ORIGINAL ARTICLE

Plate versus screw fixation and long-term ankle osteoarthritis in posterior malleolar fractures: A Bartoníček-based cohort study

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ABSTRACT

BACKGROUND: Posterior malleolar fractures play a critical role in ankle fracture stability and joint congruity. While plate and screw fixation are widely used, existing literature has primarily focused on short-term functional outcomes and reduction quality. The long-term impact of the posterior malleolar fixation technique on post-traumatic ankle osteoarthritis, particularly in relation to fracture morphology, remains insufficiently explored.

METHODS: This retrospective cohort study included 91 adult patients who underwent surgical fixation of posterior malleolar fractures between 2015 and 2021, with a minimum radiological follow-up of 36 months. Patients were treated with either posterior buttress plate fixation (n=42) or posteroanterior screw fixation (n=49). Ankle osteoarthritis was assessed using the Van Dijk classification. Fracture morphology was classified according to the Bartoníček system. Functional outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score, the Olerud–Molander Ankle Score (OMAS), and ankle range of motion (Prasad classification). Multivariable regression analyses were performed to assess the independent association between fixation method and outcomes.

RESULTS: After adjustment for age, body mass index, follow-up duration, fracture morphology, and open fracture status, screw fixation was statistically associated with a higher degree of ankle osteoarthritis compared with plate fixation (OR 11.22, 95% CI 2.17–58.04; p=0.004). However, the wide confidence intervals indicate considerable statistical uncertainty around the magnitude of this effect, likely reflecting the limited number of outcome events. Sensitivity analysis using a dichotomized osteoarthritis outcome yielded consistent results. Subgroup analyses demonstrated that the association between screw fixation and higher osteoarthritis risk was particularly pronounced in complex fracture patterns (Bartoníček types 3–4). Patients treated with plate fixation achieved significantly higher AOFAS and OMAS scores and demonstrated superior ankle range of motion at long-term follow-up. Increasing Van Dijk osteoarthritis grades were strongly correlated with worse functional outcomes.

CONCLUSION: Posterior buttress plate fixation was associated with a significantly lower risk of long-term post-traumatic ankle osteoarthritis and superior functional outcomes compared with screw fixation. These findings were especially evident in complex posterior malleolar fracture patterns, highlighting the importance of fracture morphology and fixation strategy in long-term joint preservation.

Keywords: Ankle osteoarthritis; Bartoníček classification; posterior malleolar fracture; plate fixation, screw fixation; Van Dijk classification.

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INTRODUCTION

Posterior malleolar fractures constitute a critical component of ankle fracture patterns and are most commonly encountered in trimalleolar injuries. Because the posterior malleolus forms part of the tibial plafond, involvement of this fragment directly affects ankle joint congruity and load transmission, potentially predisposing patients to long-term post-traumatic ankle osteoarthritis when inadequately treated.[1-4]

Historically, surgical decision-making for posterior malleolar fractures was largely based on fragment size, with fixation traditionally recommended when the fragment exceeded 25–30% of the articular surface.[5] However, accumulating evidence indicates that fragment size alone is insufficient to guide treatment. Contemporary concepts increasingly emphasize fracture morphology, articular congruity, and the stabilizing role of the posterior malleolus in syndesmotic integrity, leading to more individualized fixation strategies.[6-8]

Currently, two principal fixation techniques are widely used: screw fixation, commonly performed following indirect reduction, and posterior buttress plate fixation, which permits direct visualization, anatomical reduction, and biomechanically favorable resistance to posterior shear forces.[9,10] Biomechanical and clinical studies suggest that posterior plating provides superior stability and improved control of articular step-off, particularly in complex fracture patterns.[11-13] Nevertheless, screw fixation remains frequently employed due to its technical simplicity and limited soft-tissue dissection.[14]

Despite growing interest in posterior malleolar fixation techniques, the literature reports conflicting clinical results. While some studies demonstrate improved functional outcomes and radiographic alignment with posterior plating, others report comparable short-term functional scores between plating and screw fixation.[7,14,15] Importantly, most prior investigations have focused on early or mid-term outcomes—such as reduction quality and syndesmotic stability—leaving the long-term impact of fixation technique on post-traumatic ankle osteoarthritis insufficiently explored. Post-traumatic ankle osteoarthritis represents one of the most clinically relevant late complications following ankle fractures and is strongly associated with residual articular incongruity and altered joint biomechanics.[16-18]

The Bartoníček classification, which categorizes posterior malleolar fractures according to fracture pattern and fragment morphology, has been proposed as a comprehensive framework to guide surgical decision-making.[7,19] However, data evaluating whether the long-term effects of fixation technique vary across Bartoníček fracture patterns—particularly with respect to radiographically assessed ankle osteoarthritis—remain limited.

Therefore, the purpose of this study was to evaluate the long-term radiographic and functional outcomes of posterior malleolar fractures treated with plate versus screw fixation, with a primary focus on the development of post-traumatic ankle osteoarthritis assessed using the Van Dijk classification. A secondary aim was to determine whether the association between fixation method and osteoarthritis differed according to Bartoníček fracture patterns, as well as to assess functional outcomes and ankle range of motion.

MATERIALS AND METHODS

Study Design and Ethical Approval

This study was designed as a single-center retrospective cohort study evaluating clinical and radiological outcomes following surgical treatment of posterior malleolar fractures. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee in 2021 (approval number: 2021/224). Due to the retrospective nature of the study and the use of routinely collected clinical data, the requirement for informed consent was waived by the ethics committee.

Patient Selection

Patients who were diagnosed with posterior malleolar fractures and treated at our institution between January 2015 and December 2021 were retrospectively reviewed. During this period, 149 patients were identified with a diagnosis of posterior malleolar fracture. Of these, 91 patients met the predefined surgical inclusion criteria and were included in the final analysis. The remaining patients were excluded due to nonoperative management, failure to meet surgical criteria, insufficient follow-up duration, or incomplete radiographic data.

Posterior malleolar fractures in this cohort were not limited to isolated posterior malleolar injuries. The majority of cases represented posterior malleolar involvement as part of bimalleolar or trimalleolar ankle fractures. Patients with isolated posterior malleolar fractures, bimalleolar fractures including the posterior malleolus, and trimalleolar fractures were all eligible for inclusion. The presence of associated medial or lateral malleolar fractures was not considered an exclusion criterion, as the primary objective of the study was to evaluate the impact of posterior malleolar fixation technique on long-term ankle osteoarthritis, regardless of associated malleolar injuries.

Patients aged 18 years or older who sustained a posterior malleolar fracture treated surgically, had a minimum radiological follow-up of 36 months, and had complete clinical records and postoperative radiographs available were included in the study. Patients with pre-existing ankle osteoarthritis or a history of previous ankle surgery, pathological fractures, inadequate radiographic follow-up, or incomplete clinical or functional outcome data were excluded.

Surgical indication for posterior malleolar fixation was based on fracture morphology, involvement of the posterior tibial plafond, associated malleolar fractures, and radiographic evidence of ankle or syndesmotic instability, rather than fragment size alone.

Figure 1. Preoperative and postoperative imaging of a posterior malleolar fracture treated with posteroanterior screw fixation. **(a)** Preoperative lateral ankle radiograph demonstrating a posterior malleolar fracture. **(b)** Preoperative sagittal ankle computed tomography image showing involvement of the posterior tibial plafond. **(c)** Preoperative axial ankle computed tomography image illustrating the fracture morphology. **(d)** Postoperative 3-month lateral ankle radiograph demonstrating maintained reduction following posteroanterior screw fixation. **(e)** Postoperative 3-month anteroposterior ankle radiograph demonstrating maintained alignment.

Figure 2. Preoperative and postoperative imaging of a posterior malleolar fracture treated with posterior buttress plate fixation. **(a)** Preoperative lateral ankle radiograph demonstrating a posterior malleolar fracture. **(b)** Preoperative sagittal ankle computed tomography image showing involvement of the posterior tibial plafond. **(c)** Preoperative axial ankle computed tomography image illustrating the fracture morphology. **(d)** Postoperative 3-month lateral ankle radiograph demonstrating maintained reduction following posterior plate fixation. **(e)** Postoperative 3-month anteroposterior ankle radiograph demonstrating maintained alignment.

Surgical Technique

All patients underwent surgical fixation of the posterior malleolar fragment using one of two fixation methods based on surgeon preference and fracture characteristics. In both fixation groups, a posterolateral approach was utilized to allow direct visualization and anatomical reduction of the posterior malleolar fragment. Posteromedial approaches were not used in this cohort.

In the screw fixation group, fixation was achieved using posteroanterior screws inserted from posterior to anterior following direct reduction of the fragment. (Figure 1)

In the plate fixation group, the posterior fragment was stabilized using a posterior buttress plate to provide stable fixation and posterior support. (Figure 2)

All procedures were performed by experienced orthopedic trauma surgeons using standardized operative techniques.

Importantly, posterior malleolar fracture morphology as classified by the Bartoníček system was comparable between fixation groups, and fracture pattern was included as an ad-

justing variable in all multivariable regression analyses to minimize potential selection bias related to fixation choice.

Postoperative Management and Rehabilitation

Postoperative rehabilitation protocols were identical for both fixation groups. Patients were initially immobilized and maintained non–weight-bearing status, followed by progressive range-of-motion exercises and gradual weight-bearing according to radiographic and clinical healing. No differences in rehabilitation protocols were applied between the plate and screw fixation groups.

Radiological and Clinical Evaluation

Radiological evaluation was performed using standard anteroposterior and lateral ankle radiographs. Ankle osteoarthritis was assessed using the Van Dijk classification based on the latest available follow-up radiographs, with a minimum follow-up of 36 months and final evaluations extending up to December 2024. Radiographic evaluations were performed by a fellowship-trained orthopedic trauma surgeon who was independent from the treating surgical team and was not involved in the original operative decision-making process. Although complete blinding to the fixation method could not be guaranteed due to the visibility of implants on standard radiographs, the assessor was unaware of patients' clinical outcomes and group allocation at the time of grading. All assessments were conducted in a standardized and de-identified manner to minimize potential bias.

Fracture patterns were classified according to the Bartoníček classification, and ankle range of motion was assessed using the Prasad classification at final follow-up.

Clinical outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score and the Olerud–Molander Ankle Score (OMAS), both recorded at the final follow-up visit.

Table 1. Baseline demographic and fracture characteristics according to fixation method

Variable	Plate fixation (n=42)	Screw fixation (n=49)	p value
Age, years	38 (32–43)	38 (31–42)	0.820
Body mass index, kg/m²	24 (22–26)	26 (23–27)	0.094
Length of hospital stay, days	3 (2–3.75)	2 (2–3)	0.071
Follow-up duration, months	42 (36–45.5)	42 (39–48)	0.656
Female sex, n (%)	16 (38.1%)	17 (34.7%)	0.906
Left side, n (%)	18 (42.9%)	19 (38.8%)	0.856
Mechanism of injury, n (%)			0.993
Simple fall	20 (47.6%)	23 (46.9%)	
Pedestrian traffic accident (non-occupant)	7 (16.7%)	8 (16.3%)	
Motor vehicle collision (vehicle occupant)	4 (9.5%)	6 (12.2%)	
Motorcycle or bicycle accident	7 (16.7%)	7 (14.3%)	
Sports-related injury	4 (9.5%)	5 (10.2%)	
Risk factors, n (%)			0.520
None	19 (45.2%)	26 (53.1%)	
Smoking	16 (38.1%)	15 (30.6%)	
Diabetes	4 (9.5%)	2 (4.1%)	
Open fracture	3 (7.1%)	6 (12.2%)	
Bartoníček classification, n (%)			0.879
Type 1	3 (7.1%)	5 (10.2%)	
Type 2	19 (45.2%)	21 (42.9%)	
Type 3	13 (31.0%)	17 (34.7%)	
Type 4	7 (16.7%)	6 (12.2%)	
Gustilo–Anderson classification, n (%)			0.830
Grade 0 (closed)	35 (83.3%)	39 (79.6%)	
Grade 1	5 (11.9%)	8 (16.3%)	
Grade 2	2 (4.8%)	2 (4.1%)	

Values are presented as median (interquartile range) or number (percentage), as appropriate. Continuous variables were compared using the Mann–Whitney U test. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate.

Table 2. Distribution of ankle osteoarthritis severity according to the Van Dijk classification

Van Dijk grade	Plate fixation (n=42)	Screw fixation (n=49)
Grade 0	40 (95.2%)	35 (71.4%)
Grade 1	2 (4.8%)	12 (24.5%)
Grade 2	0 (0%)	2 (4.1%)
Overall distribution, p value		0.004

Values are presented as a number (percentage). The p-value refers to the overall comparison of Van Dijk osteoarthritis grade distribution between fixation methods.

Outcome Measures

The primary outcome measure was the severity of posttraumatic ankle osteoarthritis, assessed using the Van Dijk classification.

Secondary outcome measures included: AOFAS ankle-hindfoot score, OMAS score, ankle range of motion according to the Prasad classification.

Statistical Analysis

Statistical analyses were performed using standard statistical software. Continuous variables were tested for normality and are presented as median and interquartile range (IQR). Comparisons between fixation groups were conducted using the Mann–Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables, as appropriate.

The association between fixation method and ankle osteoarthritis severity was evaluated using ordinal logistic regression analysis, adjusting for potential confounders including age, body mass index, follow-up duration, Bartoníček fracture classification, and presence of open fractures. The proportional odds assumption for ordinal logistic regression models was assessed and was not violated. A sensitivity analysis was additionally performed using binary logistic regression by dichotomizing the Van Dijk classification as grade 0 versus ≥1.

Secondary outcomes were analyzed using multivariable linear regression models for AOFAS and OMAS scores, and ordinal logistic regression for ankle range of motion. Correlations between osteoarthritis severity and functional scores were assessed using Spearman correlation analysis.

A two-sided p-value of <0.05 was considered statistically significant. For subgroup analyses, posterior malleolar fractures were stratified into simple (Bartoníček types 1–2) and complex (types 3–4) patterns based on fracture morphology.

RESULTS

Patient Characteristics

A total of 91 patients with posterior malleolar fractures were included in the study, of whom 42 underwent plate fixation and 49 underwent screw fixation of the posterior fragment. Baseline demographic characteristics and fracture-related variables were comparable between the two groups (Table 1). There were no statistically significant differences with respect to age, sex distribution, body mass index, length of hospital stay, follow-up duration, injury mechanism, risk factors, Bartoníček fracture classification, or Gustilo–Anderson grade (all p>0.05).

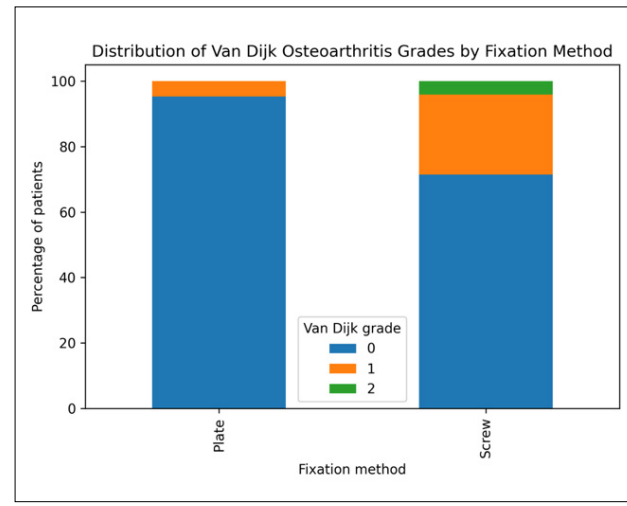

Figure 3. Stacked bar chart illustrating the percentage distribution of Van Dijk ankle osteoarthritis grades according to fixation method. Screw fixation was associated with a higher proportion of advanced osteoarthritis grades compared with posterior plate fixation.

Primary Outcome: Ankle Osteoarthritis (Van Dijk Classification)

Unadjusted Analysis

The distribution of ankle osteoarthritis severity according to the Van Dijk classification differed significantly between fixation methods as shown in Table 2. In the plate fixation group, 40 patients (95.2%) had no radiographic osteoarthritis (Van Dijk grade 0), while 2 patients (4.8%) had grade 1 osteoarthritis and none had grade 2. In contrast, in the screw fixation group, 35 patients (71.4%) had grade 0 osteoarthritis, 12 patients (24.5%) had grade 1, and 2 patients (4.1%) had grade 2 osteoarthritis. (Figure 3) This difference was statistically significant (p=0.004).

Adjusted Analysis

An ordinal logistic regression model was constructed to evaluate the independent association between fixation method and ankle osteoarthritis severity while adjusting for potential confounders, including age, body mass index, follow-up duration, Bartoníček classification, and presence of an open fracture.

After adjustment, screw fixation was independently associated with a higher degree of ankle osteoarthritis compared

Table 3. Multivariable ordinal logistic regression analysis for Van Dijk ankle osteoarthritis

Variable	Odds ratio (OR)	95% CI	p value
Screw fixation (vs plate fixation)	11.22	2.17–58.04	0.004

The model was adjusted for age, body mass index, follow-up duration, Bartoníček fracture classification, and open fracture status. The proportional odds assumption was assessed and was not violated.

Table 4. Subgroup analysis of ankle osteoarthritis according to Bartoníček classification

Bartoníček group	Fixation method	Van Dijk grade 0	Van Dijk grade 1	Van Dijk grade 2
Simple (types 1-2)	Plate (n=22)	21 (95.5%)	1 (4.5%)	0 (0%)
	Screw (n=26)	20 (76.9%)	5 (19.2%)	1 (3.8%)
Complex (types 3-4)	Plate (n=20)	19 (95.0%)	1 (5.0%)	0 (0%)
	Screw (n=23)	15 (65.2%)	7 (30.4%)	1 (4.3%)

Distribution of post-traumatic ankle osteoarthritis severity according to the Van Dijk classification, stratified by posterior malleolar fracture morphology using the Bartoníček classification. Within both fracture subgroups, screw fixation was associated with a higher frequency of advanced osteoarthritis grades, with a more pronounced difference observed in complex fracture patterns (Bartoníček types 3-4).

with plate fixation (odds ratio [OR] 11.22, 95% confidence interval [CI] 2.17–58.04; p=0.004), suggesting an association rather than a proven causal effect (Table 3). The wide confidence intervals surrounding this estimate indicate substantial statistical uncertainty regarding the exact magnitude of the association, likely reflecting the limited sample size and number of outcome events.

A sensitivity analysis using a binary outcome (Van Dijk grade 0 vs ≥1) yielded consistent results, confirming a significantly increased risk of radiographic osteoarthritis in the screw fixation group (OR 11.66, 95% CI 2.21–61.45; p=0.004).

Subgroup Analysis According to Bartoníček Classification

An interaction term between fixation method and Bartoníček classification was included in the regression model; however, no statistically significant interaction was observed (p=0.66).

Subgroup analyses were subsequently performed by stratifying fractures into simple patterns (Bartoníček types 1–2; n=48) and complex patterns (types 3–4; n=43). (Table 4) In patients with simple fracture patterns, screw fixation demonstrated a trend toward higher osteoarthritis risk compared with plate fixation, although this did not reach statistical significance (adjusted OR 10.0; p=0.078). In contrast, among patients with complex fracture patterns, screw fixation was associated with a significantly higher risk of ankle osteoarthritis compared with plate fixation (adjusted OR 18.5; p=0.021). These subgroup findings should be interpreted with caution, as the number of patients within each subgroup was limited and the analyses were not powered to detect definitive interaction effects.

Secondary Outcomes

Functional Outcomes

Patients treated with plate fixation demonstrated significantly higher functional scores at final follow-up. Median AOFAS scores were 90 (IQR 82–91) in the plate group and 80 (IQR 80–86) in the screw group (p<0.001). Similarly, median OMAS scores were 95 (IQR 80–95) in the plate group compared with 80 (IQR 75–85) in the screw group (p<0.001).

In multivariable linear regression analyses adjusting for age, body mass index, follow-up duration, Bartoníček classification, and open fracture status, screw fixation remained independently associated with lower functional scores. Screw fixation was associated with a 4.15-point decrease in AOFAS score (95% CI −6.44 to−1.86; p<0.001) and a 7.44-point decrease in OMAS score (95% CI−10.93 to −3.95; p<0.001).

Range of Motion

Ankle range of motion assessed using the Prasad classification was significantly better in the plate fixation group (median 1 [IQR 1–1]) compared with the screw fixation group (median 1 [IQR 1–2]; p=0.004). In an adjusted ordinal logistic regression model, screw fixation was associated with a significantly higher likelihood of worse range-of-motion categories (OR 5.92, 95% CI 1.80–19.47; p=0.003).

Relationship Between Osteoarthritis and Functional Outcomes

Spearman correlation analyses demonstrated a significant negative correlation between ankle osteoarthritis severity and functional outcomes. Higher Van Dijk grades were associated with lower AOFAS scores (ρ=−0.507, p<0.001) and lower OMAS scores (ρ=−0.590, p<0.001).

DISCUSSION

The most important finding of the present study is that posterior malleolar screw fixation was independently associated with a significantly higher degree of long-term post-traumatic ankle osteoarthritis compared with posterior plate fixation. This association remained robust after adjustment for relevant confounders and was confirmed by sensitivity analyses. In addition, posterior plate fixation was associated with superior functional outcomes and ankle range of motion at long-term follow-up. These findings should be interpreted in the context of the study's retrospective design and the non-randomized selection of fixation method based on surgeon preference and fracture characteristics.

Historically, the treatment of posterior malleolar fractures was primarily guided by fragment size, with fixation recommended when the fragment exceeded 25–30% of the tibial plafond.[5] However, subsequent studies have demonstrated that fragment size alone fails to capture fracture complexity and does not reliably predict clinical or radiographic outcomes.[6,8,20] As a result, contemporary treatment strategies increasingly emphasize fracture morphology, quality of reduction, and the biomechanical role of the posterior malleolus in ankle and syndesmotic stability.[6,7,21] In contrast to most previous comparative studies that have primarily emphasized short- or mid-term functional outcomes and reduction quality, the present study focuses on long-term radiographic ankle osteoarthritis as the primary outcome, highlighting joint preservation rather than early postoperative success.

Posterior buttress plate fixation has been shown to provide superior biomechanical stability compared with anteroposterior screw fixation by counteracting posterior shear forces and improving control of articular step-off.[11–13,22] Clinical studies have similarly suggested that posterior plating allows more accurate reduction and improved syndesmotic stability, particularly in complex fracture configurations.[9,10,23] Nevertheless, screw fixation remains widely used due to its technical simplicity, shorter operative time, and reduced soft-tissue exposure.[14]

Despite these advantages, most previous clinical investigations comparing plate and screw fixation have primarily focused on short-term or mid-term outcomes, including radiographic reduction quality, syndesmotic alignment, and early functional scores.[14,15,20] Long-term degenerative consequences, particularly post-traumatic ankle osteoarthritis, have received considerably less attention.[24,25]

Post-traumatic ankle osteoarthritis represents one of the most clinically significant late complications following ankle fractures and is strongly associated with residual articular incongruity, altered joint biomechanics, and subtle malreduction that may not be clinically evident in the early postoperative period.[16-18,26] The present study expands on previous work by demonstrating that the posterior malleolar fixation technique itself may influence the long-term risk of radiographic ankle osteoarthritis.

In our cohort, screw fixation was associated with an approximately 11-fold increased odds of higher Van Dijk osteoarthritis grades compared with plate fixation after multivariable adjustment. This finding suggests that indirect reduction and screw fixation may be less effective in maintaining long-term joint congruity, particularly under repetitive physiological loading.[17,18,25,27] Even minimal residual step-off or instability has been shown to accelerate cartilage degeneration and contribute to the development of ankle osteoarthritis over time.[16,24] The relatively wide confidence intervals observed in these analyses likely reflect the limited sample size and number of outcome events and indicate some degree of imprecision in the estimated effect sizes.

An important finding of this study is the influence of fracture morphology on the relationship between fixation technique and osteoarthritis. Although no statistically significant interaction was observed between fixation method and Bartoníček classification, subgroup analyses demonstrated that the association between screw fixation and higher osteoarthritis risk was particularly pronounced in complex fracture patterns (Bartoníček types 3–4). These fracture types often involve larger posterior fragments, posteromedial extension, or articular impaction, which may be inadequately addressed by indirect screw fixation alone.[19,28-31] Posterior plate fixation, by allowing direct visualization and anatomical reduction, may therefore offer a biomechanical advantage in these complex patterns. Although subgroup analyses suggested a more pronounced association between fixation method and osteoarthritis risk in complex fracture patterns, these analyses should be considered exploratory and hypothesis-generating due to limited sample sizes and the absence of a statistically significant interaction effect.

Functional outcomes mirrored the radiographic findings. Patients treated with posterior plate fixation achieved significantly higher AOFAS and OMAS scores and demonstrated superior ankle range of motion at long-term follow-up. Furthermore, increasing Van Dijk osteoarthritis grades were strongly correlated with worse functional outcomes, consistent with previous reports linking radiographic ankle degeneration to impaired function and quality of life.[16-18,32-36]

From a clinical perspective, these findings suggest that the posterior malleolar fixation technique may be considered when aiming to optimize long-term joint congruity and preserve ankle function, particularly in complex fracture patterns. In particular, fracture morphology as defined by the Bartoníček classification may help identify patients who are at increased risk of degenerative changes.

This study has several limitations. First, its retrospective design introduces the potential for selection bias, as the choice of fixation method was based on surgeon preference and perceived fracture characteristics rather than randomization. Surgeons may have been more inclined to select posterior

plate fixation for more complex fracture patterns. Although posterior malleolar fracture morphology was systematically classified using the Bartoníček system and included as an adjusting variable in all multivariable analyses, adjustment for this classification alone may not fully eliminate residual confounding related to unmeasured aspects of fracture complexity, soft-tissue injury, cartilage damage, or surgeon decision-making factors. Therefore, the observed association between fixation method and ankle osteoarthritis should be interpreted as associative rather than definitively causal. Prospective or randomized studies would be required to establish a true causal relationship between fixation technique and long-term degenerative outcomes. The relatively wide confidence intervals observed in the regression analyses further indicate some degree of imprecision in the estimated effect sizes, likely reflecting the limited sample size and number of outcome events.

Another important limitation is the heterogeneity of fracture patterns included in the cohort. The study population was not restricted to isolated posterior malleolar fractures; instead, it comprised a mixture of isolated posterior malleolar injuries as well as bimalleolar and trimalleolar ankle fractures with posterior malleolar involvement. Although this approach reflects real-world clinical practice and enhances external validity, associated malleolar fractures and overall injury severity may independently influence the development of post-traumatic ankle osteoarthritis. Consequently, outcomes cannot be attributed exclusively to the posterior malleolar fixation technique in absolute terms. Future studies focusing solely on isolated posterior malleolar fractures could provide a more homogeneous population and allow more precise evaluation of the isolated effect of fixation method.

In addition, subgroup analyses were limited by sample size, which may have reduced the statistical power to detect interaction effects and resulted in wide confidence intervals for some estimates. Furthermore, ankle osteoarthritis was assessed using standard radiographs rather than advanced imaging modalities.[36,37] Despite these limitations, the use of validated radiographic classification systems and a minimum follow-up duration of 36 months enhances the clinical relevance and robustness of the present findings.

From a practical clinical standpoint, the present findings suggest that the fixation strategy should be individualized according to fracture morphology. In simple posterior malleolar fractures (Bartoníček types 1–2), both fixation techniques may yield acceptable outcomes. However, in complex fracture patterns (types 3–4), posterior buttress plating may provide more reliable restoration of articular congruity and potentially better long-term joint preservation. These considerations may assist surgeons in preoperative decision-making, particularly when balancing surgical invasiveness with the goal of minimizing post-traumatic degeneration.

CONCLUSION

Posterior plate fixation was associated with a lower risk of long-term post-traumatic ankle osteoarthritis and superior functional outcomes compared with screw fixation. These findings represent associative observations derived from a retrospective cohort and should be interpreted cautiously rather than as definitive evidence of causality. This association appeared to be more pronounced in complex posterior malleolar fracture patterns, suggesting that posterior plate fixation may offer an advantage in long-term joint preservation in these injuries, although these findings should be interpreted cautiously, given the retrospective design and limited sample size of subgroup analyses.

Ethics Committee Approval: This study was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (Date: 19.04.2021, Decision No: 2021-08-09).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Posterior malleol kırıklarında plak ve vida fiksasyonunun uzun dönem ayak bileği osteoartriti açısından karşılaştırılması: Bartoníček tabanlı kohort çalışması

AMAÇ: Posterior malleol kırıkları, ayak bileği kırıklarında stabilite ve eklem uyumunun sağlanmasında kritik bir rol oynar. Plak ve vida tespiti yaygın olarak kullanılmakla birlikte, mevcut literatür ağırlıklı olarak kısa dönem fonksiyonel sonuçlar ve redüksiyon kalitesine odaklanmıştır. Posterior malleol fiksasyon yönteminin uzun dönem posttravmatik ayak bileği osteoartriti üzerine etkisi, özellikle kırık morfolojisi ile ilişkisi açısından yeterince araştırılmamıştır.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmaya, 2015-2021 yılları arasında posterior malleol kırığı nedeniyle cerrahi tedavi uygulanmış ve en az 36 ay radyolojik takibi bulunan 91 erişkin hasta dahil edildi. Hastalar posterior buttress plak fiksasyonu (n=42) veya posteroanterior vida fiksasyonu (n=49) ile tedavi edildi. Ayak bileği osteoartriti Van Dijk sınıflamasına göre değerlendirildi. Kırık morfolojisi Bartoníček sınıflaması kullanılarak belirlendi. Fonksiyonel sonuçlar American Orthopaedic Foot and Ankle Society (AOFAS) skoru, Olerud–Molander Ankle Score (OMAS) ve ayak bileği eklem hareket açıklığı (Prasad sınıflaması) ile değerlendirildi. Fiksasyon yöntemi ile sonuçlar arasındaki bağımsız ilişkiyi değerlendirmek amacıyla çok değişkenli regresyon analizleri yapıldı.

BULGULAR: Yaş, vücut kitle indeksi, takip süresi, kırık morfolojisi ve açık kırık varlığına göre yapılan düzeltmeler sonrası, vida fiksasyonu plak fiksasyonuna kıyasla anlamlı derecede daha yüksek ayak bileği osteoartriti şiddeti ile ilişkili bulundu (OR=11.22; %95 GA 2.17–58.04; p=0.004). Ancak geniş güven aralığı, etkinin kesin büyüklüğü konusunda belirgin istatistiksel belirsizlik olduğunu göstermektedir. Osteoartrit sonucunun ikili olarak değerlendirildiği duyarlılık analizinde de benzer sonuçlar elde edildi. Alt grup analizlerinde, vida fiksasyonu ile artmış osteoartrit riski arasındaki ilişkinin özellikle kompleks kırık paternlerinde (Bartoníček tip 3-4) daha belirgin olduğu görüldü. Plak fiksasyonu uygulanan hastalarda AOFAS ve OMAS skorları anlamlı derecede daha yüksek olup, uzun dönem takipte ayak bileği eklem hareket açıklığı daha iyi bulundu. Artan Van Dijk osteoartrit dereceleri ile fonksiyonel sonuçlar arasında güçlü bir olumsuz ilişki saptandı.

SONUÇ: Posterior buttress plak fiksasyonu, vida fiksasyonuna kıyasla uzun dönem posttravmatik ayak bileği osteoartriti riskinin daha düşük olması ve daha iyi fonksiyonel sonuçlar ile ilişkili bulunmuştur. Bu ilişkinin özellikle kompleks posterior malleol kırık paternlerinde daha belirgin olduğu gözlenmiş olup, uzun dönem eklem korunumu açısından kırık morfolojisi ve fiksasyon stratejisinin önemini vurgulamaktadır.

Anahtar sözcükler: Ayak bileği osteoartriti; Bartoníček sınıflaması; plak fiksasyonu; posterior malleol kırığı; vida fiksasyonu; Van Dijk sınıflaması.

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