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ORIGINAL STUDY

Comparison of three posterior malleolar fixation methods in trimalleolar ankle fractures

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This study aimed to compare the results of AP screws, PA screws and posterior buttress plate used in posterior malleolar fixation of trimalleolar fractures. In this study, the data of 104 trimalleolar fracture cases treated surgically between October 2011 and January 2014 were extracted from hospital records. Patient demographics (age, gender, body mass index), the presence of syndesmotic injury, fracture type (according to the Lauge-Hansen classification), the size of posterior malleolar fragment (measured on lateral radiographs) were recorded. The patients requiring postoperative care for at least a year were invited to attend an evaluation of functional and radiological outcomes. At the final follow-up examination the functional evaluation was made by using AOFAS scores, VAS scores during walking, and dorsiflexion restrictions as compared with the unaffected side. As for the radiological evaluation, the patients were assessed according to the presence of a gap or step by the direct use of graphies following the fixation and with regard to the osteoarthritic development in alignment with the Bargon criteria.
A total of 67 patients met the study inclusion criteria; 20 cases in the AP screw, 13 cases in the PA screw and 34 cases in the plate group. The mean follow-up period was 14.4 ± 2.23 months in AP, 16.3 ± 2.56 months in PA and 17.1 ± 3.01 months in the plate group. Better AOFAS scores were obtained in the PA group and the plate group compared to the AP screw group ($p < 0.001$). No statistically significant difference was found between the groups in respect of VAS scores during walking and dorsiflexion restriction. Better radiological reduction was observed in the PA screw group and the plate group ($p < 0.001$).
PA screw and posterior buttress plate fixation with direct reduction via posterolateral approach demonstrated better radiological and functional outcomes than AP screw fixation.

Keywords : Trimalleolar fractures ; posterolateral incision ; posterior malleolar fixation.

INTRODUCTION

Post-traumatic arthritis is an important problem of severe ankle fractures requiring surgical treatment. Despite 4 % of the reported overall incidences in ankle fractures, up to 34 % of incidences have been reported in cases with trimalleolar fractures *(3, 18,24)*. Although there is almost no debate about the surgery for displaced malleolar fractures, the indications for the fixation of the posterior malleolar fragment (Volkman fragment) and the fixation techniques in

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trimalleolar fractures accompanied by a posterior malleolar fracture are still not clear. It is generally accepted that the fixation of the posterior malleolar fragment is recommended in posterior malleolar fractures which include 25%-33% of the distal tibial articular surface on the lateral radiograph and it is also suggested in the presence of more than 2mm articular step and instability *(8,9,27)*. However, these criteria are also controversial. Recent studies favor the fixation of posterior malleolar fractures of less than 25 % of the distal tibial articular surface to decrease post-traumatic arthritis *(5,16)*.

Currently, the fixation of posterior malleolar fractures can be performed with three methods; screws placed in an anterior-posterior direction following indirect reduction (A-P screws), screws placed in a posterior-anterior direction (P-A screws) following direct reduction with a posterior incision, or with a plate. During the fixation using A-P screw, difficulties can be encountered while attempting to achieve a full anatomic reduction using indirect reduction maneuvers *(13)*. As these fractures are often accompanied by a lateral malleolar fracture, when fixating the lateral malleolar fracture with a posterolateral incision, a perfect anatomic reduction of the posterior malleolus can be achieved by utilizing the same posterolateral incision used for the fixation of the lateral malleolus. This exposure not only enables the placement of a P-A screw with a direct anatomic reduction, but also allows the manipulation of small fragments. It has been previously reported that the P-A screw fixation provides better fixation strength than the A-P screw fixation *(23)*. Another recently popularized method of posterior malleolar fragment fixation is the plate-screw fixation. This method enables direct fracture reduction and stable fixation. The disadvantage of this method is the close relationship between the peroneal artery and perforating branches during proximal exposure for plate placement *(22)*.

All the three methods have certain advantages and disadvantages. The aim of this study is to compare the results of AP screws, PA screws and posterior buttress plate used in the posterior malleolar fixation of trimalleolar fractures.

PATIENTS AND METHODS

In this retrospective-multicenter comparative study, the hospital records were reviewed in two university hospitals. Approval for the study was granted by the Local Ethics Committee. Data related to cases of trimalleolar fracture treated surgically between October 2011 and January 2014 was extracted from the database of each hospital. Exclusion criteria were defined as open fractures, bilateral involvement, multi-trauma cases, patients aged <18 years, the presence of ankle arthritis (inflammatory or degenerative), pathological fractures and patients for whom the posterior malleolar fragment was not fixed. The hospital records of 104 patients who underwent the fixation of the posterior malleolar fragment during surgery for trimalleolar fracture were examined. Data concerning patient demographics (age, gender, body mass index), presence of syndesmotic injury, fracture type (according to the Lauge-Hansen classsification), and the size of posterior malleolar fragment (measured on lateral radiographs) were collected. Radiographic measurements were performed using Centricity PACS-IW software (General Electric healthcare). The collected data were grouped according to the fixation method as the AP screw group, the PA screw group and the plate group.

All operations were performed by experienced orthopaedists with at least 5 years of experience in trauma and foot and ankle surgery. No specific criteria (e.g. fragment size, amount of displacement) were used for the selection of the fixation type. The method of posterior malleolar fixation was determined according to the surgeon's preference.

In the AP screw method, the patient was placed in a supine position then the fibula and the medial malleolus were fixated with direct incisions. Subsequently, the posterior malleolus reduction, which was enabled by ligamentotaxis, was checked with fluoroscopy. After the verification of the reduction, the fixation was made by using one or two partially threaded 4.5 mm canullated screws.

In the PA screw method, the posterolateral approach described by Tornetta et al. was applied to the patient who was placed in a prone position

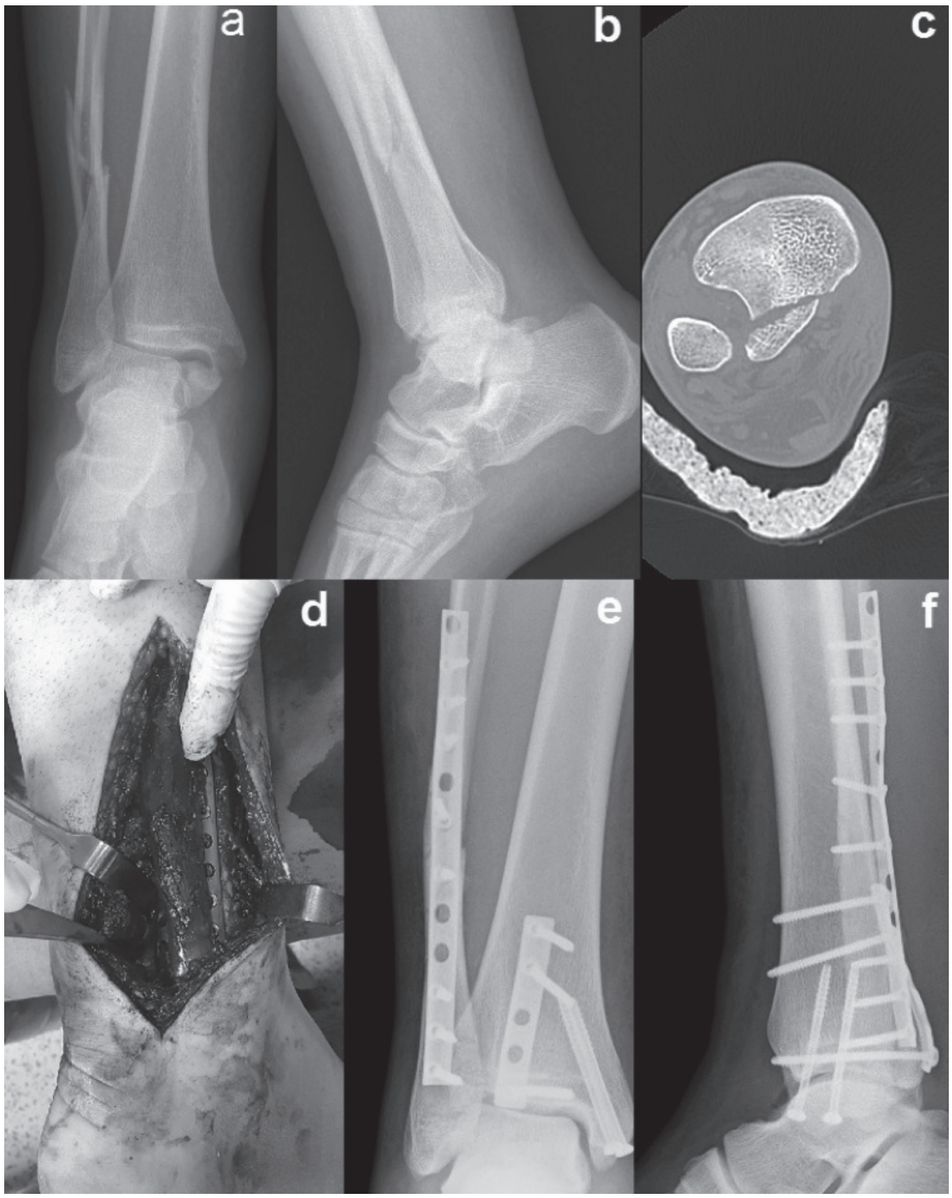

Fig. 1. — Example case of posterior plate fixation. A-P (a) and lateral (b) radiographs showing pronation-adduction type of injury; and CT image (c). Using a single posterolateral incision, both the fibula and the posterior malleolar fragment were fixed (*: fibular plate, arrow: posterior malleolar plate) (d). Post-operative A-P (e) and lateral (f) images showing good reduction and fixation.

(26). The fibula was fixed by retracting the peroneal tendons medially, and then the posteralateral tibia was exposed using the interval between the peroneal tendons and the flexor hallucis longus muscle. After direct reduction, the fixation was achieved with 1 or 2 partially threaded 4.5 mm. cannulated screws. Then, making a separate incision over the medial malleolus, medial malleolar fixation was applied.

In the plate fixation method, as in the case of the PA screw method, the posterolateral approach was applied to the posterolateral tibia. Different from the PA screw, the approach was extended

Table I. — Patient demographics, fracture characteristics and postoperative radiological evaluation

	AP Screw (n=20)	PA Screw (n=13)	PL Plate (n=34)	p- value
Age(y, mean)	43.4	48.3	40.8	
Male Gender(n)	12	5	10	P=0.85
Body Mass Index (mean,kg/m^2)	27.35±3.675	25.23±2.743	25.97±3.494	P=0.323
Fracture type (Lauge-Hansen)				
Supination External Rotation	9 (45%)	3 (23.1%)	10 (29.4%)	
Supination Adduction	0 (0%)	0 (0%)	5 (14.7%)	
	2 (10%)	0 (0%)	6 (17.6%)	
Pronation External Rotation	9 (45%)	10 (76.9%)	13 (38.2%)	
Pronation Abduction				
Syndesmotic injury	6 (30%)	3 (23.1%)	20 (58.8%)	P=0.078
Syndesmosis screw	2 (10%)	1 (7.6%)	3 (8.8%)	
Size of posterior fragment				
<10%	8 (40%)	4 (30.7%)	13 (38.2%)	
10%-25%	9 (45%)	7 (53.8%)	15 (44.1%)	
>25%	3 (15%)	2 (15.3%)	6 (17.6%)	
Post-operative radiographic evaluation				
Gap (mm.) (mean±SD, [min-max])	1±0.56 (0-2)	0.23±0.43 (0-1)	0.56±0.5 (0-1)	P<0.001
Step (mm.) (mean±SD, [min-max])	0.95±0.51 (0-2)	0.08±0.13 (0-1)	0.32±0.53(0-2)	P<0.001

proximally to facilitate the placement of a buttress plate (3.5 mm. 1/3 tubular plate). Medial malleolar fixation was then applied in a similar manner.

Following the posterior malleolar fixation, the integrity of syndesmosis was evaluated intraoperatively under imaging control. If necessary, sydesmosis was secured with one screw.

Following the fixation, the presence of gap or step was evaluated through postoperative lateral radiographs and measured in millimeters using PACS software. All of the measurements were made by a single observer to avoid measurement variations.

A plaster cast was applied to all the patients postoperatively. In the 4th week after the operation, active range-of-motion exercises were started. Full weight-bearing was allowed 3 months postoperatively.

After the collection of the operative data, the patients who needed postoperative care for at least a year were called by telephone and were asked to attend a functional and radiological outcome evaluation. At this final follow-up examination, the functional evaluation was made using AOFAS scores, VAS scores during walking were recorded, and dorsiflexion restriction status was compared with the unaffected side. The radiological evaluation was also made, including loss of fixation on lateral radiographs compared with immediate postoperative radiographs and the presence of ankle osteoarthritis according to the Bargon et al criteria *(2)*.

Statistical analyses were performed using SPSS 19.0 software (SPSS Inc., Chicago, IL, USA). Conformity to normal distribution of the data was determined by the Shapiro-Wilk test. Continuous

variables were expressed as mean±standard deviation (SD), and categorical variables as frequency and percentage. The Kruskal-Wallis test was used to determine differences between the three groups. The Dunn's test was applied as the post-hoc test after the Kruskal-Wallis test. The Chi-square test was used to determine differences between the categorical variables. A value of $p < 0.05$ was considered statistically significant for all tests.

RESULTS

Of the total 104 patients with trimalleolar fracture cases with posterior malleolar fixation, 36 did not attend the final follow up visit, and were therefore excluded from the statistical evaluation. A final total of 68 patients who attended the final follow-up examination were included in the study evaluation.

The study sample consisted of 20 cases with AP screw fixation, 13 cases with PA screw fixation and 35 cases with plate fixation. Implant failure developed in 1 patient from the plate group due to early uncontrolled weight-bearing as a result of poor patient compliance. This case was revised with early (5 months postoperatively) conversion to ankle fusion with hindfoot arthrodesis nail, and was therefore excluded from the final evaluation. A final total of 34 cases constituted the plate group. Patient demographics are summarized in Table-1. The patients in all the groups were similar in respect of age, gender, body mass index and the presence of syndesmotic injury. According to the Lauge- Hansen classification of injuries, 22 (32.8%) patients were supination-external rotation type, 5 (7.5%) were supination-adduction type, 8 (11.9%) were pronation-external rotation type and 32 (47.8%) were pronation-abduction type. The distributions of the cases according to the size of the posterior malleolar fragment relative to the length of the tibial articular surface on the lateral radiograph are shown in Table 1.

The presence of gap or step was evaluated by means of post-operative lateral radiographs. In the AP screw group, a radiologically measurable gap mean of 1 ± 0.56 mm. (range, 0-2 mm) was determined. In the PA screw group, a gap of 0.23

Table II. — Follow-up outcome data

Complications			
Reflex sympathetic dystrophy (n)	1	0	0
Superficial wound infection (n)	0	0	1
Implant failure necessitating revision (n)	0	0	1

Table III. — Postoperative complications

	AP Screw(n=20)	**PA Screw(n=13)**	**Plate (n=34)**	**p-value**
Follow up time(months)	14.4±2.23 (12-19)	16.3±2.56 (12-21)	17.1±3.01 (12-24)	
Functional outcome				
AOFAS score (mean±SD)				
Walking VAS score (mean±SD)	86,4±7.97	93,8±4.05	94,7±5.29	P<0,05
> 5°Dorsiflexion restriction (n) (%)	0.55±0.82	0.76±1,3	0.94±1.84	P=0.98
	9(45.0%)	5(38.5%)	8(23.5%)	P=0.244
Presence of radiographic evidence of arthritis	2	0	1	

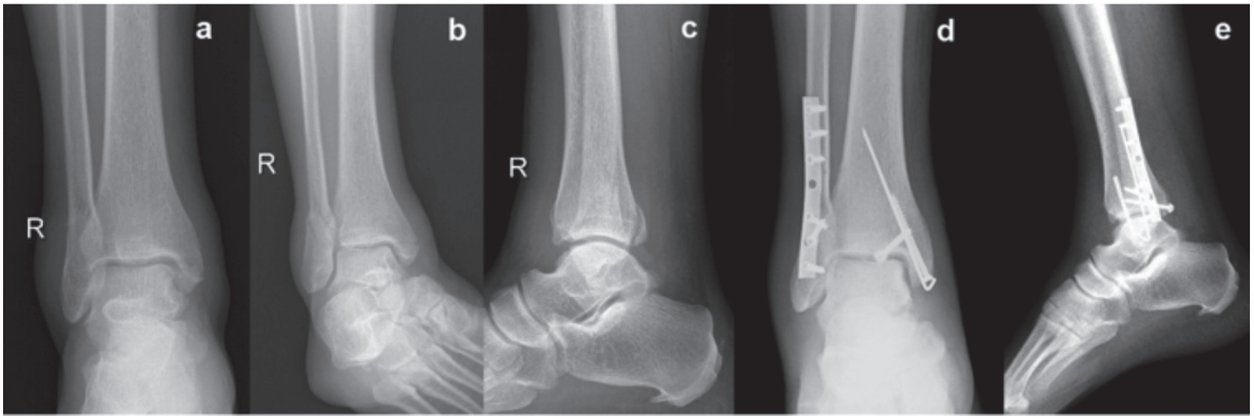

Fig. 2. — Example case of P-A screw. A-P, mortise and lateral images of a pronation-external rotation type of injury (a, b, c). Post-operative images demonstrate good reduction and fixation of the posterior malleolar fragment with a single P-A screw (e, f)

± 0.43 mm. (range, 0-1 mm) was found and in the plate group this gap was measured to be 0.56 ± 0.5 mm. (range, 0-1mm). The difference between the AP group and both the PA group and the plate groups was statistically significant ($p < 0.001$). The difference between the PA group and the plate group was not significant. When the step presence was examined, a mean of 0.95 ± 0.51 mm. (range, 0-2 mm) was found in the AP screw group, 0.08 ± 0.13 mm (range, 0-1 mm) in the PA screw group and 0.32 ± 0.53 mm. (range, 0-2 mm) in the plate group. Similar to the presence of gap, a statistically significant difference was found in respect of the presence of step in the AP screw group compared to the other groups ($p < 0.001$). The PA screw group and the plate group had better radiological reduction. No reduction loss was found on the final radiographs and radiological union was achieved in all the patients.

Residual syndesmotic diastasis following the malleolar fixation was observed intraoperatively in 3 cases in the plate group, in 1 case in the PA screw group and in 2 cases in the AP screw group. These cases were treated with one syndesmosis screw, which was removed 3 months postoperatively.

The mean follow-up period was 14.4 ± 2.23 months (range, 12-19 months) in the AP screw group, 16.3 ± 2.56 months (range, 12-21 months) in the PA screw group, and 17.1 ± 3.01 months (range, 12-24 months) in the plate group. All of the patients had mild pain and activity restriction during the follow-up period and this was reflected in the AOFAS and VAS scores. The mean AOFAS scores of the patients at the final follow-up examination were 86.4 ± 7.97 in the AP screw group, 93.8 ± 4.05 in the PA screw group and 94.7 ± 5.29 in the plate group. No statistically significant difference was found between the plate group and the PA screw group in respect of the AOFAS scores, but both groups were revealed to have better AOFAS scores than the AP screw group ($p = 0.83$, $p < 0.001$). The mean VAS scores in the walking phase at the final follow-up examination were determined as 0.55 ± 0.82 in the AP screw group, 0.76 ± 1.3 in the PA screw group and 0.94 ± 1.84 in the plate group. No statistically significant difference was found between the groups ($p = 0.98$). In the measurement of dorsiflexion restriction compared to the contralateral side at the final follow-up examination, a loss of 5° or more dorsiflexion was found in 9 patients (45.0%) in the AP screw group, in 5 patients (38.5%) in the PA screw group and in 8 patients (23.5%) in the plate group. The differences between the groups did not show statistical significances ($p = 0.244$, Table II).

In 95.5 % of the patients, no radiographic sign of osteoarthritis was observed in the follow-up radiographic evaluation. Grade 1 radiographic findings of ankle osteoarthritis were observed in 2 patients in the AP group and in 1 patient in the plate group. None of the cases developed severe osteoarthritic changes (Table II).

Complications included reflex sympathetic dystrophy syndrome in 1 case in the AP screw group, superficial wound infection in 1 case in the plate group (treated with local wound care and antibiotic treatment) and implant failure requiring revision (as stated above) (Table III).

DISCUSSION

While there is almost no debate about the treatment of lateral and medial malleolar fractures, no definitive treatment criteria have been described for the fixation of the posterior malleolar fragment (Volkman fragment) in trimalleolar fractures *(7)*. This study aimed to compare the outcomes of three different posterior malleolar fixation methods.

The aim of the posterior malleolar fixation is to achieve anatomical reduction of articular surfaces and stable fixation *(15)*. All the three methods are effective in achieving anatomical (<2 mm step) reduction of articular surfaces. In respect of radiological outcomes, a retrospective study by Xu et al reviewed 42 ankle fracture patients undergoing posterior malleolar fixation, with AP screws used as the fixation method in 19 patients and PA screws (percutaneous/open- not specified) in 23 patients. It was reported that anatomic reduction was achieved in 13/19 (68%) of the PA screw cases and 15/23 (65%) of the AP screw cases *(29)*. In another study, Erdem et al. compared P-A screw with plate fixation and anatomic reduction was achieved in 95% of the cases in both groups *(9)*. O'Connor et al. also compared AP screw with posterior buttress plate fixation and reported anatomic reduction in 9/11 (82%) of the A-P screw patients and 14/16 (87, 5%) of the plate fixation patients *(25)*. Similarly, Abdelgawad et al. reported anatomic reduction in 10/12 (83%) of the cases treated with plate fixation *(1)*. Huang et al evaluated the intraoperative images of all the patients operated on for posterior malleolar fracture with posterior plate or PA screws applied, and it was reported that step was measured as <1mm in 91% of the patients and 1-2mm in 9% of the cases *(12)*. Likewise, in the current study, the reduction quality was assessed through the millimetric measurement of the step detected on the articular surface in the early postoperative lateral ankle radiographs. No case from any of the 3 groups demonstrated >2 mm. of step. Therefore, the amount of malreduction on the articular surface was analyzed as the mean articular step or gap. The mean post-operative gap between the fragments was 1 ± 0.56 mm in the A-P screw group, 0.23 ± 0.43 mm in the P-A screw group and 0.32 ± 0.53 mm in the plate group. In a similar vein, the mean amount of step on the articular surface was

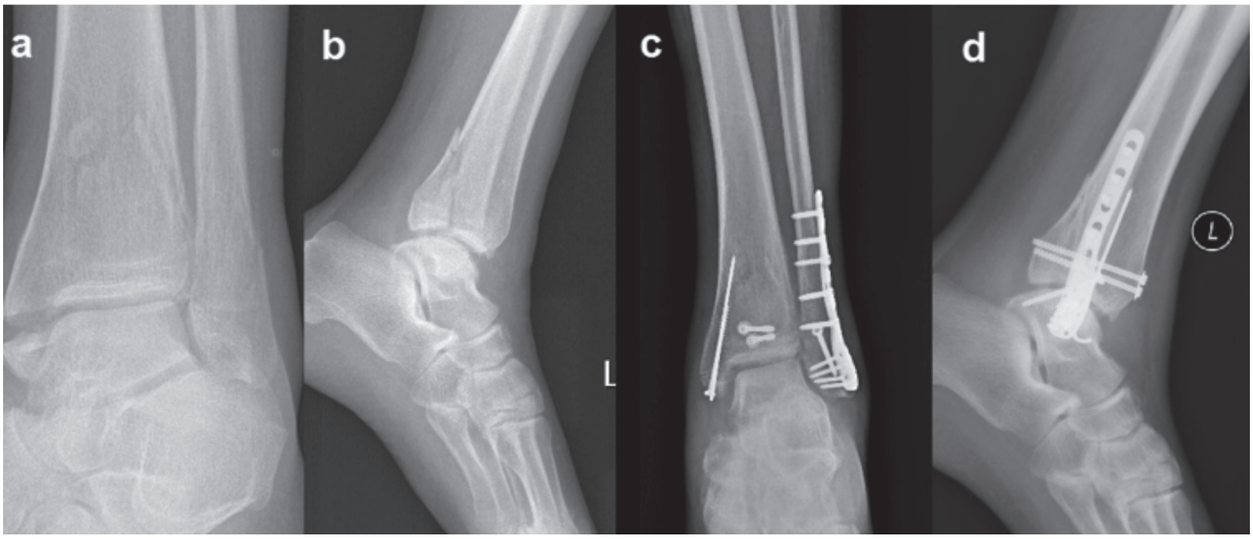

Fig. 3. — Example case of A-P screw fixation. Mortise and lateral images of a pronation-external rotation type of injury (a, b). Post-operative radiographs showing fixation of the posterior malleolar fragment with two A-P screws (c, d)

measured as 0.95 ± 0.51 mm in the A-P screw group, 0.08 ± 0.13 mm in the P-A screw group and 0.32 ± 0.53 mm in the plate group. In contrast to the previous studies which have reported similar radiographic outcomes, in this study, a statistically better reduction was observed in both the P-A screw group and the plate fixation group compared to the A-P screw group (Table I). The difference observed between the P-A screw group and the plate group was not significant. This variation from the previous studies can be attributed to the type of measurement and the method of analysis.

The functional outcomes were found to be similar to the radiological outcomes; all the three methods yielded good-excellent outcomes. Xu et al. reported mean walking VAS scores of 0.95 ± 1.80 in patients applied with AP fixation and 0.55 ± 0.70 in patients with PA fixation, without any statistical significance *(29)*. In another study, Langenhuisjen et al. reported VAS scores ranging from 3 to 3.8 *(16)*. Erdem et al. reported no difference between P-A screw and plate fixation in respect of follow-up AOFAS scores *(6)*. O'Connor et al also compared A-P screw fixation with plate fixation, reporting better SMFA scores in patients treated with plate fixation due to the direct restoration of articular anatomy *(25)*. The results of the current study were congruent with those of the previous studies. In the current study, at the end of an approximately two-year follow-up period, mean walking VAS scores were found as 0.55 ± 0.82 in the A-P screw group, 0.76 ± 1.3 in the P-A screw group and 0.94 ± 1.84 in the plate group. The differences between the groups were not significant. Similarly in the current study, although no difference was seen between the AOFAS scores of the PA screw group and those of the plate fixation group, better AOFAS scores were obtained in both of these groups in comparison with the AP screw fixation group ($p < 0.05$) (Table II). This difference can be attributed to the better reduction of fragments with direct fracture visualization and early active motion with rigid fixation.

Rather than comparing fixation methods in patients with ankle fractures and concomitant posterior malleolar fracture, Xu et al compared dorsiflexion loss in patients applied with fixation and patients not applied with fixation and reported a loss of mean 6.8° ± 9.7° compared with the uninjured side *(29)*. Verhage et al used AP screws for fixation of the large fragment in posterior malleolar fixation in 59 patients with trimalleolar fracture. The restriction in dorsiflexion compared to the healthy side was reported as a mean of 6.9° *(28)*. Erdem et al compared PA screw fixation with plate fixation and O'Connor et al compared AP screw fixation with plate fixation, and in both studies, no significant differences were found at the final follow-up in respect of the ROM compared to the unaffected side *(6,25)*. At the final follow-up examinations of the patients in the current study, a loss of 5° or more dorsiflexion was found in 9 patients (45.0%) in the AP screw group, in 5 patients (38.5%) in the PA screw group and in 8 patients (23.5%) in the plate group and there were not any statistically significant differences between the groups.

Jaskulka et al reported that it was necessary to apply osteosynthesis in patients with posterior tibial margin fractures regardless of the fragment size and there was a high risk of long-term post-traumatic osteoarthritis in patients on whom the fixation was not applied *(14)*. In the same fashion, Nelson and Jensen stated that the risk of arthrosis was high after the non-fixation of the posterior malleolar fracture *(19)*. There are also studies that have reported worse results from non-anatomic fixation compared to the non-fixation of posterior malleolar fractures in respect of arthrosis. Despite obtaining anatomic fixation, it is known that there could be a risk of arthrosis in the long-term associated with articular cartilage damage *(10,11,14,20,21)*. In a study by Huber et al, in 1 patient on whom AP screws were used, revision was necessary due to displacement and this resulted in significant osteoarthritis and no findings of arthrosis were encountered in the patients applied with posterolateral plate *(13)*. In contrast, O'Connor et al reported that Grade 2-3 arthritis developed in 6 patients on whom posterolateral plate was used and in 2 patients in the AP screw group *(25)*. In the current study, Grade 1 arthrosis was seen in 2 patients in the AP screw group and in 1 patient in the plate group. As the number of patients was too small to make a statistical evaluation, the development of arthrosis following posterior

malleolar fractures cannot be fully accounted for.

There are remarkable controversies concerning the fixation method of open reduction and the internal fixation of posterior malleolus through a posterolateral approach. Gardner et al.conducted a survey on 401 orthopedic surgeons investigating the preference of fixation method of posterior malleolar fragment via posterolateral approach *(9)*. In this study although fragment size was shown to have a strong influence on the decision for fixation, surgeons specialized in trauma surgery tend to fix posterior malleolar fragment with plate fixation ($p < 0.05$). Although plate gives the impression of a better restoration of the articular surface and relatively more stable fracture fixation, Huber et al. encountered a stability problem in 5 cases treated with plate fixation via posterolateral approach, due to the erroneously proximal placement of the plate *(13)*. In current study, the type of fixation method with posterolateral approach (screw or plate) was determined according to the surgeon's preference.

Many authors stated that due to the smallness of the posterior fragmant they used T-plates or 1/3 tubular plates in patient groups where they performed posterior malleolar fixation with posterolateral approach, and expressed that this was sufficient in terms of the strength of the fixation *(5,12,23)*. Despite the limited research into the comparison between fixed-angle plates and 1/3 tubular plates with respect to the fixation strength in ankle fractures, in their osteoporotic cadaver model study where they formed lateral malleolar fractures Davis et al. compared 1/3 tubular plate fixation with periarticular fixed-angle locked plate fixation and found no biomechanical difference *(4)*. However, Yong-duo et al. formed posterior malleolar fracture models in their cadaver study and by comparing the methods of anatomical distal Radius plate fixation and screw fixation they noted higher mechanical fixation strength of the plates in their study, where they evaluated biomechanical outcomes *(17)*. In our study, 1/3 tubular plates were used in patients on whom plate fixations were perfomed but no plate-related fixation failure was observed.

In this study, when compared to traditional AP screw fixation, better radiological and functional results were obtained with the application of P-A screw fixation and plate fixation with no major difference between the two. The PA screw technique with a posterolateral approach enables reduction by direct fracture visualization without excessive disturbance of the peroneal artery and branches, without the need for proximal dissection for plate fixation.

Limitations of the current study can be summarized as a relatively small number of subjects, the retrospective and multicenter nature of the study, selection bias due to the surgeon's preference for the method of fixation, and the use of plain radiography rather than computed tomography for the evaluation of the reduction.

CONCLUSION

P-A screw and posterior buttress plate fixation with direct reduction using a posterolateral approach demonstrated significantly better radiological and functional outcomes than A-P screw fixation following indirect reduction.

Conflicts of Interest: No conflicts declared..

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