Pilon Fracture; An Unsolved Riddle An Updated Review

Atul Dwivedi[1], Wu Xue Jian[2], Shweta Shukla Dwivedi[3], Neelam Rekha Dwivedi[4], Wu Han[5], Xiao Peng[6]

ABSTRACT

Introduction: Pilon fractures are complex and challenging as they are difficult to treat fractures of lower extremities because these are typically intra-articular and associated with extensive soft tissue damage. Treatment of these fractures has caused controversy among surgeons due to mixed outcomes.

Material and Methods: The present paper reviews and analyse comprehensive reports based on principles of management of tibial pilon fractures and the published clinical results of the established treatment options and further re-analyse the different complication rates and outcome percentage during different surgical treatment methods of Pilon fracture.

Results: Decision making depends on pattern of fractures, severity of local injuries, condition of soft tissues, patients profile, and surgeon's experience. Currently it is not clear that how much articular anatomy and perfection is required, because sometimes radiographic results doesn't match with clinical outcome.

Conclusion: No single method of fixation is ideal for all pilon fractures, or suitable for all patients. Definitive decision making is mostly dependent on the fracture pattern, condition of the soft-tissues, the patient's profile and surgical expertise.

Keywords: Pilon Fractures, Complications, Updated Review, Management

INTRODUCTION

Pilon fractures are amongst most serious fractures involving the ankle joint and persist to present a challenge to the orthopedic surgeon. They are often caused due to violent trauma and are allied with significant soft tissue damage, articular surface disruption and osseous comminution.[1]

The pilon fracture is a comminuted fracture of the distal tibia; the first recorded use of the word "pilon" in the orthopaedic literature was in 1911, by Étienne Destot, describing the anatomical region extending 5 cm from the joint line.[2]

Pilon is the French word for a pestle. Etienne Destot, a French Radiologist, is credited for using the term to describe the fracture in 1911. He compared the talus to a pestle. High-energy tibial 'pilon' fractures are due to axial loading with the talus driven into the distal tibia, exploding the distal tibial articular surface with impaction of the comminuted metaphyseal bone, and with occasional proximal diaphyseal extensions.[3]

In 1950 Bonnin, focusing on the involvement of tibiotalar articular cartilage, named these lesions as plafond fractures.[4]

Tibial fracture constitutes 7% of all tibial fractures and approximately 1% to 10% of lower limb fractures the majority of these fractures are due to high energy trauma after road traffic accident or falling from a height.[3] Despite achievements in vehicle construction safety, the proportion of foot and ankle injuries sustained by drivers in frontal crashes has not decreased over the past two decades. It appears that despite recent advancement of vehicle performance in crash tests, efforts to reduce axial forces sustained in lower extremity remain uninfluenced.[4,5] Not always is the injury obvious. In polytraumatised patients, it can be missed - in others underestimated.[6]

Management principles were originally outlined by Rüedi and Allgöwer and included reconstruction of the fibula as well as the articular surface of the tibia. The subsequent literature initially revealed high soft tissue complication rates when using these techniques and principles in high-energy injuries.[1]

Managing tibial pilon fracture has been a challenge for orthopedic surgeons. Various treatment options have been described but the results have not been impressive.

According to Ruedi and Allgower the operative principles are as follows;

- Restoration of fibula length
- Reconstruction of tibial joint articular surface
- Filling of the defect by bone grafting
- Final fixation by buttress plating.

In clinical practice, 2 incisions are commonly used for open reduction and internal fixation the lateral incision is used to fix the fibula fracture whereas the anteromedial incision is used to reconstruct and plate the distal tibia. A minimum 7cm separation 2 wounds is recommended to maintain skin bridge viability.

The fracture consists of a long oblique break extending medial to lateral, involving the dome of the distal tibial articular surface, and extending along the adjacent metaphysis. The fibula may or not be involved.[5] Pilon fractures can be partial (a part of the epiphysis is in continuity to the diaphysis) or complete. The partial can be divided into anterior: either simple (characterised by a single large articular fragment usually anterolateral, in this case the epiphysis is posteriorly connected to the diaphysis), or complex characterised by multiple articular fracture lines and posterior with usually only one large fragment. In complete articular fractures the Tillaux-Chaput tubercle is the only useful marker for the correct anatomical reduction of the fracture. This remains attached to the fibula through the syndesmosis. These fractures are often multi-fragmentary and there is the possibility of anterior, central or posterior subluxation. They

[1]Doctorate Student, Department of Orthopedics, The First Affiliated Hospital of Zhengzhou university, School of International Education [SIE], Zhengzhou University, Daxue Road - 450052, Henan, PR, China, [2]Professor, HOD and Director of Department of Orthopedics, The First Affiliated Hospital of Zhengzhou University, Henan, PR, China, [4]Professor ICMPD, Director of Standardized Patient and OSCE, XUSOM Oranjested Aruba, [5]Masters Student, 2013 Batch, Medical College of Zhengzhou University, [6]Senior Resident, The First Affiliated Hospital of Zhengzhou University, [3]Consultant Dental Surgeon, Jabalpur (MP) India

Corresponding author: Dr. Atul Dwivedi, Ram Nivas, House no. 151 A, Madhinath Road, Bareilly (UP), Pincode 243001

How to cite this article: Atul Dwivedi, Wu Xue Jian, Shweta Shukla Dwivedi, Neelam Rekha Dwivedi, Wu Han, Xiao Peng. Pilon fracture; an unsolved riddle an updated review. International Journal of Contemporary Medical Research 2017;4(3):718-725.

result from axial loading, when a combination of compression and shearing forces are produced in-between the talar dome and the distal tibial articular surface, often resulting into significant fragmentation and displacement. They are usually associated with massive swelling of the foot and ankle, as well as with open wounds, even skin defects.[7]

Distal tibial fractures involving the articular surface are fortunately rare injuries, accounting for approximately 7–10% of all tibial fractures, and less than 1% of fractures of the lower limbs. Nevertheless, their numbers are rising following the rise of the incidence of road traffic accidents, RTAs (45.5% of all pilon fractures are attributed to RTAs) and of high energy falls.[8] These mechanisms produce significant comminution with multiple displaced fracture fragments, accompanied by severe soft tissue closed or open trauma. In 85% of high energy tibial pilon fractures the fibula is fractured as well.[9]As expected, from the high energy absorption during these accidents the occurrence of associated skeletal or visceral trauma is probable, making the management of these cases more demanding. The population of these types of injuries is usually young adults with high demands and expectations for their recovery and final function. Low-energy pilon fractures are also increasing in numbers, proportionally to the aging of the world population and, of the increased level of activities of the elderly. Osteoporotic distal tibial fractures pose by themselves a challenging type of injuries. The soft tissue envelope in these cases may be inherently compromised due to comorbidities i.e. diabetes, vascular disorders, chronic intake of corticosteroids or other medication. In osteopenic bone achieving a stable osteosynthesis is difficult, healing process is slower and post-operative rehabilitation is prolonged. However, usually the bone fragments are fewer, occasionally with a spiral configuration, with relatively minimal displacement. The use of contemporary locking plating systems, minimal invasive reduction and when needed of a staged approach has been associated with fairly satisfying results.[10,11]

The treatment of pilon tibial fractures has evolved over the last century. A wide variety of treatment strategies, implants, and approaches have been utilised in order to manage this type of fractures with broad range of results.[12-16]

The aim of the present study was to review the existing evidence of the literature and comprehensively report on principles of management of tibial pilon fractures and the published clinical results of the established treatment options and further re-analyse the different complication rates and outcome percentage during different surgical treatment methods of Pilon fracture

MATERIAL AND METHODS

Data from the accumulated manuscripts were included mainly addressing the issue of principles / stages of management, methods of fixation, clinical outcome and complication rates. When possible, descriptive statistical means were used to comprehensively present the reviewed evidence. Data selection and data extraction process are mentioned in the flow diagram (figure-1).

The exclusion criteria included case reports, series of less than 10 cases, or referring to children (age<16years), editorials, letters, review studies and articles in languages other than English,

Pubmed, Medline, Embase and Springer were searched for

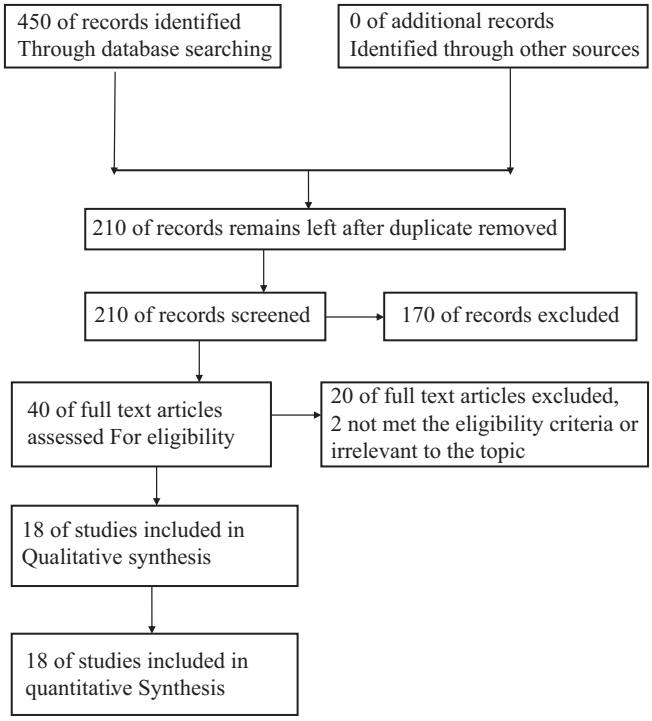

Figure-1:- Flow diagram of study selection and data extraction process

published series on Pilon fracture treatment using key words "distal tibial"or "Pilon"or "plafond"or,"ORIF", or" MIPPO" or" MIPO" or "External Fixation". We also performed a recursive search of the bibliography of articles on the topic to identify studies that were not found by searching of the above data bases. The publication language was restricted to English only. Two reviewers independently selected studies through reviewing the titles and abstracts that met the eligibility criteria and then screened the clinical reports according to our inclusion and exclusion criteria. Conflicts in opinions between investigators were resolved by consensus and consultation with the first author.

Figure 1 represents the flow diagram of study selection process. Data on the characteristic study, participants, type of surgical treatment technique or procedure were extracted in to a standardised form by 2 investigators independently. These datas were confirmed by 3 investigators. The following data items were documented; study characteristics:(primary author name), participants characteristics (no. of cases, type of surgical procedure, percentages of complication, wound dehiscence, malunion, infection rate (superficial, deep or pin site infection), arthrodesis, amputation, healing and good outcome and type of surgical method.

SPSS version 21 was used for statistical analysis. Descriptive statistics were used to interpret the results.

RESULTS

From a considerable number of initially retrieved abstracts (450), based on the inclusion/exclusion criteria described previously, we have concluded to the most cited and larger of these studies, which are summarised in chronological order (table-1,2,3).

Results in tables shows that no Method of treatment for Pilon fracture can be considered ideal because outcome and complication percentage are not making any universal

Volume 4 | Issue 3 | March 2017 | ICV (2015): 77.83 | ISSN (Online): 2393-915X; (Print): 2454-7379
International Journal of Contemporary Medical Research

Author	Treatment	No of cases	Complications%	Wound dehiscence	Malunion	Non union	infection	arthrodesis	amputation	healing	Good outcome
MC Ferran et al [18]	ORIF	52	54%	24%	6%	4%	17%	0%	0%	90%	NA
Teeny and wiss et al[19]	ORIF	60	NA	17% IN Type I-II 37% IN Type III	3%IN TypeI-II 23%IN Type III	7% IN typeI-II 27%IN type III	10% IN typeI-II 37% IN Type III	10% IN Type I-II 25% IN type III	NA	50%	25%
Wyrsch et al[20]	ORIF EXFIX	18 21	NA	33% 5%	2% 13%	NA	33% 5%	NA	16% 0%	NA	NA
Patterson etal and kapoor SK et al[21-23,24]	Medial internal osteosynthesis in 2 phases	139	2-10%	NA	2-5%	NA	NA	NA	NA	NA	NA
White TO et al[25]	Early medial internal osteosynthesis	95	6.3%	NA	NA	NA	NA	NA	NA	NA	NA
Bone et al[26]	Exfix	21	NA	NA	NA	14%	0%	9%	0%	100%	NA
Leonard M et al and kilianO et al[27,28]	Minimally invasive early medial internal osteosynthesis	51	0%	NA	3%	Na	NA	NA	NA	NA	83%
Sirkin et al[29]	2 steps procedure	56	NA	10%Skin necrosis 2 in open #	3%	6%	5% 2in open #	0%	NA	NA	NA
Patterson et al[30]	2steps procedure	22	NA	0%	4%	4%	0%	8%	NA	NA	NA
Mc Donaldet al[1,31]	Exfix	13	NA	NA	23%	8%	69%	8%	0%	52%	NA
Grose A et al[32]	Lateral internal osteosynthesis	44	5%	NA	9.5%	NA	NA	NA	NA	NA	NA
Papdokostakis et al[14]	Exfix	465	NA	NA	9%	5%	27% minor, 2%major infection	NA	NA	NA	NA
Kapoorsk et al and McCann PA et al[23,33]	External fixation bridging ankle with no epiphyseal osteosynthesis	37	0%	NA	NA	NA	NA	NA	NA	NA	NA
Anglen[34]	Hybrid Exfix Orif	29 19	2%	NA	NA	21%	21% pinsite 2% Arthritis	NA	NA	NA	52% 79%
Tornetta P etal and Salton HL et al[17]	Hybrid Exfix +minimal ORIF	26	NA	NA	4%	NA	4%superficial 4%deep	NA	NA	NA	81%
Blauth et al [35]	ORIF 2 Step procedure	15 8	NA	NA	NA	NA	NA	26% 0%	NA	NA 100%	NA 75%
Kim Hs etal, Endres T etal, kapoor Sk etal, BaconS etal and Gaudinez RF et al [23,36-38]	Hybrid ExFix with minimally invasive epiphyseal osteosynthesis	127	0-4%	NA	0-1%	NA	NA	NA	NA	NA	70-85%

Table-1: Clinical results by method

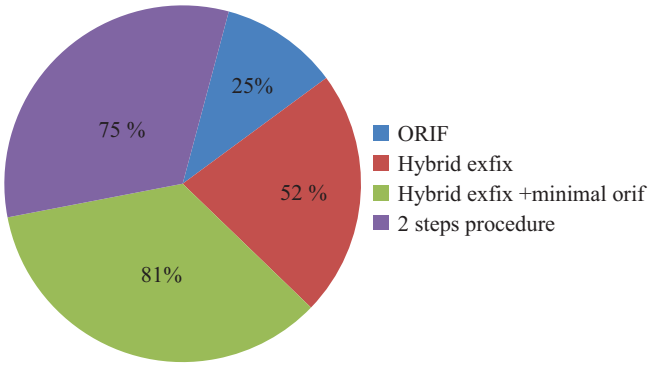

Figure-2: Pilon fracture treatment techniques vs good outcome (%)

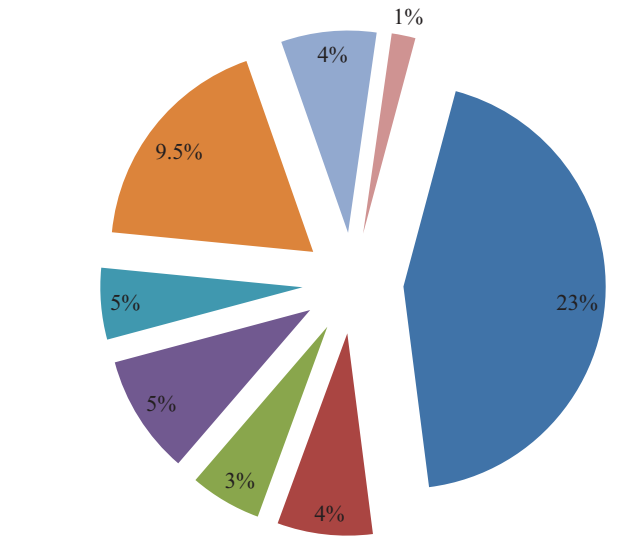

Figure-3: Pilon # RX techniques vs malunion

Name of author	Technique	No. of cases	Healing (%)
Mc Ferran et al[18]	ORIF	52	90
Teeny and Wiss et al[19]	ORIF	52	50
Bone et al[26]	Ex Fix	21	100
McDonald et al[31]	Ex Fix	13	52
Blauth et al[35]	2step procedure	8	100

Table-2: ExFix technique shows 100% and 52% healing in two different studies.and ORIF shows 90% and 50% healing in different studies, 2 step procedure also shows 100% healing

statement.Even the different reports about same procedure showing different outcome and complication percentage. On the other hand different authors reported different methods with different out come and complication percentage.

It may be because of experience of surgeons, patients general condition, type of Pilon fracture, type of injury, availability of treatment, type of implant used, choice of implant, the availability of expertise, condition of soft tissue, type of imaging techniques availability, and well trained team work, postoperative care and rehabilition methods and some hidden and Unknown factors.

Figure 2-5 and table 2,3 shows details of pilon fracture treatment techniques in relation to treatment outcome and various complications.

DISCUSSION

A comprehensive meta-analysis and comparison of the major

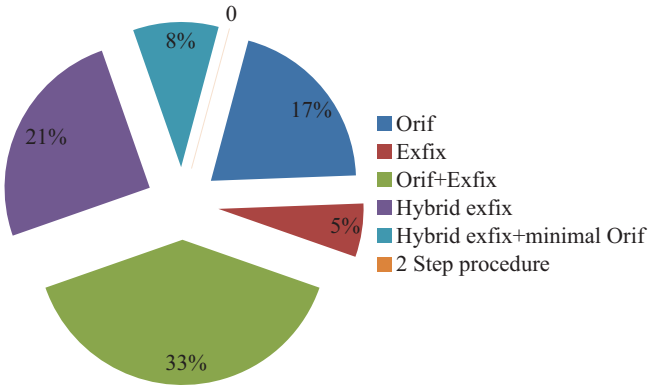

Figure-4: Pilon fracture treatment techniques vs percentage of infection

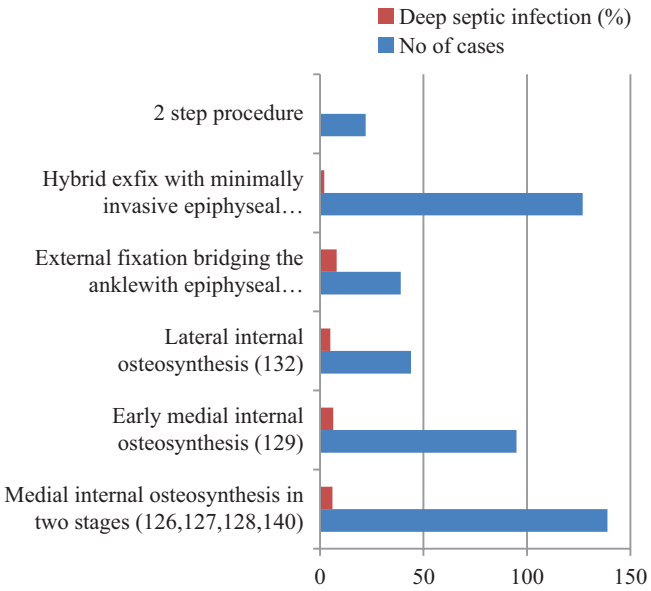

Figure-5: Number of cases and deep septic complication (%)

Treatment techniques	No. of cases	Deep septic complications (%)	Mean (%)
Medial internal osteosynthesis in two phases[21-24]	139	2-10	6
Early medial internal osteosynthesis[25]	95	6.3	Not applicable
Lateral internal osteosynthesis[32]	44	5	Not applicable
HybridExFix with minimally invasive epiphyseal Osteosynthesis[23,36-38]	127	0-4	2
2 step procedure (30)	22	0	NA

Table-3: 2 step procedure shows 0% deep septic complications

published series is difficult due to the lack of consensus in the classifications and evaluation methods.

In 1959 Jergesen asserted that open reduction and stabilisation of serious tibial pilon fractures was impossible.[39] So for years cast immobilisation has been the most popular method of treatment.[40] Conservative management gave way to surgical intervention when implants became available, but poor outcomes led to a return to cast immobilisation or limited internal fixation of the fibula only.[41] Nowadays, few authors still advocate for the nonoperative treatment, using casts/pin traction/plaster in selected, inoperable cases.[39]

Since the mid-60s the introduction of general guidelines for the treatment of fractures by the AO/ASIF,[42] for the first time structured the existing knowledge related to the management of distal tibial fractures along with the rest of the appendicular skeleton. The reconstruction of the articular congruity, the restoration of the length by internal fixation of the fibula the grafting of any bone loss at the metaphyseal site, the stability of the fixation of the metaphysis to the diaphysis and the allowance of early return to function were set as the pillars of a successful surgical intervention.[43-45]

Many authors following the pioneers of the AO/ASIF group, routinely practiced and published on the principles of anatomic reduction and rigid fixation with favourable results in up to 90% of the cases.[46-51]

Good outcomes were uniformly reported when these principles were used for low-energy injuries (Ruedi type I or II injuries).[46-52] In more severe injuries or in the presence of comorbidities and local pathologies a number of complications occurred and were gradually identified as major problems. According to McFerran et al,[18] 40% of these fractures resulted in relevant complications after ORIF treatment. Similarly, over a longer period of follow-up of 52 fractures the complication rate reached up to 54% of all cases. Teeny et al[19] identified wound dehiscence, infection, nonunion, malunion or implant failure in half of their 60 cases treated according to the AO principles for ORIF. The impact on the fracture healing process (delayed union/nonunion), wound breakdown, soft tissue and deep infections, algodystrophy, ankle joint stiffness, and poor functional outcomes were repeatedly reported by many clinicians.[48,52,53]

These complications were attributed to the iatrogenic trauma to the soft tissue envelope, the poor vascularity of the bone fragments following the osteosynthesis, and the prolongation of the surgical procedure.[54] The strict adherence to the meticulous reduction and rigid fixation of all bony fragments in high energy pilon fractures, through extensive surgical approaches, was gradually conceived as detrimental for the prognosis of the injured extremity,[52,53] making the clinician reluctant to the universal use of ORIF and to search for other alternatives (Table 1).

In order to combine the benefits of ORIF (direct visualisation and manipulation of fragments) with the advantages of external fixation (indirect reduction, soft tissue protection), a staged approach has been introduced[54,55] Table 1. Patterson et al[30] reported on 21 patients with 22 type C3 plafond fractures treated using a 2-steps approach, consisting of fibular plating and spanning external fixation followed by exchange of the external fixator to a definite internal fixation days later when the soft tissue allowed. Similarly, Sirkin et al[54] in a large series of 226 pilon fractures treated in two stages within 14 days reported an decreased incidence of deep infection at 3.4% (10.5% in the subgroup of open fractures), when compared to historical controls of single stage ORIF. treatment and the incidence of posttraumatic arthritis. The range of ankle movement, pain, return to pre-injury level of leisure and work activities were all better for the patients treated in 2 stages. Moreover, the infection rates were significantly lower in the 2-step procedures in comparison to the other groups (Table 3).

MIPO has proven its safety and efficacy as a management principle showing better results than standard ORIF.[55-58] In a comparative study with investigation arms, a staged approach with the use of MIPO as a definite fixation method was identified as superior to other concepts including ExFix and ORIF. There have been also contradicting reports raising concerns regarding the application of MIPO using modern locking plating systems.[35,46] They referred either to the specific plate design, the prolongation of the healing time when bridging techniques were used in simple fracture types, the medial approach, skin impingement and late wound infections, as well as its overall superiority.[56-59] Certain limitations as to the design of all these studies, selection bias, and differences to the methodology, timing of interventions, and surgical experience can easily be identified which restrict an all inclusive meta-analysis and the draw of robust conclusions.

Comparing some studies17,26,34,35 concerning tibial pilon fractures we observed a total success rate of 64% on 156 fractures submitted to RIF, in particular differentiating type I, II and III. We estimated a 81% rate of successful treatment in 55 fractures treated with hybrid fixation whereas; a 2-step procedure pointed out 92% of good outcomes in 86 cases. The use of external fixation led to successful healing of 330 out of 416 fractures.

It is also observed that the incidence of post-traumatic arthrodesis for osteoarthritis, nonunion and infection is reduced in the 2-steps approach vs ORIF technique. As reported by Pollak et al[60] at more than three years after the injury, pilon fractures can have persistent and devastating consequences on patients' health and well-being. Limitation of range of motion was higher in the subgroup treated with external fixation than in the other cases (27% vs 12%). According to these authors the outcome varied depending on:

1. The severity of bone and soft tissues injury
2. Delay from injury to presentation, especially in open fractures
3. 'Patients' general condition and compliance
4. Other associated injuries
5. Surgeon's experience

Moreover, the cartilage damage caused at the time of the injury often determines the bad outcome despite the often anatomic radiographic joint reconstruction. The implication of severe complications as the compartment syndrome especially if diagnosed with delay, the deep infection, and nonunion that requires secondary procedures and prolongs the immobilisation period increases further number of cases with poor outcome.[19,58] Satisfactory long-term outcomes are expected in approximately 70% of high energy fractures. Good to-excellent results have been reported in nearly 80% of low energy fractures. Results for secondary ankle arthrodesis after attempted ORIF of type

3 fractures approaches 30%. Ankle fusions may be required in approximately 3–27% of post-traumatic arthritis. Ankle replacement can be an option in selected individuals.[61]

In summary we believe that Ru¨ edi type I and II fractures, (with no soft tissue damage), allow the application of a minimal invasive internal fixation at the first 12–24 h, aiming for anatomic reduction and early function of the ankle joint.[62,63]

Ru¨ edi type III, or Tscherne type 3, or open fractures dictate a 2- step approach: temporary bridging external fixation, later substituted by an internal biological osteosynthesis or by a definitive external fixation using mostly a circular frame spanning or not the ankle joint.

The choice of implant should be based on the states of the soft tissues and the surgeon's preference. Early involvement of the plastic surgeons is often mandatory to allow optimisation of the soft tissue envelope. Non-operative management and casting still has a role and can be utilised in patients who have low demands or severe comorbidities and have minimal displacement of the fragments.[64]

The presented review and analysis clearly had limitations because of its modest sample size. The intrinsic weakness of this study is lack of powerful data and heterogeneity of the data to reveal the outcome of Pilon fracture treatment through different techniques, so we could not thoroughly compare all the studies with each other. Some other limitations might exist in this study. Last but not the least language is restricted to English for included studies, thus studies reported in other languages may be missed.

The questions remained unanswered;

1. The role of arthroscopy in the treatment of Pilon fracture?
2. The factors playing a key role in the management of Pilon fracture with satisfactory results?
3. Appropriate choices of implant for different kinds of Pilon fracture?
4. A definitive guideline for the treatment of same type of Pilon fractures?
5. What sort of new interventions needed to solve the problem of post traumatic arthritis.
6. Up till how much extent the joint reduction and fixation should be done so that radiological outcomes can be matched with clinical outcomes

We need a further research for these unsolved question.

CONCLUSION

Surgeons should handle and treat the soft tissue injury with a meticulous care to each case. Early surgery is contraindicated in case of soft tissue injury. Role of a plastic surgeon is mandatory to solve the problem of soft tissue injury in these case. Temporary reduction and stabilization are required in the immediate stage after injury. Exact joint reduction is essential but it does not guarantee that the joint will not develop post traumatic arthritis. Osteosynthesis of the fibula should be recommended. Tibiofibular syndesmosis injuries should be stabilized with specific osteosynthesis of the anterolateral tubercle or using syndesmosis.[65]

The choice of implant is also essential for the treatment techniques. No method of treatment has shown clear superiority regarding rates of nonunion, malunion, delayed union, bone healing, deep and superficial infection, arthritis symptoms or chronic osteomyelitis, therefore we can conclude (as Sirkin and Sanders[16] proposed) that surgeons should treat these complex fractures with the method with which they are most comfortable. Surgeons who feel comfortable with techniques of internal fixation are best qualified to perform open reductions, while surgeons who have experience with percutaneous fixation and hybrid external fixator application should use this method.

ABBREVIATION

AO - Arbeitsgemeinschaft furosteosynthesefragen, OTA-Orthopedic Trauma Association, MIPO- Minimally Invasive Percutaneous Osteosynthesis, MIPPO-Minimally Invasive Percutaneous Plating Osteosynthesis, MILPO- Minimally Invasive Locking Plate Osteosythesis, ExFix-External Fixation, CRIF-Closed Reduction and Internal Fixation, ITFG-Intertibiofibular Grafting, NA- Not Available, ORIF-Open Reduction Internal Fixation

REFERENCES

1. He X, Hu Y, Ye P, Huang L, Zhang F, Ruan Y. The operative treatment of complex pilon fractures: A strategy of soft tissue control. Indian J Orthop. 2013;47:487-92.
2. Jacob N, Amin A, Giotakis N, Narayan B, Nayagam S, Trompeter AJ. Management of high-energy tibial pilon fractures. Strategies in Trauma and Limb Reconstruction. 2015;10:137-147.
3. Destot EAJ. Traumatismes du Pied et Rayons X: Malleoles, Astragale, Calcaneum, avant-Pied. Paris, Ed. Masson. 1911:1–10.
4. Bonnin JG. Injuries to the ankle. 1950; William Heinemann Med Books L113. Sirkin M., and Sanders R.: The treatment of pilon fractures. Orthop Clin North Am. 2001;32:91-102.
5. Michelson J., Moskovitz P., and Labropoulos P. The omenclature for intra-articular vertical impact fractures of the tibial plafond: pilon versus pylon. Foot Ankle Int. 2004; 25:149-150.
6. Ekkehard Pietsch. Brake Pedal Injuries to the Foot: Not Always Too Obvious. EC Orthopaedics. 2016;3.5:396-398.
7. Rommens P.M., Claes P., and Broos P.L. Therapeutic strategy in pilon fractures type C2 and C3: soft tissue damage changes treatment protocol. Acta Chir Belg. 1996; 96:85-92.
8. Bourne R.B. Pylon fractures of the distal tibia. Clin Orthop Relat Res 1989; undefined: pp. 42-46.
9. Borrelli J., and Ellis E. Pilon fractures: assessment and treatment. Orthop Clin North Am. 2002;33: pp. 231-245.
10. Borens O., Kloen P., Richmond J., et al. Minimally invasive treatment of pilon fractures with a low profile plate: preliminary results in 17 cases. Arch Orthop Trauma Surg. 2009;129:649-659.
11. Bocchi L., Maniscalco P., Bertone C., et al. Fractures of the tibial plafond: a comparison of treatment methods. J Orthopaed Traumatol. 2000;1:51-56.
12. Vijay Baba N, Balaji Arumugam. Interlocked intramedullary nailing in the managenment of closed diaphyseal fractures of tibia- a prospective analysis. International Journal of Contemporary Medical Research. 2016;3:1987-1991.
13. Koulouvaris P., Stafylas K., Mitsionis G., et al. Long-term results of various therapy concepts in severe pilon fractures. Arch Orthop Trauma Surg. 2007;127:313-320.
14. Papadokostakis G., Kontakis G., Giannoudis P., and Hadjipavlou A. External fixation devices in the treatment of fractures of the tibial plafond: a systematic review of the

literature. J Bone Joint Surg Br. 2008;90:1-6.
15. Sands A., Grujic L., Byck D.C., et al. Clinical and functional outcomes of internal fixation of displaced pilon fractures. Clin Orthop Relat Res 1998; undefined: pp. 131-137
16. Sirkin M., and Sanders R. The treatment of pilon fractures. Orthop Clin North Am. 2001;32:91-102.
17. Tornetta P., Weiner L., Bergman M., et al. Pilon fractures: treatment with combined internal and external fixation. J Orthop Trauma.1993;7:489-496.
18. McFerran M.A., Smith S.W., Boulas H.J., and Schwartz H.S. Complications encountered in the treatment of pilon fractures. J Orthop Trauma. 1992;6:195-200.
19. Teeny S.M., and Wiss D.A. Open reduction and internal fixation of tibial plafond fractures. Variables contributing to poor results and complications. Clin Orthop Relat Res 1993; undefined: pp. 108-117.
20. Wyrsch B., McFerran M.A., McAndrew M., et al. Operative treatment of fractures of the tibial plafond. A randomized, prospective study. J Bone Joint Surg Am. 1996;78:1646-1657.
21. M. Sirkin, R. Sanders, T. DiPasquale, D. Herscovici Jr. A staged protocol for soft tissue management in the treatment of complex pilon fracturesJ Orthop Trauma. 2004;18: S32–S38.
22. A. Kapukaya, M. Subasi, H. Arslan Management of comminuted closed tibial plafond fractures using circular external fixators Acta Orthop Belg. 2005;71:582–589.
23. S.K. Kapoor, H. Kataria, S.R. Patra, T. Boruah Capsuloligamentotaxis and definitive fixation by an ankle-spanning Ilizarov fixator in high-energy pilon fractures J Bone Joint Surg Br. 2010:92;1100–1106.
24. M.J. Patterson, J.D. Cole, Two-staged delayed open reduction and internal fixation of severe pilon fractures,J Orthop Trauma. 1999;13:85–91.
25. T.O. White, P. Guy, C.J. Cooke, S.A. Kennedy, K.P. Droll, P.A. Blachut, et al.The results of early primary open reduction and internal fixation for treatment of OTA 43.C-type tibial pilon fractures J Orthop Trauma. 2010;24:757–763.
26. Bone L., Stegemann P., McNamara K., and Seibel R. External fixation of severely comminuted and open tibial pilon fractures. Clin Orthop Relat Res. 1993; undefined: pp. 101-107.
27. M. Leonard, P. Magill, G. Khayyat Minimally invasive treatment of high velocity intra-articular fractures of the distal tibia Int Orthop. 2009;33:1149–1153.
28. Kilian, O. Bundner, M.S. Horas U, Heiss, C. Schnettler R. Long-term results in the surgical treatment of pilon tibial fractures Chirurg. 2002;73:65–72.
29. Sirkin M., Sanders R., DiPasquale T., and Herscovici D. A staged protocol for soft tissue management in the treatment of complex pilon fractures. J Orthop Trauma. 2004;18: S32-S38.
30. Patterson M.J., and Cole J.D. Two-staged delayed open reduction and internal fixation of severe pilon fractures. J Orthop Trauma. 1999;13:85-91.
31. McDonald M.G., Burgess R.C., Bolano L.E., and Nicholls P.J. Ilizarov treatment of pilon fractures. Clin Orthop Relat Res 1996; undefined: pp. 232-238.
32. A. Grose, M.J. Gardner, C. Hettrich, F. Fishman, D.G. Lorich, D.E. Asprinio, et al. Open reduction and internal fixation of tibial pilon fractures using a lateral approach J Orthop Trauma. 2007;21:530–537.
33. P.A. McCann, M. Jackson, S.T. Mitchell, R.M. Atkins Complications of definitive open reduction and internal fixation of pilon fractures of the distal tibia Int Orthop. 2011;35:413–418.
34. Anglen J.O. Early outcome of hybrid external fixation for fracture of the distal tibia. J Orthop Trauma. 1999;13:92-97.
35. 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;15:153-160.
36. H.S. Kim, J.S. Jahng, S.S. Kim, C.H. Chun, H.J. Han Treatment of tibial pilon fractures using ring fixators and arthroscopy Clin Orthop Relat Res. 1997;334:244–25.
37. S. Bacon, W.R. Smith, S.J. Morgan, E. Hasenboehler, G. Philips, A. Williams, 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;39:196–202.
38. R.F. Gaudinez, A.R. Malik, M. Szporn Hybrid external fixation in tibial plafond fractures,Clin Orthop Relat Res, 1996;329:223–232.
39. Jergesen F. Open reduction of fractures and dislocations of the ankle. Am J Surg. 1959;98:136-151.
40. Ovadia D.N., and Beals R.K. Fractures of the tibial plafond. J Bone Joint Surg Am. 1986;68:543-551.
41. Hermans JJ,Beumer A,de Jong TA, Kleinrensink GJ.Anatomy of the distal tibiofibular syndesmosis in adults: a pictorial essay with a multi modality approach. JAnat. 2010;217:633-45.
42. Rüedi T.P., Buckley R.E., and Moran C.G. AO principles of fracture management. AO, 2007.
43. P.A. McCann, M. Jackson, S.T. Mitchell, R.M. Atkins Complications of definitive open reduction and internal fixation of pilon fractures of the distal tibia Int Orthop. 2011;35:413–418.
44. Ruedi T. Intraarticular fractures of distal tibia: results after 9 years. Arch Orthop Unfallchir. 1973;76: 248-254.
45. Rüedi T.P., and Allgöwer M. Fractures of the lower end of the tibia into the ankle joint. Injury. 1969;1:92-99.
46. Ayeni J.P. Pilon fractures of the tibia: a study based on 19 cases. Injury. 1988;19:109-114.
47. Bone L.B. Fractures of the tibial plafond. The pilon fracture. Orthop Clin North Am. 1987;18:95-104.
48. Bourne R.B., Rorabeck C.H., and Macnab J. Intra-articular fractures of the distal tibia: the pilon fracture. J Trauma. 1983;23:591-596.
49. Brennan M.J. Tibial pilon fractures. Instr Course Lect. 1990;39:167-170.
50. Cox F.J., and Laxson W.W. Fractures about the ankle joint. Am J Surg. 1952;83:674-679.
51. Heim U. Role of the fibula in distal tibial fracture. Z Unfallchir Versicherungsmed. 1990;83:187-195.
52. Kellam J.F., and Waddell J.P. Fractures of the distal tibial metaphysis with intra-articular extension – the distal tibial explosion fracture. J Trauma. 1979;19:593-601.
53. Brumback R.J., and McGarvey W.C. Fractures of the tibial plafond. Evolving treatment concepts for the pilon fracture. Orthop Clin North Am. 1995;26: 273-285.
54. Sirkin M., Sanders R., DiPasquale T., and Herscovici D. A staged protocol for soft tissue management in the treatment of complex pilon fractures. J Orthop Trauma. 1999;13:78-84.
55. Bahrain S,Lenehan B,Khan H, McElwainJP,.Minimally invasive percutaneous plate plate fixation of distal tibial fractures.Acta Orthop Belg. 2007;73:635-40.

56. Gupta R.K., Rohilla R.K., Sangwan K., et al. Locking plate fixation in distal metaphyseal tibial fractures: series of 79 patients. Int Orthop 2009.
57. Hasenboehler E., Rikli D., and Babst R. Locking compression plate with minimally invasive plate osteosynthesis in diaphyseal and distal tibial fracture: a retrospective study of 32 patients. Injury. 2007;38:365-370.
58. Lau T.W., Leung F., Chan C.F., and Chow S.P. Wound complication of minimally invasive plate osteosynthesis in distal tibia fractures. Int Orthop. 2008;32:697-703.
59. Cheng W., Li Y., and Manyi W. Comparison study of two surgical options for distal tibia fracture-minimally invasive plate osteosynthesis vs. open reduction and internal fixation. Int Orthop 2010.
60. Pollak A.N., McCarthy M.L., Bess R.S., et al. Outcomes after treatment of high-energy tibial plafond fractures. J Bone Joint Surg Am. 2003;85-A:1893-1900.
61. DeOrio J.K., and Ware A.W. Salvage technique for treatment of periplafond tibial fractures: the modified fibula-pro-tibia procedure. Foot Ankle Int 2003;24:228-232.
62. Kralinger F., Lutz M., Wambacher M., et al. Arthroscopically assisted reconstruction and percutaneous screw fixation of a pilon tibial fracture. Arthroscopy. 2003;19:E45.
63. Nehme A., Tannous Z., Wehbe J., et al. Arthroscopically assisted reconstruction and percutaneous screw fixation of a pilon tibial malunion. J Foot Ankle Surg. 2007;46:502-507.
64. Blotter R.H., Connolly E., Wasan A., and Chapman M.W. Acute complications in the operative treatment of isolated ankle fractures in patients with diabetes mellitus. Foot Ankle Int. 1999;20:687-694.
65. F.Dujardin,H.Abdulmutalib,A.C.Tobenas /orthopedics and Traumatology:Surgery and Research. 2014;100:S65-S74.

Source of Support: Nil; **Conflict of Interest:** None

Submitted: 02-03-2017; **Accepted:** 26-03-2017; **Published:** 07-04-2017