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Journal of the Chinese Medical Association 75 (2012) 216–220

www.jcma-online.com

Original Article

The role of autologous bone graft in surgical treatment of hypertrophic nonunion of midshaft clavicle fractures

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Received October 1, 2011; accepted December 22, 2011

Abstract

Background: This study was conducted to evaluate the results of treating hypertrophic nonunion of mid-shaft clavicle fracture with a limited contact dynamic compression plate (LC-DCP) without autologous cancellous bone graft.
Methods: From 1995 to 2008, 51 cases of hypertrophic nonunion of mid-shaft clavicle fracture were managed with open reduction and internal fixation by LC-DCP without bone graft involvement. Of these 51 cases, 30 had nonunion after failure of initial surgical treatment (Group 1), and 21 had nonunion after failure of conservative treatment (Group 2). Preoperative and postoperative case management were the same for both groups, with the average follow-up period being 20.4 months (range 18–36). Our study evaluated the radiographic results and functional outcomes of these cases according to the quick disability of arm, shoulder, and hand score.
Results: All 51 cases resulted in uneventful unions. There was no statistically significant difference between the two groups regarding patient demography, cause of injury, preoperative and postoperative functional scores, length of operation, union time, and duration of hospitalization ($p > 0.05$).
Conclusion: LC-DCP fixation is an effective method for treating hypertrophic nonunion of mid-shaft clavicle fracture. Local bone graft is sufficient to achieve necessary union, and autologous bone graft from other sites of the body appears unnecessary.

Keywords: bone graft; clavicle nonunion; hypertrophic; limited contact dynamic compression plate; mid-shaft

1. Introduction

Clavicle fractures represent 2.6% to 4% of all fractures suffered by adults, with mid-clavicle area fractures accounting for 69% to 82% of that number.[1–3] Nonoperative and operative treatments for mid-shaft clavicle fractures had been reported to have good outcomes.[4–8] However, regardless of the treating method used, nonunion can always be a troubling complication. Symptomatic nonunion usually requires surgery, due to the disabling properties suffered by patients. Many methods had been reported to treat the nonunion, such as open reduction internal fixation (ORIF), with plates and screws, intramedullary screws, nails, or pins, and external fixators.[9–13] Autologous bone graft is often recommended for treatment to enhance the likelihood of union accompanying the fixing procedure. In the condition of hypertrophic nonunion of the mid-shaft clavicle, the body's vigorous healing power can be observed in the sprouting callus. In procedures involving internal fixation due to nonunion, excess callus should be removed to achieve anatomic reduction of the fractured ends. Thereafter, the removed callus could be an invaluable bone graft for the nonunion site; this can positively impact one of the primary causes of nonunion involving hypertrophic callus, the instability between the fractured ends, which is apparent both in nonoperative and operative treatments. This study

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1726-4901/$ - see front matter
doi:10.1016/j.jcma.2012.04.003

focuses on the proposition that in treating hypertrophic nonunions, open reduction and rigid internal fixation can be sufficient to achieve union. Consequently, we conducted a retrospective study to evaluate the outcome of previous treatment of hypertrophic nonunion of mid-shaft clavicle fracture with a limited contact dynamic compression plate (LC-DCP), without using autologous bone graft.

2. Methods

From 1995 to 2008, 58 consecutive hypertrophic nonunions of mid-shaft clavicle fracture in 58 patients were treated with LC-DCP in our institute. Informed consent was obtained from all patients prior to enrolment. The indication for operation of these cases was symptomatic nonunion, failure of union either after operative treatment or after at least 3 months following nonoperative treatment, with pain or instability over the fracture site.[14] Forty of these patients were not managed initially in our institute. Open fracture, fracture with neurovascular injuries, fracture of the same side upper extremity, infected nonunion, or re-fracture of the same clavicle were excluded. All of the nonunions were interpreted to be hypertrophic by proof of hypertrophic callus formation by radiographic evaluation, supplemented by intraoperative evidence.[15] Patients who lacked follow-up information ($n = 6$) or who suffered repeat trauma after the nonunion surgery ($n = 1$) were excluded. The remaining 51 patients were enrolled in the final evaluation. No history of immunological disease or use of steroid was noted in these 51 patients. Also, no history of contralateral clavicle fracture was noted in any of the cases. The patients were separated into two groups according to their initial treatment for their acute fractures. Group 1 consisted of 30 patients who had received ORIF with either circlege wires (10 patients), or intramedullary nail/pin/screw (18 patients), or small dynamic compression plate (2 patients) for the acute fractures. The average patient age in Group 1 was 43.4 years (range 19–70); there were of 12 males and 18 females who suffered injury to a total of 21 left clavicles and 9 right clavicles. The mechanisms of injury of these patients were traffic accident ($n = 23$), fall from height ($n = 3$) and miscellaneous causes ($n = 4$). Eleven patients smoked. The average duration between the initial operative treatment and subsequent nonunion repair was 33.3 weeks (range 12-84). Group 2 consisted of 21 patients who had been treated nonoperatively for their acute fractures. The average age in Group 2 was 49.3 years (range 31–70); there were 13 males and 8 females with injury to 11 left clavicles and 10 right clavicles. The mechanism of injury were traffic accident ($n = 13$), fall from height ($n = 4$), and miscellaneous causes ($n = 4$). Seven patients smoked and the average duration of conservative treatment was 30.6 weeks (range 12–82). All of the 51 nonunions were treated with open reduction (with removing all the previous implant in group 1) and internal fixation by LC-DCP without using autologous bone graft. The average follow-up period was 20.8 months (range18–36) in Group 1 and 18.9 months (range 18–35) in Group 2.

All operations were performed under general anesthesia by three authors (CC Chiang, YP Su and FY Chiu). Each patients was set in the beach-chair position with their head turned to the opposing side. Prophylactic antibiotic with intravenous 500 mg cefazolin preoperatively and intravenous 500 mg cefazolin postoperatively was administered to all patients. A horizontal skin incision was made along the superior side of the clavicle and centered over the nonunion site. The skin incision was made upon the previous incision in Group1, and extended if needed. The skin, platysma, and subcutaneous tissue were incised and raised as one flap. The nonunion site was exposed, and the hardware in patients of Group 1 was excised completely. The interposed fibrous tissue between the nonunion ends was also removed. The hypertrophic callus was shaved down to reveal the normal clavicle size that would optimize the plate application and fit the opposite end. Decortication of both proximal and distal fragments were performed with osteotome on the superior and anterior surface within 1.5 cm from the fractured end. The surrounding fascial and periosteal sheaths, except the superior plate application site, were protected in order to preserve the circulation to the fracture site as much as possible. In all cases, the medullary canal was opened and reamed with a drill. A 3.5-mm LC-DCP was contoured to the clavicle shaft and applied on the superior surface of shaft. At least three screws with good bicortices purchase were obtained in both sides of the nonunion.[16,17] If there were an oblique reduction plane or a butterfly fragment, a 3.5-mm lag screw was used to get interfragmentary fixation. All the small bone chips, removed callus, and reaming dust collected during the refreshment procedure were packed back to the nonunion site after the plate and screws sufficiently set up. Finally, the wound was closed in layer, with specific attention given to the closure of the periosteal sleeve in all patients.

Postoperatively, the patient's arm was held in a sling. Passive and active mobilization was allowed and encouraged as tolerated. Gradual return to sports or heavy work of the injured limb was allowed only after solid union. Postoperatively, patients were examined at 2 weeks, 6 weeks, and then every month thereafter and radiographic evaluation with standardized anteroposterior view was performed on every follow-up visit. For purposes of clarification, union was defined as a completely bridging bone, with obliteration of the fracture gap.[18] All radiographs were evaluated by independent observers (HK Huang and CL Liu; Figs. 1 and 2). A functional evaluation of each patient was performed no earlier than the third postoperative visit, with results recorded in each following visit thereafter. The final functional evaluations were assessed and interpreted by utilizing the quick disability of the arm, shoulder, and hand (DASH) score by two authors (SH Hung and YP Su).[19] Each patient had one dedicated chart with detailed records of their personal data, which included smoking habits, mechanism and associated condition of injury, pattern of initial fracture, type and classification of nonunion, course of the management (including initial treatment), timing of treatment of nonunion, course of operation, operation time, length of hospital stay, early complications, late

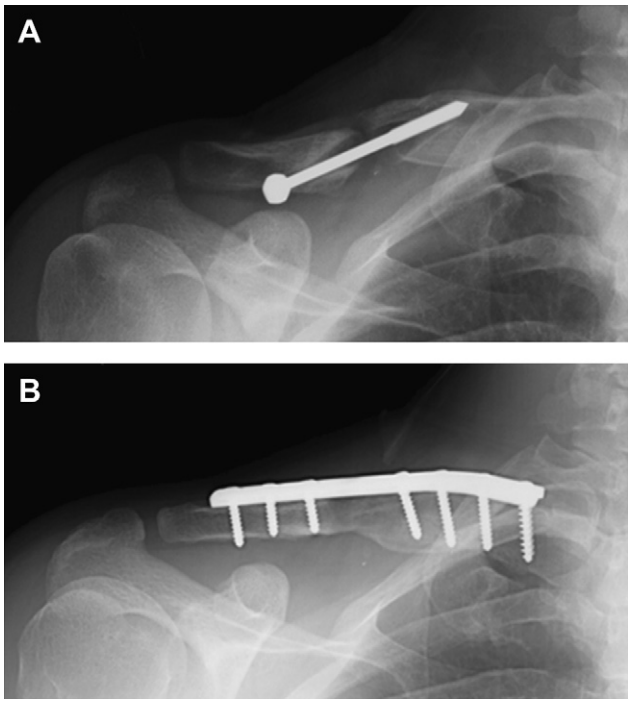

Fig. 1. Radiographs of a 48-year-old male patient, 24 weeks after initial operation, showing hypertrophic nonunion of the right clavicle (A), and bone union after being treated with LC-DCP with no autologous bone graft, radiograph at 6 months follow-up after surgery (B).

complications, condition and course of the fracture healing, and functional recovery.

All patients were measured for all response variables, which included demographic variables and important outcomes. Data were presented as mean and standard deviation for continuous response variables or percentages for discrete variables. Chi-square test was used to compare differences between the two groups for each discrete variable, and a Student t test was used for each continuous variable. SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA) was used to test the difference of the results. The p-value was set before analysis at 0.05 for each test.

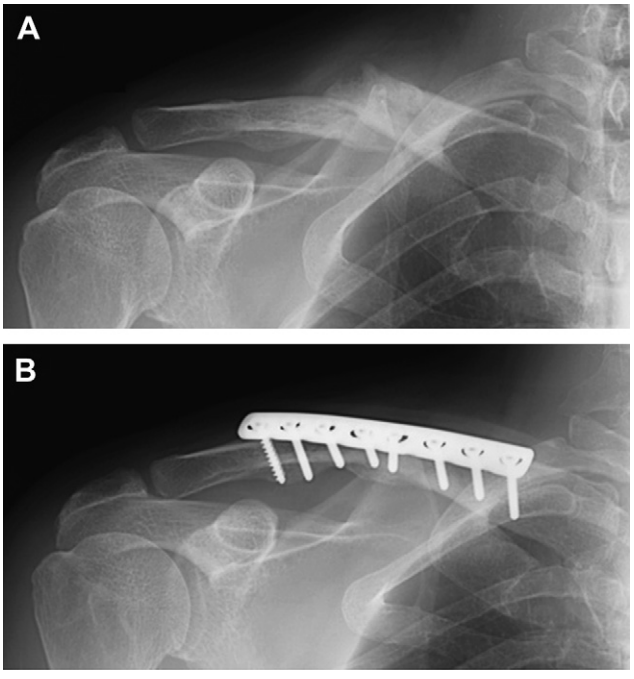

Fig. 2. Radiographs of a 58-year-old male patient, 38 weeks after injury, showing hypertrophic nonunion of the right clavicle (A), and bone union after being treated with LC-DCP with no autologous bone graft, radiograph at 6 months follow-up after surgery (B).

3. Results

All of the 51 nonunions had uneventful union, and no complications developed. There was no statistically significant difference between the two groups regarding demography, cause of injury, smoking habits, preoperative and postoperative functional scores, operative time, hospital stay, union time, shortening of the clavicle (comparing to the other side normal clavicle), and follow-up period ($p > 0.05$, Table 1). The mean union time was 9.3 weeks in Group 1 and 9.1 weeks in Group 2. Both groups had improved functional scores ($p < 0.001$). The mean shortening of the healed clavicle (compared to the contralateral normal clavicle in the radiograph) was 0.6 cm (range 0.1–1.6). All the patients subjectively reported full return to the preinjury function of their injured upper limb in their final postprocedure follow-up. Nineteen patients had their plate removed after union of the fractures. Twelve patients had their plates removed due to the prominence of the LC-DCP device, and seven more were unwilling to retain a LC-DCP in their body. No re-fracture developed.

4. Discussion

Fracture of mid-shaft clavicle is quite common, and nonunion is not an infrequent complication after nonoperative treatment. Currently, more emphasis has been placed on this issue because symptomatic nonunion with pain or instability will weaken the function of the shoulder and limb. The results of this study showed that hypertrophic nonunion of mid-shaft clavicle fractures can be managed successfully by open reduction and rigid internal fixation with LC-DCP. In this series, the union rate was 100%, and the union time was comparable to those in other series.[9–19] There were downsides to all manners of fixation, with some reports of intramedullary fixation or external fixation or double plating or locking plating for treatment of nonunion of the clavicle.[9–19] Intramedullary fixation has the disadvantage of poor rotation control, and external fixation has the disadvantages of a bulky frame, and can be technically demanding. Double plating has the disadvantages of more soft tissue stripping and impairment of local blood supply, and locking plating has the disadvantage of higher cost. All of these disadvantages limited the use of the aforementioned implants, wherein use of LC-DCP for ununited clavicle fracture could obviate these disadvantages, to the benefit of the patient.

All the cases enrolled in this series had hypertrophic nonunion after either surgical or conservative treatments. The

Table 1
Comparisons of parameters between Groups 1 and 2.

	Group 1 ($n = 30$) Mean (SD)	Group 2 ($n = 21$) Mean (SD)	p
Age (years)	43.4 (15.32)	49.3 (12.41)	0.152[a]
Sex (Male/Female)	12/18 (40%/60%)	13/8 (62%/38%)	0.160[b]
Side (Left/Right)	21/9 (70%/30%)	11/10 (52%/48%)	0.247[b]
Smoking	11 (37%)	7 (33%)	1.000[b]
Duration before operation (wk)[c]	33.3 (24.81)	30.6 (17.87)	0.646[a]
Operation time (min)	102.2 (18.69)	100.24 (19.91)	0.726[a]
Hospital stay (d)	4.0 (0.64)	3.8 (0.63)	0.194[a]
Preoperative functional score	54.2 (14.68)	55.3 (8.76)	0.748[a]
Postoperative functional score	16.4 (7.79)	20.3 (7.63)	0.088[a]
Union time (wk)	9.3 (2.19)	9.1 (1.85)	0.746[a]
Shortening (cm, compared with contralateral side)	0.7 (0.44)	0.5 (0.38)	0.095[a]
Follow-up period (mo)	15.8 (3.76)	14.9 (3.71)	0.404[a]

[a] Student t test.
[b] Chi-square test.
[c] Duration between operation for acute fracture and nonunion repair for Group 1; duration between acute fracture and nonunion repair for Group 2.

problems of the hypertrophic nonunion were primarily poor fixation and secondarily inadequate osteogenesis. The use of LC-DCP with appropriate screws fixation, according to Schwarz and Hocker,[17] with screw fixation of three to four bicortices in both proximal and distal fragments, could overcome the problem of poor fixation. To overcome the problem of inadequate osteogenesis, supplemental autologous bone graft was suggested for the clavicle nonunion in many studies.[9,11,14,20] In our study, autologous bone graft was not used, but "local bone grafting" from local callus, bone chips and reaming dust was performed. All the nonunions healed uneventfully, so this might mean that a "local bone graft" with refreshing the fracture/good bony contact/less periosteal stripping/good preservation of periosteal sleeve is sufficient to overcome the problem of inadequate osteogenesis in a non-united mid-shaft clavicle fracture. These, together with rigid internal fixation, make the problems of nonunion (either poor fixation or inadequate osteogenesis) possible to overcome and union could be achieved smoothly. The aforementioned rigid fixation and improved osteogenesis were the most important key points to get a high union rate. Autologous bone graft from the iliac crest or elsewhere might make the union more promising, but its associated clinical shortcomings (pain of operation site, significantly longer operation time, and even fracture of donor site) could not be avoided completely. Endrizzi et al even proposed that autologous bone graft is not routinely necessary for the clavicle nonunion, but the results and discussions were not specified according to the types of nonunion in their report.[18] Thus, the necessity of autologous bone graft in hypertrophic nonunion after operative or nonoperative treatments of clavicle fracture could be referenced from the results of this series.

Because the three-dimensional morphology of the clavicle is complex, plate placement should be carefully considered.[21] The superior surface was the most common place for plate fixation, where benefits include an uncomplicated approach, minimal opening of the periosteal sheath, and easy plate placement. LC-DCP placement onto the superior surface of the clavicle after contouring of the plate is also somewhat simple, and the undersurface of the plate, with its small indentations, would theoretically improve circulation to the bone in comparison to a smooth undersurface. In all our cases, the surgically attached plate was sufficiently long that it allowed sufficient room for at least three screw fixation points, with bicortices purchasing in both sides of the nonunion. The LC-DCP provides the fixation strength with less soft tissue dissection, which might protect the circulation and be better for the union. However for thin patients, a plate located in the superior region would make it prominent in skin appearance, and the additional procedure of removing the plate was requested and thought to be needed in 12 of our 51 patients (23.5%). The theoretical disadvantage of using DCP, even with LC-DCP, is an increase in soft tissue stripping. In this series, no infection or poor wound healing developed, which probably underscores the importance of meticulous soft tissue management during the surgical procedure.

There are several references to those factors that might predispose a mid-shaft clavicle fracture to postsurgical nonunion, including inadequate initial immobilization, primary open reduction of the fracture, severity of fracture displacement, age, and other various factors.[22−28] In this series, all the 51 nonunions healed smoothly after the surgery, and, no definite factors in either Group 1 or Group 2, including age, gender, smoking, mechanism of injury, and previous operation, were noted to affect the healing of treatment of nonunion. However, the risk factors for nonunion of these 51 patients could not be analyzed and evaluated satisfactorily for 40 patients, who were not managed initially in our institute.

The effect of clavicle shortening after fracture union is still controversial. Some authors consider that it will impair the shoulder function,[29−31] and some consider that it has no clinical significance.[32,33] Although shortening is not the main concern in our procedures, we still tried to avoid further shortening of the clavicle if at all possible. In this study, the mean shortening of the healed clavicle, comparing to the contralateral normal clavicle in radiograph, was 0.6 cm (range 0.1−1.6). All patients subjectively indicated a full return to the pre-injury function of their injured upper limb in their final follow-up, so the effect of shortening of the clavicle on the functional results of patients were not apparent in this study.

The functional results after treatment was completed were shown to be a return to preinjury activity level in all patients, which supports the other advantage of early passive and active range of motion exercise of the injured extremity after rigid fixation with LC-DCP. Degenerative change of the shoulder with deteriorating function would be an important factor affecting the long-term function of shoulder and upper limb, and this should be considered in the functional evaluation of patients with clavicle surgery, especially in elderly patients.

The main limitations of this study are the retrospective nature of our investigation, and the modest total size of our patient population. Thus, some bias of evaluation could not be avoided entirely. However, the results of this study were evident, and helpful for clinical reference.

In conclusion, surgery with open reduction, refreshing of the nonunion site, and rigid fixation by LC-DCP is an effective and reliable treatment for hypertrophic nonunion of mid-shaft clavicle fracture after failure of nonoperative or operative management. Using only "local bone graft" is sufficient to achieve union and autologous bone graft from other sites of body appears to be unnecessary.

References

1. Nordqvist A, Petersson C. The incidence of fractures of the clavicle. *Clin Orthop Relat Res* 1994;**300**:127–32.
2. Postacchini F, Gumina S, De Santis P, Albo F. Epidemiology of clavicle fractures. *J Shoulder Elbow Surg* 2002;**11**:452–6.
3. Robinson CM. Fractures of the clavicle in the adult. Epidemiology and classification. *J Bone Joint Surg Br* 1998;**80**:476–84.
4. Bohme J, Bonk A, Bacher GO, Wilharm A, Hoffmann R, Josten C. Current treatment concepts for mid-shaft fractures of the clavicle - results of a prospective multicentre study. *Z Orthop Unfall* 2011;**149**:68–76.
5. Khan LA, Bradnock TJ, Scott C, Robinson CM. Fractures of the clavicle. *J Bone Joint Surg Am* 2009;**91**:447–60.
6. Kim W, McKee MD. Management of acute clavicle fractures. *Orthop Clin North Am* 2008;**39**:491–505.
7. Pujalte GG, Housner JA. Management of clavicle fractures. *Curr Sports Med Rep* 2008;**7**:275–80.
8. Smekal V, Oberladstaetter J, Struve P, Krappinger D. Shaft fractures of the clavicle: current concepts. *Arch Orthop Trauma Surg* 2009;**129**:807–15.
9. Capicotto PN, Heiple KG, Wilbur JH. Midshaft clavicle nonunions treated with intramedullary steinman pin fixation and onlay bone graft. *J Orthop Trauma* 1994;**8**:88–93.
10. Enneking TJ, Hartlief MT, Fontijne WP. Rushpin fixation for midshaft clavicular nonunions: good results in 13/14 cases. *Acta Orthop Scand* 1999;**70**:514–6.
11. Hoe-Hansen CE, Norlin R. Intramedullary cancellous screw fixation for nonunion of midshaft clavicular fractures. *Acta Orthop Scand* 2003;**74**: 361–4.
12. Kabak S, Halici M, Tuncel M, Avsarogullari L, Karaoglu S. Treatment of midclavicular nonunion: comparison of dynamic compression plating and low-contact dynamic compression plating techniques. *J Shoulder Elbow Surg* 2004;**13**:396–403.
13. Schuind F, Pay-Pay E, Andrianne Y, Donkerwolcke M, Rasquin C, Burny F. External fixation of the clavicle for fracture or non-union in adults. *J Bone Joint Surg Am* 1988;**70**:692–5.
14. Khan SA, Shamshery P, Gupta V, Trikha V, Varshney MK, Kumar A. Locking compression plate in long standing clavicular nonunions with poor bone stock. *J Trauma* 2008;**64**:439–41.
15. Megas P. Classification of non-union. *Injury* 2005;**36**(Suppl):S30–7.
16. McKee MD, Seiler JG, Jupiter JB. The application of the limited contact dynamic compression plate in the upper extremity: an analysis of 114 consecutive cases. *Injury* 1995;**26**:661–6.
17. Schwarz N, Höcker K. Osteosynthesis of irreducible fractures of the clavicle with 2.7-mm ASIF plates. *J Trauma* 1992;**33**:179–83.
18. Endrizzi DP, White RR, Babikian GM, Old AB. Nonunion of the clavicle treated with plate fixation: a review of forty-seven consecutive cases. *J Shoulder Elbow Surg* 2008;**17**:951–3.
19. Beaton DE, Wright JG, Katz JN. Upper Extremity Collaborative Group. Development of the quickdash: comparison of three item-reduction approaches. *J Bone Joint Surg Am* 2005;**87**:1038–46.
20. Laursen MB, Døssing KV. Clavicular nonunions treated with compression plate fixation and cancellous bone grafting: the functional outcome. *J Shoulder Elbow Surg* 1999;**8**:410–3.
21. Mullaji AB, Jupiter JB. Low-contact dynamic compression plating of the clavicle. *Injury* 1994;**25**:41–5.
22. Boyer MI, Axelrod TS. Atrophic nonunion of the clavicle: treatment by compression plate, lag-screw fixation and bone graft. *J Bone Joint Surg Br* 1997;**79**:301–3.
23. Jupiter JB, Leffert RD. Non-union of the clavicle. Associated complications and surgical management. *J Bone Joint Surg Am* 1987;**69**:753–60.
24. Manske DJ, Szabo RM. The operative treatment of mid-shaft clavicular non-unions. *J Bone Joint Surg Am* 1985;**67**:1367–71.
25. Robinson CM, Court-Brown CM, McQueen MM, Wakefield AE. Estimating the risk of nonunion following nonoperative treatment of a clavicular fracture. *J Bone Joint Surg Am* 2004;**86-A**:1359–65.
26. Wilkins RM, Johnston RM. Ununited fractures of the clavicle. *J Bone Joint Surg Am* 1983;**65**:773–8.
27. Davids PH, Luitse JS, Strating RP, van der Hart CP. Operative treatment for delayed union and nonunion of midshaft clavicular fractures: AO reconstruction plate fixation and early mobilization. *J Trauma* 1996;**40**: 985–6.
28. Kloen P, Werner CM, Stufkens SA, Helfet DL. Anteroinferior plating of midshaft clavicle nonunions and fractures. *Oper Orthop Traumatol* 2009;**21**:170–9.
29. Lazarides S, Zafiropoulos G. Conservative treatment of fractures at the middle third of the clavicle: the relevance of shortening and clinical outcome. *J Shoulder Elbow Surg* 2006;**15**:191–4.
30. Ledger M, Leeks N, Ackland T, Wang A. Short malunions of the clavicle: an anatomic and functional study. *J Shoulder Elbow Surg* 2005;**14**: 349–54.
31. Matsumura N, Ikegami H, Nakamichi N, Nakamura T, Nagura T, Imanishi N, et al. Effect of shortening deformity of the clavicle on scapular kinematics: A cadaveric study. *Am J Sports Med* 2010;**38**: 1000–6.
32. Nordqvist A, Redlund-Johnell I, von Scheele A, Petersson CJ. Shortening of clavicle after fracture. Incidence and clinical significance, a 5-year follow-up of 85 patients. *Acta Orthop Scand* 1997;**68**:349–51.
33. Rasmussen JV, Jensen SL, Petersen JB, Falstie-Jensen T, Lausten G, Olsen BS. A retrospective study of the association between shortening of the clavicle after fracture and the clinical outcome in 136 patients. *Injury* 2011;**42**:414–7.