Journal of Orthopaedics, Trauma and Rehabilitation 15 (2011) 57–61

Contents lists available at ScienceDirect

Journal of Orthopaedics, Trauma and Rehabilitation

Journal homepages: www.e-jotr.com & www.ejotr.org

Original Article

Stainless Steel 2.0-mm Locking Compression Plate Osteosynthesis System for the Fixation of Comminuted Hand Fractures in Asian Adults
應用2.0毫米不銹鋼鎖定加壓鋼板(LCP)骨接合系統以治療亞洲成年人手部粉碎性骨折的臨床經驗

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ARTICLE INFO

Article history:
Accepted December 2010

Keywords:
hand fractures
locking compression plate

ABSTRACT

Objective: The aim of this retrospective study was to analyse the clinical outcome of the application of stainless steel 2.0-mm locking compression plate (LCP) system for the treatment of comminuted hand fractures in Asian adults.
Methods: Six patients who had comminuted hand fractures were treated by open reduction and internal fixation with the application of stainless steel 2.0-mm LCP (AO Compact Hand System; Synthes, Oberdorf, Switzerland) from December 2009 to October 2010. The total arc of motion of fingers, grip power, complications, and additional surgery were recorded.
Results: Three out of six patients eventually restored good hand functions in terms of the total arc of finger motion (>220°) and grip power. The commonest complication was skin impingement in finger region by the implant (4 cases). Another common complication was restricted range of motion (3 cases). One patient had minimal degree of malrotation of his left little finger. Additional surgery was required in all the patients for implant removal (6 cases), tenolysis (3 cases), and capsulotomy (2 cases).
Conclusions: The stainless steel 2.0-mm LCP is useful for the fixation of unstable comminuted hand fractures, especially in metacarpal bones, because of its advantage of better stability, which allows more aggressive rehabilitation. However, its design is not very versatile and, therefore, limits its use in the finger region. Its bulkiness frequently causes implant impingement. The patients must be informed about the chance of implant removal later.

中 文 摘 要

目的: 回顧研究 2.0毫米不銹鋼鎖定加壓鋼板(LCP)骨接合系統應用於治療亞洲成年人手部粉碎性骨折的臨床效果。
方法: 於2009年12月至2010年10月期間，六位有手部粉碎性骨折的病人接受了開放式復位及2.0毫米不銹鋼鎖定加壓鋼板(LCP)骨接合系統骨折內固定手術的治療。並記錄其手指的總活動弧度、手握力、併發症及附加手術。
結果: 六位病人中有三位最終恢復良好的手部功能，其手指的總活動弧度大於220度和有良好的手握力。最常見的併發症是手指的皮膚被植入的金屬鋼板撞擊(4個個案)、手指活動僵硬(3個個案)、左尾指輕微轉位異常(1個個案)。所有的病人均須接受附加的手術，當中包括拆除植入的鋼板(6個個案)、肌腱鬆解手術 (3個個案) 及關節囊切開術(2個個案)。
結論: 2.0毫米不銹鋼鎖定加壓鋼板(LCP)骨接合系統能夠應用於手部不穩定粉碎性骨折，尤其是掌骨。因它能提供良好而鞏固的骨折固定，有利於病人在手術後接受進取的康復治療。然而，它的設計不是很靈活，因此限制了它在手指區域的使用。最常見的問題是手指的皮膚被植入的厚金屬鋼板衝擊，所以病人接受有關手術前應告知日後有可能需要拆除已植入的金屬鋼板的可能性。

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doi:10.1016/j.jotr.2011.04.004

Introduction

The outcome of hand fractures correlates closely with the severity of initial injury.[1–6] The risk factors include injuries of the tendons and tendon sheaths, damage of the articular cartilage, comminution of fractures, severely crushed soft tissues, bone loss, aggressive surgical dissection, delay of treatment, and the implant itself. With better and stable implants, instrumentations, operative techniques, and rehabilitation therapy, fracture healing and better functional recovery have ensued.[7,8]

A stable bony construct that allows early tendon gliding and joint movement encourages good bone union and minimises joint and tendon complications.[9,10] In some biomechanical studies, plating for comminuted fractures provided superior rigidity when compared with other fixation methods.[11] The disadvantages of plating are their bulkiness and indulging an additional "surgical injury" to the soft tissue causing devascularisation of bone fragments, thus increasing the risks of subsequent tendon adhesions and stiffness by fibroplasia.[7,12,13] It may also interfere with tendon gliding. The removal of plate and secondary tenolysis for persistent stiffness were frequent.[3,14,15] Therefore, the application of plates is a "double-edged sword."

The main proposed advantage of the new 2.0-mm locking compression plate (LCP) system is the increased mechanical strength and improved stability of fracture fixation. The aim of this study is to review the functional outcome and complications of our Asian patients who have smaller hands compared to the Western patients.

Materials and Methods

Six Asian patients who had comminuted hand fractures undergoing internal fixation with stainless steel 2.0-mm LCP (Synthes) (Figure 1) were retrieved from December 2009 to October 2010. All patients were male adults and operated by two hand surgeons under general anaesthesia. All operations were performed electively and under mini image intensifier (Xi-scan) control. The indications were unstable fractures with comminution. We used mid-axial approach for proximal phalangeal fractures and dorsal approach for metacarpal fractures.

All patients were offered post-operative physiotherapy and occupational therapy. One patient needed extensor dynamic splint for extensor tendon rupture after its repair. Two patients had protective metacarpal braces after the fixation of the 5th carpometacarpal joint dislocation and the comminuted intra-articular fracture of the 5th metacarpal base. Otherwise, passive finger mobilisation exercise was started 3 weeks post-operatively by the physiotherapists for more aggressive rehabilitation. One patient defaulted the rehabilitation program. All patients had regular follow-up, and the clinical progress was recorded. These illustrative cases are summarised in Table 1.

Results

The average follow-up duration was 9 months. The commonest aetiology was crushing injury. All were closed fractures with various degrees of soft tissue injury. There were four cases of proximal phalangeal fractures, with two having intra-articular involvement of the base. There were three cases of metacarpal fractures, including two basal and two shaft fractures. One case was associated with extensor tendon rupture and one with dislocation of the adjacent joint. All the fractures healed uneventfully without implant failure. The total arc of motion of the injured fingers was variable. Only three out of six patients eventually restored good hand functions and returned to original duty. Their total arc of finger motion was greater than 220°, and hand grip power was good. The commonest complication was skin impingement in fingers by the implants (4 cases). Another common complication was restricted range of finger motion (3 cases). One patient had minimal degree of malrotation of his left little finger. Additional surgery was required for all patients in terms of implant removal (6 cases), tenolysis (3 cases), capsulotomy (2 cases), or combination. Skin impingement in fingers was the commonest indication for implant removal (4 cases) (Table 2).

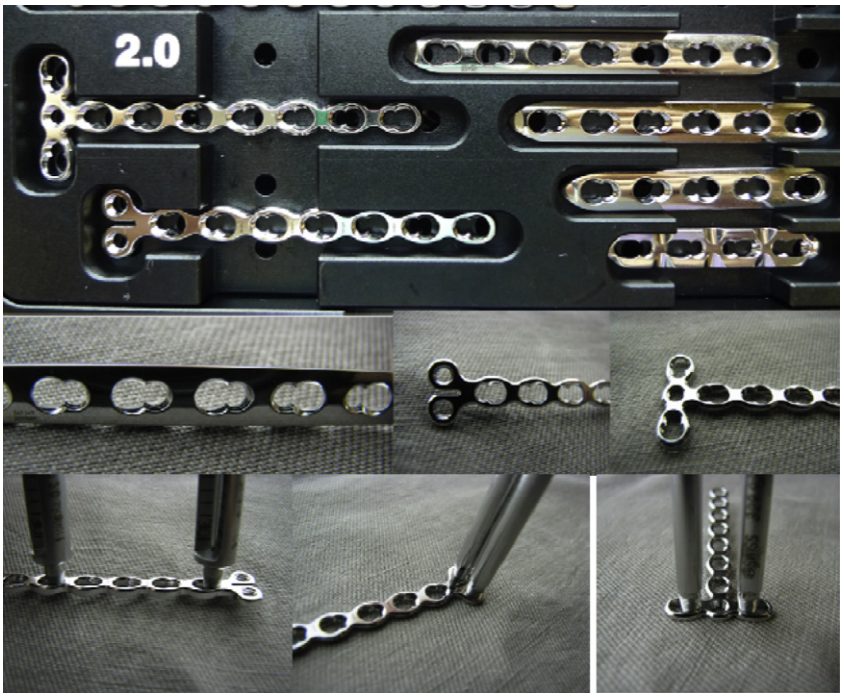

Figure 1. AO stainless steel 2.0-mm locking compression plate Compact Hand System.

Table 1
Patient demographics and fracture types

Case	Age/sex	Occupation	Aetiology	Laterality	Fracture (digit/bone/intra-articular/comminution/tendon injury)	Compound	Injury-to-surgery interval (d)
1	30/M	Manual worker	Crush	Left	Index, PP base Intra-articular, comminution	Nil	2
2	41/M	Manual worker	Crush	Right	Ring, PP shaft Comminution	Nil	11
3	19/M	Manual worker	Crush	Right	5th MC shaft Completely cut EDM tendon at Zone VI	Nil	2
4	27/M	Clerical	Contusion	Right	4th MC shaft Dorsal dislocation of 5th CMCJ	Nil	3
5	38/M	Teacher	Contusion	Right	4th and 5th MC bases Intra-articular, comminution	Nil	7
6	42/M	Clerical	Traction	Left	Ring, PP shaft Little, PP shaft and base Intra-articular, comminution	Nil	2

CMCJ = carpometacarpal joint; EDM = extensor digitorum minimus; M = male; MC = metacarpal; PP = proximal phalanx.

Discussion

The miniature plate system is particularly useful for hand fractures, especially those with severe bone comminution, segmental bone loss, intra-articular fractures and open fractures. It enables rigid fixation to decrease pain and oedema so to allow early mobilisation exercise. This can minimise the restrictive scarring that can hinder the gliding of tendinous structures surrounding the phalanges.[16]

The complications of early stainless steel mini-plate fixation resulting in pain, prominence, and impingement of the plate; infection; and tendon adhesions were high in some earlier studies.[3,8,9,14,17,18] The titanium mini-plate system has shown few complications when used in complex injuries of the hand.[1,15,19–21] However, breakage of titanium screws during screw removal or insertion and breakage of titanium plate because of delayed union or non-union were not uncommon. Moreover, significant adhesion between the tendon and the titanium plate was noted during the secondary operative procedures (including removal of the plate and screws, capsulotomy, and tenolysis). Although the initial soft tissue injury and the injury from the surgical dissection may contribute to the adhesion, it is also related to the surface topography of the titanium implant, which is neither polished nor smoothed.[22] Therefore, we prefer using stainless steel implants instead of rough titanium implants in the management of hand fractures.

We adopted mid-axial approach and lateral placement of the plates or screws for all proximal phalangeal fractures in an effort to move the zone of surgical injury away from the extensor

Table 2
Rehabilitation and outcomes with 2.0-mm stainless steel locking compression plate

Case	Approach/operation/implants	Rehabilitation	Fu (mo)	TAM (°)	Grip power (compared with other side)	Complications/additional procedure	X-ray illustrations
1	Mid-axial/ORIF/condylar plate	Early passive mobilisation	10	230	Comparable	Implant impingement Implant removal	Figure 2
2	Mid-axial/ORIF/condylar plate	Early passive mobilisation	11	185	Diminished	PIPJ 40° flexion contracture Implant impingement Implant removal and extensor tenolysis	Figure 3
3	Dorsal/ORIF/condylar plate, extensor tendon repair	Dynamic extensor splint, 3 wk	10	130	Diminished	Stiffness (extension contracture) at 5th MCPJ, only 15° of flexion range Implant removal, extensor tenolysis, and dorsal capsulotomy	
4	Dorsal/ORIF/straight plate (4th MC), CR, K-wire fixation (5th CMCJ dislocation)	Protective brace K-wire, 6 wk	9	225	Comparable	No complication Preferred implant removal	Figure 4
5	Dorsal/ORIF/T-plate (4th MC base), CR, transmetacarpal K-wire fixation (5th MC)	Metacarpal brace, 6 wk	7	230 and 240	Comparable	No complication Preferred implant removal	
6	Mid-axial/ORIF/condylar plate (ring finger) Mid-axial/ORIF/straight plate (little finger)	Early passive mobilisation	6	210 (ring) and 150 (little)	Diminished	Stiffness of MCPJ and PIPJ of little finger Mild rotational malalignment of little finger Implant impingement on both fingers Removal of implants, extensor tenolysis for both fingers, and dorsal capsulotomy of MCPJ of left little finger	

CMCJ = carpometacarpal joint; CR = closed reduction; K-wire = Kirschner wire; MC = metacarpal; MCPJ = metacarpophalangeal joint; ORIF = open reduction and internal fixation; PIPJ = proximal interphalangeal joint; TAM = total arc of motion.

Figure 2. Displaced intra-articular fracture of the base of proximal phalanx of left index finger was reduced and fixed with stainless steel 2.0-mm locking compression condylar plate.

mechanism. It could minimise the risk of tendon adhesions and decrease in stiffness as reported in literature.[23] Freeland et al[24] reported that unilateral excision of the lateral band and oblique retinacular fibres of the metacarpophalangeal joint extensor expansion could decrease the risk of post-operative adhesions, tissue irritation, and intrinsic tightness when the plate was inserted on the lateral aspect of the proximal phalanx.

The aetiology of the finger stiffness included associated soft tissue injuries, such as extensor tendon injury; bony comminution; and delayed mobilisation exercise from bracing, which resulted in tendon adhesion and secondary joint contracture. The strength of the stainless steel miniature plate could not sustain passive motion especially in case of comminuted fracture. Therefore, we attempted to use stainless steel 2.0-mm LCP system to provide a more stable fixation for the comminuted fractures of the hands to allow early passive mobilisation exercise and aggressive rehabilitation.

The indications of Arbeitsgemeinschaft für Osteosynthesefragen 2.0-mm LCP in hand fractures are the same as those for the conventional plates. However, it is particularly useful for the management of comminuted fractures of metacarpals and proximal phalanges, periarticular fractures, arthrodeses, and malunion requiring corrective osteotomy, because the locking plates can provide good stability for comminuted fractures without the application of axial compression as in conventional plates. It acts as an internal fixator requiring a minimum of two locking screws on each side of the fracture. The fixed-angle locking plate screws will add more strength to the bone-plate construct through locking mechanism to achieve more reliable fixation and greater angular stability than the conventional plate (which depends on the frictional resistance between the plate and bone to achieve the absolute stability). This is crucial for aggressive rehabilitation protocol. We do not have any implant failure in our cases. Moreover, the blood flow of the bone beneath the LCP will not be jeopardised. Furthermore, it can be used in cases of bone loss, poor bone stock, and poor bone quality. In addition, it is particularly useful for periarticular fracture pattern as two locking screws on juxta-articular fragment will be strong enough. There is no pin tract problem, which is common in percutaneous Kirschner wires or mini-external fixation.

Some drawbacks of this implant were found. First, the plate should be used only for proximal phalanges and metacarpal bone fractures because of its bulkiness. Second, because of its relatively thick plate design, it should only be placed on the lateral surface of proximal phalanx, otherwise it would interfere with tendon gliding. Third, the surgical approach is not versatile; hence, it is difficult to fix the fractures in the coronal plane. Fourth, the design

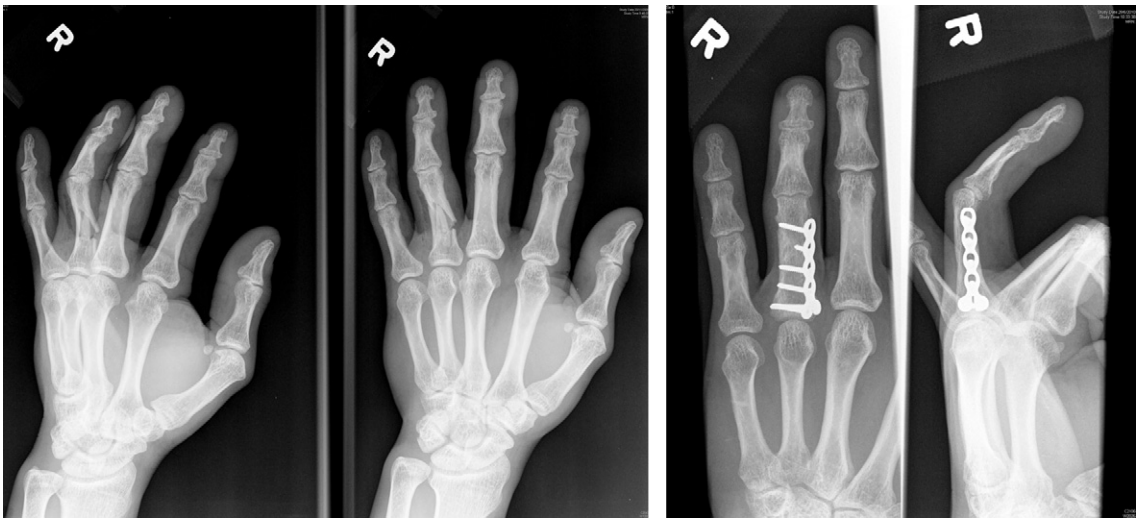

Figure 3. Displaced comminuted fracture of shaft of proximal phalanx of right ring finger was reduced and fixed with stainless steel 2.0-mm locking compression condylar plate.

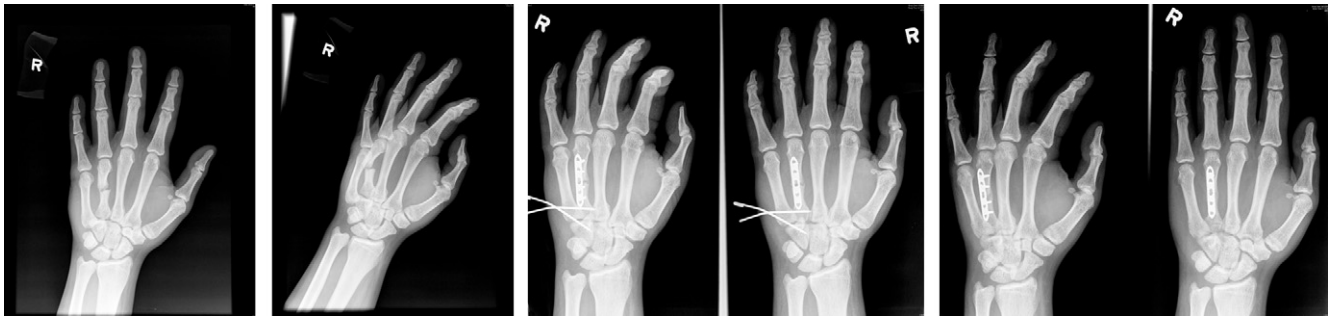

Figure 4. Displaced fracture shaft of right 4th metacarpal and dorsal dislocation of 5th carpometacarpal joint were reduced and fixed with stainless steel 2.0-mm locking compression straight plate and K-wires, respectively.

of the combi-holes makes the intervals between the screw holes wider so that a longer plate is inevitably needed. The design of combi-holes may sometimes jeopardise the fixation of periarticular fracture as less number of screws can be inserted. Finally, its significant thickness, which causes plate impingement on the skin or soft tissue, renders implant removal a frequent secondary procedure especially in fingers. These problems can be solved by using 1.5-mm titanium low-profile locking microplate system with highly polished surface because it is thinner and has coaxial locking holes design instead of combi-holes. The microplate system (1.5 mm) seems to be more suitable than mini-plate (2.0 mm) for the management of fractures distal to metacarpophalangeal joint, and the 2.0-mm LCP is more appropriate for metacarpal fractures in Asian patients who have smaller hand.

However, simple Kirschner wire fixation and conventional plating definitely still play an important role in providing cost-effective fracture management in hands worldwide. Suitable case selection for 2.0-mm LCP system is indicated because of the high cost and its limitation. Further studies to be carried out to compare the outcome for different surgical fixation methods *in vivo* are required.

In the study, we found that temporary Kirschner wire fixation of the phalangeal fractures would facilitate the application of the locking plate. Mild bending of the plate sometimes is needed for the basal fractures of proximal phalanges. In conclusion, the stainless steel 2.0-mm LCP system is useful for the treatment of comminuted hand fractures, especially metacarpal fractures, in Asian Adults. It provides a rigid and reliable fixation of the fractures with better strength through the locking mechanism between the threaded screw head and the locking plate. It also allows early passive mobilisation exercise. The commonest clinical problem is the impingement on the skin of finger regions because of its bulkiness. The patients must be informed of the chance of implant removal later.

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