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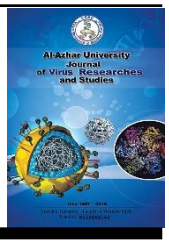

Conservative Treatment of Posterior Malleolus of the Ankle Fracture versus Internal Fixation

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Abstract

Ankle fractures are relatively common and often have involvement of the posterior malleolus. Treatment guidelines exist is limited with several controversies exist in the management of posterior malleolus fractures. The purpose of this review was to evaluate the evidence about indications, effectiveness and complications of conservative treatment and internal fixation of posterior malleolus fracture. To review the literature in last ten years about the indications, effectiveness and complications of conservative treatment of posterior malleolus of ankle fracture versus surgical internal fixation. We conducted an electronic search between 2010 to 2020 in different databases, PubMed, Scopus, Web of Science, and Cochrane Library. We included randomized controlled trials (RCTs), prospective or retrospective cohort, case control studies, and case series that were published in English with full text available. There was no restriction to age or gender of the patients during literature search. If the studies did not fulfill the inclusion criteria, they were excluded. Study quality assessment included whether ethical approval was gained, eligibility criteria specified, appropriate controls, and adequate information and defined assessment measures. The decision on whether or not to apply open reduction and internal fixation for a posterior malleolar fragment is based on insufficient evidence as most of previous studies are small in sample size with retrospective design, also there is limited data on conservative treatment. Till now the choice of line of treatment, in generally, most authors of clinical studies agree that operative treatment is indicated for large fragment and in cases with small fragment size, is left to the surgeon preference and patients' presentation.

Keywords: Posterior malleolus, ankle fracture, internal fixation, conservative treatment.

1. Introduction

A posterior malleolus fracture is a fracture of the back of the tibia at the level of the ankle joint. The posterior malleolus is involved in about 7-44% of all ankle fractures, with dimensions and morphology ranging from the simple avulsion of a posterolateral portion to the detachment of a large fragment [1]. The term "posterior malleolus" was first introduced by Cooper and Earle in 1822. In 1933, Henderson introduced the term "Tri malleolar fractures" [2]. The joint stability of the ankle is based on the integrity of the bone and ligament structures. Among the

osseous structures, the posterior malleolus plays a fundamental role as it allows a joint congruity and a homogeneous distribution of the load forces between the tibia and talus. This structure also allows posterior stability to the talus and permits a rotational stability to the ankle. In addition, the posterior malleolus forms the posterior part of the incisura tibiae (notch fibularis) which receives the distal fibula [2]. Among the ligamentous structures, the tibio-peronal syndesmosis is particularly involved in joint stability. This structure consists of the anterior tibio-fibular ligament (AITFL), the posterior tibio-fibular ligament (PITFL), and the interosseous membrane. The PITFL has a trapezoidal shape with superior fibers that fit into the tubercle of the posterior malleolus and lower fibers that originate from the articular surface of the distal tibia. The PITFL provides 42% of the mechanical resistance of the syndesmosis, 35% from AITFL and 22% from the interosseous membrana [3]. According to the Danis-Weber classification, in type B fractures -the most frequent ankle fractures - the PITFL remains intact attached to the posterior malleolus [4]. Therefore, a fracture of the posterior malleolus not only influences the load distribution between the tibia and talus, but the ligament stability of the syndesmosis as well. A bone or ligament instability of the ankle predisposes to joint degenerative processes. The biomechanical studies stated that 50% resection of the posterior articular surface of the distal tibia does not alter the joint stability, nor does it increase the tibio-talar mechanical pressures, but only a reduction of the contact surface [5].
Subsequently, studies have shown that the posterior malleolus fracture alters the distribution of mechanical forces on the articular cartilage between the tibia and the talus, with an increase in the antero-medial region in particular, producing post-traumatic arthrosis [6].
Radiological assessment of posterior malleolus fracture depends on X-ray examination in standard projections (true anteroposterior, mortise with 15° internal rotation, lateral views). For several years, the size of the posterior malleolus fragment has been evaluated proportionally to the percentage of involvement of the articular surface of the tibial plafond. In the variant of the "posterior pilon", the sign of the "double contour" or "spur sign" of the medial malleolus in the antero-posterior view is indicative of the presence of a posterior malleolus fracture with medial extension [7].
However, several authors agree that radiographic examination is not sufficient to evaluate the extent of the fracture, comminution, and degree of joint involvement and injury of syndesmosis. Performing a preoperative CT scan is useful for identifying the size and shape of the fragment and the degree of involvement of the fibular notch of the tibia and is therefore considered essential before performing surgical treatment [8] operative management of these types of injuries could expose these patients to the unnecessary risks of surgery and has been deemed as over treatment [9]. Conservative treatment is indicated in the presence of an isolated non- displacement fracture and stable syndesmosis, or in the presence of marginal bone avulsions of posterior malleolus. In consideration of recent biomechanical studies, surgical treatment is recommended in the presence of displacement fragments involving 5-10% of the articular surface [10]. The objectives of the surgical treatment are tension of the PITFL, and therefore a greater stability of the syndesmosis, anatomical reconstruction of the fibular notch to prevent the posterior translation of the fibula and restoration of the articular tibio-talar congruence in order to ensure a posterior stability of talus. This can be achieved by indirect reduction of fracture and synthesis with screws or direct reduction and plate and screws fixation [11]. There are no precise guidelines in literature on the treatment of posterior malleolus fractures due to non-

standardized clinical studies, limited patient samples and heterogeneous surgical techniques. Historically, the main indication for surgical treatment was the instability of the ankle, subsequently, greater attention was given to the restoration of the congruence of the articular surface. Other indications for surgical treatment were the presence of posterior subluxation of the talus and displacement of over 2 mm of the articular surface; the size of the fragment and the joint involvement were the main factors when considering surgical treatment [12]. Complications associated with both non operative and operative management are an important consideration in decision making. For some fracture types, e.g. stable un-displaced injuries, non-operative treatment is the most appropriate management as the complications of nonoperative treatment included malunion, nonunion, pain, loss of function, muscle atrophy, cartilage degeneration, stiff/swollen joint, deep vein thrombosis (DVT), and pulmonary embolism (PE) [13]. Complications reported include insufficient primary osteosynthesis, soft tissue necrosis, infection, osteitis, DVT, delayed union, nonunion, secondary displacement, refracture, stiffness, muscular atrophy, tendinous insufficiency, sensory deficit, tarsal tunnel syndrome and complex regional pain syndrome type 1 [14]. The Aim of this work is to review the literature in last ten years between (2010-2020) about the indications, effectiveness and complications of conservative treatment of posterior malleolus of ankle fracture versus surgical internal fixation.

2. Patients and Methods

We prepared this systematic review with careful following of the Cochrane Handbook for Systematic Reviews of Interventions. We also adhered to The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines during the design of our study.

2.1 Literature search

We conducted a literature search till (2010-2020) using PubMed, Scopus, Web of Science, and Cochrane Library. We performed a search for all published articles that evaluated the conservative or the internal fixation of posterior malleolus of the ankle fracture. We searched for article title, abstract, keywords using the following keywords. We used “OR” and “AND” operators during Literature search as following: For surgical arm: (Surgery OR surgical OR operative OR "internal fixation") AND (trimalleolar OR "posterior malleolar fracture"). For conservative arm: (Conservative OR "non operative" OR "non-surgical") AND (trimalleolar OR "posterior malleolar fracture"). The "related articles" function was used to expand the search from each relevant study identified. Bibliographies of retrieved papers were further screened for any additional eligible studies. We searched for articles that were included in previous related systematic reviews. The identified citations were retrieved using Endnote X8 software package (Thompson Reuter, USA).

2.2 Eligibility criteria

We included studies that met our following inclusion criteria:

(I) **Population**: Patients with posterior malleolar fracture.

(II) **Intervention**: Internal fixation

(III) **Comparator**: Conservative

(IV) **Outcome parameters**: Clinical, radiological outcomes and complication rates that were reported consistently across the studies.

(V) **Study design**: Clinical trials whether randomized or nonrandomized prospective and retrospective cohort studies, case-control studies, and case series. We excluded animal studies, reviews, book chapters, thesis, editorial letters, biomechanical studies and papers with overlapping dataset.

Eligibility screening was conducted in a two stepwise manner (title/abstract screening and full-text screening). Each step was done by two reviewers independently according to the predetermined criteria. There were no restrictions on language, race, or sex. The duplicated articles were removed primarily using Endnote X8 program (Thompson Reuter, USA) and manually using titles and abstracts screening.

2.3 Databases searching

For surgical arm: We obtained 324 articles from PubMed, 335 articles from Scopus, 27 articles from Cochrane library and 277 from web of science. 358 duplicated articles were removed using Endnote X8 program (Thompson Reuter, USA), 605 articles manually underwent titles and abstracts screening, and 137 articles underwent full-text review as shown Figure. 1. 32 studies finally met our inclusion criteria. For conservative arm: We obtained 47 articles from PubMed, 28 articles from Scopus, 6 articles from Cochrane library and 8 from web of science. 14 duplicated articles were removed using Endnote X8 program (Thompson Reuter, USA), 75 articles manually underwent titles and abstracts screening and 17 articled underwent full-text review as shown Figure. 2. 35 studies finally met our inclusion criteria.

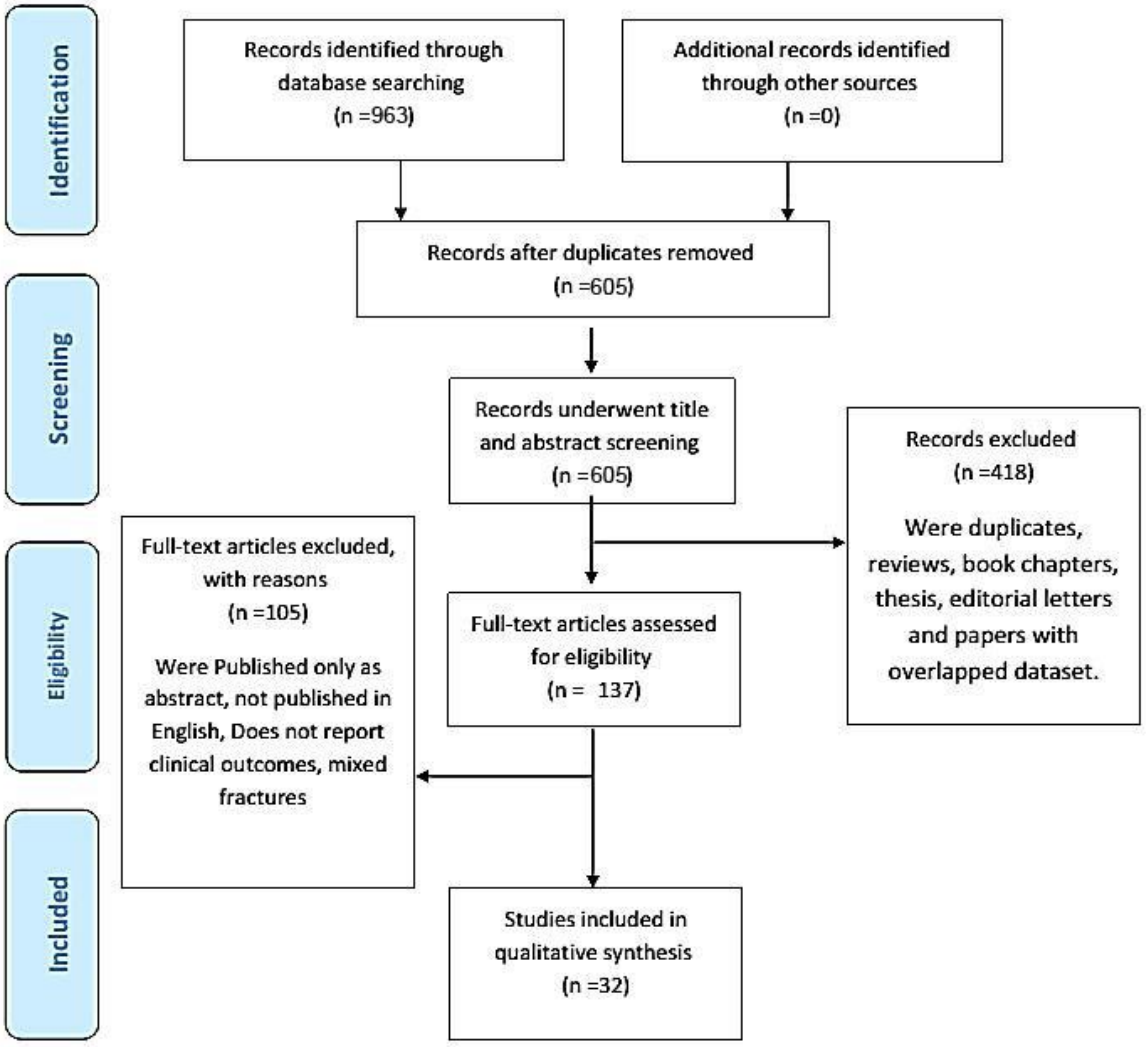

Figure (1): PRISMA flow diagram showing process of studies selection (Surgical).

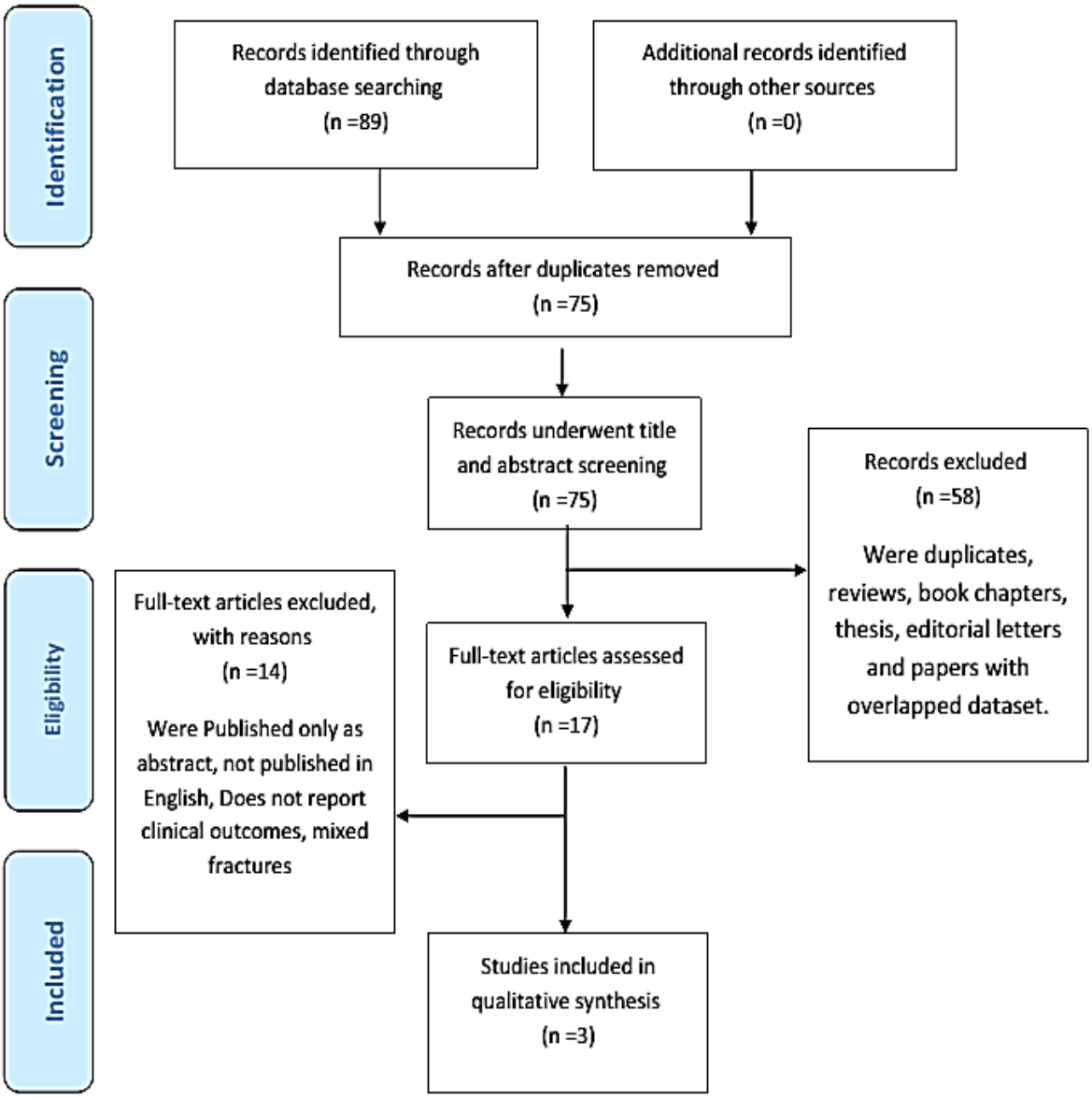

Figure (2): PRISMA flow diagram showing process of studies selection (Conservative)

3. Characteristics of included studies

We identified a total of 35 studies (including 7 studies with double arm studies that compared conservative treatment to surgical treatment directly) that evaluated conservative or the internal fixation of posterior malleolus of the ankle fracture. The majority of the studies were retrospective in nature. The overall number of patients was 1830 that were followed for variable durations of time ranging from 2 months to 6.9 years. The mean age of the patients ranged between 30 to 60 years. Summary of the treatment regimens used are shown in Table 1, 2. We pooled the data from these studies into two groups; surgical and conservatives. In the surgical group, from 33 studies, a total of 1645 patients were followed for 33.9 months with a mean age of 48.84 years. Percentage of females were higher than males (56.9% vs. 43 %.).

Table (1): Baseline Characteristics of studies with one group.

Study ID	N	Study design.	M \ F	Age (years)	Management	Time from injury to surgery (day)	Follow-up time (month)	BMI	Fragment size
van Hooff 2015	131	Retrospective	55\76	51 (24-74)	Surgical unspecified		6.9 (2.5-15.9) years	28 ± 5.2	
Xu et al. 2012	102	Retrospective	41\61	43.4 (15–80)	Surgical unspecified				
Mingo-Robinet et al. 2011	45	Retrospective	10\35	50.69 ± 17.32	Surgical unspecified				
Evers et al. 2015	42	Retrospective	16\26	52.8 (19–86)	Surgical unspecified				
Kim 2015	36	Prospective	16\20	58 (23–85)	Surgical unspecified	5 (1–22)	40 (25–62)		
Verhage 2016	52		11\41	49 (22 to 79).	Surgical PL		34 weeks (7 to 131),	29 (22 -50)	27% (10% to 52%)
Abdelgawad 2011	12	Retrospective			Surgical PL		>2 months		
Ruokun 2014	38	Retrospective		21 to 60	Surgical PL		38 (25 to 72)		
Karaca, 2016	57	Retrospective	21\36	55.9	Surgical PM	1.1 (1–3).	44.6 (24–108)	29.1±4.7	21% in 38 cases, <25%, in 19 cases,
Sukura, 2017	14	Retrospective	8\6	37.7(21–58)	Surgical PM	8.6 (6–13)	17.1 (12–24)		
Lei 2011	12	Retrospective	5\7	22 to 57	Surgical PM and PL		18.9 (12 to 30)		
Xing 2018	30	Retrospective	19\11		Surgical unspecified	7 (5–10)	13 (8–24)		
Mingo-Robinet et al. 2012	10	Retrospective		53.8(19--82)	Surgical unspecified		3.7(1-6 years). years		
Hong 2013	21	Retrospective	7\14	46.9	Surgical unspecified				
Gupta 2019	8		3\5	48.8 (30–62)	Surgical PL		12		
Yang, 2020	22		10\12	61.5 (53-67)	Surgical PM and PL			25.7	
Vidovića 2017	46	Prospective			Surgical unspecified		20.5 (12–29).		
Weigelt 2020	36	Retrospective	12\24	63 (34–80)	Surgical unspecified		7.9 (3–12) years	28.3 (19.2-41)	
Ruo-kun 2012	32		22\10	48 (21-63)	Surgical PL	7-14	28 (24-35).		
Mason, 2019	50	Retrospective	22\28	46.8 (21 to 87)	Surgical unspecified		12		
Donken 2011	19	Prospective	13\6	31 (16 to 52)	conservative		20(17 -24) years		12% (3% to 47%).
Maluta, 2021	68		18\28		conservative		53 (24–90).		

PL: posterolateral approach, PM: posteromedial approach, N: Sample size.

We pooled the data from these studies into two groups: surgical and conservatives. In the surgical group, from 33 studies, a total of 1645 patients were followed for 33.9 months with a mean age of 48.84 years. Percentage of females were higher than males (56.9% vs. 43 %.). In the conservative group, from 6 studies, a total of 260 patients were followed for 89.5 months with a mean age of 38.85 years. Percentage of males were equal to females (50% vs. 50 %.) Table 3.

Table (2): Baseline Characteristics of studies with two groups or more.

Study ID	N	Study design	Group 1	Group 2	N		M \ F		Age		Time from injury to surgery (day)		Follow-up time (month)		BMI		Fragment size	
					G 1	G 2	G 1	G 2	G 1	G 2	G 1	G 2	G 1	G 2	G 1	G 2	G 1	G 2
Wang 2020	243	Retro	Fragment of ≥ 15	< 15%	136	107							12 .					
Kalem, 2018	67	Retro	AP Screw	PA Screw PL Plate	20	13 34	12\8	5\8 10\24	43.4	48.3			17.1		27.35	25.23 25.97		
Pilskog, 2020	86	Pros	Posterior Approach	Traditional Approach	43	43	15\28	8\35	53	60			26 .				17% .	
Ko, 2020	**32**		**PMF fixed**	**PMF not fixed**	**20**	**12**	**14\6**	**8\4**	**46.8**	**51.8**			**50.9**	**51.2**	**24**	**24.6**	**24.6%**	**22.1%**
Saygılı 2017	**73**	**Retro**	**PMF fixed**	**PMF not fixed**	**27**	**46**	**12\15**	**22\24**					**2 years**					
Kang, 2019	**62**		**PMF fixed**	**PMF not fixed**	**32**	**30**	**19\13**	**16\14**	**51.1**	**50.3**			**24**					
Shi 2017	116	Pros	DR	IR	64	52	28\36	31\21	49.0	48.1	4.3	4.5	19.9	20				.
O'Connor et al. 2015	27	Retro	AP Screw	PL Plate	11	16	4\7	7\11	45.5	47.8			32	54.9	32.6	29.6		
Erdem et al 2012.	40	Pros	PL plate	PL screw	20	20	9\11	11\9	50.2	47.6			39.2	37.2				
Zhong 2017.	48	Retro	PM	PL	20	28							21.3	21.0				
Xing 2018	69	Retro	Ankle dislocation approach	PL\PM	36	33	22/14	19/14	36.36	38.73	7.62	6.87	17.6	15.94	.	.		.
Ribeiro 2020	64	Retro	osteosynthesis	non-osteosynthesis	20	44			56.1	59.7			43.1		.	.	14.7%. .	
Hosny 2020	**20**	**Pros**	**PMF fixed with or without syndesmotic screw.**	**conservative treatment with Syndesmotic screw**	**10**	**10**	**6\4**	**5\5**	**39**	**38**								**.**

PL: posterolateral approach, PM: posteromedial approach, N: Sample size, Retro: Retrospective, Pros: Prospective, AP: anterior to posterior. PA: posterior to anterior. DR: direct reduction, IR: indirect reduction. Traditional Approach**:** The PMF has traditionally been treated with closed, indirect **,**reduction, and, if needed, anteroposterior screw fixation

Table (3): Pooled data demonstrating demographic characteristics for surgical and conservative group.

Variables	Surgical	Conservative
NO. Studies	32	8
Study Design	Prospective =6 Retrospective =20 Unspecified =6	Prospective =2 Retrospective =3 Unspecified =3
Total number of included patients	1358	472
Males	(43%)	(50%)
Females	(57%)	(50%)
Age (Years)	48.84	38.85
Time from injury to surgery (day)	5.46	_____
Follow-up time (month)	33.9	89.5

Not all cases reported all of these variables. Se, we pooled data for each variable form the available cases.

3.1 Data extraction

Data were extracted by two independent authors and revised by another two independent authors. We extracted the characteristics of each study as follows: first author, study design, sample size and intervention description. Additionally, we extracted clinical, radiological outcomes and complication rates.

3.2 Different fixations methods

We found patients underwent conservative treatment with syndesmotic screw had higher rate of superficial infection and dorsiflexion restriction than those underwent PMF fixation with or without syndesmotic screw. A summary of rest fixations techniques is shown in Table 4.

3.3 Fixation according to the size of the fragments

Studies compared the outcomes between different sizes of fragments. The studies were not consistent in reporting the appropriate cutoff if the fixation size. However, there was a trend of better outcomes in smaller sizes Table 5.

Table (4): Comparison between different fixations methods.

Study ID	N		G1	G2	AOFAS		step-off		VAS		Superficial infection			Dorsiflexion restriction
Zhong 2017.	20	28	PM	PL	92.9 (86-100),	91.9 (77–100)	1(2-mm)	1(3-mm)			5%	5%		
Erdem et al. 2014	20	20	PL plate	PL screw	93.5	94.5	1(2-mm)	1 (3-mm)						
O'Connor et al. 2014	11	16	AP Screw	PL Plate			2(2-mm)	2 (2-mm)						
Shi 2017	64	52	DR	IR	87(58 -95)	80(59 -95)	5 (7.8%) (> 2-mm)	9 (17.3%) (>2-mm)	2 (0-7)	2 (0-7)	3%		5.2°	6.1°
Vidovića 2017			AP	PA									6.45°	5.96°
Kalem, 2018	20	13 34	AP Screw	PA Screw PL Plate					86,4±7.97	93,8±4.05 94,7±5.29	0%	0 % 2%	9%	5% 8%
Pilskog, 2020	43	43	Posterior Approach	Traditional Approach					2 (1-4)	1 (0-3)	14 %	12%		
Ko, 2020	12	8)	AP screw	PA screw	90.0 (83.8-97.3)	99.5 (94.5-100)			1 (0-2.2)	0.5(0-1)			5°	0°
Hosny 2020	10	10	PMF fixed with or without syndesmotic screw.	conservative treatment with Syndesmotic screw							0%	10%	20%	40%

Table (5): Different outcomes after fixation according to the size of the fragment.

Study ID	Outcome	<25%	≥25%	
Evers et al. 2015	AOFAS	69.2 (29.62)	70.9 (22.6)	
Mingo-Robinet et al. 2011		Excellent or Good 88.9%	Excellent or Good 61.9%	
Weigelt 2020	AAOS	95	96	
Mingo-Robinet et al. 2011	Olerud and Molander Score	Excellent or Good 66.7%	Excellent or Good 42.9%	
Weigelt 2020	VAS	1	1	
		<10 %	**10–25**	**≥25%**
Xu et al..2012	AOFAS	95.6±7.0	96.8±4.8	93.7±6.6
Xu et al..2012	VAS	0.51±1.74	0.18±0.45	0.51±0.95
		(<5%)	**(5-25%)**	**(>25%)**
van Hooff 2015	AOFAS	95 (14-100)	88 (11-100)	81 (20-100)
van Hooff 2015	VAS	8 (0-94)	5 (0-85)	16 (0-80)
van Hooff 2015	AAOS	94 (37-100)	91.5 (13-100)	88 (16-100)
van Hooff 2015	Dorsiflexion restriction	5.5 (9.6)	6.6 (6.7)	6.2 (11.6)
Wang 2020		**≥ 15**	**< 15%**	
Wang 2020	AOFAS	(PA) screw 91.5 [87.6,96.2] AP) screw 91.8 [89.2,95.1] Posterior plate 90.8 [88.5,93.2]	(PA) screw 92.3 [88.0,94.9] (AP)screw 91.9 [89.7,94.0] Posterior plate 84.1 [80.5,86.5]	
Wang 2020	Dorsiflexion restriction	(PA) screw 5.0 [3.9,7.8] (AP) screw 5.4 [4.0,7.9] Posterior plate 5.6 [4.7,6.8]	(PA) screw 5.1 [3.8,6.1] (AP) screw 4.7 [3.7,6.6] Posterior plate 6.3 [5.1,7.9]	

4. Results

Outcomes

Clinical and radiological outcomes

Several outcomes were reported including Visual Analog Score pain (VAS), American Academy of Orthopedic Surgeons foot and ankle questionnaire (AAOS), American Orthopedic Foot and Ankle Society score (AOFAS), and Olerud & Molander score. The incidence of poor AOFAS score was higher in the surgical group (12.7% vs., 1.5%); however, the incidence of excellent scores was higher in the surgical group (44.4% vs., 37.9%). Regarding AAOS score, majority of surgically treated patients had excellent scores (90.3%) compared to the conservative group (26.5%). Table 6. There was a tendency of better outcome in surgical arm which was proved by good pain control. In AOFAS score, which is regarded as the most popular used tool for evaluation of outcome of treatment in patients who sustained a complex ankle, surgical group had higher incidence of excellent AOFAS score (44.4% vs. 37.9%), but this is not conclusive enough as surgical group had higher incidence of poor AOFAS score (12.7% vs. 1.5%). The reason for this contradiction is probably attributed to the included studies were heterogeneous in the mode of injury in the patients as some included patients had higher energy trauma while others fall from height. Additionally, the morphology and association with injuries to the medial or lateral structures might affect treatment outcome. However, In AAOS score, the superiority of surgical treatment was apparent, the percentage of patients with excellent score were 90% in the surgical group compared to only 26.5% in the conservative group. But the sample size used to evaluate AAOS score was 270 patients in the surgical group versus 113 patients in the conservative group while the

sample size used to evaluate AOFAS score was 493 patients in the surgical group versus 253 patients in the conservative group. This is a major limitation here in our study as the low sample size may overpower the results in certain outcomes. We could have overcome this problem if we have data regarding the baseline scores for AOFAS and AAOS so we could estimate precisely the exact degree of improvement between the preinjury score and post treatment score. Also, the conservative treatment performed well also in certain clinical outcomes as in patients with type 1 Kruskal-Wallis classification fracture had excellent AOFAS and Olerud & Molander scores. Besides, the results in the conservative group were based on the long term of follow up compared to the surgical groups that might indicate surgical arm results does not reflect the whole process of healing. On the same line, results from previous studies had similar findings to our study. Data form eight (15–22), studies that compare operative to conservative treatment in fragments less than 25% suggested that both modalities of treatments showed comparable results except in four studies (16,19,20,22), the surgical arm had a little better clinical outcomes. (16,19,20,22).

4.1 Complications rates

In surgically treated patients, the most reported complication was removal of disturbing hardware (16.6%), and step-off (9.1%) with only low incidence of reflex sympathetic dystrophy syndrome (RSDS) (1.6%), reduction loss (1.1%), and affection of sural nerve (2.9%). In conservatively treated patients, higher incidence of dorsiflexion restriction was found (40% vs. 20%) with comparable rates of infection in surgical and conservative group (3.5% vs. 3.4%) Table 7.

Table (6): Comparison between the two study groups regarding secondary outcomes including maternal weight gain and birth weight.

Variables	Surgical	Conservative
AOFAS, N/Total (%) Excellent = above 90% Good = between 90% to 70% Poor = below 70%	Excellent = 219/493 (44.4%) Good = 234/493 (47.4%) Poor = 63/493 (12.7%)	Excellent = 96/ 253 (37.9%) Good = 153/253 (60.4%) Poor = 4/253 (1.5%) According to Kruskal-Wallis classification (Total= 68) Cases with Type 1: Excellent Cases with Type 2: Good Cases with Type 3: Poor
AAOS Excellent = above 90% Good = between 90% to 70% Poor = below 70%	Excellent= 188/ 270 (90.3%) Good = 26/270 (9.6%) Poor = 0/270 (0%)	Excellent= 30/ 113 (26.5%) Good = 83/ 113 (73.4%) Poor = 0/ 113 (0%)
VAS, N/Total (%)	Above 8 = 181/ 295 (61%) Between 8 to 5 = 0/ 295 (0%) Below 5 = 114/ 295 (38.6%)	----------
Olerud & Molander score, N/Total (%) Excellent = above 90% Good = between 90% to 70% Poor = below 70%	Excellent= 29/ 156 (%) Good = 76 / (%) Poor = 50/ (%)	- According to Kruskal-Wallis classification (Total= 68) Cases with Type 1: Excellent Cases with Type 2: Good Cases with Type 3: Poor

VAS: Visual Analog Score pain, (AAOS): American Academy of Orthopedic Surgeons (AOFAS): American Orthopedic Foot and Ankle Society scores.

Table (7): Complication rates for surgical and conservative group.

Variables	Surgical	Conservative
Any complications, N/Total (%)	6/203 (2.9%)	0/19 (0%)
OA, N/Total (%)	47/297 (15%) Cases with Grade 3 or more = 11/297 (3%)	Cases with Grade 3 or more = 1/19 (5%)
RSDS, N/Total (%)	2/122 (1.6%)	_____
Superficial infection, N/Total (%)	11/314 (3.5%)	1/29 (3.4%)
step-off, N/Total (%)	8/88 (9.1%)	_____
Reduction loss, N/Total (%)	2/172 (1.1%)	_____
Removal of disturbing hardware, N/Total (%)	59/354 (16.6%)	_____
Affection of sural nerve, N/Total (%)	5/168 (2.9%)	_____
Dorsiflexion restriction, N/Total (%)	2/10 (20%)	4/10 (40%)

RSDS: reflex sympathetic dystrophy syndrome

5. Discussion

Posterior malleolar fractures (PMFs) account for 7% to 44% of all ankle fractures and typically result from rotational ankle injury and rarely occur in isolation [23]. Ankle fractures involving PMFFs have worse clinical outcomes than uni-or bimalleolar fracture **[24].** Despite a large amount of literature about PMF, there are no clear guidelines for its treatment. Most orthopedic surgeons consider a PMF fragment larger than 25% to 33% an operative indication [7]. Interestingly, after careful evaluation of the available literature, there does not seem to be hard evidence for these numbers. There is no high level of evidence that internal fixation of posterior malleolar fractures improves outcome [25]. Some experts suggest that there is a risk of posterior talar displacement in these fractures, but few studies showed that the risk of talar displacement is low if the lateral column (fibula and anterior tibiofibular ligament) and the medial column (medial malleolus and deltoid ligament) are intact with no regard to the size of the fragments [26]. Other experts argue for fixation with the increases in fragment size the as it increases the contact pressures changes in the joint [27], [28]. To resolve this controversy, we pooled data form identified studies in order to establish the superiority the surgical or the conservative treatment. We include a total of 1645 patients in the surgical group and another 260 patients in the conservative group which denote that there is a lake of studies that reported data about patients who were treated conservatively compared to the surgical treatment. The mean age in the surgical group was higher than conservative group (48.84 vs. 38.85 years); we might justify this by that older patients have poor bone quality and healing while younger patients have better healing outcome [27] so this may be a reason for this relation between age and the choice management modality. Based on the finding results, we could not reach a solid conclusion whether to choose conservative or surgical treatment. Also, most of the data

we have are based on a retrospective studies and small sample size. Another point to rise is the uniformity in the diagnosis of injuries such as using X- ray as imaging modalities. Some studies demonstrated analysis of lateral X-rays does not reveal the course and size of the PMF and the size of the PMF was often overrated according to plain lateral X-rays by approximately 8.1% (range: 3–15%) since the fracture line of the posterior malleolus is hardly ever perpendicular to the distal tibial articular surface [15,29,30]. Additionally, we found that not all outcomes were reported consistently across the studies which hinder our ability to compare the whole patients in each group to the other. This is because some studiers focused on mobility scores and other focused pain scores so it makes it hard to compare the results the studies and we could not the man scores for all patients. We have a concern of bias as some patients were lost in follow-up without knowing a valid reason for their loss especially; the surgical arm had shorter duration of follow up than the conservative group.

In order to establish the role of fragment size on the treatment outcome, we included data from studies [15,16,20,21,31] that compare the surgical treatment outcomes in different fragment sizes. Unfortunately, we could not pool these data into a single estimate as we did previously in the clinical outcomes because of the studies included different sizes of fragments. In Van Hooff et al [22] scores were not significantly different between larger (>25%) fragment groups compared to the smaller fragments (10%–25% and smaller than 5%). Similarly, Weigelt et al [31] reported no difference between fragment size above and below 25% on VAS and AOFAS. On the contrary, Mingo-Robinet et al. (21), Xu et al. [27] and Evers et al [15] reported significant better outcomes in smaller fragments (<25%).

The reason for contradiction of finding in Van Hooff et al [20] Weigelt et al [31] might be explained by the fact that the small fracture fragment group was relatively small and Van Hooff et al [20] enrolled one patient with very poor results with an AOFAS and AAOS score and if the patients were excluded this would lead to much better results in the small fragment group.

Despite the above-mentioned studies showed the importance of size of fragments, we found some factors other than the size of PMF have a prognostic role. Langenhuijsen et al., included 57 trimalleolar fractures, the effect of size, internal fixation, and anatomic reduction of the PMF on the prognosis was assessed. A modified Weber protocol was used for comprehensive patient evaluation. Size of the fragments did not influence prognosis but joint congruity in fragments > 10% of the articular surface was a significant factor influencing prognosis [32].

Osteoarthritis is one of the long-term complications that reported in literature. Ankle joint fractures can reportedly easily cause traumatic arthritis if it involves the posterior malleolus, and the fracture prognosis is poor [33]**.** Arthritis triggered by change in the stress distribution on the articular surface, which is caused by change in the articular surface area at the distal end of the tibia after posterior malleolus fracture [34]**.** Several variables were potential risk factors for development of osteoarthritis in PMF patients: age, fragment size, fragment fixation and postoperative step-off > 1 mm and gap > 1 mm.

We found that both the surgical and conservative arm had similar incidence of OA but the number of patients in the conservative arm was very lower than surgical arm so the sample size might have been too small to detect the actual incidence of osteoarthritis in the conservative arm.

Similarly, one study the treated patients conservatively reported low number (5%) of patients with limited osteoarthritis [35]. This was similar to surgically treated patients: Van Hooff et al (6%) [20],

verhage et al (7%) [36], Ruokun et al (2%) [37], Xing et al (0%) [38], Weigelt et al. (8%)[31] and Mingo-Robinet et al. 2012 (0%) [39]. These scores were comparable to our study despite the fact that these studies used different scoring systems to evaluate osteoarthritis and these scores used relative terminology that may make patients is subjective.

Moreover, Van Hooff et al [20] reported more osteoarthritis occurred in ankle fractures with medium and large PMFFs compared to small fragments. Also, osteoarthritis occurred more frequently when postoperative step-off was 1 mm or more, whether the posterior fragment was fixed or not**.** In another study, the size of the fragment were not associated with the development of osteoarthritis or with functional outcome and high BMI along with osteoarthritis were independent and significant risk factors for worse functional outcome [40]**.**

There are also disputes on the posterior malleolus fixation mode. A cross sectional study was conducted to evaluate the practice among orthopedic surgeons regarding the management of PMFs. 400 hundred orthopedic surgeons responded to the survey. Results showed that direct open reduction techniques for the posterior malleolus were favored with low percent of surgeons' chose posterolateral approach plating as preferred method of fixation. High variability regarding surgical treatment of medium-sized fragments (approximately 20% of the articular surface) [41]**.** In this study, we included several studies compared different fixation methods to each other's. In studies that compared plate to screw fixation [19,42,43,44], Erdem et al [42] and Ko et al [19] reported equivalent scores results were obtained using the 2 techniques. While O'Connor et al [45] reported PL plates was superior to AP screws and Kalem et al [43] reported PA screw and PL plates were than AP screw. The reason for this finding may be attributed to the superior biomechanical strength of PL plates compared with AP screw fixation which achieves anatomic reduction more frequently [44]. Moreover, PL plates approach also allows for fixation of smaller fracture fragments that could not be well fixed with AP screws [45]. Kalem et al [43] rationale the superiority of e PA screw technique by its ability to direct fracture visualization without excessive disturbance of the peroneal artery and branches, without the need for proximal dissection for plate fixation. Interestingly Wang et al [46] compared plated and screws fixation according to the fragment size. In fragment size of ≥15%, there was no statistical difference between them. For fragment size of < 15%, both PA and AP screws provide good fixation, cause less surgical trauma, and promote postoperative functional recovery. Usually, both modes of fixation i.e., front-to-back and back-to-front fixation had advantages and disadvantages. Front-to-back fixation is simple in operation and convenient in removal but difficult to reach firm pressurization while back-to-front fixation has a sound pressurization effect, the operation and removal during the second phase are difficult. Xu and his colleagues reported that both modes of fixation had similar outcomes regarding AOFAS, VAS, arthritis, and patient satisfaction scores [21]**.** Ligaments of the ankle joint play an important role in joint stability and may be affected during injury. The posterior-inferior tibiofibular ligament (PITFL) originates from the fibula and attaches to the PM. This ligament contributes 42% of the stability that the tibiofibular syndesmosis (TFS) ligament complex provides [47].

PITFL generally remains intact; PM fractures disrupt the stability of the TFS. Fixation of the PM provides 70% of the TFS stability in ankle fractures that involve PM fractures, whereas TFSS provides only 40%. Thus, open reduction of the PM ensures its proper PITFL length and restores stability of the TFS by preventing posterior translation of the fibula [48]**.**

Kim and Lee reported that PITFL release is often required, sometimes only partially, to reduce the posterior malleolar fragment However, caution should be used because any elevation of the PITFL on approach to the PM F may eliminate some of the stabilizing force. Authors showed that direct visualization and reduction of PMFs through PITFL release led to satisfactory clinical and radiographic outcomes without causing ankle instability after a follow up period of 26.7 months [49]**.**

Miller et al. evaluated a protocol involving both direct syndesmosis visualization and meticulous tibial incisura reconstruction via the posterior malleolus fracture fragment. The suggested protocol was compared to a control group, fixation through indirect, fluoroscopic reduction and syndesmotic screws. The protocol group had a significant reduction in the incidence of incongruent joints (16% vs. 52%) [50]**.**

Hoelsbrekken et al. investigated the possibility of non-operative treatment of nondisplaced medial malleolus in bimalleolar and trimalleolar fractures. Despite, it seems to be an interesting treatment option as usually medial malleolus may realign after ORIF of the lateral malleolus, the result of study showed elevated rates of nonunion (it did not seem to worsen the functional outcome) and it wasn't clear regarding it impact on the development of arthritis on the long term [51]**.**

Giving the data provided above, generally, most authors of clinical studies agree that operative treatment is indicated for large fragments and prefer conservative treatment in small fractures. But still some suggested to adopt ORIF in small sized fragment as it led to more ankle stability. Evidence from these studies is relatively weak due to the retrospective nature of their design.

Overall, it is difficult to reach a firm conclusion, because the published data are heterogeneous in terms of the study designs, methodology used and consistency in reporting certain outcomes. However, we provided a comprehensive evaluation for evidence regarding PMF in the literature.

6. Conclusion

The decision on whether or not to apply open reduction and internal fixation for a posterior malleolar fragment is based on insufficient evidence as most of previous studies are small in sample size with retrospective design, also there is limited data on conservative treatment. Till now the choice of line of treatment, in generally, most authors of clinical studies agree that operative treatment is indicated for large fragment and in cases with small fragment size, is left to the surgeon preference and patients' presentation.

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References

1. Abdelgawad AA, Kadous A, Kanlic E. Posterolateral approach for treatment of posterior malleolus fracture of the ankle. J Foot Ankle Surg. 2011;50(5):607-11

2. Bartoníček J, Rammelt S, Kostlivý K, Vaněček V, Klika D, Trešl I. Anatomy and classification of the posterior tibial fragment in ankle fractures. Archives of orthopaedic and trauma surgery, 2015; 135(4), 505-516.

3. Berkes MB, Little MT, Lazaro LE, Pardee NC, Schottel PC, Helfet DL, Lorich DG. Articular congruity is associated with short-term clinical outcomes of operatively treated SER IV ankle fractures. JBJS, 2013; 95(19), 1769-1775.

4. Brockett CL. 'Biomechanics of the ankle', Orthopaedics and Trauma. Elsevier Ltd, 2016 pp. 1–7.

5. Brodsky JW, Polo FE, Coleman SC, Bruck N. Changes in gait following the Scandinavian total ankle replacement. J Bone Joint Surg Am Vol Oct 19, 2011; 93A: 1890-6.

6. De Asla RJ, Wan L, Rubash HE, Li G. Six DOF in vivo kinematics of the ankle joint complex: application of a combined dual- orthogonal fluoroscopic and magnetic resonance imaging tecnique. J Orthop Res 2006; 24: 1019-27.

7. De Vries JS, Wijgman AJ, Sierevelt IN, Schaap G. "Long-term results of ankle fractures with a posterior malleolar fragment." The Journal of foot and ankle surgery. 2005; 44(3): 211-217.

8. Donken CC, Goorden AJ, Verhofstad MH, Edwards MJ, van Laarhoven CJ. The outcome at 20 years of conservatively treated 'isolated'posterior malleolar fractures of the ankle: a case series. The Journal of bone and joint surgery. British volume. 2011; 93(12):1621-5.

9. Drijfhout van Hooff C, Verhage S, Hoogendoorn J. Influence of fragment size and postoperative joint congruency on long- term outcome of posterior malleolar fractures. Foot Ankle Int. 2015;36(6):673-678.

10. Fitzpatrick DC, Otto JK, McKinley TO, Marsh JL, Brown TD. Kinematic and contact stress analysis of posterior malleolus fractures of the ankle. Journal of orthopaedic trauma. 2004; 18(5):271-8.

11. Fitzpatrick E, Goetz JE, Sittapairoj T. Effect of posterior malleolus fracture on syndesmotic reduction: a cadaveric study. J Bone Joint Surg Am. 2018;100(3):243-248.

12. 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(4):309-14.

13. Gardner MJ, Streubel PN, McCormick JJ, Klein SE, Johnson JE, Ricci WM. Surgeon practices regarding operative treatment of posterior malleolus fractures. Foot & ankle international. 2011; 32(4):385-93.

14. Gardner MJ, Brodsky A, Briggs SM, Nielson JH, Lorich DG. Fixation of posterior malleolar fractures provides greater syndesmotic stability. Clinical Orthopaedics and Related Research®. 2006; 447:165-71.

15. Roos EM, Brandsson S, Karlsson J. Validation of the foot and ankle outcome score for ankle ligament reconstruction. Foot & Ankle International. 2001; 22(10):788-94.

16. Evers J, Barz L, Wähnert D, Grüneweller N, Raschke MJ, Ochman S. Size matters: The influence of the posterior fragment on patient outcomes in trimalleolar ankle fractures. Injury. 2015; 46 Suppl 4:S109-13.

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(2):141-5.

18. Saygılı MS, Özkul B, Çetinkaya E, Tekin AC, Bayhan AI, Kalkar I, Akbulut D, Demir B. Operative versus non-operative treatment of posterior malleolus fragment in trimalleolar fracture: A retrospective cohort study. Biomedical Research. 2017;28(14):6498-503.

19. Kang C, Hwang DS, Lee JK, Won Y, Song JH, Lee GS. Screw Fixation of the Posterior Malleolus Fragment in Ankle Fracture. Foot Ankle Int. 2019; 40(11):1288-1294.

20. Ko JW, Lee G-W, Lee K-B. Comparing Outcomes of Screw Fixation and Non-Fixation for Small-Sized Posterior Malleolar Fragment in Ankle Trimalleolar Fractures. J Korean Fract Soc. 2021; 34(1):8-15.

21. Van Hooff CCD, Verhage SM, Hoogendoorn JM. Influence of fragment size and postoperative joint congruency on long-term outcome of posterior malleolar fractures. Foot Ankle Int. 2015; 36(6):673-8.

22. Xu, Hai Lin, Xuan Li, Dian Ying Zhang, Zhong Guo Fu, Tian Bing Wang, Pei Xun Zhang, Bao Guo Jiang, Hui Liang Shen, Gang Wang, Guang Lin Wang, and Xin Bao Wu. A retrospective study of posterior malleolus fractures. Int Orthop. 2012; 36(9):1929-36.

23. Hosny GA, Bayomy EM, Abouzied M, Abdallah AA. Comparative Study between Fixation of Small Size Posterior Malleolus and Conservative Treatment. Benha J Appl Sci. 2020; 5(3):163-167.

24. Thur CK, Edgren G, Jansson K-Å, Wretenberg P. Epidemiology of adult ankle fractures in Sweden between 1987 and 2004: a population-based study of 91,410 Swedish inpatients. Acta Orthop. 2012;276-81.

25. Singh R, Kamal T, Roulohamin N, Maoharan G, Ahmed B, Theobald P. Ankle fractures: a literature review of current treatment methods. Open J Orthop. 2014;4(4):292-303.

26. Lovy, Andrew J., James Dowdell, Aakash Keswani, Steven Koehler, Jaehon Kim, Steven Weinfeld, and David Joseph. Nonoperative Versus Operative Treatment of Displaced Ankle Fractures in Diabetics. Foot Ankle Int. 2017; 38(3):255-260.

27. Raasch WG, Larkin JJ, Draganich LE. Assessment of the posterior malleolus as a restraint to posterior subluxation of the ankle. J Bone Jt Surg - Ser A. 1992; 74(8):1201-6.

28. Macko VW, Matthews LS, Zwirkoski P, Goldstein SA. The joint-contract area of the ankle. The contribution of the posterior malleolus. J Bone Jt Surg - Ser A. 1991; 73(3):347-51.

29. Haraguchi N, Haruyama H, Toga H, Kato F. Pathoanatomy of posterior malleolar fractures of the ankle. J Bone Jt Surg - Ser A. 2006; 88(5):1085-92.

30. Büchler L, Tannast M, Bonel HM, Weber M. Reliability of radiologic assessment of the fracture anatomy at the posterior tibial plafond in malleolar fractures. J Orthop Trauma. 2009; 23(3):208-12.

31. Gonzalez O, Fleming JJ, Meyr AJ. Radiographic Assessment of Posterior Malleolar Ankle Fractures. J Foot Ankle Surg. 2015; 54(3):365-9.

32. Weigelt L, Hasler J, Flury A, Dimitriou D, Helmy N. Clinical and radiological mid- to long-term results after direct fixation of posterior malleolar fractures through a posterolateral approach. Arch Orthop Trauma Surg. 2020; 140(11):1641-1647.

33. Langenhuijsen JF, Heetveld MJ, Ultee JM, Steller EP, Butzelaar RMJM. Results of ankle fractures with involvement of the posterior tibial margin. J Trauma. 2002; 53(1):55-60.

34. Xu, Hai Lin, Li Min Liu, Xuan Li, Dian Ying Zhang, Zhong Guo Fu, Tian Bing Wang, Pei Xun Zhang, Bao Guo Jiang, Hui Liang Shen, Gang Wang, Guang Lin Wang, and Xin Bao Wu. Multicenter follow-up study of ankle fracture surgery. Chin Med J (Engl). 2012; 125(4):574-8.

35. McKinley TO, Rudert MJ, Koos DC, Brown TD. Incongruity versus instability in the etiology of posttraumatic arthritis. In: Clinical Orthopaedics and Related Research. 2004. (423):44-51.

36. Donken CCMA, Goorden AJF, Verhofstad MHJ, Edwards MJ, Van Laarhoven CJHM. The outcome at 20 years of conservatively treated “isolated” posterior malleolarfractures of the ankle: A case series. J Bone Jt Surg - Ser B. 2011; 93(12):1621-5.

37. Verhage SM, Boot F, Schipper IB, Hoogendoorn JM. Open reduction and internal fixation of posterior malleolar fractures using the posterolateral approach. Bone Jt J. 2016; 98-B (6):812-7.

38. Ruokun, Huang, Xie Ming, Xiao Zhihong, Fang Zhenhua, Zhao Jingjing, Xiao Kai, and Li Jing. Postoperative radiographic and clinical assessment of the treatment of posterior tibial plafond fractures using a posterior lateral incisional approach. J Foot Ankle Surg. 2014; 53(6):678-82.

39. Xing, Wenzhao, Yanfeng Wang, Liang Sun, Linjie Wang, Zhigang Kong, Chunpu Zhang, and Zhiguo Zhang. Ankle joint dislocation treating dislocated trimalleolar fractures accompanied with the complex posterior malleolus fracture without separation of the tibiofibular syndesmosis. Med (United States). 2018; 97(37):e12079.

40. Mingo-Robinet J, Abril Larrainzar JM, Valle Cruz JA. Posterolateral approach in trimalleolar ankle fractures. Surgical technique. Rev Española Cirugía Ortopédica y Traumatol (English Ed. 2012; 56(4):313-8.

41. Verhage SM, Krijnen P, Schipper IB, Hoogendoorn JM. Persistent postoperative step-off of the posterior malleolus leads to higher incidence of post-traumatic osteoarthritis in trimalleolar fractures. Arch Orthop Trauma Surg. 2019; 139(3):323-329.

42. Gardner MJ, Streubel PN, McCormick JJ, Klein SE, Johnson JE, Ricci WM. Surgeon practices regarding operative treatment of posterior malleolus fractures. Foot Ankle Int. 2011; 32(4):385-93.

43. 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(10):1022-30.

44. Kalem M, Şahin E, Songür M, Keser S, Kinik H. Comparison of three posterior malleolar fixation methods in trimalleolar ankle fractures. Acta Orthop Belg. 2018; 84(2):203-212.

45. Horisberger M, Valderrabano V, Hintermann B. Posttraumatic ankle osteoarthritis after ankle-related fractures. J Orthop Trauma 2009; 23:60-7.

46. Li Y duo, Liu S mao, Jia J sheng, Zhou J lin. [Choice of internal fixation methods for posterior malleolus fracture in both biomechanics and clinical application]. Beijing Da Xue Xue Bao. 2011; 43(5):718-23.

47. Wang, Zheng, Jianbin Sun, Jun Yan, Pengcheng Gao, Hao Zhang, Yong Yang, and Qunhua Jin. Comparison of the efficacy of posterior-anterior screws, anterior-posterior screws and a posterior-anterior plate in the fixation of posterior malleolar fractures with a fragment size of ≥ 15 and < 15%. BMC Musculoskelet Disord. 2020;21(1):1–9.

48. Lee AY, Ha AS, Petscavage JM, Chew FS. Total ankle arthroplasty: A radiographic outcome study. Am J Roentgenol. 2013; 200(6):1310-6.

49. 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.

50. Kim YJ, Lee JH. Posterior Inferior Tibiofibular Ligament Release to Achieve Anatomic Reduction of Posterior Malleolar Fractures. J Foot Ankle Surg. 2018; 57(1):86-90.

51. Miller AN, Carroll EA, Parker RJ, Boraiah S, Helfet DL, Lorich DG. Direct Visualization for Syndesmotic Stabilization of Ankle Fractures. Foot Ankle Int. 2009; 30(5):419-26.