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Supracutaneous plate: A comparable alternative to external fixator in the treatment of open fracture

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Abstract
Open fracture is one of the common health care problems in clinical orthopedic practice. Incidence of open fracture rate is increasing, especially in working age groups in industrialized society. Treatment of open fractures is still challenging since surgeons have to tackle not only fracture and also risk of infection, soft tissue coverage and neurovascular injury. Traditionally, external fixator (EF) device was used to fix the open fracture as an emergency or definitive management. In recent years, there was the introduction of locked compression plate (LCP) as an alternative to the conventional external fixator. There are not too many studies regarding the outcome, biomechanics and complications regarding LCP as an external fixator. Based on the available resources, we have reviewed some journals. We would like to comment that usage of LCP as an external fixator in the treatment of long bone fractures shows acceptable outcome. There is no significant difference in operation time between LCP and EF. The rates of union and complication are comparable to that of the conventional external fixator. There is no enough report about a biomechanical comparison study between LCP and EF. Patient acceptance may be higher in LCP than in EF however; there is very little research for the time being. We would like to recommend further research in this area.

Keywords: Open fracture, locking plate, external fixator, biomechanics

Introduction
Locked plates have been used successfully as an alternative to conventional plates since they can be used as "bridge plates" to preserve fragmentary blood supply. The fundamental principles of bridge plates and external fixators are similar. This principle has been applied to locked plates and used as an external fixator [1]. By using locked plates, we can avoid joint stiffness due to the long bar of external fixator. It is also cosmetically more acceptable than traditional external fixator. Outcomes are comparable with external fixators. Disadvantages are difficult to do dynamization or re-adjustment.

Methods
A literature search was conducted on the PubMed database with the help of keywords: "Open fracture", "Locking Plate", "Biomechanics" and "External Fixator". The search was extended to other online resources such as JBJS, Science direct and Elsevier. The result showed there were not too many articles related to supracutaneous plate. Article from Singapore, China, India, Iran and USA were worth, the source of information and helped to accomplish this review. Three research papers, two systematic reviews and two case series relevant to the objective of this review article were selected.

Introduction
Open fracture is one of the common health care problems in clinical orthopedic practice. Incidence of open fracture rate is increasing, especially in working age groups in industrialized society. In working age groups, high-energy injury is the major cause of open fracture and in older age groups, low energy open fractures are common [2]. The choice of the optimal implant when managing open fractures have historically been one of the most controversial issues in fracture treatment. In the literature, the earliest history of the locking plate was the monocortical fixator by Carl Hansman in 1886 [3].

The technique of plate fixation outside the skin was first described in Poland in the 1970s. In the early years, the aim of plate fixation outside the skin was to reduce the stress on bone and periosteum. In 1987, there was one biomechanical study regarding external plate fixation using Zesopl osteosynthesis system [4-5]. This initial study was not to use alternative to the traditional external fixator in the management of open fracture but to replace the compression plate in the treatment of closed fractures. In 2000s, locked compression was progressively modified by AO group. The locking compression plate (LCP) has emerged as an external fixator for subcutaneous bone with satisfactory outcomes when used on the tibia and clavicle [6]. This is because external application of an LCP has many advantages, including angular stability from the locking-head mechanism, reduced irritation because of its low profile compared with traditional external fixators and preservation of ankle movement [7]. To the best of our knowledge, there were very few research or case reports regarding supracutaneous plate in the treatment of open fractures. In the current decade, locked plate was not very widely accepted in every country. This may be due to less knowledge about usefulness, lack of adequate evidence regarding its biomechanics and outcome, price of locked plate is higher than traditional EF in some countries. This paper will help to organize some concrete evidences that LCP can safely be used as a good alternative to EF and some additional benefits such as patient's acceptance in term of cosmetic reason. Traditional EF is high profile, heavy, bulky, uncomfortable and tend to cause stiffness in long term and causing impediment daily activity. There is some drawback of LCP such as the inability to do readjustment after fixation, although LCP has granted good alternative to traditional EF.

Biomechanical studies

LCP has been successfully used as a good internal fixation implant, however the stability of LCP as an external fixator was questioned until now. One of the studies from Taiwan compared biomechanics of internal LCP, external LCP and traditional EF. It was found that the axial stiffness of the internal locked plate was highest; 347.06^{+}/-17.06 N/mm. External locked plate was stiffer than traditional external group 66.75+/- 7.95 N/mm and 22.80+/- 2.10 N/mm respectively. There was statistically significant difference among the group (P= 0.002). However, there was no significant difference in torsional stiffness among the group [8]. The study used 15 reinforced solid, fourth-generation composite large tibia samples and 13 holes distal femur LISS (less invasive stabilization system, Synthes Inc). In that study, a titanium 14 holes broad 4.5/5 mm LCP (Syntheses) with 5 mm diameter locking screw were used in third and seventh hole. The distance between the bone and the plate was 20 mm. If there was no soft tissue problem, 20 mm offset bone distance was the best choice for better stability. In some cases, distance of 30 mm and up to 60 mm were used. In a study Ahmed *et al*. In 2007, they stated that axial stiffness and torsion of compression plate would be significantly reduced when the distance between the plate and the bone surface was above 5 mm [9]; however, we did not see a significant difference in the above study.

In a comparative study from Singapore, there was no significant difference in mean axial stiffness between LCP (stainless steel) (525 N/mm), LCP (titanium) (496 N/mm) and EF (528 N/mm). (P= 0.171). However, there was a significant difference in mean torsional between LCP (stainless steel) (0.639 N/mm) (0.686 Nm/degree) LCP (titanium) and EF (0.512 Nm/degree) (P=0.013) [4]. That study used 15 synthetic tibias bone model and standard AO technique for the fixation of construct. In their study, LCP was able to withstand up to three times the body weight of an average 70 kg adult on axial loading. However, further mechanical testing is required to ascertain the fatigue strength.

In a biomechanical study from Beihang University, China, they compared stiffness of internal tibia LCP, external fixation using femur LCP and external fixation using tibia LCP. It was found that there was a significant difference in axial stiffness. The axial compression stiffness across samples in each group was 177.9 ± 20.31 N/mm, 84.38 ± 14.37 N/mm, 25.04 ± 2.19 N/mm, for internal LCP, EF-femur LCP, and EF-tibia LCP groups respectively. The torsional rigidity was 0.89 ± 0.17Nm/deg, 1.29 ± 0.14Nm/deg, 0.34 ± 0.05Nm/deg, for internal LCP, EF-femur LCP, and EF-tibia LCP groups respectively [10]. That study stated that distal femur LCP was recommended as an external fixator in treating distal tibia fractures. One study from Taiwan stated that the use of femur metaphyseal locked plate for external fixation was a highly acceptable alternative to the traditional external fixator in tibia fracture [8].

There were slight differences in the biomechanical testing results between those studies, however, it can be concluded that LCP can be used as an external fixator alternative to a traditional EF without compromising axial and torsional stiffness.

Outcomes

In a study from Sichuan, China, locking compression plate was used as an external fixator for treating infected nonunion of the humeral diaphysis. In that study, a series of seven patients with infected nonunion of the humeral diaphysis were treated with LCP as an external fixator. All fractures united in the average time of 7.9 months and infections were eventually resolved without recurrent in a mean follow up time of 26.3 months [6]. In a study from Taiwan, 54 open tibia fractures were fixed with external LCP. According to the Gustilo classification of open fractures, the cases were ranged from Grade II to Grade III C. The mean follow up time was 38 months and the average fracture healing time was 34.5 weeks. All of the patients had a successful bone union. Knee flexion was from 85° to 145°, ankle dorsiflexion from 0 to 20° and planter flexion from 0-50° [8]. In a case series from India, 8 cases of open fractures of distal femur or proximal tibia were fixed with external LCP and followed up for one year. Their study found that 87.5% showed radiological union in average post-operative period of 14.2 weeks. The final outcome of the study based on knee society score was 4 excellent (50%), 3 good (37.5%) and 1 fair (12.5%) [11] In average, partial weight bearing started after 4 weeks. In a case series of 5 cases from India with open tibia fractures Gustilo type I and II, all the fractures healed within average plate in situ time of 24 weeks. There were no clinically significant complications [12].

In a study from Ningbo, China and University of Toledo, Ohio; 116 tibia fractures (85 closed and 31 open fractures) were treated with LCP external fixator using Femoral LISS (Less Invasive Stabilization System; Synthes, West Chester, Pennsylvania). Their results were quite promising. During the mean follow up time of 22 months, all the fractures were united with the average union rate of 12-24 months and return to their activity level eventually [13]. In a case series of 16 open fractures from Tehran, Iran, tibia open fractures were

treated using locking plate as a definitive external fixator. All the fractures were united without noticeable complications such as pin tract infection, nonunion or broken screw or plate. The mean healing time was 18 weeks and full weight bearing was allowed after four weeks. The mean American orthopedic foot and ankle society (AOFAS) score was 93 and 95 out of 100 points at 4 weeks post-operatively and final follow-up (mean period of 16 months) [14].

Complication

In a study from Sichuan, China, a locking compression plate was used as an external fixator for treating infected nonunion of the humeral diaphysis. It was found that one case of pin tract infection, one case of transient radial nerve palsy and average shortening of upper limb was 3 cm [6]. In a study of 54 open fractures, the most common complication was screw tract infection (26.96%). This could be due to the threaded shaft of the locking screw. All the cases were treated well with screw removal, dressing and oral antibiotics. There was no report of deep infection or osteomyelitis. There were six screw loosening in five cases at the metaphyseal part of the tibia. Four screw broken out in three cases. But all these cases did not affect the external locking plate construct. There was no report of broken plate. Loosening of one screw may be regarded as dynamization of a static interlocking nail [8]. Some cases of malunion and limb length discrepancy were noted in type III B fractures, but this could be due to severity of fracture.

In a case series of 8 cases from India, one case of superficial infection and one case of screw loosening were observed, however, there was no report of plate broken or osteomyelitis [10]. In a study of 116 cases from Ningbo, China and Toledo, Ohio there was no report of deep infection, nonunion and broken screw or plate. They have reported only 8 cases of superficial infection and treated well without compromising the stability of LCP external fixator [13].

Discussion

Management of open fractures has been perplexing for caretakers decades long. The key aspect of challenge is what to choose as an alternative to internal fixation since it is contraindicated. From POP with window dressing to Ilizarov technique, we have come across with multiple drawback from stiffness to cosmetic reason. The idea of external plate is not a new however tedious choice of surgeons. This may be due to lack of clear biomechanical studies and proven benefits. Locking compression plate as an external device is superior and advantageous than traditional external fixator or Ilizarov in term of weight and cosmetic reason. Removal of plate external fixator can be done under local anaesthesia. It provides a small silhouette in imaging and less disturbance in the monitoring of fracture healing. In some situation, controlled dynamization is possible by removing some screws.

It has been idle for many decades and starting from the popularity of LCP as internal fixation, the idea of external plate fixation become popular starting from 2000s. The use of LCP as an external fixator has proven beneficial not only in open fractures, also a good alternative in infective nonunion. Since the plate does not cross the knee or ankle joint, physiotherapy can be done easily and functional recovery is expected faster. Another beneficial finding is that the skin and subcutaneous tissue adhere easily to locking screws without pin-site infection [15]. For surgical perspective, the expanded outline of the distal part of the metaphyseal LCP is similar to that of the distal tibia. This structural feature is beneficial when applied to the distal tibia and the plate provides multiple locking holes distally, which allows the surgeon to choose the screw holes for distal fixation depending on the fracture pattern, as opposed to when using the traditional external fixator pins [16]. The same principle can be applied to proximal tibia fractures.

There is no comparative study between the operating time between traditional EF and external LCP. But in one study, it was recommended to use traditional EF more suitable than the external LCP in case of poly trauma and damage control situation. We believe that this will widely depend on surgeon's expertise. Regarding choice of implant, we have found that femur metaphyseal locking plate is the most suitable for tibia fracture. Since the stiffness is dramatically changed if the plate is more than 2 mm from bone, tibia plate is not recommended to use as an external fixator for tibia fractures. The number of screws may vary depend on the pattern of fractures and we have found that minimum two screws each proximally and distally to grant adequate stability. The main disadvantage of using external LCP is difficult to perform readjustment after fixation, which is possible in traditional EF. Therefore, accurate alignment is mandatory during reduction before fixation with screws. There is no significant difference between LCP and traditional EF in other complications such as pin tract infection, nonunion or limb length discrepancy. Almost all of the studies showed minimal or no complications. Especially in the case of Gustilo Type I and Type II fractures, it was reported that there is no complication. Most of the complications we have noticed were common to traditional EF. The complications because of biomechanical failure are unnoticeable.

Conclusion

In the above studies, different number of cases were observed. Regarding the biomechanics, it was obvious that internal fixation of LCP was stronger than the LCP as external fixator. However, there were no noticeable differences between the traditional EF and LCP as an external fixator in term of biomechanics. All of the studies immensely supported that the clinical outcome of LCP as an external fixator is comparable to traditional EF with minimal complications. It is difficult to conclude the actual infection rate as a whole, since some studies included close fractures and some studies included infective nonunion. We would like to comment that usage of LCP as an external fixator in the treatment of long bone fractures shows acceptable outcome. To the best of our knowledge, we do not see adequate systematic review and meta-analysis. Henceforth, we would like to recommend further systematic review and meta-analysis of effectiveness of LCP as an external fixator.

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