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Systematic Review

Treatment of choice for bicondylar tibial plateau fractures between open reduction with internal fixation versus hybrid circular external fixator: a systematic review

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ABSTRACT

The high complication rate is closely related to the incidence of bicondylar tibial plateau fractures (BTPF) due to the involvement of the articular surface. The aim of this study is to compare open reduction with internal fixation (ORIF) and hybrid circular external fixation (HCEF) as the choice of surgical procedure for BTPF because these two procedures is still controversial until now. A systematic review using Cochrane library, PubMed, and Google Scholar was conducted based on PRISMA guideline. Inclusion criteria were studies comparing HCEF and ORIF of BTPF. Studies of only one surgical technique modality, schatzker types I-IV tibial plateau fractures, and case reports were excluded, resulting in six included studies. There is no significant difference in radiographs, functional and anatomical outcomes in both group (ORIF vs HCEF). Complications that measured are higher infection rate found in the ORIF group. Blood loss was higher in the ORIF group, while both procedures have similar operation time and functional outcome. The mean of hospital length of stay (LoS) seems to be higher 6.83 days (95%CI 0.96-12.70; P<0.00001) on ORIF group from the random effect of forest plot evaluation. According to this study, HCEF is more beneficial in terms of blood loss and hospital LoS. But overall ORIF and HCEF carry similar operation time, functional outcome, union rate, and complication.

Keywords: Open reduction internal fixation, Hybrid circular external fixation, Bicondylar tibial plateau fracture

INTRODUCTION

Tibial plateau fractures accounted for 1 to 2% of all the fractures, approximately 8% of them occurred in elderly and over half of the cases were male. One type of tibial plateau fracture is bicondylar tibial plateau (Schatzker type VI) fractures which are rare and comprising 20% of tibial plateau fractures.[1] Tibial plateau fractures are usually resulting from high-energy trauma, with associated soft-tissue damage. This kind of fracture involving the articular surface is difficult to treat. The pattern of injury depends on the magnitude of force through the proximal tibia, the bone quality, and the age of the patient. They constitute high-energy injuries with associated insult on the soft tissue envelope.[2] Due to the complex anatomy of the tibial plateau, intra-articular lesions, severe soft tissue damage, osseous compromise of the proximal tibia and high risk of complications.[2,3] All kinds of treatment, from conservative treatment to surgical management, were aimed at anatomic reduction of the articular surface, restore of tibial length and alignment and prevent secondary displacement of the fracture fragments.[1,2]

In the current medical literature, there is no consensus about the best approach to treat these fractures. The standard treatment for these fractures has been open reduction and internal fixation using the extensile anterior approach. The anterior approach enables visualisation of the fracture fragments for anatomical reconstruction of the joint surfaces. However, this exposure requires extensive soft-tissue dissection, which may devascularize the fracture fragments and lead to wound breakdown and infection. With the advent of periarticular locking plates, there is the possibility of obtaining secure fixation and good functional outcomes, which combined with more minimally invasive techniques, results in sparing the soft tissues from further trauma. However, as complex tibial plateau fractures associated with severe soft tissue damage, ORIF often led to a higher rate of complications over the past two decades. Despite the evolution of treatment strategies and the quality of fixation implants, a poor outcome reported continuously.[1,4]

Young and Barrack in Bove et al reported infection in seven of eight patients with bicondylar tibial plateau fractures treated with medial and lateral buttress plates through an anterior incision, with two patients requiring amputation. A study by Moore et al. in Bove et al reported deep infection in eight of eleven patients, and Mallik et al in Bove et al also found infection complicated four of five such injuries.[5] As the bad effect of excessive dissection of the tenuous soft-tissue envelope and devascularisation of the osseous fragments became apparent, several alternative methods of treatment have been popularised such as hybrid circular external fixation (HCEF), have been developed and have obtained excellent results. HCEF is applied by closed reduction, the stabilisation of smaller bone fragments with percutaneous screws and fixation with traction, using ligamentotaxis principle.[6,7]

HCEF represents a valid alternative method because of its easy application and minimal surgical exposure. It may also allow early weight-bearing and shorter hospital stay with its attendant benefits. Problems with these techniques include the inconvenience of an external apparatus that requires careful maintenance, the possibility of pin tract infection and subsequent collapse with lack of reduction of the fragments. But this technique also has problems such as the inconvenience of external apparatus that requires careful maintenance, the possibility of pin tract infection and collapse with lack reduction of the fragments.[1,4,6] Both of those methods, ORIF and HCEF are the most common surgical methods. Only a few studies compare the effectiveness of those two methods, which it is essential to know both the advantage and disadvantage of those methods so we can choose wisely the best option for treat BTPF. This systematic review will elaborate both methods and aim of this study was to compare the results of bicondylar tibial plateau fractures (BTPF) treated by ORIF versus HCEF in term of clinical and functional outcomes such as operation time, functional outcome, union rate, complication and length of hospital stay.

METHODS

Study eligibility

We included study with some eligibility criteria; they are an original article written in English, comparing between ORIF and HCEF treatment for bicondylar tibial plateau fracture. The inclusion criteria of the studies are: (i) studies on the bicondylar tibial plateau or complex tibial plateau, (ii) studies directly compare the effectiveness of two methods they are ORIF and HCEF, (iii) do the post-operative follow up and (iv) measuring outcomes such as complications. Studies excluded if they employed only one surgical technique modality, Schatzker types I-IV Tibial Plateau Fractures, and case reports.

Search strategy

We conducted a comprehensive search for online literature or studies from 2009 until 2019. We explored evidence using the following database Cochrane Library, PubMed, and Google Scholar. The keywords used to obtain the relevant study include “ORIF” AND “hybrid external fixator” AND “tibial plateau fracture”. We used a Boolean operator to specify the finding result further. We also search for evidence that listed in article references and chooses study which met eligibility criteria.

Study selection

Working independently, one reviewer screened all related articles for inclusion based on topic, study design, comparison group, and language used in the full text. We reviewed the abstract first and then the full version. Finally, the selected literature assessed for their evidence before being included in the final review (Figure 1).

Data collection

Literature that was identified then merged and managed for further analysis. All of the selected literature was thoroughly read and apprehended to extract the principle of the literature.

Data synthesis

All relevant studies regarding ORIF and HCEF as a treatment for BTPF included in a narrative synthesis. As a qualitative report, this systematic review and meta-analysis tried to figure out compare two treatments, ORIF and HCEF as the choice of surgical procedure for BTPF that still controversial until now. The narrative synthesis was conducted systematically to gain a conclusion of which technique is better as a treatment for BTPF.

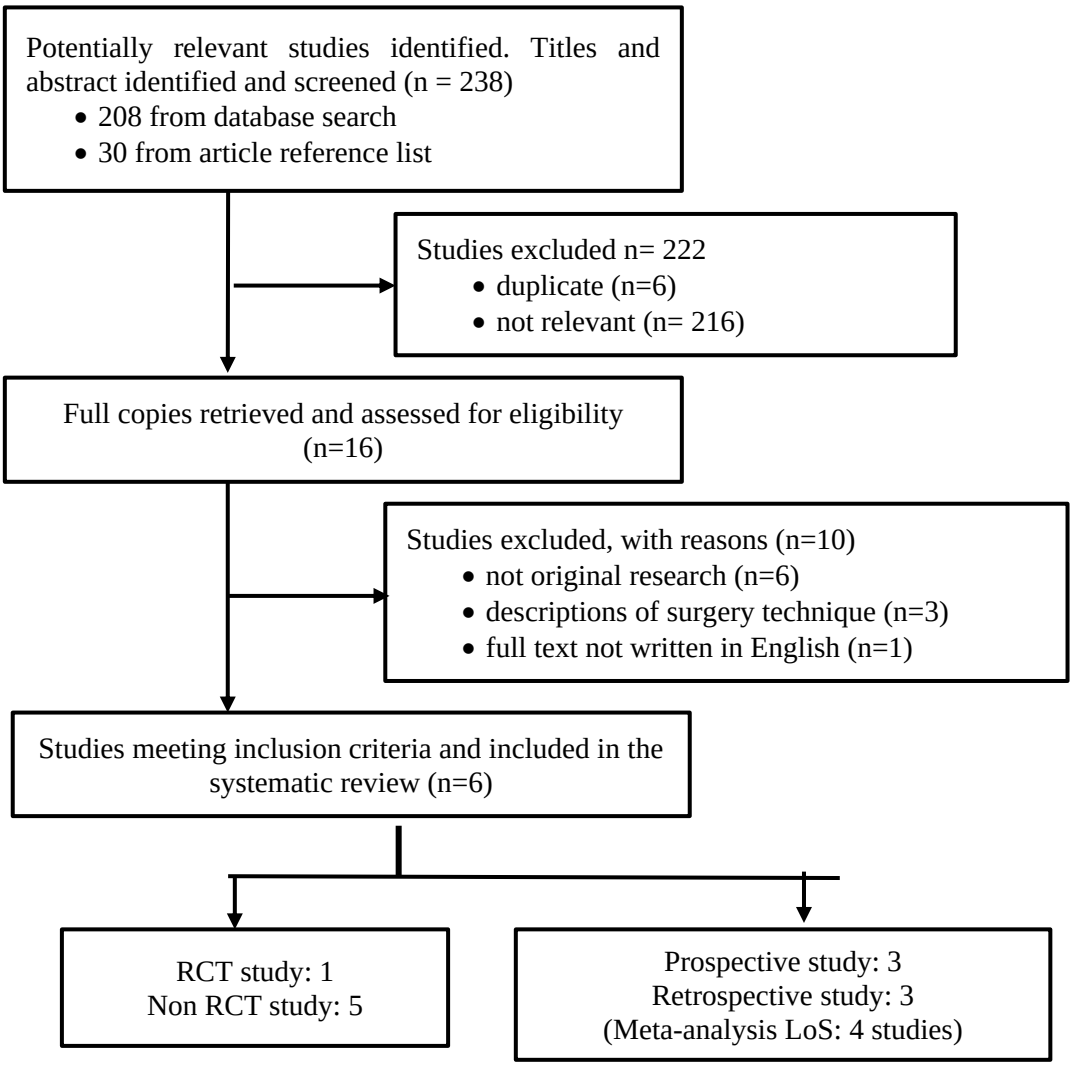

Figure 1: The PRISMA diagram of literature selection of this study.

RESULTS

Initially, 16 works of literature regarding bicondylar tibial plateau fractures and comparing between ORIF and HCEF as the treatment of choice identified. But 6 of them were not original research; they consisted of review, case series, systematic review, and meta-analysis. The other three described surgery technique and one of the full-text articles written in Spanish. Finally, only six literature was retrieved to know about the comparison between ORIF and HCEF as the treatment of choice for bicondylar tibial plateau fractures. They included five non-randomized controlled trials and only one randomised controlled trials. Among them, the number of retrospective and prospective studies are equal.

Study characteristics

All of the included studies are five non RCT and only one RCT. The total sample of all studies is 378 patients with 172 (45.5%) of them undergo ORIF. All of the that included in the study are bicondylar tibial plateau fractures categorised into Schatzker type V or VI. One RCT study in this review was a large multi-centre trial in which patients with bicondylar tibial plateau fractures were randomised to either ORIF (with medial and lateral plates) or application of a circular fixator with percutaneous/limited open fracture reduction. The primary outcome that measured is the Hospital for special surgery (HSS) knee score, which incorporates pain, function, range of motion, muscle strength, flexion contractures, and instability. The secondary outcomes measure was western ontario and mcmaster universities osteoarthritis index (WOMAC), complications, reoperation, the quality of radiographic reduction, the presence of degenerative osteoarthritis, and scores on the short-form 36 (SF-36) health status questionnaire.[6]

The other five non-RCT studies consisted of two prospective and three retrospective studies with heterogenicity in interventions technique. Each study reported has a range of ORIF and HCEF techniques using multiple devices. Devices use for ORIF are lateral locking plate, medial plate fixation, buttress plate and medial and lateral non-locking buttress plates with and

without bone grafting. While for HCEF group used devices such as taylor spatial frame, ring rod system, truelok hexapod system and ilizarov circular frame. Parameters that measure in those non-RCT studies are radiographs outcome to assess post-traumatic osteoarthritis, which recorded if there was progressive obliteration of joint space, osteophyte formation and subchondral sclerosis. The other parameters are functional outcomes that assess using rasmussen's system of grading, which evaluated joint depression, condylar widening and varus or valgus angulation. The WOMAC index of osteoarthritis used to assess functional and anatomical outcomes, Hospital for special surgery knee score (HSS score) at two years postoperatively, and scores on the short-form 36 (SF-36) health status questionnaire. The other parameters that assess are complications such as superficial infections, deep infections, consolidation delay, and secondary malalignment, blood loss in hospital. Follow up time for each study are different but mostly follow up done until 2 two years post-operatively.[1-5]

Table 1: Studies evaluating ORIF) versus HCEF as the treatment of choice for bicondylar tibial plateau fractures.

Author	Design study	Sample size		Intervention	Follow up & outcomes	Key findings
		ORIF	HCEF			
Ahearn et al[2]	Non-RCT, retrospective	34	21	ORIF: lateral locking plate ± medial plate fixation HCEF: Taylor Spatial Frame	ORIF:40.5 mo HCEF: 31 mo WOMAC, SF-36, satisfaction scale, VAS, complications, reoperations, radiological outcomes	Treatment of complex bicondylar tibial plateau fractures with either a locking plate or a TSF gives similar clinical and radiological outcomes.[2]
Ali et al.[3]	Non-RCT, Prospective	20	20	ORIF: standard open reduction and internal fixation+ standard AO buttress plate, HCEF: percutaneous and limited open fixation and application of a hybrid fixator	3,6,12 months Rasmussen, WOMAC, blood loss, complications, LoS	Closed reduction with hybrid fixator is marginally superior to ORIF and should be considered in the treatment of difficult to treat proximal tibial fractures.[3]
Bertrand et al.[4]	Non-RCT, Prospective	26	67 (19 and 48)	ORIF: ORIF with two buttressing plates HCEF: hybrid external fixator after open reduction or after close reduction	3,6,18,24 mo Time to operation, articular ROM, complications, reoperations, LoS	No statistical differences found between treatment with ORIF or HEF. But if external fixation followed open reduction, both superficial and deep-infection rates were higher.[4]
Bove et al.[5]	Non-RCT, Retrospective	14	14	ORIF: minimal invasive angle locking plates HCEF: taylor spatial frame, ring rod system, truelok hexapod system.	Follow up until radiographic healing or up to a year after surgery. ASAMI outcome scores and complications.	Both techniques, circular external fixation or fixed angle locking plates, provide satisfactory fracture reduction.[5]
Conserva et al.[1]	Non-RCT, Restrospective	38	41	ORIF: LCP ± bone graft substitute HCEF: Percutaneous lag screw + hybrid external fixator	ORIF:35.1mo HCEF:39.4 mo Rasmussen, WOMAC, NRS, complications, reoperations	ORIF or HEF represents a valid treatment option in complex tibial plateau fractures. But, HEF has relative better functional outcome results, a relatively lower rate of infection and decreased hospital stays.[1]

Continued.

The Canadian Orthopaedic Trauma Society (COTS), 2011.	RCT, Prospective	40	43	ORIF Medial and lateral non-locking buttress plates ± bone grafting HCEF: Percutaneous lag screw, and Ilizarov circular frame	6,12,14 mo HSS knee score, WOMAC, and SF-36, complication, reoperation.	Both ORIF and HCEF provide a satisfactory quality of fracture reduction. HCEF resulted in a shorter hospital stay, fewer and less severe complications, faster return of function, and superior clinical outcomes compared with ORIF.[6]

TSF=Taylor Spatial Frame, ROM= Range of Motion, LCP=locking compression plate, LoS=Length of Stay.

Radiographic outcomes

Radiological outcomes observed only in the study by Ahearn et.al. Radiographic parameters that used are joint reduction that achieved (p=0.5), metaphyseal-diaphyseal alignment (p=0.8) and is there any joint collapse (p=0.3).[2] Their study showed all patients achieved full union confirmed from their final postoperative radiographs. One patient in the ORIF group required further surgery with bone grafting to achieve union at five months following initial fixation. There is no statistical difference in the reduction or alignment that was achieved in the two groups (ORIF and HCEF).[2]

Functional outcomes

The functional outcomes using Rasmussen observed in two studies, by Ali et al and Conserva et al. Rasmussen score consisted of an assessment of functional and anatomical grading based on subjective complaints and clinical signs. The subjective complaints consist of pain and walking capacity while clinical signs including extension, range of motion and stability. For anatomical grading evaluation based on presence of depression, condylar widening and angulation (varus/vagus). Ali et al found the mean Rasmussen anatomical score was 17.1 for the hybrid group. The mean depression score was 5.5. The condylar widening was 5.8 mm which fall between the good and excellent range. In study by conserva et al found that the mean Rasmussen score at the last follow-up was 24.9 (good) in the patients treated with ORIF and 25 (good) in patients treated with HCEF. With respect to the rasmussen score, the difference was not significant between the groups (t-test, p = 0.47).[1,3]

Functional outcomes using WOMAC observe in 4 studies which measured in terms of pain, stiffness, and physical function. They are, study by Conserva et al highlighted a relatively higher score in the EF group (80.5 ORIF–84.2 EF); however, this difference was not statistically significant (t-test; p=0.28), study by Ahearn et.al showed there was no significant difference in the mean WOMAC between two groups, study by Ali et.al showed a mean score of 55.5 against a maximum score of 68 and the last study by COTS found two years after injury, the WOMAC scores was not significantly different between the groups measure from stiffness (p=0.604), pain (p=0.923) or function (p=0.827) categories. This study also found that two years after the injury, the SF-36 scores significantly decreased for both groups.[1-3,6]

Complications

All of the studies in this systematic review assess complications as the outcome measure. Study by Ali et al. found that the mean duration of hospital stay and the average blood loss were significantly less in the hybrid fixator group (p<0.001) Duration of hospital stay in days was found to be extremely high for ORIF group nearing two weeks (13.5 days) whereas in HCEF it was only one week (6.75 days).[3] But in the study by Bertrand et al found the overall length of hospital stay was 6.09 days (95% CI: 5.35-6.82) and there were no significant differences between the groups (p=0.536).

Similarly, average blood loss was high with 498.5 ml in the ORIF group against 222 ml in HCEF group. A study by Bertrand et al found no statistical differences were found between the groups for complications (infection, consolidation time, or malalignment), but four patients (10.5%) in the ORIF group has a deep infection, while only two patients (4.9%) in HCEF group. These findings lead to conclusion that the fracture should not be opened up for reduction when a pin fixator is subsequently to be inserted.4 Study by Ahearn et. al. found that there was no significant difference between the patients treated with ORIF and HCEF regarding pain, satisfaction following treatment, return to pre-injury occupation and sporting or leisure activities.[2]

DISCUSSION

As we know, BTPF is a complex tibial plateau fracture that very challenging due to severe bone and soft tissue injury, which led to high complication rates and poor clinical outcomes. High energy trauma considered as a significant cause of poor results in the treatment of tibial plateau fractures. Bicondylar tibial plateau fracture needs a surgical procedure to achieve an anatomical reduction of the articular surface and stable fixation to achieve bone healing.[2,8] The choice of the safest surgical option can be very challenging. Open reduction and internal fixation (ORIF) using medial and lateral plating or double plating first proposed as a possible treatment in 1969.[1] The

results of ORIF were variable, especially for comminuted articular or open fractures. The complications included infection (ranging from 50% to 87.5% of all reported cases), post-traumatic osteoarthritis, skin complications and tibial axial deviation.[7,9] This can be related to the need for extensive surgical exposures, damaging periosteal vascularisation and resulting in an unacceptable rate of wound dehiscence, deep bone infection and delayed bone healing. External circular fixation has been reported to contribute to decreasing the risk of infection in BTPF lesions. Soft-tissue-related complications are also rare when combining minimally-invasive plating with external fixation.[1,6]

HCEF is one of the treatment options for tibial plateau fracture beside ORIF.[9,10] This technique principle is by bridging the epiphysis part of the bone to the diaphysis part, while the fixator stabilises the meta-diaphyseal part. The complex proximal fracture can be held by using a ring fixator. That ring fixator and then attached to the tibial shaft using pins and rods, this called by hybrid fixator. This technique was done under spinal or general anaesthesia.[9,11] There are several steps to do HCEF first is patient preparation; this procedure usually is done with the patient in a supine position. The next step is planning wire placement using 2 mm diameter wires recommended. Good knowledge of anatomy is obligatory to perform the correct installation of the K-wires as they go through both cortices. The wire corridors must be chosen carefully due to all important neurovascular structures layin the posterior part.[9,12]

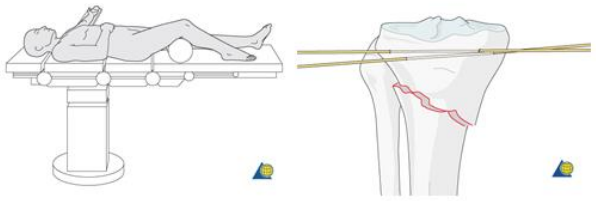

Figure 2: Patient positioning in supine position and insertion of wire, at least two wires were used.[12]

Wires should be positioned as proximal as possible but not through the joint and should be at least 14 mm below the articular surface due to distal capsular insertion. With only two wires, stability is limited. We should maintain an overall arc of 60-80° between the wires improves stability and adding a third wire or a threaded pin gives more excellent stability, where at least two wires must be used. To put the wires a stab incision and blunt dissection down to the bone was done. The wire placed parallel to the knee joint under image intensification, for example, using fluoroscopy until the wire penetrates the cortex. The rest wire inserts by hand until the wire extends an equal length on both sides of the tibia and we should make sure that the wire does not impale tendons or neurovascular structures.[12]

After that, the wires and the ring connected and the clamps tighten to attaching ring to wires. The next step is to tensioning the wire for mechanical stability. Generally, a strain of 100 kg force is appropriate. The next step is pin placement, for safe pin placement make use of the safe zones, and the surgeon should be familiar with the anatomy of the lower leg. There are several choices for tibial pin placement, but a trajectory angle of 20-60 degree for the proximal fragment and of 30-90 degree for the distal fragment is recommended. The pins may be placed more anteriorly to avoid the frame catching on the opposite leg. The drill bit started with the tip just medial to the anterior crest, and with the drill bit perpendicular to the anteromedial surface. For finalizing HCEF, a ring to rod connection should be done by placing the proximal pin very close to the fracture.[10,12]

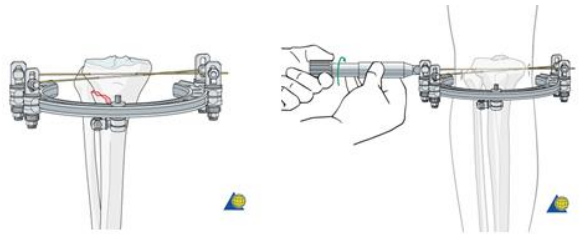

Figure 3: Wires attachment to the ring and tensioning the wire.[12]

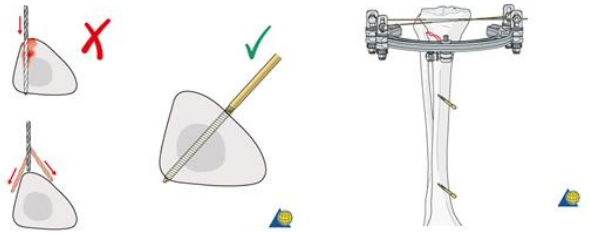

Figure 4: The right position for pin placement.[12]

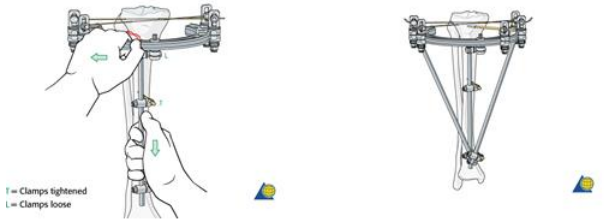

Figure 5: Reduction and fixation the ring and the rod. One or two Schanz pins may be added and connected with the ring for additional stability of the tibial head frame.[12]

The second pin must be placed as distally as possible because the further the pins are apart, more stable the construct will be. The pins should connect with one rod and tighten the clamps and continue with connecting the

rod to the ring. The rod-to-ring clamp can be left loose enough to allow manipulation. After that reduction and fixation can be done by using ring and rod as reduction handles, we should restore length, alignment and rotation and check the reduction clinically and with image intensification. If reduction is satisfactory, we can tighten the rod-to-ring clamp. One or two tubes can be added to the construct for additional stability of the frame. For stronger durability of the tibial head frame, one or two Schantz pins may add and connected with the ring.[12] All patients were instructed on fixator care and taught to do daily pin sites cleansing with Povidone-Iodine solution. They started on passive range of motion exercise on the third post-operative day and active motion by the first week. The non-weight bearing initiated at 6-8 weeks, followed by partial weight-bearing ambulation depending on the amount of callus formation. Full weight-bearing has given after removal of the fixator. Serial radiographs in AP and lateral planes were performed postoperatively.[2,12]

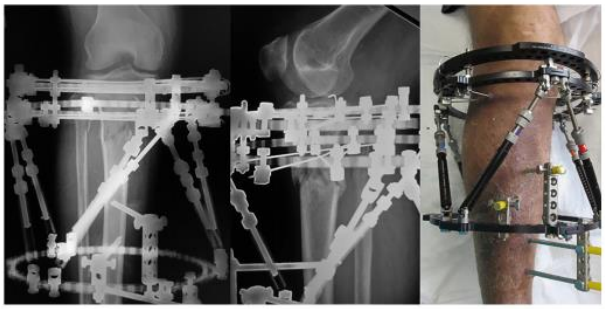

Figure 6: The final result of HCEF both clinically and from the radiograph.[2]

Findings by Ahearn at al suggest that treatment of complex bicondylar tibial plateau fractures with either a locking plate or a TSF, regardless of the skill of the treating surgeon, gives similar clinical and radiological outcomes.2 The other study by Conserva et al. also stated similar conclusion, that both internal and external fixations represent a valid treatment option in complex tibial plateau fractures with the expectation of consistent results.[1] However, HCEF has shown relative better functional outcome results and a relatively lower rate of infection. Moreover, HCEF is associated with a shorter length of hospital stay, and thus it is cost-effective, especially in older patients with multiple comorbidities. The Canadian orthopedic trauma society and Ali et al. also stated the same, that closed reduction and application of an HCEF resulted in a shorter hospital stay, fewer and less severe complications, faster recovery time, and similar or superior clinical outcomes compared with conventional ORIF.6 A study by Bertrand et al. stated that although there was no statistical difference between ORIF and HCEF in treatment of BTPF, open reduction when using external fixation does not appear to be advisable due to soft tissue damage and fracture complexity are the main issues of BTPF. HCEF also should be more considered as the treatment of choice for BTPF due to its shorter hospital LoS which may minimalise infection risks and costs.[4]

A study by the Canadian Orthopaedic Trauma Society, Ahearn et al. and Ali et al. found that HECF group has shorter hospitalisation time comparing with the ORIF group. There are several hypotheses for the explanation. The first is, patient in the ORIF group has more complications that develop during post-operative care and required more multiple procedures. The complications such as superficial infection, deep infection, and septic arthritis. The HCEF group has a lower number of infections for both superficial and deep infections. A lower number of infections resulted in shorter hospitalisation period. The other reason is as stated by Ahearn et al HCEF technique, for example, using Taylor Spatial Frame method has several benefits due to limited direct approach and compression screw fixation, or peri-articular locking plates, there is no need for an extensile incision. This technique may reduce post-operative pain and the risk of wound breakdown and deep infection, thereby minimising the potential complications of septic arthritis and osteomyelitis and thus shortens the duration of hospitalisation. The other thing is external fixation may also allow earlier mobilisation, avoid stiffness of the knee results in earlier recovery and earlier discharged time from the hospital.

CONCLUSION

Based on our analysis results, most of the studies stated there is no significant difference between ORIF and HCEF in treatment for BTPF. But HCEF has relative better functional outcome results, a relatively lower rate of infection and decreased the length of stay in hospital. HCEF may offer some advantages in terms of soft tissue healing. The currently existing studies didn't give us a clear recommendation on whether HCEF was better than ORIF in managing BTPF. Thus, longer duration studies on comparing ORIF and HCEF were required. Further, randomised controlled and multicenter studies should be implemented to get a more reliable and clear result.

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REFERENCES

1. Conserva V, Vicenti G, Allegretti G, Filipponi M, Monno A, Picca G, et al. Retrospective review of tibial plateau fractures treated by two methods without staging. Injury. Epub ahead of print. 2015.
2. Ahearn N, Oppy A, Halliday R, Rowett-Harris J, Morris SA, Chesser TJ, et al. The outcome following fixation of bicondylar tibial plateau fractures. Bone Jt J. Epub ahead of print. 2014.
3. Ali F. No Title. Treat Outcomes Bicondylar Tibial Plateau Fract by Hybrid Fixator with open Reduct Intern Fixat. 2017;13:28-31.

4. Bertrand ML, Pascual-López FJ, Guerado E. Severe tibial plateau fractures (Schatzker V–VI): open reduction and internal fixation versus hybrid external fixation. Injury. Epub Ahead Print. 2017.
5. Bove F, Sala F, Capitani P, Thabet AM, Scita V, Spagnolo R. Treatment of fractures of the tibial plateau (Schatzker VI) with external fixators versus plate osteosynthesis. Injury. 2018:3:12-8.
6. Swiontkowski MF. Open Reduction and Internal Fixation Compared with Circular Fixator Application for Bicondylar Tibial Plateau Fractures: Results of a Multicenter, Prospective, Randomized Clinical Trial. Yearb Orthop 2008;2008:53-5.
7. Zhao X, Ma J, Ma X long, Jiang X, Wang Y, Li F, et al. A meta-analysis of external fixation versus open reduction and internal fixation for complex tibial plateau fractures. International Journal of Surgery. Epub Ahead Print. 2017.
8. Ali AM. Yang L, Hashmi M, Saleh M. Bicondylar Tibial plateau fractures managed with the Sheffield Hybrid fixator. Biomechanical study and operative technique. Injury.
9. Babis GC, Evangelopoulos DS, Kontovazenitis P, Nikolopoulos K, Soucacos PN. High energy tibial plateau fractures treated with hybrid external fixation. J Orthop Surg Res. 2011.
10. Watson JT, Ripple S, Hoshaw SJ, Fhyrie D. Hybrid external fixation for tibial plateau fractures: Clinical and biomechanical correlation. Orthop Clin North Am.
11. Metcalfe D, Hickson CJ, McKee L, Griffin XL. External versus internal fixation for bicondylar tibial plateau fractures: systematic review and meta-analysis. J Orthopaed Traumatol. 2015.
12. Buckley RE, Moran CGAT. AO Principles of Fracture Management. 3rd edition. 2017. Available at: https://www2.aofoundation.org/wps/portal/surgerymobile?bone=Tibia&segment=Proximal&showPage=preparation. Accessed on 20 May 2020.

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