Management of open fractures using a noncontact locking plate as an internal fixator

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Abstract

Background: The treatment of open fractures leads to major problems which may be due to various reasons. It mainly causes soft tissue problems due to the absorption of a large amount of energy by the soft tissues and bone tissues. Although some recent treatment protocols have eliminated many problems regarding delayed soft tissue closure, it still remains a big challange. This study uses a method called the internal fixator technique with noncontact locking plate (NC-LP) which involves the use of a combination of advantages of open and closed fixation techniques.

Materials and Methods: 42 patients (32 men and 10 women) having a mean age of 34.11 years (range 17–56 years) with open fractures operated using internal fixator technique between 2007 and 2012 were included in this study. A retrospective chart review was conducted to record the following: age, gender, anatomic region of fractures, fracture etiology, classification of open fractures by Gustilo–Anderson and AO classification, surgeries, length of hospitalization, location and pattern of fracture, length of followup, and complications.

Results: The fractures were caused by traffic accidents, shotgun injuries, falls from heights, and industrial crush injuries. Based on the Gustilo–Anderson classification, 31 fractures were Type III and 11 were Type II, where 23 were localized in the tibia and 19 in the femur. Patients delay for a mean of 13.5 h (range 6–24 h) for operation and the mean followup interval was 27.8 months (range 16–44 months). The mean union time was 19.7 weeks (range 16–29 weeks). One patient had delayed union and implant failure, one patient had osteomyelitis, five suffered from surface skin necrosis, and one patient had an angulation of 17° in the sagittal plane, for which no additional intervention was performed.

Conclusions: This case series demonstrates that an “internal fixator technique” is an acceptable alternative to the management of open fractures of the femur or tibia in adult patients. The NC-LP method provided opportunities to achieve a stable fixation with noncontact between the implant and the bone tissues, and the fractures were sufficiently stabilized to allow union with a low complication rate.

Key words: Internal fixation, noncontact plate, open fracture
MeSH terms: Bone plates, open fractures, osteomyelitis

Introduction

Delayed union and infection are major problems encountered in the treatment of open fractures. These complications may arise for various reasons. Among them, the large amount of energy absorbed by the soft and bone tissues in the injury is a significant factor. Recent developments in reconstructive surgery have eliminated many problems regarding delayed soft tissue closure. However, there are ongoing arguments about the timing of skin closure operations. Some studies argue that the acute management of skin closure may yield successful outcomes[1,2] while others report that acute skin closure may be harmful and thus closure should be performed in 2–7 days following the initial debridement.[3] Another major challenge in the management of open fractures is

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Access this article online	
Quick Response Code:	Website: www.ijoonline.com
	DOI: 10.4103/0019-5413.205686

How to cite this article: Yildirim A, Kapukaya A, Mertsoy Y, Yiğit Ş, Çaçan MA, Atiç R. Management of open fractures using a noncontact locking plate as an internal fixator. Indian J Orthop 2017;51:312-7.

stabilization of the fracture with a method that minimizes the infection risk since the materials employed in the detection of fragments significantly influence infection and bone union. They include external fixators, intramedullary nails, and plate/screw systems. Plate/screw systems are rarely used in the management of open fractures because they can cause high rates of infection and other complications.[4] Similarly, external fixators have frequently been used in the past, but they are currently used relatively rarely due to several disadvantages.[4,5] Although intramedullary nails remain as the method of choice in the management of open fractures due to the fact that the advantage of these nails is based on their biomechanical superiority in the stabilization of the fragments, they can also cause severe complications.[6] In particular, deep infection caused by the implantation of intramedullary nails has been reported to be the most resistant type of infection in the treatment of open fractures.[7]

This manuscript presents the clinical outcome of a series of adults who have effectively received the treatment of the internal fixator technique (noncontact locking plate [NC-LP] method).

Materials and Methods

42 consecutive patients (10 females and 32 males) with a mean age of 34.11 years (range 17–56 years) admitted between 2005 and 2012 were treated by internal fixator. Patients whose extremities were thought to be salvageable according to Lange's criteria[8] were included in the study. Patients with segmental defect, Type I fractures and intraarticular fractures were excluded. A retrospective chart review was done to record the following: Age, gender, etiologies of the fractures, previous treatment attempts, the location and pattern of fracture, time of fracture healing, and time of antibiotic treatment. The following parameters were also recorded for each patient: Medical history, clinical examination, a baseline blood workup measuring the erythrocyte sedimentation rate, C-reactive protein level, white blood cell count, and radiographs. The mechanisms of the injuries were traffic accidents (n = 11), shotgun injuries (n = 14), falls from heights (n = 12), and industrial crush injuries (n = 5). The fractures were categorized based on the Gustilo–Anderson classification as follows: 31 fractures were Type III (21 Type A and 8 Type B and 2 Type C) and 11 were Type II [Table 1]. Tibial fracture types were classified according to the AO classification as follows: 4 Type B1, 2 Type B2, 9 Type C1, 6 Type C2, and 2 Type C3. Femoral fractures were classified according to the AO classification as follows: 3 Type B1, 5 Type B2, 5 Type C1, 5 Type C2, and 1 Type C3. Ipsilateral fibula fracture was present in all tibial fracture cases. A medial malleolus fracture was present in 2 cases. Of the fractures, 23 were localized in the tibia and 19 in the femur. The localization of the fractures was as follows; 35 in diaphyseal and 7 in metaphyseal. The first intervention for all patients occurred in our clinic; all were treated using the internal fixator technique. The patients were taken to the operation room within a mean of 13.5 h (range 6–24 h), and the mean followup interval was 27.8 months (range 16–44 months). Informed consent was taken from all the patients.

Operative procedure

Operations were performed under general anesthesia in supine position without tourniquet. The lateral approach was used for femur, while the anterolateral and anteromedial were used for tibia. The surgical procedure began with debridement. All necrotic soft tissues and all loose cortical bone particles that had no contact with the soft tissues were debrided. Then a 10-L lavage with normal saline solution containing rifocin[9] was performed in each case. At the end of these processes, suitable locking plates were chosen depending on the size and nature of each fracture and the location of the fractures. The plates were then inserted with a distance of at least 3 mm from the cortex. After the fracture reduction, primarily, the proximal and distal screw holes were prepared consistent with the guidelines of the locking plate technique. Once fixation was achieved, radiographs were obtained to check the spacing between the plate and the cortex and to ensure that the screws had been correctly placed through both the cortices. Additional screws were placed where necessary avoiding the excessive use of screws along the fracture line [Figures 1A and 1B]. Following the fixation, autogenous spongious grafting was performed in

Table 1: Mechanism of injury, classification, location, and complications

Mechanism of injury	Gustilo–Anderson classification and location of fractures	Complications	Soft tissue coverage	Union time (week)
Traffic accident, (n=11)	Type III, 31 case (21A, 8B, 2C)	Delayed union and implant failure, one case	Soleus muscle flap and split-thickness in 6 cases	Type II - 17.4
Shotgun injury, (n=14)	Type II, 11 cases	Chronic osteomyelitis, one case	Fasciocutaneous rotational flap and split-thickness in 2 cases	Type IIIA - 19.1
Fall from height, (n=12)	23 were localized tibia	Surface skin necrosis, five cases	No delayed primary closure	Type IIIB - 19.2
Industrial crush injury, (n=5)	19 were localized femur	Angulation of sagittal plane, one case	Acute primary skin closure in 34 cases	Type IIIC - 28.5

Figure 1A: Clinical photograph of leg showing (a) type 3 open fracture (b) Wound was closed after irrigation

Figure 1B: X-ray of leg bones anteroposterior view showing (a) comminuted fracture tibia middle third and segmental fracture fibula (b) Early postoperative anteroposterior view showing plate as internal fixator (c) Early postoperative lateral view showing plate as internal fixator

all patients. The surgical approach for bone grafting was determined according to the fracture configuration and the condition of the surrounding soft tissue. Grafts were placed in the posterior and lateral parts of the tibia, as well as between fragments.[10] Aerobic, anaerobic, fungal, and mycobacterial cultures were not performed. Reconstruction of the skin and soft tissues was done in a single session in all patients. For wound closure, acute primary skin closure was used in 34 patients, a soleus muscle flap and split-thickness was used in 6 patients, and a fasciocutaneous rotational flap and split-thickness was used in two patients. Hemovac drain was not placed in any patients. All dressings were changed daily. Cast or splint immobilization was not used postoperatively. Antibiotic therapy given was based on the type of fracture: Type II fracture received cefazolin and Type III received a combination of cefazolin, aminoglycoside, and metronidazole. Total therapy duration was 3 weeks. Our clinical experience shows that the 3-weeks period would be appropriate. All patients were discharged after the 1st week. Inflammatory markers were routinely measured during the followup. Patients were allowed to mobilize via crutches after 3 days. After at least 6 weeks, they were allowed for partial load following the radiographic consolidation. If the union signs were not observed after 8 weeks, this was accepted as the time for the delayed union. Plates were removed in all the patients after a period of 1.5–2 years.

Statistical analysis

Dataset used in the study is not suitable for testing statistical hypothesis due to unattainable randomization of the sample and certain problems for conducting a designed representative control experiment. However, the study assesses the performance of "internal fixator technique" via descriptive statistics and certain quantities/measurements for those are given in the results section.

Results

All the patients (n = 42) were either open tibia or femur fractures based on the They were Type 2 or Type 3 fractures as per Gustilo–Anderson classification. None of the patients had received any intervention elsewhere before being admitted to our clinic. Complete union was achieved in all the fractures within a mean period of 19.7 weeks (range 16–29 weeks) [Figure 1C]. However, complications occurred in eight patients [Table 1]. One patient experienced delayed union (Type 3C) and implant failure (implant bent), and the plate was exchanged for a longer one and autogenous cancellous bone grafting was added again to the therapy. The plate breakage and impingement was not observed in any patients. Another patient developed chronic osteomyelitis despite multiple debridement. Five other patients developed surface skin necrosis following primary skin coverage; four underwent only debridement, whereas the other underwent debridement and split thickness grafting. Another patient who underwent a

Figure 1C: (a) Late postoperative anteroposterior view showing fracture started uniting (b) Late postoperative lateral view showing fracture started uniting (c) After implant removal late postoperative anteroposterior view showing complete union (d) After implant removal, late postoperative lateral view showing complete union

rotational fasciocutaneous flap and split thickness grafting had partial necrosis during the application of split thickness grafting. This patient recovered spontaneously with no need for any secondary procedure. Another patient had an angulation of 17° in the sagittal plane. The deformity was localized in the distal diaphyseal area of the tibia. No intervention was performed because the patient refused to undergo a correctional osteotomy. During the followup, we did not observe any complications (such as growth and infection) in the location where grafts were taken as well as plates were applied. All patients had restricted articular movement in the knee and ankle. After rehabilitation, six patients had plantar and dorsiflexion restriction in excess of 20° in ankle movements and four had flexion restriction of less than 30° in knee range of movement.

Discussion

In open fractures, the factors determining prognosis are multiple.[11] There are two very important factors that the orthopedic surgeon can effect. First, the planning of the soft tissue coverage and the selection of the optimal technique and material for fracture stabilization. Hertel *et al*.[12] mentioned the performance of soft tissue coverage immediately after debridement, irrigation, and stabilization, in patients with complex open fractures. Although their patients were Type IIIB or IIIC, no patient presented with a deep infection. In contrast, some researchers argue that aggressive treatment of fractures may lead to severe infections, such as clostridial infection.[13] Therefore, it is believed that performing soft tissue coverage between days 2 and 7 is likely to produce more reliable outcomes.[13] In soft tissue coverage operations, the incidence rate of infection is ~6% for operations within the first 72 h and ~30% for those after 72 h.[2] However, the rate is only ~0–1% in patients who receive closure management immediately after debridement, irrigation, and stabilization.[1,12] The presence of local soft tissue loss and periosteal stripping may facilitate the formation of deep infection and also results in problems for bone union. Moreover, the fixation methods and materials for fixation of the fracture are also significant factors in the development of deep infection.[14] Thus, it is clear that the stabilization of the fracture, the method being used, the fixation materials, and its biomechanical properties are of great importance in the management of open fractures. Intramedullary nailing is the current choice of employment in open fracture.[14,15] The important advantages of this technique are elastic fixation, early loading, early postoperative rehabilitation, and perfect stabilization, especially in diaphyseal fractures. However, it bears some disadvantages such as resistant anterior knee pain, the difficulty in providing the required stability in the tissues close to the metaphyseal fractures, and adverse affect on endosteal circulation. Moreover, infection is the most common complication secondary to the implementation of this approach.[12] Indeed, the incidence rate of infection following intramedullary nailing has been reported to be 24% in even Type I and II open fractures.[16] This high rate has been attributed to the technique used in the fixation of intramedullary nails.[17] Besides, some studies indicate that the cortical blood flow is reduced by 70% following the reaming process.[18-20] In this regard, it is believed that managing open fractures with small nails and without reaming may lead to lower complication rates. Studies have shown that both techniques result in temporary cortical necrosis at various levels.[20] Even if the resultant necrosis has a short time, this complication plays a key role in the development of resistant and deep infection,[21] whose rate may vary with the type of fractures depending on the technique.[22] The indications for the external fixator method have been restricted due to low patient tolerance, the need for frequent checks, the high risk of pin tract infections, and the risks of instability and malunion.[22,23] This system, particularly Ilizarov external fixator, is still the method of choice for defective open fractures and contaminated fractures. The design, size, surface conditions, and biocompatibility of the implant used play major roles in bacterial colonization and biofilm development.[17,24,25]

The implant/bone tissue contact surface and implant compression on the endosteum and periosteum are also responsible for the formation of biofilms. The optimal design of implants should maintain blood supply and avoid bone necrosis because the size of the contact surface between the implant and the bone tissues and the amount of compression on the periosteum and endosteum are correlated with the risk of infection development.[15,24] To reduce the development of infections around after internal fixation, the vitality of the bone should be preserved to optimize cellular and humeral host defense mechanisms. The intramedullary nailing technique provides the largest implant/bone tissue contact surface, and it also leads to serious compression on the vascular tissues in the endosteal area. Both traumatic damage to the periosteal circulation and iatrogenic damage to the endosteal circulation are predisposing factors for the development of severe complications such as infection and nonunion.

Sanders *et al.*[26] reported the union times as 4.7 months in Type II, 8.27 months in Type IIIA, and 9.30 months in Type IIIb fractures. These union times were also confirmed by other studies in the literature.[27,28] The shorter duration (19.7 weeks) observed for the union in our study is one of the advantages of our technique. In open fractures, we assume that NC-LP technique covers the advantages of both internal and external fixation materials because the external fixator's contact with the bone tissue is as much as a K-wire or a Steinman pin diameter. This feature is an important factor in minimizing the infection since there is a direct correlation between the amount of a material's contact with the bone tissue and infection.[24,25] However, in the NC-LP technique, the amount of contact between implant and bone tissue is just as much as the screws' width used. On the other hand, in this technique, as the leverage arm is not as long as external fixator, it provides a stabilization equal to or close to a conventional plate screw system.[29] This feature is an important factor in the fracture union as well. As a result, in the NC-LP technique, as the amount of contact between implant and bone tissue decreases, we conclude that it minimizes the two important features of bacteria such as colonization and biofilm. On the other hand, we are of the opinion that a stabilization is obtained at a desired level, which minimizes the bone union problem.

Our results are satisfactory compared with those of other studies. Nevertheless, further investigation and experimentation with larger series are necessary.

Conclusion

The NC-LP method with aggressive debridement and wound cleansing followed by early prophylactic bone grafting in open fractures is recommended for achieving stable fixation with no contact between the implant and the bone tissues, and it also reduces nonunion and delayed union rates, shortens the time to union, and does not increase the infection while maintaining the blood supply. Nevertheless, further investigation and experimentation with larger series are necessary.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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