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ORIGINAL

EFFECTIVENESS OF OPEN REDUCTION INTERNAL FIXATION AND EXTERNAL FIXATION FOR PILON FRACTURES IN ATHLETES

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ABSTRACT

Objective: This study aims to evaluate the effectiveness of ORIF versus EF in treating Pilon fractures in athletes. **Methods:** A comprehensive literature search spanning January 2007 to December 2018 was conducted across databases including EMBASE, PubMed, and the Cochrane Library. The QUADAS score assessed the quality of the included studies. Data extraction was performed using Revman software. **Results:** Out of 413 initial papers, 10 met the inclusion criteria. The studies compared the incidence of superficial and in-depth infections, arthritis, malunion, and nonunion between ORIF and EF groups, as well as the time to bone healing. The ORIF group showed a significantly lower occurrence of superficial infections (OR= 0.33, P<0.05), malunion (OR= 0.33, P<0.05), and nonunion (OR= 0.45, P<0.05), with no significant differences in in-depth infections, arthritis, and bone healing time. **Conclusion:** ORIF is more effective than EF in reducing the risk of superficial infections, malunion, and nonunion in athletes with Pilon fractures, with comparable outcomes in in-depth infections, arthritis, and bone healing time.

KEY WORDS; Athletes; Sports Injuries; Open reduction and internal fixation; External fixation; Pilon fracture; Meta-analysis

1. INTRODUCTION

Pilon fractures, complex injuries occurring at the lower end of the tibia, present a significant challenge in orthopedic trauma, particularly in athletes. These fractures often result from high-energy impacts, a common occurrence in competitive sports(Biz et al., 2018; Burton, Aynardi, & Aydogan, 2021). The treatment of pilon fractures in athletes is crucial not only for immediate injury management but also for ensuring a return to prior levels of athletic performance. This study focuses on evaluating the effectiveness of two primary surgical interventions for pilon fractures in athletes: Open Reduction Internal Fixation (ORIF) and External Fixation(Carbonell-Escobar, Rubio-Suarez, Ibarzabal-Gil, & Rodriguez-Merchan, 2017).

The selection of an appropriate surgical technique is paramount in treating pilon fractures, as it significantly influences the healing process, recovery time, and the potential return to athletic activity(McAndrew, Ricci, Miller, & Avery, 2018). ORIF, a procedure involving the surgical opening of the fracture site for direct bone alignment and stabilization using internal hardware, is widely used for its precision in anatomical reduction(Li et al., 2020). (Lu et al., 2022).

However, the invasiveness of the procedure, along with potential complications such as infection and the need for subsequent hardware removal, poses challenges(Chen, Li, Ouyang, & Zhang, 2022). On the other hand, External Fixation, a less invasive technique involving stabilizing the fracture from outside the body using pins and wires connected to a stabilizing frame, offers the advantage of reduced soft tissue disruption(Kurylo, Datta, Iskander, & Tornetta III, 2015).

While this method is advantageous in managing soft tissue injuries and reducing infection rates, it may not always provide the same level of precision in bone alignment as ORIF(Davidovitch, Elkhechen, Romo, Walsh, & Egol, 2011; Duckworth, Jefferies, Clement, & White, 2016).Athletes, as a specific patient population, present unique considerations due to the demands of their sport and the necessity for rapid, complete recovery(McKissack et al., 2019).

The physical stress and strain that athletes place on their bodies mean that the chosen surgical intervention must not only facilitate healing of the fracture but also ensure long-term structural integrity and function of the leg(Haller et al., 2020). Additionally, the psychological aspects of recovery, including the athlete's confidence in the injured limb, are crucial factors in the treatment decision-making process(Guan, Huang, Wang, Chen, & Wang, 2019).

This study aims to compare the outcomes of ORIF and External Fixation in the treatment of pilon fractures in athletes(Milenković et al., 2013). We will evaluate factors such as the time to bone healing, rate of complications, functional outcomes, and the time taken to return to sports(Krettek & Bachmann, 2015). By focusing on these key metrics, the study endeavors to provide a comprehensive understanding of which surgical technique better aligns with the needs and recovery goals of the athletic population (Harold, 2022). The findings of this research are expected to offer valuable insights for orthopedic surgeons, sports medicine specialists, and athletes themselves in making informed decisions about the management of this challenging injury.

2. MATERIALS AND METHODS

2.1 Literature search and screening

2.1.1 Literature Search Methods

Search Pubmed, EMBASE, and the Cochrane Library databases. The search years were: from January 2007 to December 2018. The search terms were: pilon fracture (tibial pilon fracture, tibial plafond fracture), external fixation (external fixator, external fixation, EF), open reduction and internal fixation (ORIF).

2.1.2 Inclusion and Exclusion Criteria

Inclusion criteria: (1) Published case-control studies, cohort studies, or randomized controlled trials. (2) Patients with Pilon fractures treated with open reduction or internal fixation and external fixator combined with limited internal fixation. (3) Age >18 years. (4) Follow-up time >9 months. (5) Outcomes that contain the outcome indicators required for this study and for which reliable data can be extracted from the full text.

Exclusion criteria: (1) Case reports, reviews, animal studies, and systematic evaluations. (2) With severe underlying disease such as diabetes, severe heart disease, chronic kidney disease, or in combination with their severe trauma. (3) Pathological fractures or old fractures of the distal tibia. (4) History of previous ankle trauma.

2.1.2 Data Extraction

Two authors performed the extraction of data from the included literature separately: basic information including 1st author, publishing year, nation, follow-up time, sample size, mean age, sex ratio, staging of Pilon fractures, occurrence of complications such as infection, arthritis, malunion, nonunion, and time of bone healing.

2.1.3 Quality evaluation

A literature search as well as a full-text reading was conducted by 2 researchers, followed by literature screening based on inclusion and exclusion criteria. The results of both were cross-referenced and in case of disagreement, the final results were decided by a joint discussion between a third researcher. The quality of the study literature was assessed according to the QUADAS score (Table 2) and the Cochrane Risk of Bias Assessment Tool was used for bias assessment. (Figure 7).

2.2 Statistical Methods

Data analysis was performed using RevMan and forest plots were generated. The heterogeneity of each study index was tested by I^2 test, and $I^2 < 50\%$ indicated homogeneity among the studies, and then the included data were analyzed by fixed effect model; If $I^2 \geq 50\%$, heterogeneity was considered among the studies and analyzed by random effect model. When $P < 0.05$, the distinction was indicated as obvious. The included studies were analyzed for bias using funnel plot precision, and funnel plots were drawn for infection rate, occurrence of arthritis, occurrence of malunion, occurrence of bone nonunion, and healing time, which were found to be largely symmetrical, indicating a small bias (Figures 8-12). The results of the analysis were presented by drawing a forest plot. The 95% confidence intervals and the MD or OR values between the outcome indicators were used for analysis and description.

3. RESULTS

3.1 Basic information

The initial search of the literature was conducted according to the search strategy and the principle of inclusion of references, and a total of 413 articles were obtained. 308 articles remained after removing duplicate articles, and 186 articles were included after reading the abstracts and article titles, at which time the literature was screened according to the inclusion and exclusion criteria, and 10 articles were finally included (Figure 1). The basic information of the included literature was extracted and summarized (Table 1). The quality of the included literature was evaluated, and the QUADAS score revealed that the quality of the included literature for analysis was high. (Table 2)

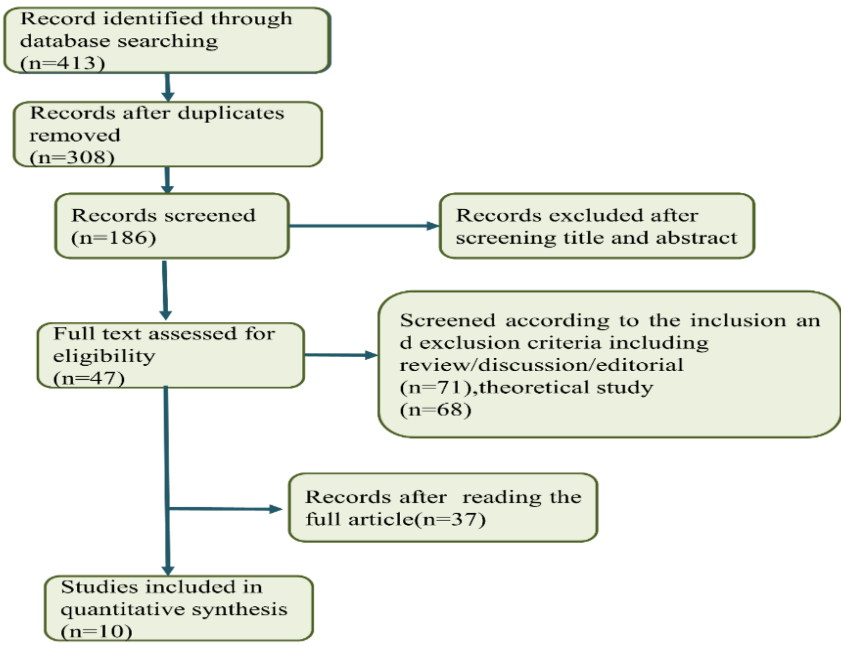

Figure 1 Steps for inclusion in the literature

Table 1: Basic information of the included literature

STUDY	STUDY TYPE	LOCATION	DURATION OF FOLLOW UP (MONTHS)	PATIENTS (N)	MALE （N）	FEMALE （N）	AGE	FRACTURES CLASSIFICATION (N)
Richards, 2012 (Richards et al., 2012)	Retrospective cohort	US	12	45	NS	NS	ORIF: 46.961 3.1 EF: 40.66 ± 13.3	AO/OTA C1:2 C2:6 C3:37
Bacon, 2008 (Bacon et al., 2008)	Retrospective cohort	US	12	38	31	7	37.0 ± 11.3	AO/OTA C1:4 C2:10 C3:24
Koulouvaris, 2007 (Koulouvaris et al., 2007)	case-control study	US	80	55	NS	NS	42(22-74)	AO/OTA B:19 C:36
Danoff, 2015 (Danoff, Saifi, Goodspeed, & Reid, 2015)	Retrospective cohort	US	36	28	13	15	43 (24-82)	AO/OTA B:2 C:26
Rayan, 2018 (Rayan et al., 2018)	Prospective randomised	Egypt	24	42	27	15	ORIF: 31.3 ± 9.4 EF: 33.8 ± 6.4	Rüedi & Allgöwer II:18 III:24
Davidovitch, 2011 (Roy I. Davidovitch et al., 2011)	Retrospective cohort	US	12	47	29	17	42.5	AO/OTA C1:5 C2:10 C3: 32
Deivaraju, 2015 (Deivaraju, Vlasak, & Sadasivan, 2015)	Retrospective cohort	US	9	65	NS	NS	NS	NS
Cisneros, 2016 (Cisneros et al., 2016)	Retrospective cohort	India	24	31	14	17	48（19-82）	AO/OTA A:11 B:4 C:16
Wang, 2010 (Cheng Wang, Ying Li, Lei Huang, & Manyi Wang, 2010)	Randomized controlled trial	China	24	56	51	5	40.1 ± 10.7	AO/OTA B3:5 C1:16 C2:23 C3: 12
Guo, 2015 (Guo, Tong, Li, & Liu, 2015)	Retrospective cohort	China	16	78	22	56	ORIF: 40.7±10.1 EF:41.2±9.6	Rüedi & Allgöwer: III:78

Table 2: QUADAS score evaluation

	SPECTRUM COMPOSITION	SELECTION CRITERIA	REFERENCE STANDARD	DISEASE PROGRESSION BIAS	PARTIAL VERIFICATION	DIFFERENTIAL VERIFICATION	INCORPORATION BIAS	INDEX TEST EXECUTION	REFERENCE STANDARD EXECUTION	TEST REVIEW BIAS	REFERENCE STANDARD REVIEW BIAS	CLINICAL REVIEW BIAS	UNINTERPRETABLE TEST RESULT	WITHDRAWLS	TOTAL
Richards et al. (Richards et al., 2012)	Yes	Yes	Yes	No	Whole sample	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	13/14
Bacon et al (Bacon et al., 2008)	Yes	Yes	No	Yes	Whole sample	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	11/14
Koulouvaris et al (Koulouvaris et al., 2007)	Yes	Yes	Yes	Yes	Whole sample	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	12/14
Danoff et al (Danoff et al., 2015)	Yes	Yes	Yes	Yes	Whole sample	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	13/14
Rayan et al (Rayan et al., 2018)	Yes	Yes	No	Yes (up to 4 weeks)	Whole sample	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	12/14
Davidovitch et al (Roy I. Davidovitch et al., 2011)	Yes	Yes	Yes	Yes	Whole sample	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	13/14
Deivaraju et al (Deivaraju et al., 2015)	Yes	Yes	Yes	Yes	Whole sample	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	13/14
Cisneros et al (Cisneros et al., 2016)	Yes	Yes	Yes	Yes	Whole sample	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	13/14
Wang et al (Cheng Wang et al., 2010)	Yes	Yes	Yes	Yes	Whole sample	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	14/14
Guo et al (Guo et al., 2015)	Yes	Yes	Yes	Yes	Whole sample	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	13/14

3.2 Comparison of the occurrence of infection

The occurrence of infection was divided into superficial and in-depth infections in the included studies, so subgroup analysis was taken. A total of 7 studies compared the superficial occurrence of infection in the ORIF group with the EF group, and 9 studies involved the occurrence of in-depth infection in the ORIF group with the EF group, and all chose fixed-effects models due to the small heterogeneity of (df=6 (P=0.58), I^2=0%), (df=8 (P=0.62), I^2=0%), respectively. The indicator results were dichotomous variables, and OR was used to express them, and finally we got OR= 0.33(0.18,0.60) for superficial infection (P<0.05), OR= 1.27(0.65,2.50) for in-depth infection (P=0.49).

From the results, it is clear that the ORIF group had a lower occurrence of superficial infection compared to the EF group, and the distinction was obvious, and there was no obvious distinction in the occurrence of in-depth infection in the ORIF group compared to the EF group. And the overall occurrence of infection was lower in the ORIF group (OR=0.60 (0.39,0.92) (p<0.05)). (Figure 2)

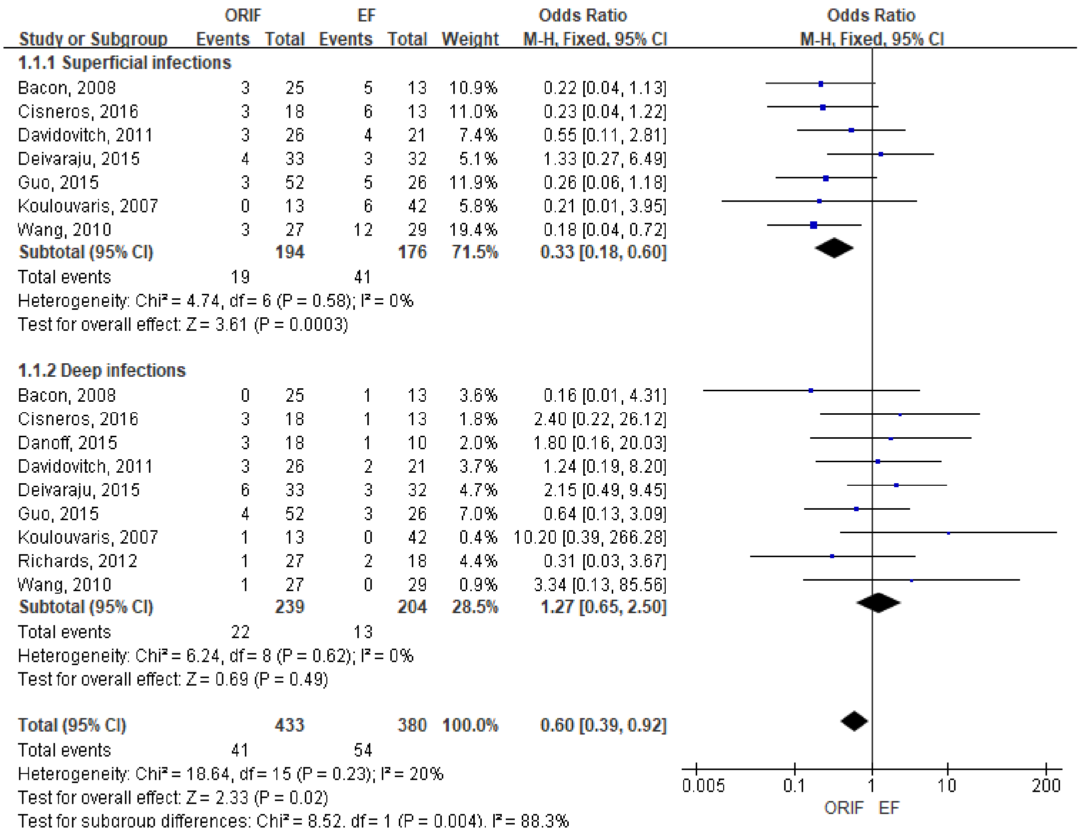

Figure 2 Forest plot of the occurrence of infection

3.3 Comparison of the occurrence of arthritis

Among the included studies, 5 studies compared the occurrence of arthritis in the ORIF group with the EF group, and due to the small heterogeneity (df=4 (P=0.79), I^2=0%), a fixed effects model was chosen for the analysis. The indicator results were dichotomous variables and were expressed using OR, and the analysis yielded OR= 0.70(0.39,1.26) (P=0.24), and from the results, it is clear that there was no obvious distinction in the occurrence of arthritis in the ORIF group in comparison with EF. (Figure 3)

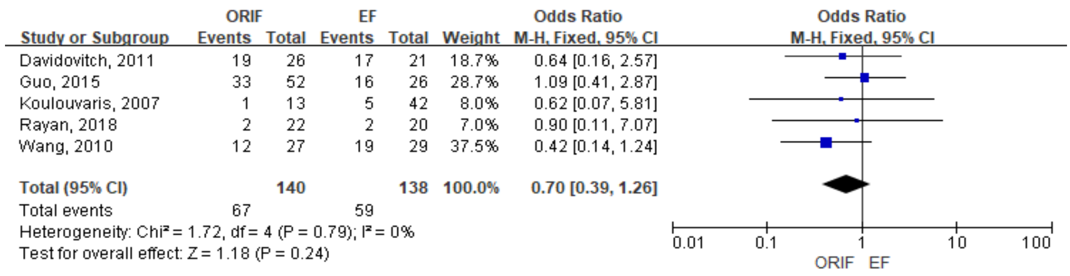

Figure 3 Forest plot of the occurrence of arthritis

3.4 Comparison of the occurrence of malunion

8 of the included literature compared the occurrence of malunion. Due to the small heterogeneity (df=6(P<0.95), I^2=0%), a fixed effects model was employed. The results were dichotomous variables, so OR was used to express the results, and the analysis yielded OR= 0.33(0.03,3.42) (P<0.05), from the results it is clear that the occurrence of malunion was lower in the ORIF group compared to the EF, and the distinction was obvious. (Figure 4)

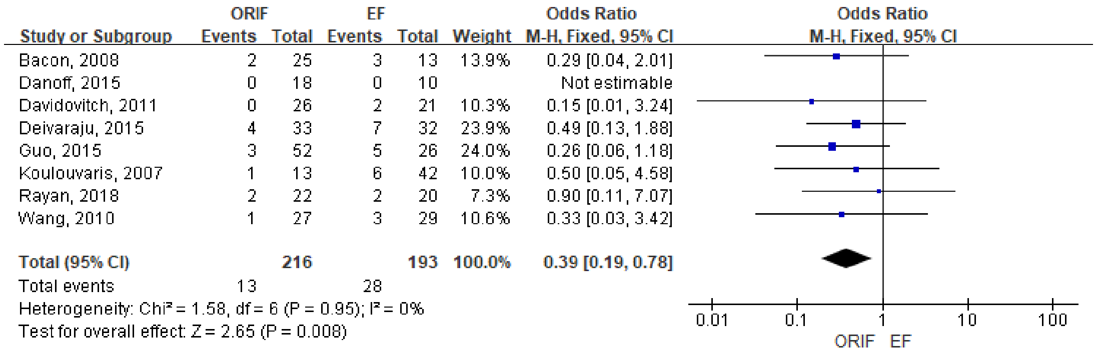

Figure 4 Forest plot of the occurrence of malunion

3.5 Comparison of the occurrence of nonunion

8 studies in the included literature compared the occurrence of nonunion. Due to the small heterogeneity (df=5(P=0.77), I^2=0%), a fixed effects model was employed. The ending index was a dichotomous variable, so it was expressed by OR, and the analysis yielded OR= 0.45(0.20,0.98) (P<0.05), and from the results it is clear that the occurrence of nonunion was lower in the ORIF group compared to the EF, and the distinction was obvious. (Figure 5)

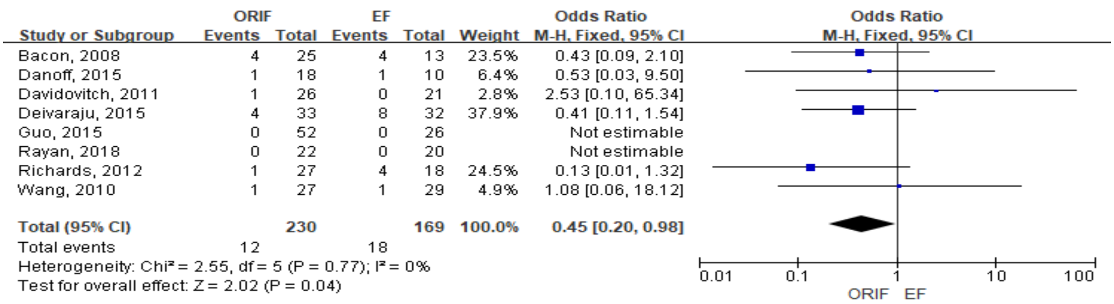

Figure 5 Forest plot of the occurrence of nonunion

3.6 Comparison of bone healing time

7 studies compared bone healing time in the ORIF group with the EF group, and due to the small heterogeneity (df=6(P=0.77), I^2=0%), a fixed effects model was employed. The ending index was a continuous variable, so it was expressed by MD, and the analysis yielded MD= -0.22(-1.65,1.21) (P<0.05), from the results, it is clear that the distinction in bone healing time was not obvious. (Figure 6)

	ORIF			EF				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Bacon, 2008	9.12	8.1	25	5.72	4.5	13	0.6%	3.40 [-0.61, 7.41]
Cisneros, 2016	5.09	2.41	18	4.46	1.26	13	5.3%	0.63 [-0.68, 1.94]
Davidovitch, 2011	5.2	1	26	5.5	1	21	27.5%	-0.30 [-0.88, 0.28]
Guo, 2015	4.9	1.5	52	5.6	2.2	26	10.3%	-0.70 [-1.64, 0.24]
Koulouvaris, 2007	5.1	0.5	13	5.2	1.7	42	26.9%	-0.10 [-0.68, 0.48]
Rayan, 2018	3.76	1	22	3.29	1	20	24.8%	0.47 [-0.14, 1.08]
Wang, 2010	6.33	2.5	27	6.55	2.95	29	4.5%	-0.22 [-1.65, 1.21]
Total (95% CI)			**183**			**164**	**100.0%**	**-0.02 [-0.32, 0.28]**

Heterogeneity: Chi^2 = 9.34, df = 6 (P = 0.16); I^2 = 36%
Test for overall effect: Z = 0.14 (P = 0.89)

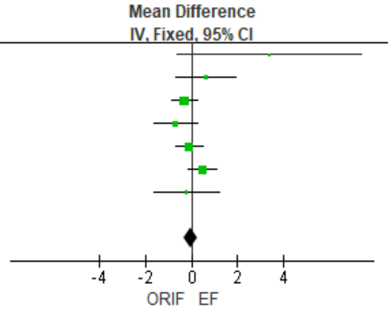

Figure 6 Forest plot of bone healing time

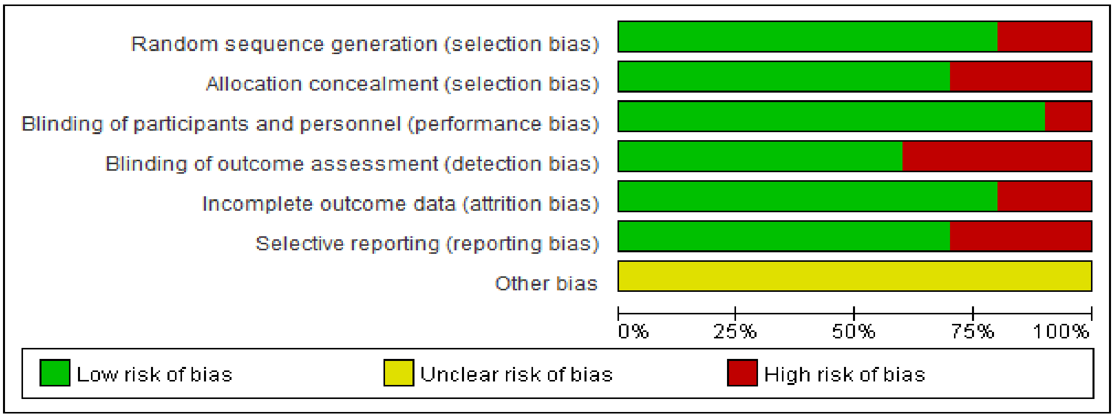

Figure 7 Cochrane Risk Bias Assessment Chart

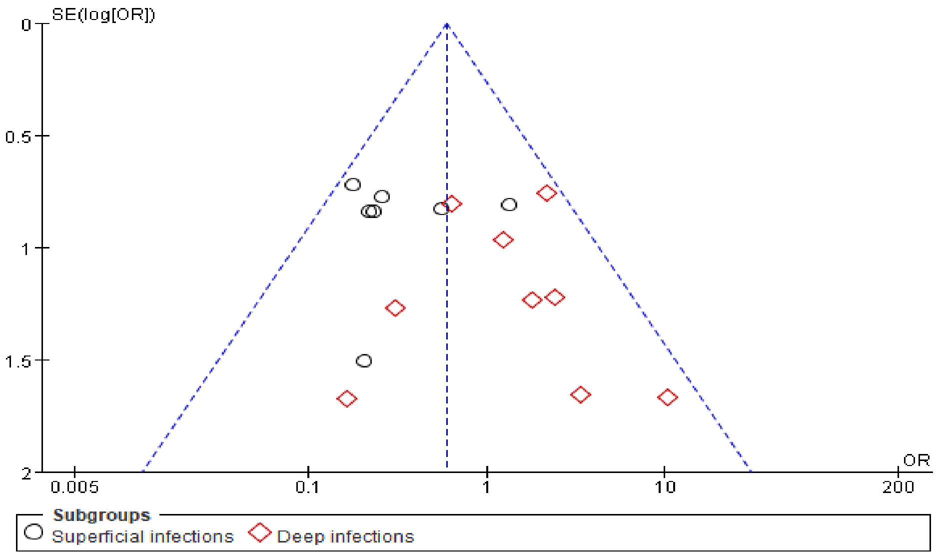

Figure 8 Funnel plot of the occurrence of infection

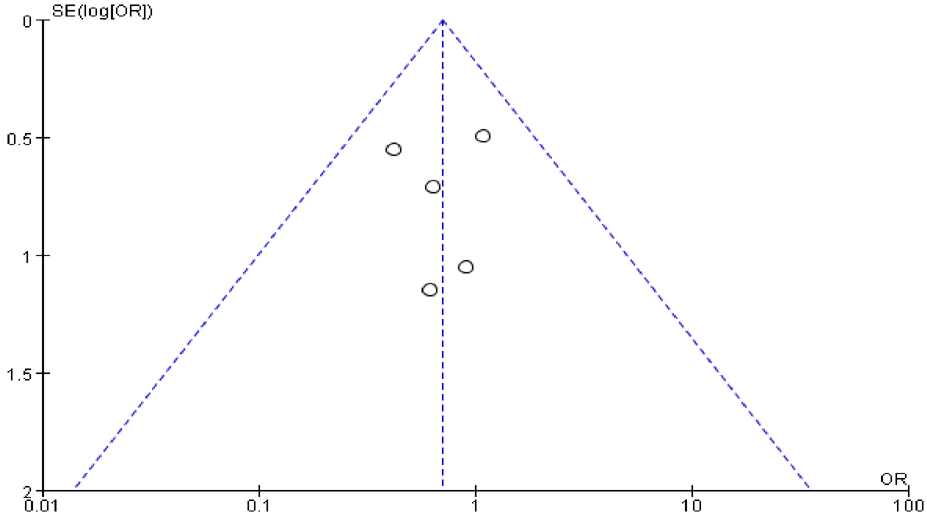

Figure 9 Funnel plot of the occurrence of arthritis

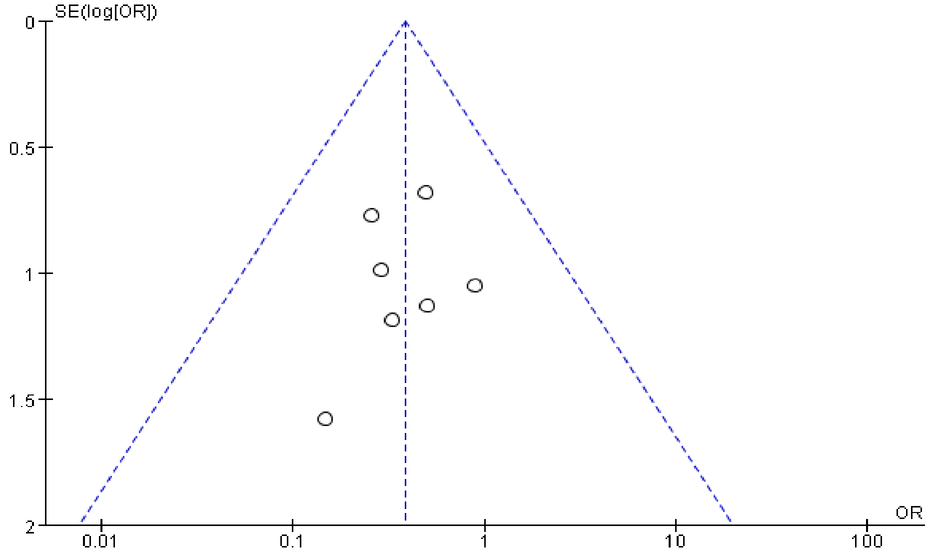

Figure 10 Funnel plot of the occurrence of malunion

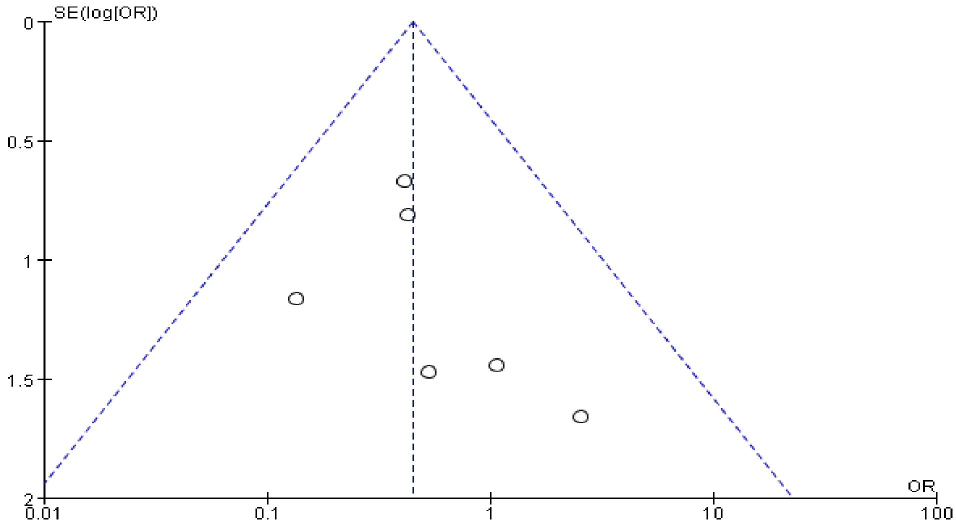

Figure 11 Funnel plot comparing the occurrence of nonunion

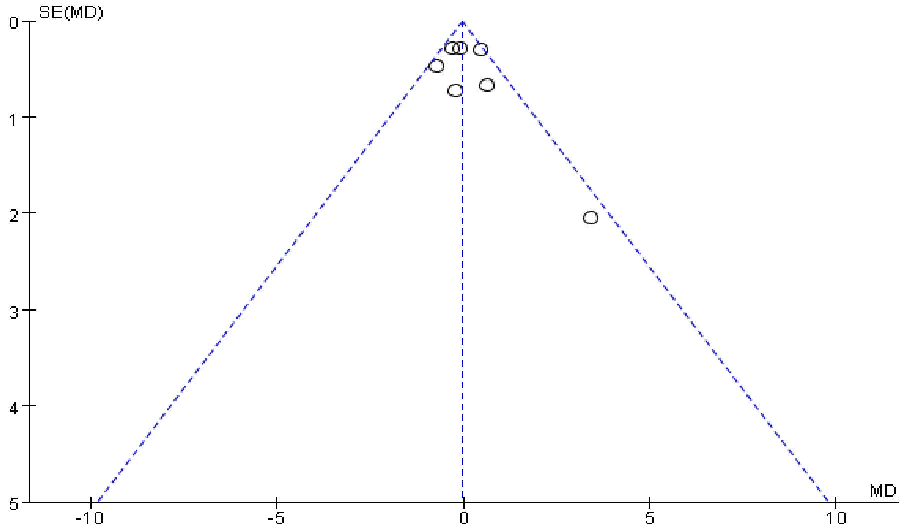

Figure 12 Funnel plot of bone healing time

4. DISCUSSION

With the rapid development of construction industry and traffic roads in China, the occurrence of Pilon fracture has also increased(Misir, Kizkapan, Yildiz, Uzun, & Ozcamdalli, 2019). Pilon fracture accounts for about 1% of lower limb fractures and 5%-10% of tibial fractures, mostly combined with severe soft tissue injury, fracture comminution with obvious displacement and joint surface collapse(Olson et al., 2021). Pilon fractures have complex anatomical structures, difficult intraoperative anatomical repositioning, much bleeding, and long operative time(Poutoglidou, Metaxiotis, Vasiliadis, & Mpeletsiotis, 2021). Postoperatively, it is prone to serious complications such as soft tissue infection, necrosis, deformed fracture healing, ankle stiffness, and even traumatic arthritis(Rubio-Suarez, Carbonell-Escobar, Rodriguez-Merchan, Ibarzabal-Gil, & Gil-Garay, 2018). Hence, intraoperative anatomical repositioning, lower limb force line restoration, and reliable internal fixation of the fracture play an extremely important role in postoperative functional recovery(Silluzio et al., 2019).

In practice, the choice of surgical option for the therapy of Pilon fractures remains a challenge, with no definitive evidence as to which ORIF or EF option is more effective or which is associated with more complications and is inproper(Sommer et al., 2017). For surgeons, most clinical studies are case-control retrospective studies(van der Vliet et al., 2019). Although randomized controlled trials can achieve good comparative efficacy observations, such experimental studies are ethically and morally constrained, and clinical trials cannot achieve satisfactory efficacy observations(Vidović et al., 2015). Meta-analysis can help clinicians and guideline makers by summarizing the pros and cons of different interventions(Wei, Xu, Xiang, & Ye, 2021). One-stage external fixation can help reduce soft tissue injury, promote anatomical repositioning of the fracture, promote the growth of the fracture end and fracture healing by stabilizing the joint and maintaining the alignment of the fracture end, and promote postoperative ankle rehabilitation exercises and recovery of ankle function(C. Wang, Y. Li, L. Huang, & M. Wang, 2010). In this study, we found that the ORIF group had a lower occurrence of superficial infection, overall infection, malunion healing, and bone discontinuity compared to the EF.

The advantage of the ORIF technique is the small incision and the small local tissue destruction and exposure, which protects the soft tissue resistance and the risk of skin necrosis is reduced. The EF technique, on the other hand, damages the soft tissues more severely. In fact, both procedures have advantages and disadvantages. The long surgical time and anesthesia of EF increase the risk of infection of the incision and in-depth tissues(Zitsch et al., 2022). If the infection is serious, even with medication, it is difficult to maintain an effective concentration in the bone marrow cavity, and the patient is likely to gradually develop chronic osteomyelitis, which, if left untreated for a long time, may cause skin necrosis due to long-term irritation of the surrounding skin and soft tissues(Yaradilmis et al., 2020).

The ORIF procedure does not fully expose the articular surface of the fracture and does not allow for the repair of the articular surface under direct visualization when fixing the fracture with kerf pins or screws, which does not ensure the integrity and smoothness of the articular surface and increases the area of wear and tear, resulting in pain, limited movement, and eventually traumatic arthritis. It can also protect the smoothness of the joint surface and reduce wear(Rubio-Suarez et al., 2018). Overall, fewer randomized controlled studies were included, the evidence was relatively weak, and the results of this study should be treated with caution. A better Meta-analysis is one that requires a large number of randomized controlled studies so that the evidence is better and more supportive of clinical work and therapy of the disease.

5. Conclusion

The comparative study of Open Reduction Internal Fixation (ORIF) and External Fixation in treating pilon fractures among athletes has provided critical insights into optimizing recovery and functional outcomes in this specialized patient group. Our findings suggest that while ORIF offers more precise anatomical alignment, essential for athletes' high-performance needs, it also carries a higher risk of complications such as infections. External Fixation, with its less invasive approach, showed a favorable profile in terms of reduced soft tissue complications and faster initial recovery, but was sometimes less effective in achieving long-term structural integrity essential for athletic activities.

Crucially, the time to return to sports was similar in both groups, but the choice of technique depended heavily on individual fracture characteristics and the athlete's specific sport-related demands.

This study underlines the importance of a tailored approach in surgical decision-making for athletes with pilon fractures, balancing the immediate benefits of accurate bone alignment against the risk of post-operative complications and the long-term functional demands of their sports careers.

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