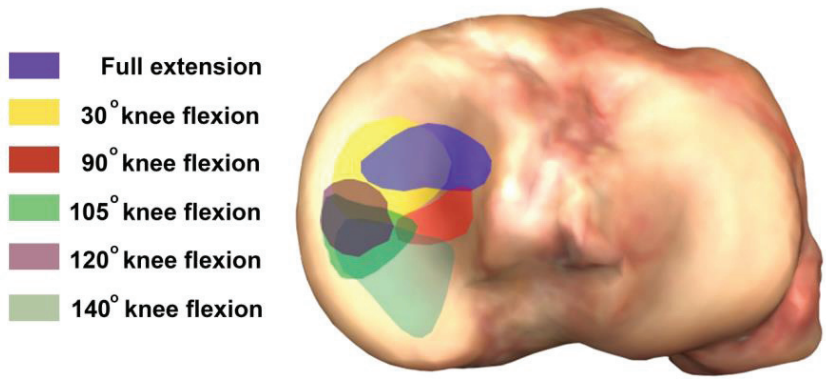

Figure 1. Map of femorotibial contact areas on the medial tibial plateau. Colors represent contact area at various degrees of knee flexion (Adapted from Immerman et al.)(27).

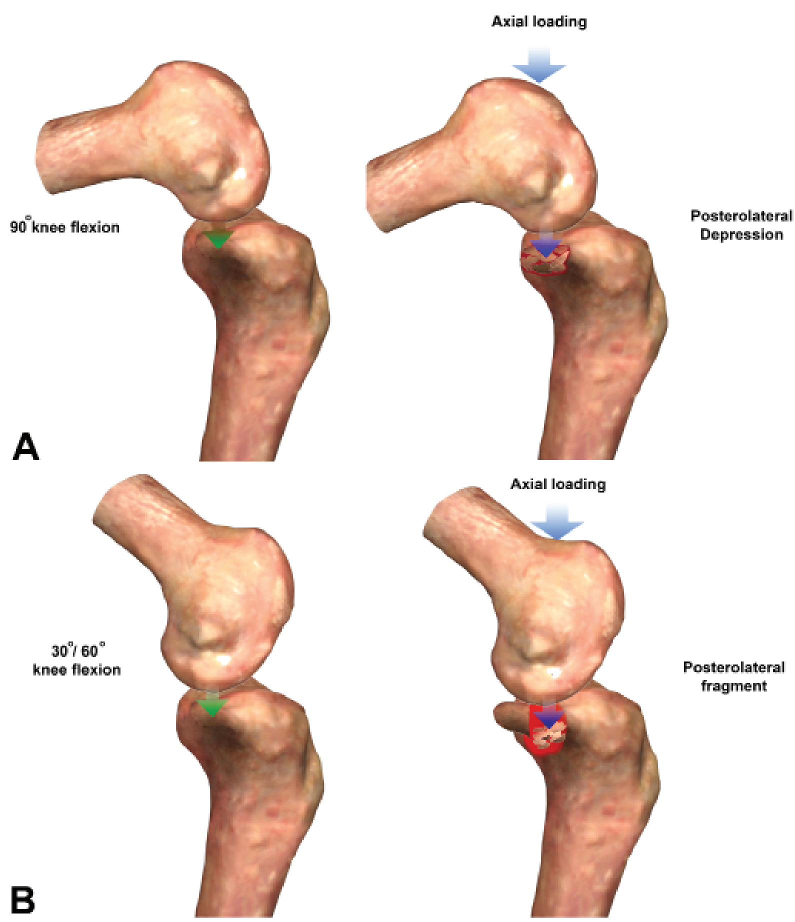

Figure 2. Relationship of knee flexion and fracture morphology of posterolateral fragment. (A) 90° knee flexion with axial loading is associated with depression fractures. (B) 30° and 60° knee flexion with axial loading is associated with split fractures. (Adapted from Zhu et al.) (11)

Eggli et al. (30) proposed that the difference of anatomical tibial plateau surface on the medial (concave) and the lateral (convex) side are possibly related to specific fracture fragment characteristics. Axial compression loading force of the femoral condyle against the concave surface of the medial plateau results in a split posteromedial fragment, while compression on the convex lateral plateau results in comminution and broadening of the lateral joint. Published reports on fragment characteristics (Tables 2 and 3) indicate that posteromedial fragments involve greater plateau articular area and have greater fragment height than posterolateral fragments. Molenaars et al. (20) recently reviewed CT scans of 127 tibial plateau fractures and created a "fracture map". This fracture map indicates the comminuted zone of bicondylar tibial plateau fractures involving the posterolateral area (19 of 48 cases; 40%). In addition, the fracture line density on the lateral tibial plateau is higher than on the medial tibial plateau. Additional studies of tibial plateau fracture morphology using CT data were conducted by Chen et al. (13) Interestingly, both studies, "Heatmap of Depression Zone" by Chen et al. (13) and "Fracture Mapping" by Molenaars et al. (20), reported that the location of the depression (or comminution) zone in high energy fractures (Schatzker types V and IV) was in the posterolateral corner area of the lateral tibial plateau. This area is described as "Postero-lateral-central (PLC)" in the ten segment classification system (4). Anatomically, the PLC area is difficult to access. A direct posterolateral approach is useful for direct visualization and plate buttressing; however, most surgeons are unfamiliar with this approach. Barei et al. showed that good quality articular surface reduction of the tibial plateau improves patient functional outcomes (31); however, developing a new treatment strategy to deal with a comminuted PLC area is challenging.

Morphology of posteromedial and posterolateral fragments

Barei et al. (18) and Higgins et al. (19) retrospectively studied the morphologic characteristics of posteromedial fragments in CT scans (Table 2) and proposed a technique of measurement which was later used by Sohn et al. (10), Xiang et al. (21) and Zhu et al. (11) to analyze posterolateral fragments. The posteromedial fragment is larger than the posterolateral fragment, so some posteromedial fragments can be fixed using an anterolateral locking plate. The posterolateral fragment has an inverted conical shape and extends over nearly one-third of the surface area of the lateral tibial plateau (Table 3). However, most posterolateral fragments are located posteriorly to the screw purchase area in anterolateral locking plate fixation. For that reason, fixing a posterolateral fragment via the anterolateral approach using only an anterolateral plate raises critical concern for posterolateral fragment fixation stability (32).

This information on fracture morphology could be incorporated in fracture simulation models representing common fracture characteristics. Such models could, in turn, be used to create fracture-specific plate designs (33, 34).

Table 2. Posteromedial fragment morphology

Parameters	Barei et al. 2008 (18)	Higgins et al. 2009 (19)
Number of patients in the study	57	148
Major Medial articular fracture angle (MAFA)	-9° (-45°-30°)	-21.4° (-87°-52.1°)
Maximum posterior cortical height (PCH)	42 mm (16-59 mm)	45 mm (22-72 mm)
Posterior sagittal fracture angle (SFA)	81° (33°-112°)	73° (33°-96°)
Articular surface involvement	58% (19.3%-98%)	25% (7%-43%)

Table 3. Results of posterolateral fragment morphology

Parameters	Sohn et al. 2014 (11)	Xiang et al. 2013 (21)	Zhu et al. 2014 (12)
Number of patients	190	36	164
Lateral major articular fracture angle (LMFA)	12.69 ° (-56.02°-72.44°)	23°±24° (-43°-62°)	12.94° (-60.5°-69.88°)
Posterior major articular fracture angle (PMFA)	19.13° (-39.47°-61.10°)	-	-
Diagonal distance	32.75 mm (15.03-59.14 mm)	-	-
Lateral AP distance	10.22 mm (-11.18-31.17 mm)	-	-
Posterior horizontal distance	22.93 mm (4.1-49.95 mm)	-	-
Posterior cortical height	31.12 mm (10.84-63.93 mm)	29±7 mm (18-42 mm)	29.6 mm (10.7-53.1 mm)
Sagittal fracture angle	78.48 ° (41.69°-105.12°)	77°±12° (58°-97°)	72.06° (7.11°-104.5°)
Articular surface area	522.18 mm2 (14.5% of total articular surface)	14.3%±6.3% (8-32%)	-
Size of displacement	-	10.5±5.2 mm (2-19 mm)	-
Major posterolateral articular fragment proportion (PL-AFP)	-	-	15.43% (5.90-38.61%)
Size of major posterolateral articular depression proportion (PL-ADP)	-	-	16.74% (3.82-35.48%)
Maximum posterolateral articular depression height (PL-ADH)	-	-	24.7 mm (1.8-64 mm)

Furthermore, fracture morphology can guide surgeons in selecting an appropriate surgical treatment strategy and avoiding common pitfalls while performing surgery. The posterior cortical height of the posterolateral fragment is approximately 30 mm (10, 11, 21). Based on that anatomy, the popliteal artery branches to the anterior tibial artery (ATA) at approximately 50 mm distal to the level of the tibial plateau (35, 36). Thus, in some cases where the posterolateral approach is required, the distal extension of the surgical dissection must be performed with particular care. Oblique placement of the distal end of the posterolateral buttress plate is needed to prevent an iatrogenic ATA injury. Posterolateral fractures are quite small (the mean posterior horizontal distance is 22.93 mm) and are located at the far lateral corner (10), making buttressing of the posterolateral fragment using the posteromedial approach impossible in some cases. Orapiriyakul et al. demonstrated limitations on using the posteromedial approach with a posterolateral fragment (37). If the posterolateral fragment is located at a distance of more than 43.72% of the lateral condylar width, the fragment may be invisible with the posteromedial approach. In that case, a combination of the posterolateral and posteromedial approaches is needed.

Conclusions

Posterior tibial plateau fracture fixation cannot be overlooked, especially in bicondylar tibial plateau fractures. As described in this review, the posteromedial fragment is characteristically a large and simple type. For biomechanical reasons, a posteromedial buttressing plate is recommended. The posterolateral fragment is small, comminuted and located at the far lateral corner. To deal with a posterolateral fragment, direct visualization is required. Pre-operative surgical planning is compulsory for posterior plateau fracture treatment. In cases where the posterolateral approach is needed, dissection must be performed meticulously.

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References

1. Luo CF, Sun H, Zhang B, Zeng BF. Three-column fixation for complex tibial plateau fractures. J Orthop Trauma. 2010;24:683-92.
2. Chang SM, Hu SJ, Zhang YQ, Yao MW, Ma Z, Wang X, et al. A surgical protocol for bicondylar four-quadrant tibial plateau fractures. Int Orthop. 2014;38:2559-64.
3. Chen HW, Chen CQ, Yi XH. Posterior tibial plateau fracture: a new treatment-oriented classification and surgical management. Int J Clin Exp Med. 2015;8:472-9.
4. Krause M, Preiss A, Müller G, Madert J, Fehske K, Neumann MV, et al. Intra-articular tibial plateau fracture characteristics according to the "Ten segment classification". Injury. 2016;47:2551-7.
5. Kim CW, Lee CR, An KC, Gwak HC, Kim JH, Wang L, et al. Predictors of reduction loss in tibial plateau fracture surgery: Focusing on posterior coronal fractures. Injury. 2016;47:1483-7.
6. Weaver MJ, Harris MB, Strom AC, Smith RM, Lhowe D, Zurakowski D, et al. Fracture pattern and fixation type related to loss of reduction in bicondylar tibial plateau fractures. Injury. 2012;43:864-9.
7. Waldrop JI, Macey TI, Trettin JC, Bourgeois WR, Hughston JC. Fractures of the posterolateral tibial plateau. Am J Sports Med. 1988;16:492-8.
8. Yang G, Zhai Q, Zhu Y, Sun H, Putnis S, Luo C. The incidence of posterior tibial plateau fracture: an investigation of 525 fractures by using a CT-based classification system. Arch Orthop Trauma Surg. 2013;133:929-34.
9. Zhai Q, Hu C, Xu Y, Wang D, Luo C. Morphologic study of posterior articular depression in Schatzker IV fractures. Orthopedics. 2015;38:e124-8.
10. Sohn HS, Yoon YC, Cho JW, Cho WT, Oh CW, Oh JK. Incidence and fracture morphology of posterolateral fragments in lateral and bicondylar tibial plateau fractures. J Orthop Trauma.2015; 29:91-7.
11. Zhu Y, Meili S, Dong MJ, Zhai QL, Yao L, Wang JC, et al. Pathoanatomy and incidence of the posterolateral fractures in bicondylar tibial plateau fractures: a clinical computed tomography-based measurement and the associated biomechanical model simulation. Arch Orthop Trauma Surg. 2014;134:1369-80.
12. Zhu Y, Yang G, Luo CF, Smith WR, Hu CF, Gao H, et al. Computed tomography-based Three-Column Classification in tibial plateau fractures: introduction of its utility and assessment of its reproducibility. J Trauma Acute Care Surg. 2012;73:731-7.
13. Chen P, Shen H, Wang W, Ni B, Fan Z, Lu H. The morphological features of different Schatzker types of tibial plateau fractures: a three-dimensional computed tomography study. J Orthop Surg Res. 2016;11:94.
14. Chang SM, Zheng HP, Li HF, Jia YW, Huang YG, Wang X, et al. Treatment of isolated posterior coronal fracture of the lateral tibial plateau through posterolateral approach for direct exposure and buttress plate fixation. Arch Orthop Trauma Surg. 2009;129:955-62.
15. Chen HW, Liu GD, Ou S, Zhao GS, Pan J, Wu LJ. Open reduction and internal fixation of posterolateral tibial plateau fractures through fibula osteotomy-free posterolateral approach. J Orthop Trauma. 2014;28:513-7.
16. Tao J, Hang DH, Wang QG, Gao W, Zhu LB, Wu XF, et al. The posterolateral shearing tibial plateau fracture: treatment and results via a modified posterolateral approach. Knee. 2008;15:473-9.
17. Liu GY, Xiao BP, Luo CF, Zhuang YQ, Xu RM, Ma WH. Results of a modified posterolateral approach for the isolated posterolateral tibial plateau fracture. Indian J Orthop. 2016;50:117-22.
18. Barei DP, O'Mara TJ, Taitsman LA, Dunbar RP, Nork SE. Frequency and fracture morphology of the posteromedial fragment in bicondylar tibial plateau fracture patterns. J Orthop Trauma. 2008;22:176-82.
19. Higgins TF, Kemper D, Klatt J. Incidence and morphology of the posteromedial fragment in bicondylar tibial plateau fractures. J Orthop Trauma. 2009;23:45-51.
20. Molenaars RJ, Mellema JJ, Doornberg JN, Kloen P. Tibial Plateau Fracture Characteristics: Computed Tomography Mapping of Lateral, Medial, and Bicondylar Fractures. J Bone Joint Surg Am. 2015;97:1512-20.
21. Xiang G, Zhi-Jun P, Qiang Z, Hang L. Morphological characteristics of posterolateral articular fragments in tibial plateau fractures. Orthopedics. 2013;36:e1256-61.
22. Schatzker J, McBroom R, Bruce D. The tibial plateau fracture. The Toronto experience 1968-1975. Clin Orthop Relat Res. 1979;(138):94-104.
23. Wang Y, Luo C, Zhu Y, Zhai Q, Zhan Y, Qiu W, et al. Updated Three-Column Concept in surgical treatment for tibial plateau fractures - A prospective cohort study of 287 patients. Injury. 2016;47:1488-96.
24. Yao X, Xu Y, Yuan J, Lv B, Fu X, Wang L, et al. Classification of tibia plateau fracture according to the "four-

column and nine-segment". Injury. 2018;49:2275-83.
25. Yao J, Lancianese SL, Hovinga KR, Lee J, Lerner AL. Magnetic resonance image analysis of meniscal translation and tibio-menisco-femoral contact in deep knee flexion. J Orthop Res. 2008;26:673-84.
26. Johal P, Williams A, Wragg P, Hunt D, Gedroyc W. Tibio-femoral movement in the living knee. A study of weight bearing and non-weight bearing knee kinematics using 'interventional' MRI. J Biomech. 2005;38:269-76.
27. Immerman I, Bechtel C, Yildirim G, Heller Y, Walker PS, Egol KA. Stability of the posteromedial fragment in a tibial plateau fracture. J Knee Surg. 2013;26:117-26.
28. Cuéllar VG, Martinez D, Immerman I, Oh C, Walker PS, Egol KA. A biomechanical study of posteromedial tibial plateau fracture stability: Do they all require fixation? J Orthop Trauma. 2015;29:325-30.
29. Kennedy JC, Bailey WH. Experimental tibial-plateau fractures. Studies of the mechanism and a classification. J Bone Joint Surg Am. 1968;50:1522-34.
30. Eggli S, Hartel MJ, Kohl S, Haupt U, Exadaktylos AK, Röder C. Unstable bicondylar tibial plateau fractures: a clinical investigation. J Orthop Trauma. 2008;22:673-9.
31. Barei DP, Nork SE, Mills WJ, Coles CP, Henley MB, Benirschke SK. Functional outcomes of severe bicondylar tibial plateau fractures treated with dual incisions and medial and lateral plates. J Bone Joint Surg Am. 2006;88:1713-21.
32. Kim Y, Yoon YC, Cho JW, Cho WT, Jeon NH, Oh CW, et al. Rim plate augmentation of the posterolateral bare area of the tibial plateau using a 3.5-mm precontoured locking compression plate: A cadaveric study. J Orthop Trauma. 2018;32:e157-e60.
33. Chen P, Lu H, Shen H, Wang W, Ni B, Chen J. Newly designed anterolateral and posterolateral locking anatomic plates for lateral tibial plateau fractures: a finite element study. J Orthop Surg Res. 2017;12:35.
34. Jian Z, Ao R, Zhou J, Jiang X, Zhang D, Yu B. A new anatomic locking plate for the treatment of posterolateral tibial plateau fractures. BMC Musculoskelet Disord. 2018;19:319.
35. Heidari N, Lidder S, Grechenig W, Tesch NP, Weinberg AM. The risk of injury to the anterior tibial artery in the posterolateral approach to the tibia plateau: a cadaver study. J Orthop Trauma. 2013;27:221-5.
36. Sun H, Luo CF, Yang G, Shi HP, Zeng BF. Anatomical evaluation of the modified posterolateral approach for posterolateral tibial plateau fracture. Eur J Orthop Surg Traumatol. 2013;23:809-18.
37. Orapiriyakul W, Apivatthakakul T, Phornphutkul C. Posterolateral tibial plateau fractures, how to buttress? Reversed L posteromedial or the posterolateral approach: a comparative cadaveric study. Arch Orthop Trauma Surg. 2018;138:505-13.

ความสำคัญของภาวะกระดูกผิวข้อส่วนหลังของกระดูกทิเบียส่วนต้นหัก (Posterior tibial plateau fracture) –ทบทวนวรรณกรรมในเรื่องอุบัติการณ์ ลักษณะชิ้นกระดูกหัก และกลไกการเกิดภาวะกระดูกหัก

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ภาวะกระดูกผิวข้อส่วนหลังของกระดูกทิเบียส่วนต้นหัก (posterior tibial plateau fracture) พบร่วมได้บ่อยในภาวะกระดูกผิวข้อทิเบียส่วนต้นหักชนิดซับซ้อน (complex tibial plateau fracture) เนื่องด้วยลักษณะชิ้นกระดูกหักของผิวข้อด้านหลังส่วนใน (posteromedial) และส่วนนอก (posterolateral) มีลักษณะจำเพาะ กอปรกับกลไกการเกิดกระดูกหักที่หลากหลาย ส่งผลต่อการเลือกการรักษาที่เหมาะสม บทความปริทัศน์ฉบับนี้ ชี้ให้เห็นถึงความสำคัญของภาวะกระดูกหักดังกล่าว โดยทบทวนอุบัติการณ์การเกิดกระดูกหัก ลักษณะชิ้นกระดูกหัก และกลไกการเกิดภาวะกระดูกหัก อันเป็นประโยชน์เพื่อการประยุกต์ใช้ประกอบการเลือกวิธีการผ่าตัดที่เหมาะสม **เชียงใหม่เวชสาร 2562;58(2):113-21.**

คำสำคัญ: ผิวข้อกระดูก กระดูกทิเบีย กระดูกแข้ง อุบัติการณ์การเกิดภาวะกระดูกหัก กลไกการเกิดภาวะกระดูกหัก ลักษณะชิ้นกระดูกหัก กระดูกหัก