OPEN AIMJ ORIGINAL ARTICLE

Orthopedic Surgery

External fixator supplemented with screw fixation versus staged open reduction and internal fixation of tibial pilon fracture

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Received *for publication May 10, 2021; Accepted August 30, 2021; Published online August 30, 2021.*

doi: 10.21608/aimj.2021.75964.1472.

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ABSTRACT

Background: Tibial plafond fractures are life-changing events that affect the patient's life.
Aim of the study: to compare the clinical and radiological outcomes of two different surgical techniques for treatment of tibial pilon fractures.
Patients and Methods: Those who matched completely with inclusion criteria were included until fully gaining required sample size. Prospective comparative controlled study using the foot and ankle outcome questionnaire of AAOS. The study was carried on patients with distal tibial fractures that are types 43 (B&C1, C2, C3) AO/OTA classification of distal tibial fractures. patients divided for two groups according to surgical technique: group (A):(30) patients managed with primary external fixator with screws. group (B):(30) patients Managed with staged ORIF.
Results: Group B showed a higher AAOS Foot and Ankle Normative score and AAOS foot and ankle core scale standardized mean and shoe comfort standardized mean and shoe comfort normative score and SF36 physical functioning% than Group A. Group A showed a less time interval from injury till fixation than Group B. From statistical point of view the two groups showed no significant difference regarding incidence of acquired complications.
Conclusion: The two-stage ORIF gained a reduced risk of postoperative complications related to superficial infections, and bone healing problems. The ORIF 2 stage has several advantages, such as the ability to handle soft tissues including the periosteum, tendons(PTT), and ligaments that may be contained within fragmented fracture.

Keywords: *Tibial pilon fracture; external fixator; fixator aided with screws; staged open fixation.*

Disclosure: *The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.*
Authorship: *All authors have a substantial contribution to the article.*

INTRODUCTION

Tibial plafond fractures are life-changing events that affect the patient's life. It keeps a unique place as an ideal opposing traumatic injury to each orthopedist. The main goals in treating such injuries are to reconstruct the articular surface that should be repaired conveniently and modulary, along with stable fixation that allows for an early range of motion to avoid stiffness. All these goals must be taken into account regarding the state of the soft tissues as it is the mostly affected injury site. The main intent is to avoid complications such as infection, wound dehiscence, and osteomyelitis that may lead to amputation, which is the frustrating end. [3] Fractures of the distal tibia due to either low-energy rotational injury or high-energy axial compression mechanisms. The higher energy mechanism is associated with further crushing and large soft tissue injury. Due to the axial injury mechanism, the exclusion of concomitant injuries is very important from the ipsilateral foot to the lumbar spine. Companionship between compartment syndrome and pilon is low (occurs in 0% to 5% of cases) in contrast to the more proximal tibial ones. [8]

Soft tissue management is the primary determinant of fracture healing and restoration of affected limb function. Of the skin delicate inspection of abrasions, open wounds and blisters should be performed on the association with a complete vascular evaluation of the affected limb. It is imperative to realize that many concurrent comorbidities can affect definitive treatment of open fractures as well as soft tissue injuries. Thus, having a history of the concurrent diseases of the patient (diabetes, and ischemic disorders, chronic venous insufficiency, and nutritional deficiencies, autoimmune connective tissue disorders), the use of nicotine (peripheral vascular disease) is of great value.[16,29]

It is interesting to note that some of the key factors purposefully lead to poor outcomes as published by Pollack et al. In his retrospective analysis of 103 patients who underwent surgical treatment for pilon fractures, they proposed that those who had two or more accompanying chronic diseases, married, annual compensation of less than $ 25,000, and had no high school diploma obtained unsatisfactory outcome. [29,28]

Ruedi & Allgower suggested [29] surgical tactics to help facing such injuries. They emphasized the importance of ideal restoration of fibular length with ideal reduction and fixation as it is considered the lateral column to help correct the distal tibial valgus deformity with subsequent anatomical restoration of articular surface with metaphyseal grafting associated with medial tibial buttressing to neutralize rotational forces and prevent varus angulation.. [24]

Careful planning for the usage of exhaustive investigations like CT is mandatory for best outcomes as it can provide a thorough picture of injury pattern that facilitates confronting the problem., Classically it is best to use it after interim stabilization to delineate the fragmentation pattern extension . [12]

Lateral column or fibular fixation remains a surgeon preference issue. Fibular length and rotation must be ideally retained with careful stabilization tactic as these injuries are more complicated than the other simpler malleolar patterns. [1]

The final tibial fixation method is multifactorial and predictable based on the experience of the surgeon, the extent of fragmentation, and the degree of soft tissue damage. Bearing in mind that each surgical procedure owns favors and disfavors, Pilon fractures can be permanently repaired with an external fixator of the Ilizarov type or hybrid ring, or minimally invasive tactic, or LCP, or a combination thereof. [1]

It is crucial to recognize that such injuries has evermore accompanied with perspicuous metaphyseal & articular fragmentation, extensive displacement, articular cartilage impaction, with articular debris are usually seen. Dual staged protocol involve interim external fixator construct that aids ideal ankle alignment with subsequent resolution of attacked soft tissues gathered with ideal restoration of ankle joint dimensions to facilitate final surgery. Angular distortions in either the sagittal or coronal direction must be corrected using external tibia construct, and early fixation of the fibula may help make this more predictable. Skin vitality with potential damage due to stress from displaced bony fragments should be considered and corrected to avoid future complications and skin necrosis. [14]

Eventual fixation of pilon fractures with external fixators has been described by several surgeons. Several authors described multiple studies using different types of external fixators, and many proposed the results to nearly identical to staged open fixation. [25] These methods have typically been associated with mini-invasive tactic to deal with joint surface. [25] Plafond fractures are evidently different from the more commonly noticed malleoli fractures caused by weaker influencing forces on the ankle. Health outcomes and quality of life are among the most important elements to consider in management for such injuries. [6]

PATIENTS AND METHODS

Patients selected from orthopedic casualty. Those who matched completely with inclusion criteria were included until fully gaining required sample size.

Patients selection was according to certain criteria:-

Pilon fractures are types 43 (B&C1, C2, C3) AO/OTA Classification of distal tibial fractures.
Primary surgery.
Age group was between18-60 years old.
Exclusion criteria:
Patients with two or more comorbidities (Malnutrition, Alcoholism, Diabetes, Neuropathy, , Peripheral Vascular Disease and Osteoporosis, long term steroid use)
Pathological fractures.
Mangled foot injury with transection of the posterior tibial nerve.
AO/OTA types 43 A (1,2,3) distal tibial fractures.
The patients ' ages ranged between 2^{nd} &6^{th} decades with an average age of 40.6 years , 11 ladies (18%) And 49 male patients (81.6%) included. 28 patients were enrolled with the right leg affected (46.6%) While the remaining 32 patients were left sided (53.3%). Relying on OTA , AO classification system (Figure 1) this study included one patient with 43B1 , And ten Patients with 43B2 , And four patients, type 43B3 And twenty-three patients of type 43C2. Finally, 22 patients were of type 43C3.

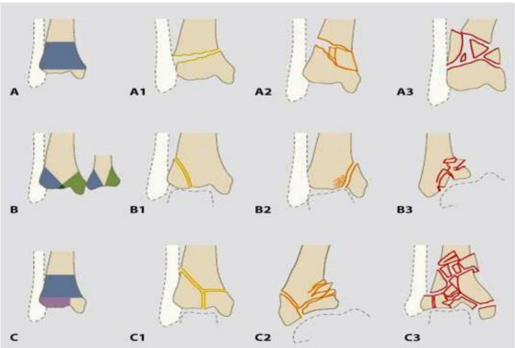

Fig 1: Simplified schematic representation of AO/OTA classification of distal tibial fractures where (A) is extra articular,(B)is partial articular injury and(C)is complete articular injury.

Methods:

Life support and general management of polytrauma patients(ATLS protocol).

Preoperative assessment: Patient evaluation, Radiographic Evaluation, and Planning and time of surgery.

Surgical technique.

Surgical steps: Reduction of the pilon fracture was either through open approach or closed techniques, starting usually with fixation of the lateral malleolus followed by tibial pilon. In some cases that fibular fracture is stable with no shortening or rotation fixation of fibula not done.

Reduction techniques:

Operative procedure using external fixator aided with screws maneuver:

Done closed mainly with percutaneously reducing the major articular parts , and fixation by supplementary internal fixation with either percutaneous screws Or wires under the image intensifier, or through open reduction and fixation with screws then we fixed the hinged block to the shaft and the metaphyseal area, then an external fixation framework is applied with the aim of preserving reduction. When an open reduction is required, we begin with the grinded portion to change the fracture into a more stable pattern (Figures. 2,3,4).

Fig 2: Preoperative, **a**: skin condition, **b**: preoperative x rays AP, **c**: lateral View**, d & e**, C.T. scan axial, **f**: C.T. scan sagittal.

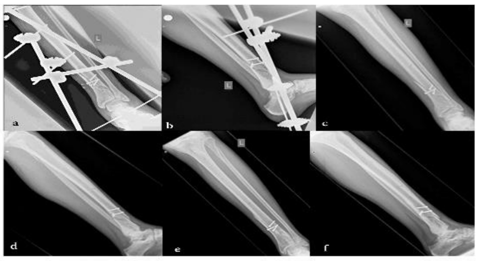

Fig 3: a & b: post operative with external fixator., AP view& lateral view, **c & d**: Postoperative after frame removal, **e & f**,: after full union AP view& lateral View

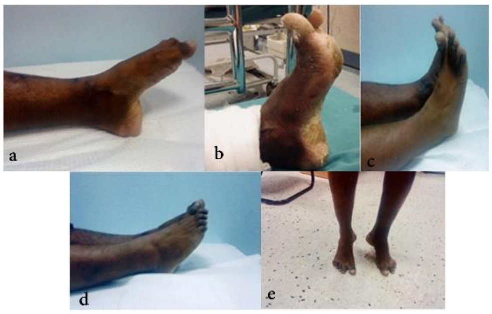

Fig 4: After complete union, range of ankle motion. **a**, Planter Flexion., **b**: Dorsiflexion, **c:** bilateral dorsiflexion, **d**: plantarflexion, and **e**: During standing, and walking.

Operative procedure using staged fixation maneuvers:

The long-term consequences of Pilon fractures are primarily influenced by the concomitant soft tissue conditions. Aid in the evolution of orthopedic concepts for damage control innovated the idea of maneuvers that aid in early care of a fracture without compromising severely injured soft tissues. These injured structures are allowed to heal while the patient prepares for another procedure that helps rebuild deformed fractured bones.

Timing of surgery:

The condition of affected soft tissues is the main factor in predicting the time of surgery, the presumed optimal surgical tactic. Injured limb initially is deformed, shortened and swollen due to formed hematoma. After 8-12 hours, interstitial edema is the main cause of swelling and is the most important factor in controlling successful wound healing. Poor outcome should be anticipated and so delicate careful inspection of marked soft tissue injury markers as skin and subcutaneous fat contusion with skin blisters and deep abrasions associated with pronounced oedema should be taken into consideration. Blisters filled with blood are a bad sign of complete detachment of the skin, which often indicates poor wound healing, so the skin should be avoided in this area by planning the incision. In some cases, the affected soft tissue area has a wide area of transmission that extends away from the fracture site. Moreover, ischemia develops in the affected area and becomes a maximum of 24 hours and usually develops within 3 to 6 days, so planning needs to be done. The surgeon crucially obliged to consider all these disturbing events to avoid disastrous results.

Surgical steps:

Initially, we start with the external fixator application for the first 24 hours as a damage control measure. We begin with the oscalcis pin insertion (half a pin is inserted when planning the medial delta frame) with the proximal pins closely inserted into the tibia with additional pin inserted into the1st. metatarsal to avoid equinus and finally to form the simplest shape of the delta frame gathered with correcting any sagittal, coronal or transitional distortions and then maintaining reduction by using an external stabilizer. Fibular fixation was performed in some cases but was delayed in most cases with final fixation (Figures 5,6)

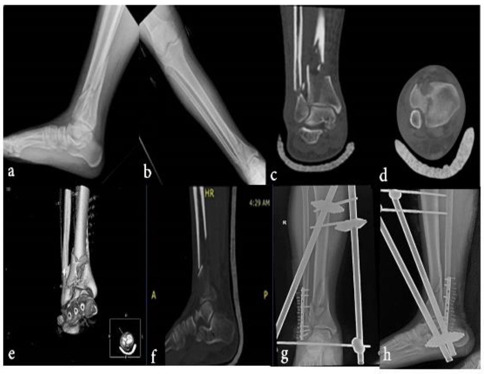

Fig 5: preoperative x rays, **a:** Lateral X-rays, **b**: X-rays AP , **c**: Coronal Computed tomography , **d**, axial , **e:** Three-dimensional, **f:** Sagittal computed tomography , **g & h**: immediate post fixation with external fixator.

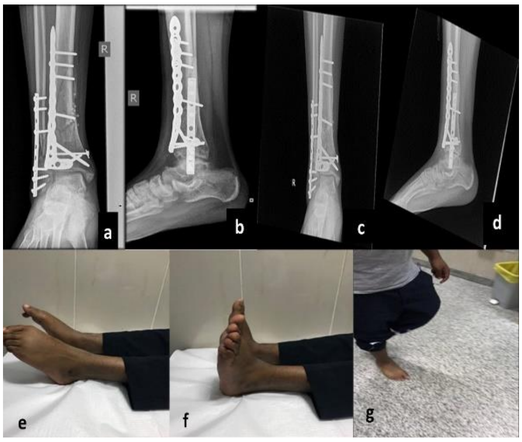

Fig 6: Early after ORIF, **a & b**: AP.& Lateral respectively . **c d**: completely healed fracture AP& LAT. Respectively. **e, f & g**: range of motion of ankle joint, Plantarflexion, Dorsiflexion , & walking respectively.

IV- Postoperative management and follow up.

Follow up using AAOS foot and ankle outcome questionnaire with added SF36 (figure 7) health survey**.** The American Academy of Orthopedic Surgeons (AAOS) foot and ankle questionnaire (12, 13) is a foot and ankle-related disability score (0-100). Higher scores indicate better foot function.

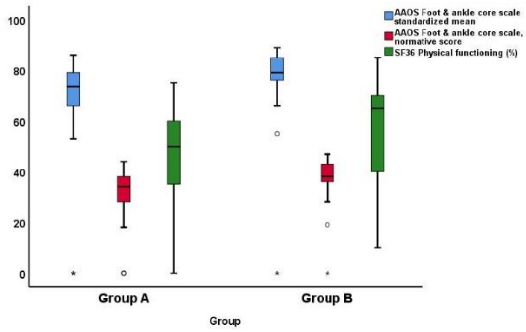

Fig 7: Box plot for Comparison between the two studied groups according to score.

RESULTS

In this study, we've got a study showed excellent results in every outcome measure. The current study compared the two study groups according to different variables,: There was a notable difference between the variables in the two groups. Group B showed a higher score than Group A. The AAOS questionnaire includes the Baseline Foot and Ankle Score (20 items) and the Footwear Comfort Scale (five items)[19,26]. This score is scored on a scale from 0-100 with a high score representing better results. The score for the AAOS foot and ankle was 76.13 ± 16.04 in group B and 67.57 ± 20.71 in group (A). There was a difference in the mean standard measurement of the AAOS foot and ankle score in the two groups. Group B showed the mean standardized foot and ankle score of AAOS higher than Group A. There was a notable difference in the Normative score of AAOS Foot and Ankle in the two groups. Group B showed the score higher than Group A. Group B showed a higher score regarding standardized mean and normative scores for shoe comfort than group A. Regarding the mean SF36% physical performance in the two groups. Group B showed a higher physical performance of SF36% than Group A.

In group A; 15 (50.0%) of cases had no complications. 15 (50.0%) of cases had complications: 2 (6.7%) of cases were Nonunuion. 4 (13.3%) of the cases were Malunion. 7 (23.3%) of the cases had a wound problem. 3 (10.0%) of the cases were profound infection. 10 (33.3%) of the cases had ankle joint osteoarthritis. 1 (3.3%) of the cases were CRPS. 4 (13.3%) of the cases was loss of reduction. 1 (3.3%) of the cases were tibiofibular fusion. In group B; 13 (43.3%) of cases had no complications. 17 (56.7%) of cases had complications: 3 (10.0%) of cases were Nonunion. 2 (6.7%) of the cases were Malunion. 3 (10.0%) of the cases had a wound problem. 4 (13.3%) of the cases were profoundly infected. 8 (26.7%) of the cases were ankle joint arthritis. 3 (10.0%) cases were CRPS.1 (3.3%) of cases was the loss of reduction. 1 (3.3%) of the cases were tibiotalar fusion, 1 (3.3%) of the cases were amputations and 1 (3.3%) of the cases were tibiofibular fusion(Figure 8). In this study, Group A showed a shorter period of time from exposure to fixation compared to Group B. No dissimilarity was noted in the average period of time until the Union in the two groups . There was no dissimilarity- between the two groups with regard to complications.

There is a negative relation between Age (years) and AAOS foot and ankle core scale standardized mean in group B. There is a negative correlation between Time interval from injury till fixation and AAOS foot and ankle core scale standardized mean in group B (Tables 1,2,3,4,5).

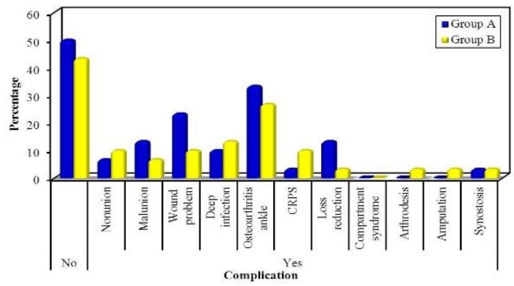

Fig 8: Comparison between the two studied groups according to complication.

AO classification	Group A (n = 30)		Group B (n = 30)		χ^2	^{MC}p
	No.	%	No.	%		
43B1	0	0.0	1	3.3	2.250	0.783
43B2	4	13.3	6	20.0		
43B3	2	6.7	2	6.7		
43C2	11	36.7	12	40.0		
43C3	13	43.3	9	30.0		

Table 1: Comparison between the two studied groups according to AO classification (χ^2: Chi-square test, MC: Monte Carl p: p-value for comparing between the studied groups).

Fibular fixation	Group A (n = 30)		Group B (n = 30)		χ^2	^{MC}p
	No.	%	No.	%		
Not fixed	0	0.0	5	16.7	52.531^*	$<0.001^*$
Not fractured	3	10.0	1	3.3		
Fixed early with 1st.maneuver	27	90.0	3	10.0		
Fixed Late with 2nd stage	0	0.0	21	70.0		

Table 2: Comparison between the two studied groups according to fibular fixation (χ^2: Chi-square test, MC: Monte Carl p: p-value for comparing between the studied groups).

	Group A (n = 30)	Group B (n = 30)	U	p
AAOS foot and ankle core scale standardized mean	67.57 ±20.71	76.13 ±16.04	281.50^*	0.012^*
AAOS F and A core normative score	30.83 ± 11.26	37.17 ± 9.19	265.50^*	0.006^*
Shoe comfort standardized score	38.87 ± 16.04	47.33 ±15.01	297.0^*	0.018^*
Shoe co normative score	36.67 ± 10.71	39.80 ± 8.83	315.0^*	0.038^*
SF36 physical functioning%	46.67 ± 19.53	59.17 ±21.22	282.0^*	0.012^*
SF36role limitation due to physical health%	12.50 ± 18.28	360.0±1821.0	347.50	0.092
SF36role limitation due to emotional problem%	48.89 ± 36.87	72.23 ± 58.77	342.0	0.100
SF36 energy fatigue%	52.0 ± 15.73	59.67 ± 16.71	424.0	0.695
SF36 emotional well-being%	60.88 ± 22.42	60.40 ± 17.84	412.0	0.573
SF36 social functioning%	48.10 ± 20.91	53.32 ± 20.72	415.0	0.600
SF36 pain%	53.03 ± 19.14	58.83 ± 12.31	372.0	0.241
SF36 general health%	310.8 ±1358.0	71.40 ± 12.56	374.50	0.261
SF36 health changes%	69.17 ± 29.86	77.50 ± 22.12	389.5	0.347
Time interval till union	19.14 ± 5.10	18.41 ± 5.55	317.0	0.151
Time interval from injury till fixation	1.73 ± 3.47	10.87 ± 5.35	28.0^*	$<0.001^*$

Table 3: Comparison between the two studied groups according to AAOS foot and ankle core scale standardized mean, AAOS Foot and Ankle core normative score, Shoe comfort standardized score, Shoe comfort normative score, SF36 physical functioning%, SF36role limitation due physical health%, SF36role limitation due emotional problem%, SF36 energy fatigue%, SF36 emotional well-being%, SF36 social functioning%, SF36 pain%, SF36 general health%, and SF36 health changes% (U: Mann Whitney test)

		AAOS foot and ankle core scale standardized mean	AAOS F and A core normative score	Shoe comfort standardized score	Shoe core normative score
Age (years)	r_s	0.093	0.069	-0.069	-0.069
	p	0.624	0.716	0.716	0.716
Time interval from injury till fixation	r_s	0.006	-0.021	-0.047	-0.047
	p	0.976	0.914	0.811	0.811
Time interval till union	r_s	-0.173	-0.200	-0.190	-0.190
	p	0.359	0.290	0.314	0.314

Table 4: Correlation between different parameters in group A (n= 30) (r_s: Spearman coefficient; *: Statistically significant at $p \leq 0.05$).

		AAOS foot and ankle core scale standardized mean	AAOS F and A core normative score	Shoe comfort standardized score	Shoe co normative score
Age (years)	r_s	-0.367	-0.392	-0.150	-0.104
	p	0.046*	0.032*	0.430	0.583
Time interval from injury till fixation	r_s	-0.502	-0.501	-0.242	-0.198
	p	0.006*	0.006*	0.206	0.303
Time interval till union	r_s	-0.230	-0.227	-0.096	-0.082
	p	0.222	0.227	0.613	0.668

Table 5: Correlation between different parameters in group B (n= 30) (r_s: Spearman coefficient; *: Statistically significant at $p \leq 0.05$).

DISCUSSION

The current study compared the two study groups according to different variables,: There was a notable difference between the variables in the two groups. Group B showed a higher score than Group A. The score results were significantly higher in group B compared to group A. Regarding SF36 Questionnaire, there was no significant difference between the two groups except for physical functioning which was higher in group B, (P value =0.012). The score for the AAOS foot and ankle was 76.13 ± 16.04 in group B and 67.57 ± 20.71 in group (A). Time needed till union showed no difference between the study groups, (P value =0.151)

The two-stage ORIF has several advantages, such as the ability to remove mollusk tissue, including the periosteum, torn muscles, ligaments & tendons included in the fracture portion. In addition, the use of ORIF permits visualization of the joint surface and achieves anatomical reconstructions. Therefore, a two-stage protocol was used including preservation of fibular length, initial external fixation of the leg and then delaying ORIF post soft tissue optimization. [9,18,23]

Regarding surgical strategies acquired deficits. In group A; 15 (50.0%) of cases had no complications. 15 (50.0%) of cases had complications:. In group B; 13 (43.3%) of cases had no complications. 17 (56.7%) of cases had complications.

In a retrospective study by Dickson et al. [9], they proposed that dual staging tactic allowed them to restore articular surface anatomically within 96% of study patients. Lavinia et al introduced another concept owed to their experience that keeping the fixator post ORIF permitted them to gain worthy outcome regarding soft tissue condition gathered with overall complication rate reduction. [17]

Controversies opposing delayed ORIF involved high incidence of hospital acquired infection associated with high propensity of articular mal reduction due to proposed fibrous union in addition to anticipated high financial burden. [11,22,24] These problems have prompted some surgeons to consider ORIF for Pilon fractures. White and colleagues adopted ORIF for management of 95 candidates with plafond injuries.[5,10]

Sirkin et al. [23] adopted the dual approach tactic with singular strategy that involved interim stabilization with outside fixator with initial fibular definitive stabilization followed by articular anatomical restoration and stabilization after soft tissue condition stabilization. They proposed that early ORIF is not recommended and has marked level of soft tissue compromise. Studies of Marsh et al. [13]Boone et al. [15] mentioned that outside fixator construct has consistently been associated with higher rates of device-pin tract infection, mal - union, non-union.

In this study, there was no statistical considerable issue in the meantime period until union in the two groups. Bacon and colleagues [2] compared the results of the two-stage method with the final external fixation. Conclusion indicates that the fracture union period was longer for the two-stage group (1.39 to 5.24 weeks), but bone healing complications and soft tissue infections were higher with fixator group.

However, no dissimilar differences were noted between the two groups. They were not able to outweigh the balance of either strategy on the other and advised further broader studies for more evaluation.

Blauth and colleagues [4] study was considerable as it included 51 candidates with nearly 4/5th of them were type C-AO-OTA system, although used tactics were questionable. They adopted 3 different surgical strategies one of them named staged fixation strategy which included 2 stages but with unique modification as they targeted the articular tibial surface within the first stage. Although they concluded the superiority of the dual stage maneuver due to high functional results but no statistical variations were noted among groups.

Danoff et al. [7] had a unique tactic to overcome miserable consequences of open plafond fractures. They adopted mainly the dual stage strategy with various modifications. Their main idea was to reconstruct the articular surface anatomically only after complete recovery of soft tissue through repetitive eradication of unhealthy damaged tissues or even performing a plastic surgery before optimum stabilization. Their study used the same AAOS score of our study with final anatomical reconstruction of articular fracture by screws with the advent of either plating or elizarof fixator to rebuild the linkage to metaphyseal portion. lastly they proposed that their approach had good final outcome although limitations of the study.

Wang et al. [30] were fans of the dual stage strategy through a comparative study of closed injury pattern to LIFEF. They proposed that smoking and fracture pattern had the highest impact on final outcome. They concluded that both tactics have similar results but staged technique had less radiation exposure ($P < 0.001$)and wound infection rate ($P < 0.05$)in contrast to LIFEF which had greater incidence of soft tissue infection and radiation exposure..

Scholes et al. [21] adopted the dual staged strategy to interpret with retrospective research design using a unique LCP Locking plating system . They proposed that dual stage strategy gained less local complications with good functional outcome.

Wang et al. [31]proceeded with the two stage open fixation protocol with the use of V.A.C system for all included cases which were all type C pilon fractures. They used the anteromedial approach with keeping the tibialis anterior tendon sheath intact as their surgical tactic. The AO FAS(American Orthopedic Foot and Ankle Society scale) supplemented with V.A.S. scale for pain were elected to fully assess the results. They reported excellent to good score for all patients (average 86.5 AO.FAS) with no detected postoperative complications (skin necrosis, nonunion, or fixation failure) with postoperative radiographs showed excellent treatment effects .With the visual analog scale pain scores were 0.7 ± 0.8, 0.9 ± 0.7, and 1.4 ± 1.0 during rest, active movement, and weight-bearing, respectively. Finally they recommended the effectiveness of the combined usage of the two staged system protocol with added V.A.C system in the treatment of Pilon fractures to help eliminate deep infection and get impressive results.

CONCLUSION

In conclusion, current evidence demonstrates that the two-stage ORIF operation is associated with a reduced hazard of postoperative difficulties related to superficial infection, reduced adhesion, and bone healing problems with better foot and ankle regained functional abilities. The two-stage ORIF has several advantages, such as the ability to handle soft tissues including the periosteum, tendons(PTT), and ligaments that may be contained within fragmented fracture

REFERENCES

1. Abdelgaid SM, Ahmed MA and Abdelmageed EG. Minimally Invasive Treatment Protocol for Closed Pilon Fractures. *Clin. Res. Foot Ankle*, 2013; 1(2): 108.
2. Bacon S, Smith WR, Morgan SJ, et al. A retrospective analysis of comminuted intra-articular fractures of the tibial plafond: open reduction and internal fixation versus external Ilizarov fixation. *Injury*, 2008; 39(2):196-202.
3. Barei DP. Pilon fractures. Rockwood and Green, Fractures in adult. *8th edition, Philadelphia, PA: Lippincott, Williams & Wilkins;* 2015: 1511.
4. Blauth M, Bastian L, Krettek C, et al. Surgical options for the treatment of severe tibial pilon fractures: a study of three techniques. *J Orthop Trauma*, 2001; 15(3):153-60.
5. Chen DW, Li B, Aubeeluck A, Yang YF, et al. Open reduction and internal fixation of posterior pilon fractures with buttress plate. *Acta Ortop Bras*., 2014; 22(1):48-53.
6. Craig SB, Jesse CH, Jonathan SH, et al. Fractures of tibial pilon. chapter 65, skeletal trauma. *basic science management and reconstruction*, browner et al 5th edition, 2015.
7. Danoff JR, Saifi C, Goodspeed DC, et al. Outcome of 28 open pilon fractures with injury severity-based fixation. *Eur J Orthop Surg Traumatol*., 2015; 25(3):569-75.
8. David W, Sanders MD, FRCSC Kenneth A, et al. Fractures of the Ankle and Tibial Plafond. *AAOS comprehensive orthopedic review*. 2014.
9. Dickson KF, Montgomery S and Field J. High energy plafond fractures treated by a spanning external fixator initially and followed by a second stage open reduction internal fixation of the articular surface-preliminary report. *Injury*, 2001; 32(4): 92-8.
10. Gao H, Zhang CQ, Luo CF, et al. Fractures of the distal tibia treated with polyaxial locking plating. *Clin Orthop Relat Res*., 2009; 467(3):831-7.
11. Hoiness P and Stromsoe K. The influence of the timing of surgery on soft tissue complications and hospital stay: a review of 84 closed ankle fractures. *Ann Chir Gynaecol*., 2000; 89(1): 6-9.

12. Ivan ST and Peter A. Cole, Tibial Pilon Fractures, *foot & ankle, core knowledge in Orthopedics.* 2007. https://journals.sagepub. com/ doi/abs/ 10.1177/1071100714552077
13. Marsh JL, Bonar S, Nepola JV, et al. Use of an articulated external fixator for fractures of the tibial plafond. *J Bone Joint Surg Am*. 1995; 77:1498-509.
14. Jacob N, Amin A, Giotakis N, et al. Management of high-energy tibial pilon fractures, Strat. Traum, Limb Recon., 2015; 10:137–47.
15. L Bone , P Stegemann, K McNamara, et al. External fixation of severely comminuted and open tibial pilon fractures. *Clin Orthop Relat Res*. 1993; 292:101-7.
16. Langdon A, Hartsock MD, FACS Peter H. et al. Distal Tibial Pilon Fractures, *Orthopedic Knowledge Update(OKU)*: Trauma 5, © American Academy of Orthopedic surgery 2016.
17. Lavini F, Dall'Oca C, Mezzari S, et al. Temporary bridging external fixation in distal tibial racture. Injury, 2014; 45(6):58-63.
18. Patterson MJ and Cole JD. Two-staged delayed open reduction and internal fixation of severe pilonfractures. *J Orthop Trauma*., 1999; 13(2): 85- 91.
19. Riskowski JL, Hagedorn TJ and Hannan MT. Measures of Foot Function, Foot Health, and Foot Pain. *Arthritis Care & Research*, 2011; 63(011):229–39.
20. Saithn A, Moody W, Jenkinson E, et al. The influence of timing of surgery on soft tissue complications in closed ankle fractures. Eur J Orthop Surg Traumatol., 2009; 19(7):481-4.
21. Schulz AP, Fuchs S, Simon L, et al. Severe Fracture of the Tibial Pilon: Results with a Multidirectional Self-locking Osteosynthesis Plate Utilizing a Two-stage Procedure. *Eur J Trauma Emerg Surg*. 2008 Aug;34(4):391-6.
22. Singh BI, Balaratnam S and Naidu V. Early versus delayed surgery for ankle fractures: a comparison of results. *Eur J Orthop Surg Traumatol*., 2005; 15(1):23-7.
23. Sirkin M, Sanders R, DiPasquale T, et al. A staged protocol for soft tissue management in the treatment of complex pilon fractures. *J Orthop Trauma*. 2004; 18(8):32-8.
24. Sitnik A and Beletsky A. Steven Schelkun Intra-articular fractures of the distal tibia, current concepts of management. *EFORT Open Rev*., 2017; 2(8):352-61.
25. Spiegel A, Mark JJ and Michael J. Gardner, Ankle and Pilon Fractures, chapter 23, *Orthopedic Knowledge Update(OKU)*: Foot and Ankle 5, American Academy of Orthopedic Surgeons, 2014; 464.
26. Suk M, Hanson BP, Norvell DC, et al. Musculoskeletal Outcomes Measures and Instruments, 2nd edn. Ann R Coll Surg Engl., 2011; 93(1): 89.
27. Tang X, Tang PF, Wang MY, et al. Pilon fractures: a new classification and therapeutic strategies. *Chin Med J (Engl).*, 2012; 125(14):2487- 92.
28. Tomás-Hernández J. High-energy pilon fractures management, state of the art. *EFORT Open Rev*.,2016 , 1(10): 354–61.
29. Topliss CJ, Jackson M and Atkins RM. Anatomy of pilon fractures of the distal tibia. *J Bone Joint Surg [Br]*., 2005; 87:692-7.
30. Wang C, Li Y, Huang L, et al. Comparison of two-staged ORIF and limited internal fixation with external fixator for closed tibial plafond fractures. *Arch Orthop Trauma Surg,* 2010; 130: 1289–97.
31. Wang Z, Qu W, Liu T, et al. A Two-Stage protocol with vacuum sealing drainage for the treatment of type c pilon fractures. *J Foot Ankle Surg*., 2016; 55(5):1117-20
32. White TO, Guy P, Cooke CJ, et al. The results of early primary open reduction and internal fixation for treatment of OTA 43.C-type tibial pilon fractures: a cohort study. *J Orthop Trauma,* 2010; 24(12):757-63.