J Orthop Sci (2009) 14:596–601
DOI 10.1007/s00776-009-1382-3

JOURNAL OF
ORTHOPAEDIC SCIENCE

Original article

Analysis of early failure of the locking compression plate in osteoporotic proximal humerus fractures

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Abstract
Background. Although there has been continuous evolution in the management of fracture fixation, treatment for osteoporotic proximal humerus fractures is still challenging to trauma surgeons. The purpose of this study was to report early failure of the locking compression plate (LCP) in the treatment of osteoporotic proximal humerus fracture and characterize the mode of failure.
Methods. Nine patients, older than 65 years, underwent internal fixation with the use of a locking compression plate and had early failure within 4 weeks postoperatively. According to Neer's classification, five were included in a two-part surgical neck fracture, three in a three-part fracture, and one in a four-part fracture.
Results. All failures occurred with back-out of the plate–screw construct, leading to varus displacement in eight patients and plate breakage in one. Revision surgery was performed in six patients using replating and tension band wiring with a bone graft, and three patients underwent hemiarthroplasty. The average UCLA score was 25 points for the hemiarthroplasty group and 30 points for the reconstruction group.
Conclusions. Early postoperative failure of the LCP developed within 4 weeks with a presentation of en bloc back-out of the plate–screw construct and plate breakage. Possible risk factors included malreduction, loss of medial support, and negligence of tension band sutures on the tuberosities.

Introduction

Proximal humeral fractures are now recognized as an increasingly common fracture, accounting for 4%–5% of all fractures and 45% of all humeral fractures.[1–3] Most (75%) of these fractures are undisplaced or minimally displaced fractures that can be treated with a sling and swathe, which usually provides good results.[4,5] For displaced, complicated fractures, surgical treatment is often warranted for early mobilization of the shoulder.[3] Often, anatomical reconstruction is challenging, and loss of fixation due to severe osteoporosis may lead to fracture redisplacement and nonunion.[6,7]

Operative treatments include closed reduction and percutaneous K-wire fixation,[8] intramedullary nailing with a tension band,[7,9] plate-and-screw fixation,[4,7] and hemiarthroplasty.[3,7] Although there has been continuous evolution in the management of fracture and fixation devices, treatment of the osteoporotic fractures in the proximal humerus is still challenging to trauma surgeons.[6,10–12] A locking compression plate (LCP) system has been developed and reported to have numerous advantages for treating the osteoporotic fractures in the biomechanical point of view with respect to conventional plates.[4,6,13] The high stability of the LCP without compression of the plate onto the bone is achieved by angular and axial stability of a plate–screw construct using a conically threaded screw head under the surface and a corresponding conically threaded plate hole. This reduces the chance of screw back-out with a solid locking mechanism between the screw and plate, which is often a problem in osteoporotic factures.[14,15] However, the LCP system is rather complicated and requires careful attention to biomechanical principles. A number of potential pitfalls need to be considered.[16]

We have experienced a series of patients with a failed LCP applied in proximal humerus fractures that occurred during the early postoperative period. We analyzed the patients' clinical data to identify potential risk factors from the surgical perspective in addition to the mode of failure and reconstructive procedure. Such knowledge of this would provide surgeons with some answers on how to avoid similar complications and achieve better clinical outcomes.

Offprint requests to: I.-H. Jeon
Received: March 19, 2009 / Accepted: June 19, 2009

Table 1. Details of the patients' data

Case no.	Age/sex	Neer's fracture type	Initial treatment	Interval between initial operation and failure (weeks)	Mode of failure	Second operation
1	70M	4 — Surgical neck	OR/IF with cloverleaf LP	3	Plate back-out + varus	OR/IF with PH LCP + BG + TBS
2	75F	2 — Surgical neck	OR/IF with cloverleaf LP	3	Plate back-out + varus	OR/IF with PH LCP + BG + TBS
3	69M	3 — Surgical neck	OR/IF with cloverleaf LP	4	Plate back-out + varus	OR/IF with PH LCP + BG + TBS
4	68F	2 — Surgical neck	OR/IF with cloverleaf LP	3	Breakage at the 2nd hole	OR/IF with PH LCP + BG + TBS
5	68F	2 — Surgical neck	CR & K-wires → OR/IF with cloverleaf LP	2	Plate back-out + varus	Hemiarthroplasty
6	66M	2 — Surgical neck	OR/IF with PH LCP	2	Plate back-out + varus	Hemiarthroplasty
7	67F	3 — Surgical neck	OR/IF with cloverleaf LP	3	Plate back-out + varus	OR/IF with PH LCP + BG + TBS
8	75F	3 — Surgical neck	OR/IF with PH LCP	3	Plate back-out + varus	OR/IF with PH LCP + BG + TBS
9	70F	2 — Surgical neck	OR/IF with PH LCP	4	Plate back-out + varus	Hemiarthroplasty

CR, closed reduction; OR/IF, open reduction and internal fixation; BG, bone graft; cloverleaf LP, cloverleaf locked plate; PH LCP, proximal humerus locking compression plate; Plate back-out + varus, back-out of the plate and screw construct + varus displacement of the fracture; TBS, tension band suture

Materials and methods

Between October 2004 and July 2006, a total of 95 patients were surgically treated for a proximal humeral fracture. Among them, 34 patients > 65 years of age at the time of treatment were treated with LCP, with 9 (26.5%) of them having failure of the LCP before fracture union and requiring further surgery. Failures related to postoperative infection were not included in the study.

Three independent reviewers and each surgeon assessed the union (i.e., radiographic trabecular bridging of the fracture gap) on plain radiographs obtained preoperatively, immediate postoperatively, and at follow-up visits 4, 8, 12, and 16 weeks after surgery. The medical records, including associated surgical procedures with additional imaging studies, were reviewed to identify the complications during the period. The clinical evaluation was performed based on the UCLA evaluation system.[17] This study was approved by the institutional review board.

There were three men and six women with average age of 69.8 years (range 66–75 years). The cause of injuries was low-energy trauma (fall from the same level or a slip) in all patients. Review of the medical notes showed that three had diabetes, one had ischemic heart disease, and the remaining five had no metabolic or underlying medical disease.

The fractures were classified based on Neer's system[18]; there was one four-part fracture, three three-part fractures, and five two-part surgical neck fractures (Fig. 1A; Table 1). Preoperative anteroposterior (AP) and axial radiographs showed comminution in the medial cortex of the proximal humerus in all patients.

All operations were carried out through an anterior approach through the deltopectoral groove. All fractures were fixed with a locking compression plate and cloverleaf plate with locking system (Synthes, Paoli, PA, USA). In five patients, closed reduction and immobilization was attempted at first but was unsuccessful; thus, open reduction and internal fixation was used for the initial operation. Three patients were treated surgically within 24 h after the fracture. Passive range of motion exercise (pendulum exercise) was allowed in 3 weeks after the operation and active exercise beginning at 6 weeks.

Operative records showed that none of the patients underwent bone graft to the fracture site. With regard to the fixation, all fractures were fixed with locking screws into the humeral head without additional tension band sutures or wiring on the tuberosities. Three to five locking screws were inserted into the humeral head, and the length of the screws into the heads was not uniform, ranging from 25 to 30 mm. Three to four screws were inserted into the shaft.

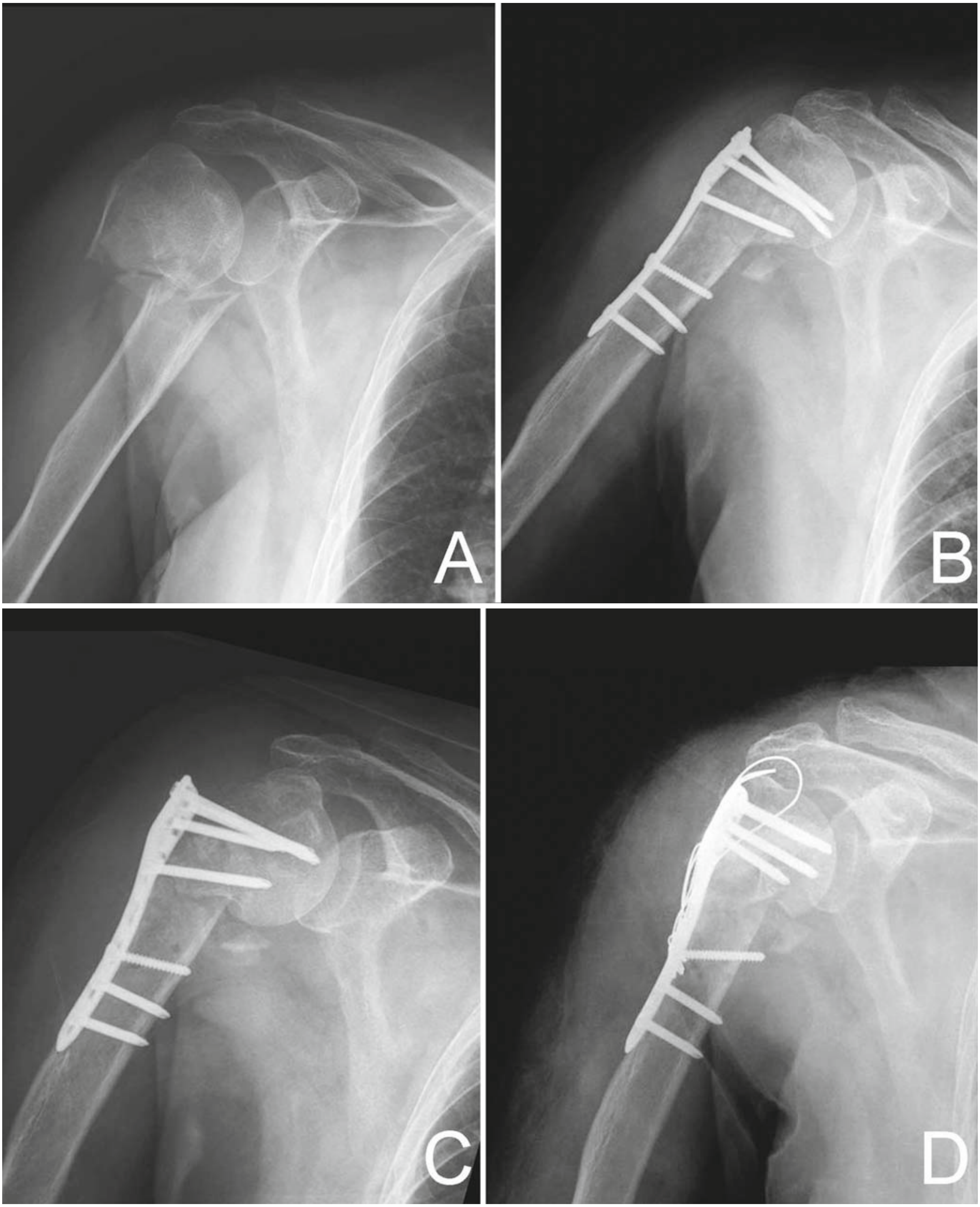

Fig. 1. **A** A 75-year-old woman sustained a two-part proximal humerus fracture due to a fall on the outstretched hand. The preoperative radiograph shows medial comminution. **B** Postoperative radiograph shows anatomical reduction and short locking screws placed in the head that did not reach subchondral bone. **C** En bloc back-out of the plate and screw construct from the head and varus displacement at the fracture site occurred 3 weeks after the operation. **D** Radiograph after the revision operation that included replating, tension band wiring in the supraspinatus, and bone grafting in the medial bone defect

Postoperative radiographs showed anatomical reduction (fracture gap < 2 mm) in six patients (Fig. 1B) and malalignment in three patients, whose definition is an angular deformity > 20° and displacement of > 1 cm. Cortical contact in the neck was not achieved in all patients. None of the screws into the head reached the subchondral bone. The directions of the screws were variable depending on the position of the plate in the proximal humerus.

Results

Failure of the LCP was recognized by the treating surgeons within 4 weeks postoperatively. Two failures occurred within 2 weeks after the operation and seven failures between 2 and 4 weeks.

Mode of failure

Analysis of the failure of the LCP indicated that back-out of the plate–screws construct from the humeral head occurred in eight cases, which caused varus displacement of the fracture. The LCP plate–screws construct was intact without screw loosening. The gap between the plate and humeral head ranged from 3 to 12 mm. Failure occurred in the interface between the plate and bone, not between the plate and screws (Fig. 1C). The screws in the plate shaft were all intact, and no cutting out from the humeral shaft was noted. One patient had mechanical failure of the plate at the junction between shaft and head of the plate, which corresponded to the level of the fracture site (through the second plate hole) at 3 weeks postoperatively. In all cases, the varus collapse was due to the lack of medial support.

Revision surgery

The mean time until revision surgery was 3 weeks (range 2–4 weeks) after identification of the failure. Three patients were treated with hemiarthroplasty because of their age and the patients' request. The remaining six patients underwent a planned operation, which consisted of (1) compression of the fracture gap by removing fibrous tissue that had interposed and reduce the gap in the medial bone defect if present; (2) autogenous corticocancellous bone graft into the medial comminution; (3) replating with a proximal humeral LCP using the maximum length of screws into the head under the guidance of an image intensifier; (4) an augmentation tension band suture or metal wire to the greater tuberosity to resist varus malalignment after plate fixation (Table 1, Fig. 1D).

Clinical and radiological outcome

Three patients who underwent hemiarthroplasty showed an average of 80° of flexion with a UCLA score of 25 (range 15–25) at last follow-up. The other six patients who underwent revision surgery with plating achieved solid bone union at an average of 14 weeks (range 8–20 weeks). The mean head–shaft angle on postoperative radiographs was 115° (range 100°–135°). Clinically, all achieved a functional shoulder with minimal or no pain; the average flexion angle was 120° (range 75°–160°), and the mean UCLA score was 30 (range 20–30).

Discussion

Early postoperative failure of the LCP was different from that of conventional plates. Pull-out of the plate–screw construct with varus displacement of the fracture was evident, and there were several characteristics related to this early postoperative failure. The mode of failure observed in this series is similar to that previously described[19] — there is varus angulation and closure of the medial defect, especially when there is comminution in the medial cortex. Thus, we used an autogenous bone graft to the medial bone defect to reduce early failure from the mechanical and biological point of view and tension band sutures applied over the tuberosity to achieve additional stability.

Numerous devices for fixation of displaced fractures have been described in the literature.[3] The most common devices include plate fixation, fixed-angle plate fixation, antegrade intramedullary fixation, tension-band wiring, and percutaneous fixation.[3,4,7–9] However, there is still concern regarding secure fixation of the osteoporotic head fragment and displaced tuberosity.[3,9] LCP has advantages in dealing with loosening in the osteoporotic fractures compared to a conventional plate, which gets its primary stability by friction between the plate and bone.[3,4,13–15] The LCP system provides angular stability through the use of locking screws and allows exploitation of different biomechanical principles, which should be carefully considered in each case.[20,24]

Chudik et al.[20] reported from their biomechanical study that LCP showed better results in comminuted and noncomminuted fractures under physiological loads than the conventional T-plate. Good clinical results with different types of the LCP have been reported in the literature, especially for proximal humerus fractures.[14]

Our study documents possible complications in fracture patterns with missing medial support and demonstrates the limits of the LCP system in osteoporotic bone when used without additional surgical procedures. In our experience, these complications in the treatment of proximal humeral fractures using LCP occurred because of technical errors during the surgery that included no tension band wiring to the tuberosities, inadequate medial support when the screws did not reach subchondral bone in the head, and no bone graft applied in the medial comminution and bone defect. In the revision cases, we achieved union during the second attempt in six patients when we restored medial support and provided an augmentation by tension banding and bone graft as proposed by several authors in the recent literature. The present study led to documentation of the possible complications of the applications of the LCP system to the proximal humerus fractures.

When screws and plates are used for open reduction and internal fixation of proximal humerus fractures, a major mode of failure is loss of fixation within the humeral head. In the study of Liew et al,[21] optimal screw purchase with respect to bone fixation was achieved by conventional screws located in the center of the humeral head in the subchondral position. They further advised that the anterosuperior position of the head should be avoided to minimize screw fixation failure. A histomorphometric and bone strength study reported by Hepp et al.[22] and Lill et al.[23] analyzed the structural parameter of the proximal humeral head including trabecular thickness and bone strength distribution. They concluded that the maximum bone strength was found in the medial and dorsal aspect of the proximal humeral head, and the histomorphometric parameters and bone strength decreased caudally. This implied that the screws should be placed in exactly those areas of maximum bone stock, and stabilization must respect the existing trabecular network. In this series, the screws were relatively short and did not reach the subchondral bone. This is partly because of our limited range of choice in locking screws' length. Tightening a locked screw in the plate hole provides a feeling of firm stability to the surgeon, but the effective hold of the screw in the bone cannot be felt. This might lead the surgeon to overestimate the achieved stability and hence insert an insufficient number of screws.[16] The lack of tension band wiring of the tuberosities is a possible cause of fixation failure because the dispersion of the tension forces by using tension band principles in the proximal humerus clearly share some load on the implant used to create stability between the metaphysis and the diaphysis.

During the revision operation, authors paid special attention to several procedural factors: (1) anatomical reduction with minimal bone defect into the medial cortex of the metaphysis and autogenous bone graft in fractures with medial comminution and bone defect; (2) longer screws to the humeral head to purchase the subchondral bone; (3) use of the drill sleeve always for proper angular stability; and (4) tension band suture or metal wire to the tuberosities to obtain additional stability and avoid plate back-out and sequential varus malalignment during the early postoperative period. Even if LCP provides better holding power in osteoporotic bone, the intrinsic stability by proper reduction of the fracture is crucial, especially in osteoporotic fractures of the proximal humerus.

The weakness of this study is the small number of cases with retrospective review. There are also no systematic studies that have investigated the general bone quality of the patients. In summary, we found that most of the early failures are caused by technical problems in application of LCP system.

This study showed that the risk factors for early failure of LCP plates include proximal humeral fractures in older patients and fractures with medial comminution. Knowledge of these risk factors and failures help the surgeon to keep in mind the importance of detailed biomechanical principles of plate fixation as well as careful preoperative planning for successful use of the LCP system in proximal humerus fractures.

Acknowledgments. This study was supported by a grant of the Korea Healthcare technology R&D Project, Ministry for Health, Welfare & Family Affairs, Republic of Korea (A084177).

The authors declare that we have no commercial affiliations, consultancies, stock ownership, or patent-licensing arrangements that could be considered to pose a conflict of interest regarding the subject of this article.

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