Posterior Malleolus Fractures in Trimalleolar Ankle Fractures: Malleolus versus Transyndesmal Fixation

Abstract

Background: In ankle fractures involving the posterior malleolus, the issue of which types of fractures require posterior malleolus fixation is still controversial. Recent studies have demonstrated that trimalleolar fractures adversely affect the functional outcomes in comparison to bimalleolar fractures of the lateral and medial malleolus. The purpose of this study was to assess the effects of posterior malleolus fixation on the functional and radiological outcomes. **Materials and Methods:** Reduction quality, development of posttraumatic ankle osteoarthritis, and functional outcomes in 49 consecutive trimalleolar ankle fractures were evaluated retrospectively in patients with and without posterior malleolus fixation. Group I consisted of 29 patients, in which posterior malleolar fracture was left untreated. Twenty patients in Group II, posterior malleolar fragment was fixed directly by screws alone or plate screw. Twenty-one of these 49 patients were male (43%). The mean age was 47 years (range 20-82 years). **Results:** The mean followup was 12 to 51 months with a mean of 15 months (range 12-51 months). Statistically significant differences were found between Group I and Group II in terms of ankle arthrosis. American Orthopaedic Foot and Ankle Society score was significantly lower in Group I compared to Groups II. **Conclusions:** These results demonstrate that posterior malleolar fracture fixation is closely related to successful radiological and functional outcomes after trimalleolar fractures. Transyndesmal screw fixation may not be needed in the cases where the posterior malleolar fracture fixated. For these reasons, we recommend that all posterior malleolar fractures have to be fixed regardless of size.

Keywords: *Ankle fracture, malleolar fracture, posterior malleolus, posterolateral approach*
MeSH terms: *Ankle joint; ankle injuries; fracture fixation*

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Introduction

Posterior malleolar fractures are observed in approximately 14%–44% of all ankle fractures.[1,2] These types of fractures usually include the posterior tubercle of the distal tibia or posteromedial tibial plafond.[3] The most common type of posterior malleolar fracture involves the posterior tubercle, resulting in an avulsion of the posterior inferior tibiofibular ligament (PITFL) following a rotational ankle injury.[4] Large posterior malleolar fracture fragments with posteromedial involvement occur along with the axial loading and posterior shearing forces to the ankle mortise.[3]

Recent studies have demonstrated that functional outcomes are adversely affected in trimalleolar fractures in comparison to bimalleolar fractures of the lateral and medial malleolus.[2,5-9] Due to the important biomechanical function of the posterior tibial margin in weight-bearing and ankle stability, the affected ankle is prone to degenerative ankle arthritis.[10]

The treatment of ankle fractures with the involvement of posterior malleolus remains a subject of debate. Most authors recommend fixation when the fracture comprises >25% of the articular surface.[2,5,7,8,10-14] Surgical treatment with open reduction and internal fixation is the accepted method of treatment for medial and lateral malleolus fractures. Posterior malleolus fractures are frequently left unfixed because they are expected to be reduced spontaneously after open reduction of the lateral malleolus.[15] When a posterior fragment is present, surgical technique fails more often in the anatomic reduction of the joint.[2] As the surgical treatment of posterior malleolus fracture requires approaches other than traditional medial or lateral incisions, orthopedic surgeons may have a tendency to neglect the posterior malleolus fractures or underestimate the size of the fragment.

In ankle fractures involving the posterior malleolus, the issue of which type of fractures require posterior malleolus fixation is still controversial,[13,16] suggesting that a trans-

How to cite this article: Tosun B, Selek O, Gok U, Ceylan H. Posterior malleolus fractures in trimalleolar ankle fractures: Malleolus versus transyndesmal fixation. Indian J Orthop 2018;52:309-14.

Access this article online
Website: www.ijoonline.com
DOI: 10.4103/ortho.IJOrtho_308_16
Quick Response Code:

syndesmotic fixation may be adequate instead of posterior malleolar fixation.[17] Only a few surgical methodologies concerning the ankle for open reduction and internal fixation of posterior malleolar fragments have been described, whereas a reasonable approach for different fracture patterns and the method of posterior malleolus fixation for trimalleolar fractures have not been addressed in the literature at all.

This study compares the results after posterior malleolus and trans syndesmal fixation while considering the reduction quality, development of posttraumatic ankle osteoarthritis, and functional outcomes in trimalleolar ankle fractures.

Materials and Methods

A retrospective review conducted between 2009 and 2014 identified 64 patients with posterior malleolar fracture, a component of trimalleolar fracture. Nine patients with a fracture-dislocation injury were excluded from the study. Five patients were lost during followup and one patient was in pediatric age were excluded from the study. The remaining 49 patients operated by two authors (BT, OS) were included in the study.

All patients had immediate prereduction radiographs of the ankle including anteroposterior and lateral views. Preoperative computed tomography (CT) was also taken for planning of the surgery.

Forty nine patients were retrospectively placed in one of the treatment groups. Posterior malleolar fracture was left untreated in Group I [Figure 1]. Posterior malleolar fragment was fixed directly by screws alone or plate screw using a posterolateral ankle approach in Group II [Figure 2]. Group I comprised 29 patients and Group II comprised 20 patients. The mean age was 47 years (range 20-82 years). The details of the patient demographics are given in Table 1. The fractures were classified according to the Lauge-Hansen and AO/OTA. There were 33 cases of type 44-B/SER (67.3%) and 16 cases of 44-C/PER (32.7%).

Posterior malleolar fragment was fixed according to fragment size and surgeons' preference in the earlier cases. Then, afterward, posterior malleolus fracture management was done regardless of the size of the fracture fragment.

Conventional lateral and medial approaches to the ankle were used in Group I to reduce and fixate the lateral and medial malleolar fractures. A trans syndesmotic fixation was determined based on intraoperative lateral translation stress test and an external rotation stress mortis fluoroscopic view. The trans syndesmotic fixation was not used when the rotational stability was achieved with fracture fixation alone. Specifically, 3.5 mm cortical or 4.5 mm malleolar screw was inserted tricortically from fibular plate to the tibia just 3.5–4.5 cm above from the ankle joint. In Group II, we used a posterolateral approach to the ankle to treat the posterior malleolar fracture and associated fibular fractures. Fixation of medial malleolus was performed using a mini medial approach.

Followup radiographs were obtained at 1, 3, and 6 months and 1 year postoperatively. At each followup, patients were assessed for syndesmotic reduction, loss of fixation, and implant failure. The reduction in quality was evaluated on immediate postoperative radiography. Functional score and degenerative changes were assessed on the last followup records by one author. Postoperatively, a short-leg splint was applied to Group I patients for 6 weeks but not to Group II patients because of posterior malleolar fixation. Passive range of motion exercises of the ankle

Table 1: Clinical details of patients

Number of patients	49
Male: female	21:28
Average age (range)	47 years (20-82)
Average followup (range)	15 months (12-51)
Average time to surgery (range)	5.7 days (0-15)
Comorbidities	Type 2 diabetes: 5 patients Hypertension: 8 patients

Figure 1: (a) Preoperative sagittal computed tomography scan showing posterior malleolar fracture with displacement. (b) Early postoperative anteroposterior and lateral radiographs of ankle joint showing that medial malleolus fixed with tensions band wiring lateral malleolus with plate. One syndesmotic screw is also seen. But the posterior fragment is left alone (Group 1). (c) Anteroposterior and lateral radiographs of ankle joint showing degenerative arthritis at 3 years followup

Figure 2: Group II - (a) Sagittal computed tomography scan showing a posterior malleolar fragment >25% of the articular surface with displacement. (b) Transverse view of computed tomograph scan showing a large posterolateral fragment of the tibial plafond. (c) Anteroposterior and lateral radiographs of ankle joint, 1 year after surgery showing anatomically reduced posterior fragment. Lag screws were used to fix the posterior malleolus

was applied to Group II just after the operation. The patients were mobilized toe-touch weight-bearing with a walker or double crutches for 6–12 weeks.

The University's Ethics Review Board for research involving human subjects approved the study. Patients with trimalleolar ankle fracture were included as long as clinical followup was available for a minimum of 12 months (mean 15 months, range 12–51 months). The data abstracted from the medical records included patient age, gender, fracture pattern, type of surgical treatment, quality of reduction according to the scoring criteria of Ovadia and Beals,[18] functional outcomes including the American Orthopaedic Foot and Ankle Society (AOFAS), and the severity of osteoarthritis of the ankle using the grading system of van Dijk *et al*.[19]

The size of the posterior malleolar fragment was defined as the percentage of the distal tibial articular surface on the most involved slice, as measured on the preoperative sagittal plane CT scans. The length of the articular surface of the fragment was divided by the length of the distal tibial articular surface, including the articular surface of the fragment, and multiplied by 100.

Statistical analysis

SPSS version 17.0 for Windows (SPSS Inc. Chicago, IL, USA) was used for statistical analysis. Categorical variables were described by their frequency distribution. The categorical factors were analyzed using Chi-square test. In the cases of continuous variables, the mean and its standard deviation were used, after assessment of normal distribution. The normality of data between groups was confirmed by Kolmogorov–Smirnov test. The median values were calculated for discrete variables. Mann–Whitney U-test was used to evaluate the statistical significance of discrete variables. $P < 0.05$ was considered statistically significant.

Results

In all patients, fracture healed within 3 months after the surgical fixation. No loss of reduction occurred on radiographic followup, and no hardware irritation or loosening was seen. Four patients in Group I and one patient in Group II developed a wound dehiscence or wound erythema. Three patients in Group I with skin edge necrosis were treated with split thickness skin graft after local debridement. Two patients healed with local wound care. One patient in Group II diagnosed with deep vein thrombosis was treated by a low molecular weight heparin.

The mean size of the posterior malleolar fragment was 21.3% ± 7.5% in Group I and 28.9% ± 10.5% in Group II [Table 2]. Eight of the twenty patients in Group II who received fixation of the posterior malleolar fragment had a fragment smaller than 25%. Eleven patients had plate fixation, and nine patients had lag screw fixation for posterior malleolar fragment in Group II.

The median value of reduction of the tibial joint surface based on initial postoperative radiographs revealed a 1 (0–1.5) mm of displacement (step off) of the posterior malleolar fragment in Group I and 0 (0–0.75) mm in Group II ($P = 0.016$) [Table 2]. The reduction quality in Group II exhibits more robust statistical significance than in Group I ($P < 0.001$).

Trans-syndesmotic fixation was required in 15 patients of Group I. However, in Group II, trans-syndesmotic fixation was performed only in one patient. This difference was statistically significant ($P = 0.002$).

The degree of arthrosis was Grade 0 in 3 ankles, I in 12 ankles, II in 8 ankles, and III in 6 patients in Group I at the last followup. In Group II, 9 ankles had Grade I and 2 ankles had Grade II arthrosis. Grade III arthrosis was not seen in Group II, 9 ankles remained in Grade 0 [Table 2]. Statistically significant differences were found between Group I and Group II ($P = 0.007$) in terms of ankle arthrosis.

The median of AOFAS score of the patients was 70 (64–83.5) in Group I and 92 (84.5–95) in Group II [Table 2]. AOFAS score was significantly lower in Group I compared to Group II ($P < 0.001$).

Table 2: Results according to groups

	Group I (*n*=29)	Group II (*n*=20)
Fragment size (%) (range)	21.3±7.5 (6-32)	28.9±10.5 (12-45)
Postoperative articular step off (mm)* (range)	1.000 (0-1.5)	0.000 (0-0.75)
AOFAS score* (range)	70 (64-83.5)	92 (84.5-95)
Arthrosis degree		
Grade 0	3	9
Grade I	12	9
Grade II	8	2
Grade III	6	0

*The median values were given for discrete variables.
AOFAS=American Orthopaedic Foot and Ankle Society

Discussion

Ankle fractures are common and account for 3.92% of all fractures sustained in the entire body.[20] Posterior malleolus fractures accompany about 7%–44% of ankle fractures.[21,22] The injury ranks secondary to external rotation of the talus under the tibial plafond with the foot in a pronated or supinated position.[23-25]

In ankle fractures, an orthopedic surgeon usually tends to attach a plate for lateral malleolus fracture and fix the medial malleolus with a screw in almost all cases due to the simplicity of the procedure. Since both malleoli stay just underneath the skin, there is no need for surgical exploration. Thus, the posterior malleolus is left unfixed.

The PITFL complex is regarded as core for the stability of the ankle syndesmosis.[26-29] Posterior malleolus fractures alter the tibiofibular syndesmotic stability.[30] When the posterior malleolus is fractured, the posterior syndesmotic ligaments may remain intact and attached to the fragment. Failure through the bone usually suggests the integrity of the PITFL.[31] Rigid fixation of the fibula followed by reduction and fixation of the posterior malleolar fracture may restore the ligamentous tension of the PITFL adequately and stabilize the syndesmosis without trans-syndesmotic fixation.[31] In a biomechanical study of Gardner *et al*., 70% stiffness of the distal tibiofibular articulation was restored by reducing and stabilizing the posterior malleolus compared to 40% through the use of a syndesmotic screw.[31]

Numerous authors prescribe resorting to posterior malleolar stabilization with internal fixation when the fragment involves >25% of the articular surface.[2,8,11,13,17,28,32-34] This recommendation is based on the biomechanical evidence of decreased joint surface contact area stemming from the posterior tibial fragment size and resulting in tibiotalar instability rather than on the presumed goal of restoring rotator ankle stability.[11,13,32] Van den Bekerom *et al*. detected a shift in the location of the contact stresses to a more anterior and medial location after a displaced posterior malleolar fracture using biomechanical model.[35]

Many authors addressed the ankle fractures with posterior malleolus. Rigid fixation of lateral malleolus could yield a near anatomic reduction of the posterior malleolus.[15,36] Although the posterior malleolus reduces with a closed reduction, maintaining the reduction may prove unfeasible without a rigid fixation. The decision about surgical fixation of the posterior malleolus is traditionally made based on its size, and small avulsion fractures are usually left unfixed.[2,11] Larger fragments involving >25% of the tibial plafond require surgical reduction and fixation.[2,5,7,8,10-14] However, newer literature does not rely on size of post malleolus for fixation. Heim claimed that all posterior fragments, except for the avulsion lip fractures, should be fixed internally.[33]

Studies of posterior malleolus fractures have analyzed relatively small patient group sizes.[30] Classification of these fractures, indications for surgical intervention, surgical approach, and operative technique remain subject of debate. Bois and Dust found radiographic osteoarthritis of Grades II or III in 67% of their series at an average of 9.4 years after ankle fracture. They concluded that radiographic changes consistent with ankle osteoarthritis might be well tolerated early in the disease process.[3]

Park *et al*. treated 29 ankle fractures with a posterior malleolar fragment. Syndesmotic screw fixation was used in 15 cases, whereas 14 cases were treated using posterior malleolar fixation. They found no statistical difference in the quality of reduction, grade of ankle arthrosis, and clinical scores between groups.[37] Chung *et al*. treated 15 cases of posterior malleolus fracture, yielding 5 excellent and 7 good outcomes.[38] Lee *et al*. investigated ten cases of trimalleolar fractures. All patients in their series received excellent AOFAS score following open reduction and internal fixation of posterior malleolar fragment.[39] Xu *et al*. found no statistical difference in the treatment effect between 42 cases of fixed and 60 cases of unfixed posterior malleolus fragment groups.[21]

Gardner *et al*. treated syndesmotic instability with traditional trans-syndesmotic fixation methods that have been found to have a 52% rate of malreduction, as evaluated by CT compared to plain radiographs that show well-reduced fractures.[40] Miller *et al*. suggested that fixation of posterior malleolus fracture is more likely to restore stability to the syndesmosis compared to trans-syndesmotic fixation alone.[16] Ogilvie-Harris *et al*. showed that the PITFL alone makes up 42% of the strength of the syndesmosis.[41] Gardner *et al*. evaluated the integrity of PITFL after ankle fractures associated with posterior malleolar fracture and suggested that this kind of fracture has an intact PITFL.[31] Based on these studies, it may be concluded that, in most ankle fractures involving a posterior fragment, PITFL can be repaired by reduction and fixation of posterior malleolus, thereby providing fixation of the syndesmosis and eliminating the need for syndesmotic transfixation.

In our earlier cases, posterior malleolar fixation was decided according to fragment size and surgeons' preference.

Our preferred method of fixation for ankle fractures with posterior malleolus fracture is fixation of the posterior malleolus with the lateral malleolus through a posterolateral approach, regardless of the size of the fracture fragment and the fixation of medial malleolus fracture from a separate medial incision. In our study, trans-syndesmotic fixation was performed to 15 patients in Group I, whereas only one patient in Group II. We believe that the stabilization of the syndesmosis through the intact PITFL by direct reduction of posterior malleolar fragment results in more anatomic reduction of the tibiofibular articulation.

The posterolateral ankle approach provides a real internervous plane between the flexor hallucis longus and peroneal muscles. However, the sural nerve, which passes directly just beneath the skin, is potentially at risk of iatrogenic injury over the whole length of the incision during the posterolateral approach. Jowett *et al*.[42] demonstrated the course of the sural nerve that passes at the midportion 56.7 mm to 61 mm of the posterolateral incision midway between the lateral malleolus and the Achilles tendon in their cadaveric study. When performing a posterolateral approach to the ankle, particular care should be taken at the midpoint of the incision.

This study has some limitations due to its retrospective design and a relatively small number of patients. The assessment of articular reduction was performed on the immediate postoperative radiographs. Postoperative CT could be more sensitive in determining the reduction quality compare to a lateral radiography. However, it was not used as a tool due to high radiation exposure.

Our results regarding wound healing, fracture reduction quality, and arthrosis development are consistent with other studies of the posterolateral approach of the ankle.[16,43] The worst outcomes both radiologically and functionally were obtained when the posterior malleolus was not addressed, and syndesmosis was not restored. In our study, degenerative changes were more obvious in ankles where the posterior malleolar fracture was not treated. We believe that orthopedic surgeons can witness the radiological signs of ankle arthrosis in the cases where the syndesmosis is restored without posterior malleolus fixation after a longer period. Radiographic changes of ankle osteoarthritis may be well tolerated early in the disease process; however, a longer followup time is needed to confirm late radiological results.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Koval KJ, Lurie J, Zhou W, Sparks MB, Cantu RV, Sporer SM, *et al.* Ankle fractures in the elderly: What you get depends on where you live and who you see. J Orthop Trauma 2005;19:635-9.
2. Jaskulka RA, Ittner G, Schedl R. Fractures of the posterior tibial margin: Their role in the prognosis of malleolar fractures. J Trauma 1989;29:1565-70.
3. Bois AJ, Dust W. Posterior fracture dislocation of the ankle: Technique and clinical experience using a posteromedial surgical approach. J Orthop Trauma 2008;22:629-36.
4. Marsh JL, Saltzman CL. Ankle fractures. In: Bucholz RW, Heckman JD, Court-Brown CM, editors. Rockwood and Green's Fractures in Adults. 6th ed. Philadelphia, PA: Lippincott Williams and Wilkins; 2005. p. 2147-235.
5. De Vries JS, Wijgman AJ, Sierevelt IN, Schaap GR. Long term results of ankle fractures with a posterior malleolar fragment. J Foot Ankle Surg 2005;44:211-7.
6. Langenhuijsen JF, Heetveld MJ, Ultee JM, Steller EP, Butzelaar RM. Results of ankle fractures with involvement of the posterior tibial margin. J Trauma 2002;53:55-60.
7. Lindsjö U. Operative treatment of ankle fracture-dislocations. A followup study of 306/321 consecutive cases. Clin Orthop Relat Res 1985;199:28-38.
8. McDaniel WJ, Wilson FC. Trimalleolar fractures of the ankle. An end result study. Clin Orthop Relat Res 1977;122:37-45.
9. Borg T, Larsson S, Lindsjö U. Percutaneous plating of distal tibial fractures. Preliminary results in 21 patients. Injury 2004;35:608-14.
10. Macko VW, Matthews LS, Zwirkoski P, Goldstein SA. The joint-contact area of the ankle. The contribution of the posterior malleolus. J Bone Joint Surg Am 1991;73:347-51.
11. Broos PL, Bisschop AP. Operative treatment of ankle fractures in adults: Correlation between types of fracture and final results. Injury 1991;22:403-6.
12. Brown TD, Hurlbut PT, Hale JE, Gibbons TA, Caldwell NJ, Marsh JL, *et al.* Effects of imposed hindfoot constraint on ankle contact mechanics for displaced lateral malleolar fractures. J Orthop Trauma 1994;8:511-9.
13. Hartford JM, Gorczyca JT, McNamara JL, Mayor MB. Tibiotalar contact area. Contribution of posterior malleolus and deltoid ligament. Clin Orthop Relat Res 1995;320:182-7.
14. de Souza LJ, Gustilo RB, Meyer TJ. Results of operative treatment of displaced external rotation-abduction fractures of the ankle. J Bone Joint Surg Am 1985;67:1066-74.
15. Talbot M, Steenblock TR, Cole PA. Posterolateral approach for open reduction and internal fixation of trimalleolar ankle fractures. Can J Surg 2005;48:487-90.
16. Miller AN, Carroll EA, Parker RJ, Helfet DL, Lorich DG. Posterior malleolar stabilization of syndesmotic injuries is equivalent to screw fixation. Clin Orthop Relat Res 2010;468:1129-35.
17. Mingo-Robinet J, López-Durán L, Galeote JE, Martinez-Cervell C. Ankle fractures with posterior malleolar fragment: Management and results. J Foot Ankle Surg 2011;50:141-5.

18. Ovadia DN, Beals RK. Fractures of the tibial plafond. J Bone Joint Surg Am 1986;68:543-51.
19. van Dijk CN, Verhagen RA, Tol JL. Arthroscopy for problems after ankle fracture. J Bone Joint Surg Br 1997;79:280-4.
20. Salai M, Dudkiewicz I, Novikov I, Amit Y, Chechick A. The epidemic of ankle fractures in the elderly – Is surgical treatment warranted? Arch Orthop Trauma Surg 2000;120:511-3.
21. Xu HL, Li X, Zhang DY, Fu ZG, Wang TB, Zhang PX, *et al.* A retrospective study of posterior malleolus fractures. Int Orthop 2012;36:1929-36.
22. Court-Brown CM, McBirnie J, Wilson G. Adult ankle fractures – An increasing problem? Acta Orthop Scand 1998;69:43-7.
23. Lauge-Hansen N. Fractures of the ankle. II. Combined experimental-surgical and experimental-roentgenologic investigations. Arch Surg 1950;60:957-85.
24. Peter RE, Harrington RM, Henley MB, Tencer AF. Biomechanical effects of internal fixation of the distal tibiofibular syndesmotic joint: Comparison of two fixation techniques. J Orthop Trauma 1994;8:215-9.
25. Yde J. The Lauge Hansen classification of malleolar fractures. Acta Orthop Scand 1980;51:181-92.
26. Burns WC 2nd, Prakash K, Adelaar R, Beaudoin A, Krause W. Tibiotalar joint dynamics: İndications for the syndesmotic screw – A cadaver study. Foot Ankle 1993;14:153-8.
27. Close JR. Some applications of the functional anatomy of the ankle joint. J Bone Joint Surg Am 1956;38-A: 761-81.
28. Scheidt KB, Stiehl JB, Skrade DA, Barnhardt T. Posterior malleolar ankle fractures: An *in vitro* biomechanical analysis of stability in the loaded and unloaded states. J Orthop Trauma 1992;6:96-101.
29. Stormont DM, Morrey BF, An KN, Cass JR. Stability of the loaded ankle. Relation between articular restraint and primary and secondary static restraints. Am J Sports Med 1985;13:295-300.
30. Erdem MN, Erken HY, Burc H, Saka G, Korkmaz MF, Aydogan M. Comparison of lag screw versus buttress plate fixation of posterior malleolar fractures. Foot Ankle Int 2014;35:1022-30.
31. Gardner MJ, Brodsky A, Briggs SM, Nielson JH, Lorich DG. Fixation of posterior malleolar fractures provides greater syndesmotic stability. Clin Orthop Relat Res 2006;447:165-71.
32. Harper MC, Hardin G. Posterior malleolar fractures of the ankle associated with external rotation-abduction injuries. Results with and without internal fixation. J Bone Joint Surg Am 1988;70:1348-56.
33. Heim UF. Trimalleolar fractures: Late results after fixation of the posterior fragment. Orthopedics 1989;12:1053-9.
34. Meyer TL Jr., Kumler KW. A.S.I.F. technique and ankle fractures. Clin Orthop Relat Res 1980;150 211-6.
35. van den Bekerom MP, Haverkamp D, Kloen P. Biomechanical and clinical evaluation of posterior malleolar fractures. A systematic review of the literature. J Trauma 2009;66:279-84.
36. Tornetta P 3rd. Trimalleolar ankle fracture. Case profile. J Orthop Traumatol 2001;15:588-90.
37. Park SJ, Jeong HJ, Shin HK, Seo DS, Choi YM, Kim E Results of syndesmotic screw fixation versus posterior malleolus fixation in syndesmotic injury at pronation external rotation stage IV ankle fracture with posterior malleolus fracture: Postoperative one year followup. J Korean Foot Ankle Soc 2014;18:29-35.
38. Chung HW, Kim DH, Yoo SH, Suh JS. Treatment of the posterior malleolar fracture using posterior approach. J Korean Fract Soc 2010;23:50-6.
39. Lee JY, Ha SH, Noh KH, Lee SJ. Treatment of the posterior malleolar fragment of trimalleolar fracture using posterolateral approach – Preliminary report. J Korean Orthop Assoc 2009;44:422-8.
40. Gardner MJ, Demetrakopoulos D, Briggs SM, Helfet DL, Lorich DG. Malreduction of the tibiofibular syndesmosis in ankle fractures. Foot Ankle Int 2006;27:788-92.
41. Ogilvie-Harris DJ, Reed SC, Hedman TP. Disruption of the ankle syndesmosis: Biomechanical study of the ligamentous restraints. Arthroscopy 1994;10:558-60.
42. Jowett AJ, Sheikh FT, Carare RO, Goodwin MI. Location of the sural nerve during posterolateral approach to the ankle. Foot Ankle Int 2010;31:880-3.
43. Forberger J, Sabandal PV, Dietrich M, Gralla J, Lattmann T, Platz A. Posterolateral approach to the displaced posterior malleolus: Functional outcome and local morbidity. Foot Ankle Int 2009;30:309-14.