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EFFECTIVENESS OF LOCKING VERSUS DYNAMIC COMPRESSION PLATES FOR DIAPHYSEAL FOREARM FRACTURES

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ABSTRACT

This study compares the results of the locking compression plate (LCP) and the dynamic compression plate (DCP) in the treatment of diaphyseal forearm fractures in adults and defines the indications for the use of the LCP. Forty-two patients with diaphyseal forearm fractures were retrospectively analyzed. Of those, 22 had been treated with the LCP (LCP group) and 20 had been treated with the DCP (DCP group). The AO/ASIF classification was used to classify the fractures. Patients were assessed using the Grace-Eversmann criteria and the Disabilities of the Arm and Shoulder and Hand questionnaire during the final follow-up. Mean follow-up was 21 months (range, 20-24 months) in the LCP group and 23 months (range, 19-26 months) in the DCP group. Union was achieved in all patients. Mean time to union was 15 weeks (range, 12-25 weeks) in the LCP group and 17 weeks (range, 13-24 weeks) in the DCP group. In each group, 1 patient experienced delayed union, which required no additional surgical intervention. No significant difference was found regarding the time to union between the groups ($P > .05$). No significant difference existed between the 2 groups in terms of Grace-Eversmann criteria and Disabilities of the Arm and Shoulder and Hand scores (both $P > .05$). The results of these different fixation methods for forearm fractures in adults are similar. As such, the correct selection and application of surgical technique is more important than the type of plate used.

A

B

Figure: Preoperative lateral radiograph of the forearm showing fracture of both bones (A). Lateral radiographs taken 10 months after locking compression plate fixation showing fracture union (B).

In the treatment of adult forearm fractures, the main goals are to reestablish forearm length, restore axial and rotational alignment and maintain them until union is achieved.[1] Open reduction and internal fixation with the use of a dynamic compression plate (DCP) is a recognized method for the treatment of diaphyseal forearm fractures in adults.[1-3]

Cortical porosis and refractures were considered secondary to excessive plate– bone contact in DCPs that interfered with cortical perfusion.[4] According to this theory, the limited contact DCP (LC-DCP) was developed to reduce the plate's interference with cortical perfusion, thus decreasing cortical porosis.[5] The subsequent development of the point contact fixator reduced plate–bone contact to the point that it was essentially negligible.[6]

Recently developed locking compression plates (LCPs) combine the properties of both locking plates and DCPs.[7] With their combined hole, an unlocked compression screw and a locking screw can be used.[7] Locking compression plates have been shown to provide a stronger fixation compared with DCPs in biomechanical studies.[8] In addition, LCPs can be placed using a bridging plate technique, allowing biological fixation for the treatment of comminuted fractures.[7] These advantages of the LCP have been considered to accelerate fracture healing and reduce the problems of delayed union and nonunion.[8]

However, LCPs have some disadvantages, including difficulties during removal and a higher cost.[9] A limited number of studies compare LCPs with conventional plates and have reported similar results with both implants in the treatment of diaphyseal forearm fractures.[10,11] Although LCPs have some theoretical advantages, the superiority of the LCP over conventional plates remains to be proven.

The goal of the current study was to compare the results of LCPs and DCPs in the treatment of diaphyseal forearm fractures in adults and to define the indications for the use of LCPs.

MATERIALS AND METHODS

A total of 51 patients treated with the DCP or LCP due to forearm fractures between 2008 and 2010 and 42 patients who had adequate follow-up were included in the study. Of those, 22 patients (17 men and 5 women; mean age, 28 years [range, 16-74 years]) were treated with the LCP (LCP group) and 20 patients (14 men and 6 women; mean age, 32 years [range, 16-69 years]) were treated with the DCP (DCP group). The AO/ASIF classification was used for fracture classification (Table 1).[12] The distribution of patients according to the fractured bone is shown in Table 2. In the LCP group, 2 patients had Gustilo-Anderson grade 1 fractures and in the DCP group, 1 patient had a Gustilo-Anderson grade 2 open fracture.[13] Patients with pathologic fractures, rheumatoid arthritis treated with corticosteroids for a long period of time, functional loss prior to the fracture, and inadequate follow-up were excluded from the study.

In the LCP group, 16 (73%).

Table 1: Distribution of Fractures According to AO/ASIF Classification

AO/ASIF Classification	LCP Group	DCP Group
A1	4	3
A2	2	2
A3	8	6
B1	1	1
B2	1	1
B3	3	5
C1	2	2
C2	1	0
C3	0	0
Total	22	20
Abbreviations: DCP, dynamic compression plate; LCP, locking compression plate.		

Table 2: Distribution of Patients According to the Fractured Bone

Fractured Bone	LCP Group	DCP Group
Radius	4	2
Ulna	5	6
Radius & ulna	13	12
Total	22	20
Abbreviations: DCP, dynamic compression plate; LCP, locking compression plate		

In the LCP group, 16 (73%) patients experienced low-energy trauma and 6 (27%) experienced high-energy trauma. In the DCP group, 13 (65%) patients experienced low-energy trauma and 7 (35%) experienced high-energy trauma. In the LCP group, 19 (86%) patients had an isolated forearm fracture and 3 (14%) had multiple fractures. In the DCP group, 16 (80%) patients had an isolated forearm fracture and 4 (20%) had multiple fractures.

All patients were administered 1 g of a first-generation cephalosporin 30 minutes preoperatively as a prophylactic measure (continued for 24 hours). Average time from injury to surgery was 3 days (range, 1-8 days) in the LCP group and 4 days (range, 1-6 days) in the DCP group.

Surgical Technique

A volar Henry incision was used for radius fractures of the third middle and distal region and a dorsal Thompson incision was used for the proximal third region. The ulna fractures were approached through an incision of the subcutaneous border. Care was taken to not damage the periosteum.

To determine the length and alignment of both bone forearm fractures, the simple fractures were stabilized first. In the absence of specific references to the rotation, the fracture was reduced temporarily and the rotation was controlled after reduction of the other fracture. In the simple transverse fractures treated with the LCP, the locking screw was placed in the other holes after the application of compression with at least 1 unlocked screw proximal or distal to the fracture line. In the oblique fractures in which the LCP was used, the locking screw was placed in the other holes after obtaining compression on the fracture line with the interfragmenter lag screw technique using the hole on the plate. In the comminuted fractures in which the LCP was used, fixation was provided by locking screws after obtaining the length and alignment by selecting the appropriate length of plate using the bridging technique. In patients who underwent fracture fixation using the DCP, 2 compression screws were inserted proximal and distal to the fracture line after fracture reduction, followed by the insertion of other screws.

In all patients, 3.5-mm LCP or DCP plates were used. The authors attempted to provide fixation with a total of 3 screws (6 cortex) on both sides of the fracture line. After the tourniquet was removed and hemostasis was obtained, a hemovac drain was placed and the wound was closed. A splint was applied for 2 weeks. Elbow and wrist exercises were started immediately while the arm was still in the splint.

The patients were followed up with radiographic studies once per month until fracture union was achieved. The quality of fracture reduction was evaluated according to the criteria proposed by Leung and Chow.[14] According to this definition, anatomic reduction refers to full reduction in which the complete length and alignment are achieved and the compression of the butterfly fragments is provided by means of the lag screws. Nonanatomic reduction refers to an incomplete anatomic reduction in which the length and alignment of the fracture fragments are achieved.

Bone union was defined as the presence of bridging the periosteal callus in 3 or 4 cortexes or the primary closure fracture line on anteroposterior and lateral radiographs.[15] According to the criteria proposed by Anderson et al,[1] fracture healing in less than 6 months was considered union, fracture healing lasting longer than 6 months without the need for additional surgical intervention was considered delayed union and the absence of fracture healing requiring additional surgery was considered nonunion. Callus formation on the fracture line was classified as absent, poor, moderate, or good.

For functional evaluation, the system described by Grace and Eversmann[2] was used. Accordingly, complete fracture union with at least 90% rotation of the forearm was considered a perfect result, complete fracture union with at least 80% forearm rotation was considered a good result, complete fracture union with at least 60% forearm rotation was considered an acceptable result, and nonunion of the fracture with a forearm rotation less than 60% was considered a poor result.

Patient satisfaction was assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire.[16] In this scoring system, which is used to indicate the functional status of the upper extremity, 0 reflects an excellent extremity and 100 reflects a nonfunctional extremity.

Data were analyzed using SPSS version 16 statistical software (SPSS Inc, Chicago, Illinois). Mann-Whitney *U* test was performed. A *P* value less than .05 was considered statistically significant.

RESULTS

Union was achieved in all patients in both groups. Mean follow-up was 21 months (range, 20-24 months) in the LCP group and 23 months (range, 19-26 months) in the DCP group. Mean operative time was 76 minutes (range, 62-98 minutes) in the LCP group and 88 minutes (range, 58-102 minutes) in the DCP group. Mean time to union was 15 weeks (range, 12-25 weeks) in the LCP group (Figure 1) and 17 weeks (range, 13-24 weeks) in the DCP group (Figure 2). No difference existed between the 2 groups in terms of operative time and time to union (both $P > .05$).

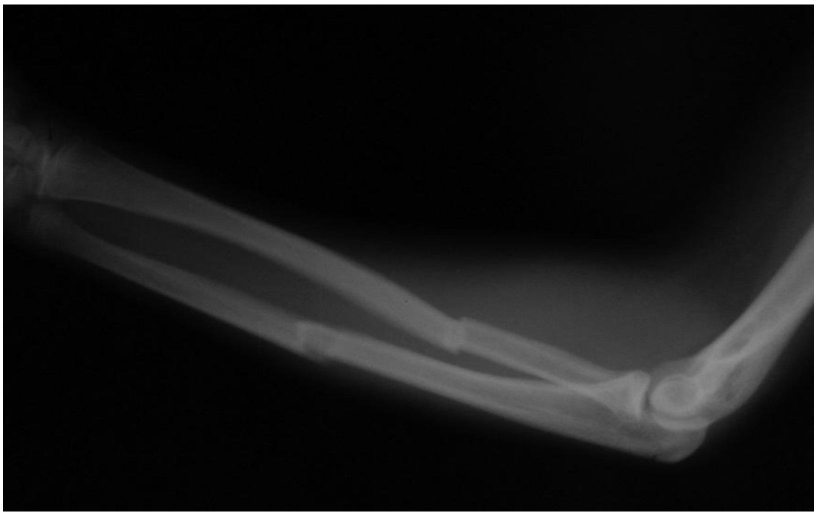
1A

1B

1C

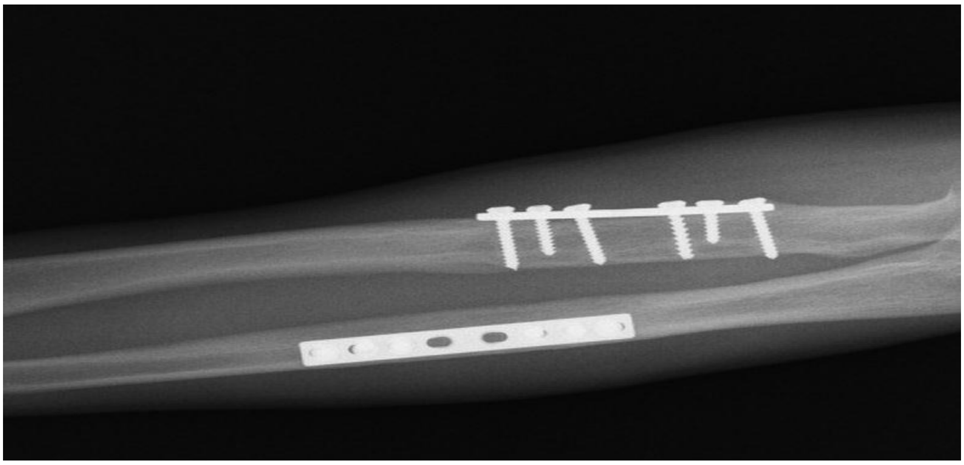
1D

Figure 1: Preoperative anteroposterior (A) and lateral (B) radiographs of the forearm showing fracture of both bones. Anteroposterior (C) and lateral (D) radiographs taken 10 months after locking compression plate fixation showing fracture union.

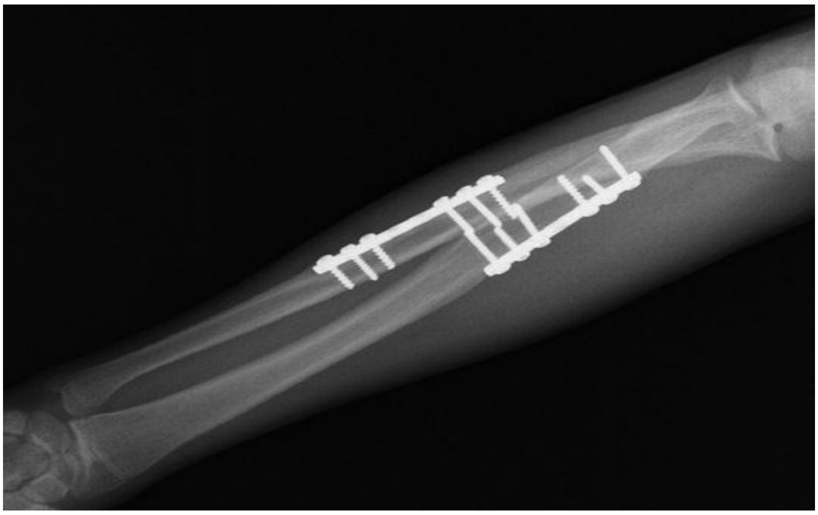


2A

2B



2C



2D

Figure 2: Preoperative anteroposterior (A) and lateral (B) radiographs of the forearm showing fracture of both bones. Anteroposterior (C) and lateral (D) radiographs taken 18 months after dynamic compression plate fixation showing excellent fracture union.

Anatomical fracture reduction was achieved in 22 (63%) patients in the LCP group and 26 (79%) patients in the DCP group. In the remaining cases, fracture fixation was obtained with nonanatomic reduction. No significant difference existed in terms of time to union between the 2 groups (*P* > .05).

In the LCP group, of the 19 fractures without an anatomical reduction, callus formation was seen in 15 (79%) patients. In the DCP group, of the 6 fractures without an anatomical reduction, callus formation was seen in 4 (67%) patients. In the LCP group, of the 16 fractures with an anatomical reduction, callus formation was seen in 2 (13%) patients. In the DCP group, of the 26 fractures without an anatomical reduction, callus formation was seen in 2 (8%) patients. In both groups, a significant difference existed between the subgroups with and without anatomic reduction in terms of callus formation (*P*5.003 and .004, respectively).

According to the Grace-Eversmann criteria, in the LCP group, 16 patients had excellent results, 4 patients had good results, and 2 patients had acceptable results. In the DCP group, 14 patients had excellent results, 5 patients had good results and 1 patient had acceptable re-sults (Table 3). Mean DASH score was 14 (range, 5-34) in the LCP group and 18 (range, 6-43) in the DCP group. No significant difference existed between the 2 groups in terms of Grace-Eversmann criteria and DASH scores (both *P* > .05).

Table 3: Functional Results

Result	**LCP Group**	**DCP Group**
Mean DASH score	14	18
(range)	(5-34)	(6-43)
Grace-Eversmann criteria, No. (%)		
Excellent	16 (73)	14 (70)
Good	4 (18)	5 (25)
Acceptable	2 (9)	1 (5)
Abbreviations: DASH, Disabilities of the Arm, Shoulder and Hand; DCP, dynamic compression plate; LCP, locking compression plate		

The plates that caused discomfort under the skin were removed 18 months postoperatively. In the LCP group, plates and screws were removed in 6 patients. During removal in 2 patients, cold fusion was observed between the locked screw head and the plate. Because the screws could not be separated from the plate, the plate was left in situ. In the DCP group, the implants were removed in 10 patients with no difficulties. No patient in either group experienced refracture after implant removal.

No patient had deep infection, synostosis, plate fracture, compartment syndrome, or iatrogenic neurological or vascular damage. One patient in each group had delayed union; both had open fractures. However, the fractures healed with no additional surgical procedures. Superficial infection occurred in 2 patients in the LCP group and 1 patient in the DCP group; all recovered with local wound care and antibiotic treatment.

DISCUSSION

This study compared LCPs and DCPs for the treatment of diaphyseal forearm fractures in adults. Similar results were obtained in terms of operative time, time to union, complications, and range of motion.

Anatomic reduction and stable internal fixation are effective methods for achieving optimal functional results for diaphyseal forearm fractures in adults.[1-3] Union rates ranging from 92% to 98% after treatment with a DCP have been reported in many studies.[1,2,15] However, cortical porosis and refracture observed in the DCP design were attributed to decreased blood flow due to increased friction and intimate contact between the plate and bone[4] Development of the LC-DCP and point contact fixator was based on the theory that, if friction and intimate contact between plate and bone reduces, vascular damage, osteonecrosis and cortical porosis beneath the plate will be reduced.[5,6] Jain et al[17] measured cortical blood flow of canine tibias fixed with the LC-DCP or DCP and found no significant difference in cortical blood flow between the groups. Uthoff et al[18] found no positive correlation between necrosis and porosis, and they explained porosis by stress shielding. Moreover, the reduced contact area (LC-DCP) and limited unicortical fixation without compression (point contact fixator) failed to improve the clinical outcome in diaphyseal forearm fractures.[19]

The recently developed LCP has properties of the DCP and point contact fixator, which provide locking and compression via its combined hole.[7] The locking compression plate acts as a fixed-angle device and provides stronger fixation than conventional plates.[20] In addition, the LCP can be used as a bridging plate, allowing biological fracture fixation in comminuted fractures.[20] In this way, it provides relative fixation, facilitating callus formation and secondary fracture healing.[21] Due to these advantages, the LCP has recently began to replace conventional plates in the treatment of patients with osteoporosis, fractures close to the joint, and fractures of the upper extremity.[22]

Diaphyseal fractures of the forearm are commonly encountered in the daily practice of orthopedic surgeons. With the theoretical advantages and the expansion of indications for locked plate systems, the question remains whether LCPs are more effective than conventional plates in the treatment of forearm fractures.[10,11] Although LCPs are increasingly preferred in the treatment of forearm fractures, a limited number of studies compare the effectiveness of LCPs and conventional plates.[10,11]

In a series of 36 patients with forearm fractures, Saikia et al[11] compared LCPs and LC-DCPs (18 patients in each group). All patients achieved union, which occurred at an average of 16 weeks in the LCP group and 14 weeks in the LC-DCP group. One case of delayed union occurred in the LC-DCP group, and 1 case of synostosis and 1 case of osteomyelitis occurred in the LCP group. The authors concluded that the LCP and LC-DCP provided similar results.[11]

In 32 patients (45 fractures) with forearm fractures who were treated with LCPs, Leung and Chow[14] reported that union was achieved at an average of 20 weeks. However, they encountered delayed union in 2 (6.3%) cases. Anatomic reduction was obtained in 33% of patients. No or minimal callus formation occurred in 56% of patients, and moderate callus formation occurred in 44% of patients. The authors reported that LCP was effective as a bridging device in the treatment of comminuted diaphyseal forearm fractures.[14]

In the current study, mean time to union was 15 weeks in the LCP group and 17 weeks in the DCP group. These results are comparable with those in the literature.[11,14] Callus formation was significantly higher in the LCP group than in the DCP group. This finding supports previous studies.[11,14] Furthermore, in both groups, callus formation was more prominent when anatomic reduction was not achieved. Nonanatomic reduction (especially in comminuted fractures) was obtained using the bridging technique, in which the fracture was not completely separated from the soft tissues to keep the blood supply intact. This technique provided callus formation in both groups.

Stevens and ten Duis[10] compared DCPs and LCPs in the treatment of type A diaphyseal forearm fractures. Union was obtained in all cases. However, time to union was an average of 10 weeks shorter when compression was applied in both groups. The authors concluded that time to union is determined by the axial compression applied to the fracture line rather than by the type of plate.[10]

Simple transverse or short oblique fractures require maximum compression for optimal healing. Because of the combined hole in the LCP, one can apply compression at the fracture surfaces using screws through the plate eccentrically. For this reason, the current authors applied compression using a combined hole in the LCP group when possible. After achievement of compression at the fracture surface, locking screws were added to the fixation with the purpose of neutralization. However, the number of locking screws necessary for additional fixation remains to be evaluated.

The risk of refracture after plate removal has been reported to range from 4% and 22%.[1,11,23] Leung and Chow[14] reported 2 (9%) cases of refracture in patients treated with the LCP during removal at approximately 12 months. These were both simple transverse fractures and healed primarily without callus formation. The authors recommended the removal of the plate after 18 months to reduce the risk of refracture.[14]

Problems encountered during locked plate removal have been increasingly reported. In a series of 43 patients with forearm fractures, Henle et al[9] reported cold fusion of the plates with at least 1 screw head in 6 of 10 patients in whom material removal was attempted. They also reported an ulnar fracture during removal. It was necessary for the authors to use special devices to remove these screws. The authors proposed manual tightening of screws to avoid cold fusion.[9]

In the current study, the authors did not remove the plates routinely due to the risk of refracture. However, the plates that caused discomfort under the skin were removed 18 months postoperatively. In the LCP group, of the 8 patients with an indication for removal of the plates, 2 patients experienced cold fusion of the locked screw head and the plate. Therefore, the plate was left in place in these 2 patients. However, in the DCP group, the implants were removed in 10 patients (14 fractures) with no difficulties. The authors concur with Henle et al[9] with regard to hand-tightening the locked screws. Furthermore, patients who want to have the locking plate removed should be informed preoperatively that not every plate can be removed. However, during the removal procedure, a special screw removal kit should be available.

In a radius cadaver model, Gardner et al[24] reported that the biomechanical properties of LCPs and DCPs are similar. However, in a biomechanical study of an osteoporotic bone model, Snow et al[25] found the LCP, which was used as a bridge plate, more successful in the axial compression test compared with conventional plates. In addition, a biomechanical study of an osteoporotic diaphyseal fracture model by Doornink et al[26] demonstrated that hybrid plates delivered higher torsional strength, similar bending strength, and a minimal decrease in axial strength than all locked plates.

Experimental studies have reported that LCPs are superior to DCPs and all locked plates in osteoporotic fracture models.[25,26] However, clinical trials have failed to demonstrate the superiority of LCPs over conventional plates in forearm fractures.[10,11] The series reported by Stevens and ten Duis[10] consisted of only A-type simple fractures. Similarly, in a study by Saikia et al,[11] most fractures were type A and B, and only 5% were type C. Although the type C fracture rate in the current study was slightly higher (9% and 6% in the LCP and DCP groups, respectively) than in the study by Saikia at al,[11] it was not sufficient to compare the efficacy of the LCP and DCP in type C fractures. Therefore, future studies are needed to compare the LCP and DCP to determine their efficacy in comminuted or osteoporotic fractures.

Increasing medical care costs is an important problem affecting patients and the health care budgets of many countries. Locking compression plates are 3 times more expensive than DCPs. The findings of the current study and others in the literature demonstrate that the DCPs provide similar results to the LCPs in type A and B diaphyseal forearm fractures.[10,11,14] Therefore, using DCPs in these fracture types seems to be more reasonable.

This study has several limitations. First, it is retrospective and comprises a relatively small number of patients. Second, a comparison could not be made between subgroups of the diaphyseal forearm fractures (eg, comminuted or osteoporotic fractures). Future studies consisting of homogeneous subgroup types with similar degrees of osteoporotic bone may reveal more accurate results for the indications and effectiveness of LCPs and DCPs.

CONCLUSION

Locking compression plates and DCPs have similar functional and radiological results in the treatment of adult diaphyseal forearm fractures. Therefore, the authors believe that the correct surgical technique is more important than the plate type in such fractures. Future studies with a larger series can provide definite conclusions for the use of LCPs.

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