Internal fixation of fractures of both bones forearm: Comparison of locked compression and limited contact dynamic compression plate

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Abstract

Background: The locking compression plate (LCP) with combination holes is a newer device in fracture fixation. We undertook a study comparing the LCP with limited contact dynamic compression plate (LC-DCP) in the treatment of diaphyseal fractures of both bones of the forearm.

Materials and Methods: This is a prospective comparative study, 36 patients (18 in each group) with fractures of both the forearm bones (72 fractures) were treated with one of the two devices. The average age of the patients was 30.5 years (range 16–60 years) with mean followup of 2.1 years (range 1.5–2.8 years). The patients were assessed for fracture union and function and complications and by Disabilities of the Arm, Shoulder and Hand (DASH) score for patient related outcome at the latest followup.

Results: There was no significant difference in two groups with respect to the range of movements or grip strength. One case had delayed union (LC-DCP group) and another had synostosis (LCP group). Plate removal was done in four cases within the study period with no refracture till the presentation of this report.

Conclusion: LC plating is an effective treatment option for fractures of both bones of forearm. The present study could not prove its superiority over LC-DCP.

Key words: Diaphyseal forearm fractures, limited contact dynamic compression plate, locking compression plate, plate fixation, radius and ulna

Introduction

It is essential to regain length, apposition, axial alignment and normal rotational alignment while treating diaphyseal fractures of the radius and the ulna to gain good range of pronation and supination. The chances for the occurrence of malunion and non-union are greater because of the difficulties in reducing and maintaining the reduction of two parallel bones in the presence of the pronating and supinating muscles, which have angulatory as well as rotatory influences.[1] Open reduction and internal fixation with plating is generally accepted as the best method of treatment for displaced diaphyseal fractures of the forearm in the adult.[2] The value of compression in obtaining rigid internal fixation had been noted by various authors.[3-5] Compression techniques have a lower incidence of non-union and are found to hasten rehabilitation, with less joint stiffness.[6-11] In conventional plating, the actual stability results from the friction between the plate and the bone, which in turn may prevent periosteal perfusion.[12,13] The biologic plating entails a sufficiently stable fixation of the bone fragments, allowing early mobilization without major disturbance of the vascularization.[14] The limited contact dynamic compression plates (LC-DCP), developed in 1991, was said to reduce the bone–plate contact by approximately 50% to minimise the disruption of periosteal blood vessels beneath the plate.[13] But the LC-DCP still relied on the plate–bone interface for stability[12,13] and the problem of confluent contact areas was not completely resolved. Later on, the Point Contact Fixator (PC-Fix), which did not have surface contact with the bone but only point contacts, was developed.[12] Leung *et al*. in a prospective, randomized trial comparing the LC-DCP with the PC-Fix in the treatment of forearm fractures concluded that the two

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implants appeared to be equally effective for the treatment of diaphyseal forearm fractures.[12]

Locking compression plate (LCP) was devised by combining the features of a LC-DCP and a PC-Fix.[12] Theoretically, this allows for more rapid bone healing besides decreasing infection, bone resorption, delayed union/non-union and secondary loss of reduction.[13] But reports on the results of clinical application of LCP are few, especially on its efficacy, or superiority over other plates in the treatment of diaphyseal fractures of forearm bones.[2,15-17] Hence, we considered it worthwhile to conduct a comparative study to assess the superiority of LCP over LC-DCP, if any, in the treatment of fractures of both bones of forearm.

Materials and Methods

This prospective comparative study, conducted from May 2006 to March 2009, consists of 36 patients of fractures of both bones of forearm, who gave informed consent. The ethical clearance was obtained from institutional ethics committee. Inclusion criteria were (i) age between 16 and 60 years, (ii) fresh (<21 days old) closed or Type I compound diaphyseal fracture of both bones of forearm, (iii) competent neurological and vascular status of the affected extremity, (iv) with good function of shoulder, elbow, wrist and finger joints and (v) without any other associated ipsilateral or contralateral major limb injury affecting treatment or rehabilitation protocol. Cases with pathological fracture, history of long-term steroid therapy and clinically detectable disease like rheumatoid arthritis were excluded from the study.

The patients were randomly assigned to either of the two groups after block randomization with a random number table. There were 25 males (70%) and 11 females (30%), with an average age of 30.5 years (range 16–60 years). Fourteen (39%) of the patients had a high-energy trauma as the causative injury while the rest 22 (61%) were with history of low-energy trauma. The fractures were classified according to the AO alpha-numeric classification system [Table 1]. One group (18 cases) was treated with open reduction and internal fixation with LCP, and the other group (18 cases) was treated with LC-DCP. 3.5 mm titanium LCP and LC-DCP were used (Synthes, Switzerland) for fixation. There were eight Type I compound fractures according to Gustilo and Anderson classification, of which four each were fixed with LCP and LC-DCP. Operations in both the groups were performed by three experienced surgeons, employing surgical techniques described by the AO/ASIF group. In LCP fixation for axial compression, the plate was first fixed with a conventional screw after reducing the fracture, followed by another conventional screw in the opposite fragment. Locking head screws were used for the rest of the screw holes. For the bridging technique, only locking head screws were used. We uniformly used bicortical locking head screws.

The patients were followed up clinicoradiologically for a minimum period of 6 months. Initially the patients were evaluated every 3–4 week intervals till the fractures union, every 6 weeks thereafter for 3 months and then at 3 monthly intervals. The results were evaluated on the basis of fracture union, range of movements, muscle (grip) strength and complications. Union was assessed based on the criteria of Anderson *et al*.[3] Fractures which healed in less than 6 months were classified as unions; those which required more than 6 months to unite but without any additional operative procedure were classified as delayed unions; and those which failed to unite without further operative intervention were classified as non unions. The functional outcome was assessed using the criteria [Table 2] of Anderson *et al*.[3] The quality of reduction of the fractures was assessed using the criteria of Leung *et al*.[2] Anatomical reduction indicates precise anatomical alignment with reduction of wedge fragments and fixation with lag screws. In nonanatomical reductions, the main fragments are adapted but not compressed, and no precise anatomical reduction of fragments is achieved. The complications were evaluated in terms of infections (superficial or deep or chronic osteomyelitis), non-union, synostosis, implant loosening and secondary loss of reduction, implant breakage, refracture, fracture at the end of the plate, and fracture through the compression hole. Grip strength was tested using a hand-held dynamometer by one of the authors. The values at the latest followup

Table 1: Fracture pattern based on AO classification

AO type	No. of patients		
	LCP	LCDCP	Total
22-A3.1	3	6	9
22-A3.2	4	7	11
22-A3.3	1	0	1
22-B3.1	3	0	3
22-B3.2	2	3	5
22-B3.3	4	1	5
22-C1.2	0	1	1
22-C2.2	1	0	1

AO: Arbeitsgemeinschaft für osteosynthesefragen; LCP: Locking compression plate; LCDCP: Limited contact-dynamic compression plates

Table 2: Anderson *et al.*[3] criteria for assessment of functional outcome

Result	Union	Flexion and extension at wrist joint	Supination and pronation
Excellent	Present	<10° loss	<25% loss
Satisfactory	Present	<20° loss	<50% loss
Unsatisfactory	Present	<30° loss	>50% loss
Failure	Non-union with or without loss of motion		

were used. The patient rated outcome was assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, a 30-item questionnaire intended to assess the function and symptoms of patients with disorders of the upper limb.

Statistical analyses were made using the software "GraphPad InStat". Differences were considered significant when the P value was <0.05.

Results

The time required for LCP fixation (mean 93.05 min, range 75–180 min) was found to be more than that required for LC-DCP (mean 81.94 min, range 60–100 min). But this time difference was not significant ($P=0.09$, unpaired t test).

Sixty-seven percent ($n=12$) of the fractures in the LCP group and 86% ($n=15$) of those in the LC-DCP group were found to have anatomical reduction and the rest had non-anatomical reduction. This difference was not be significant ($P=0.09$, Fischer's exact test). The amount of callus formed at the fracture site was assessed [Figure 1] using the criteria of Leung *et al.*[2] Fifty-six percent ($n=10$) of the forearms in the LCP group healed with radiological evidence of callus formation of which 17% ($n=3$) showed abundant callus formation, 22% ($n=4$) showed moderate callus, 17% ($n=3$) showed minimal callus and the rest 44% ($n=8$) had no callus formation. In the LC-DCP group, 83% ($n=15$) of the forearms did not show any callus formation, 11% ($n=2$) showed minimal callus, 6% ($n=1$) showed moderate callus while none had abundant callus. The two groups were found to differ significantly ($P=0.04$, Fischer's study exact test) when compared with respect to the number of forearms that healed with abundant or moderate callus and those that healed with minimal or no callus radiologically. One out of the eight anatomically reduced forearms (12.5%) fixed with LCP showed callus formation while none of the 14 anatomically reduced forearms fixed with LC-DCP showed any evidence of callus formation. Of the non-anatomically reduced forearms, 90% (9 out of 10 forearms) of those fixed with LCP showed evidence of callus in comparison to 75% (3 out of 4 forearms) in the LC-DCP group. In both the LCP and the LC-DCP groups, the difference between the cases that had been reduced anatomically and non-anatomically, with respect to the presence of callus, was found to be very significant ($P=0.002$ and 0.004, respectively).

One patient of LC-DCP group had delayed union, which ultimately united without any secondary procedure. The mean time of union for the forearms fixed with LCP was found to be 14.16 weeks (range 8–21 weeks) in comparison to 16.27 weeks (range 10–29 weeks) for the LC-DCP group. This difference was statistically not significant ($P=0.09$, unpaired t test).

The mean ranges of elbow, wrist joint and pronation–supination movements in the LCP group were 146.9, 147.77 and 145°, respectively, while they were 141.4, 140.55 and 141.66°, respectively, for the LC-DCP group. The two groups were not significant with respect to these range of movements ($P=0.09$, 0.14 and 0.66, respectively, unpaired t test). We had excellent functional outcome [Table 3] in 32 patients (89%), satisfactory outcome in 3 (8%), unsatisfactory outcome in 1 (3%) without any failure case. Reduction in the ranges, if any, was expressed as percentage. The statistical data provided are the ones comparing each of the three movements for LCP and LC-DCP groups.

The grip strength of the involved side ranged from 80 to 100% of that of the contralateral side in the LCP group and from 60 to 100%, in the LC-DCP group. The two groups did not reveal any significant variation with respect to the grip strength ($P=0.40$, unpaired t test). The DASH questionnaire was used to assess the outcome subjectively. The score was seen to be higher in patients who did not regain their full range of motions at the wrist and forearm. Overall, the patients were satisfied with the outcome in both the groups. The DASH scoring was performed from 6 months onward. The score at the latest followup was considered. The raw scores ranged from 0 to 22.32 in the LCP group and from 0 to 44.44 in the LC-DCP group.

A patient of the LC-DCP group developed transient radial nerve palsy postoperatively, which improved with

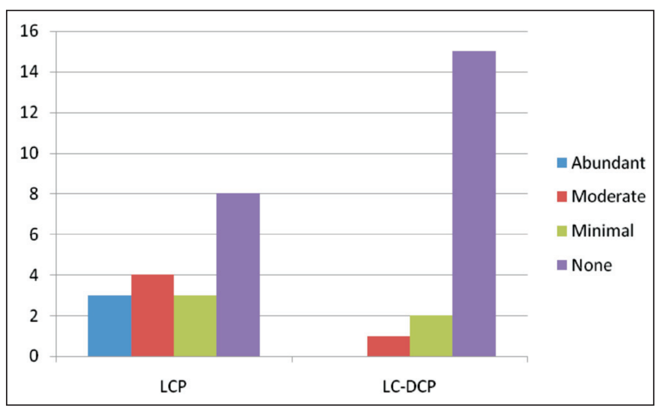

Figure 1: The graphic representation of callus formation; LCP: locking compression plate; LC-DCP: limited contact-dynamic compression plates

Table 3: Functional outcome

Group	Excellent	Satisfactory	Unsatisfactory	Failure
LCP	16 (88)	2 (12)	0	0
LC-DCP	16 (88)	1 (6)	1 (6)	0

LCP: Locking compression plate; LC-DCP: Limited contact-dynamic compression plates conservative management by the 6th postoperative week and recovered fully by the end of 12th week.

Two patients (closed fractures) fixed with LC-DCP had superficial infection, which subsided uneventfully following antibiotic therapy. One patient belonging to the LCP group developed deep infection, which progressed to osteomyelitis, with lytic areas in the bones beneath the plates. The infection subsided completely with third generation cephalosporin antibiotics and the fractures healed uneventfully by the 21st week with moderate callus, without any secondary surgical intervention.

We came across a radio-ulnar synostosis in a patient of the LCP group. We did not remove implants for at least 18 months postoperatively or unless clearly indicated. We removed implants in one of our patients in 15 months following painful bursa formation over the ulnar side. Another three patients had implants removed after 18 months (LCP-1, LC-DCP-2).

Discussion

Open reduction and plate fixation has been the standard treatment of adult diaphyseal forearm fractures.[2] But the most effective type of plate fixation for diaphyseal fractures of forearm bones has not been well defined.[12] Locked plates the "internal external fixators", does not rely on frictional force between the plate and the bone to achieve compression and provide absolute stability. Thus, the local blood supply under the plate to be preserved,[13] thereby leading to superior bone healing and minimal complications. It has been proved to be valuable in situations like osteoporosis, comminuted fractures, complex intraarticulaar fractures or fractures in close proximity to the joints, upper extremity fractures.[18-20] Atsunori *et al*. had stated that LCP is now considered to be superior to the conventional plating system in the treatment of forearm fractures.[21] But there is scarcity of information comparing LCP with conventional plating in the literature.

LCP fixation was found to consume more time (mean 93.05 minutes) compared to that required for LC-DCP fixation (mean 81.94 min). This time difference was statistically not significant.

Leung *et al*. in their randomized control trial (RCT) comparing LC-DCP with PC-Fix had found 100% union with a mean period of 17 and 18 weeks, respectively, for closed fractures.[12] In his another series of LCP, there was 100% union, with a mean of 20 weeks.[2] The more recent study of Stevens *et al*. had 100% union rates in both LCP and DCP groups. They even found the consolidation time favoring the DCP.[17] Our study had a union rate of 100%, with one delayed union in the LC-DCP group and none in the LCP group. The mean time of union (14.16 weeks, range 8–21 weeks) in the LCP group [Figure 2] was found to be lesser in comparison to LC-DCP group [Figure 3]. The efficacy of the two implants with respect to the different fracture morphologies was not compared since we felt that the subgroups did not have adequate numbers for the results to be significant.

In non-anatomical reduction plate was applied in a bridging mode, or a conventional mode without compression, or where small comminuted fragments are not precisely adapted for fear of avascularity. Since callus formation was found to be more in the non-anatomically reduced forearms, we agree with Leung[2] that it is the quality of reduction and control of stability in LCP which determine the type and speed of healing. It also supports Wagner's view that the locked internal fixator technique allows but does not require precise reduction and that it gives priority to biology over mechanics.[22] The two

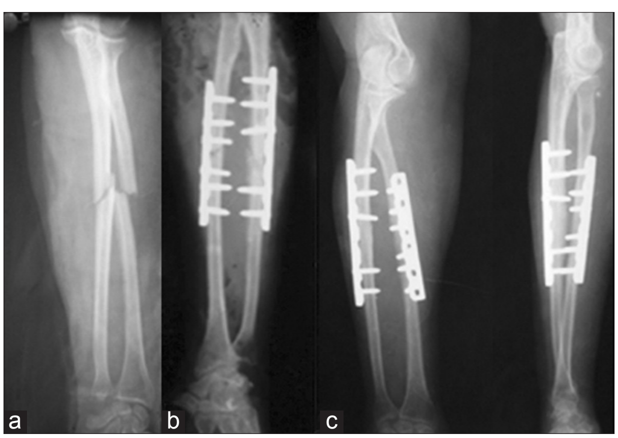

Figure 2: (a) Preoperative X-ray of the forearm shows fracture of both bones; (b) immediate postoperative X-ray (anteroposterior and lateral views) following LCP fixation and; (c) X-ray (anteroposterior and lateral views) after 10 months of followup shows fracture union

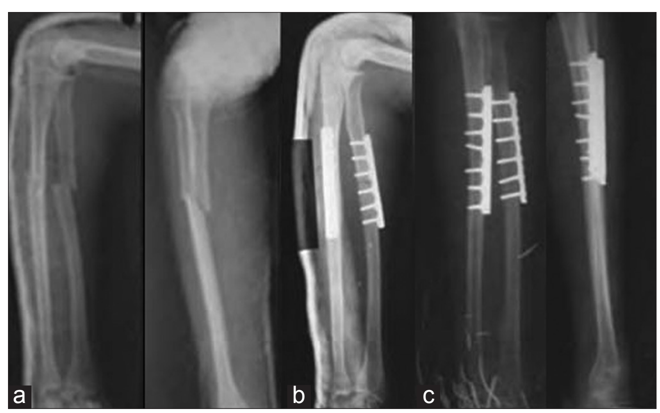

Figure 3: (a) Preoperative X-ray anteroposterior and lateral views showing fracture of both bone forearm; (b) immediate postoperative X-ray following LC-DCP fixation and; (c) X-ray (anteroposterior and lateral views) of LC-DCP fixation after 15 months of followup shows sound union

groups were found to differ significantly with respect to callus formation, which obviously highlights the biologic nature of LCP plating. Locked plates are already known to function as internal fixators in fractures with a wider gap and strain less than 10%, providing a sufficient stability conducive to secondary bone healing through enchondral ossification.[13] Osteomyelitis had occurred in one case with 22-C2.2 fracture. Even though there was severe lysis of the underlying bone beneath the plate, there were no signs of screw backout or plate loosening. The fractures healed by the 21 week with moderate callus formation without any implant loosening, breakage, delayed/non-union, synostosis or refracture and need for secondary surgical procedure. The locking screw into the plate ensures angular as well as axial stability, eliminates the possibility for the screw to toggle, slide or dislodge, and thus strongly reduces the risk of postoperative loss of reduction.[22] We could not bring out statistically significant difference in the other outcome parameters between the two groups treated with LCP and LC-DCP. Thus, the results of the present study are comparable with the reported literatures[2,3,6,12,17] in terms of functional outcome and complication rates and are rather found to be superior in terms of union rates.

The risk of refracture following plate removal has been reported to be between 4 and 25%.[3,6,23,24] Leung *et al*. had reported one refracture in both the groups after implant removal in his RCT comparing LC-DCP with PC-Fix.[12] He also reported 2 refractures in his LCP series, where the plates were removed by 12 months and he recommended not to remove the implants within 18 months of fixation.[2]

The limitation of this study is small sample size study from a single center hence significant conclusions could not be drawn.

LC plating is an effective treatment option for fractures of both bones of forearm. The outcome is determined by using proper principles of plating. The present study could not prove its superiority over LC-DCP. It is the proper application of the principles of plating and not the type of plate which decides the outcome. Further long-term multicentric study is required to *prove* behaviors of the implant.

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