Comparison of radiographic outcomes between beta-tricalcium phosphate bone graft and autogenous bone graft in corrective osteotomy of malunited distal radius

Nuttorn Darapongsataporn, MD[1], Chairoj Uerpairojkit, MD[2]

[1]*Nan Hospital, Mueang Nan, Nan, Thailand*

[2]*Institute of Orthopaedics, Lerdsin Hospital, Bangrak, Bangkok, Thailand*

Purpose: *To compare radiographic outcomes after placement of beta-tricalcium phosphate bone grafts (BPBG) and autogenous iliac bone grafts (IBG) in corrective osteotomy of malunited distal radius fractures with volar locking plates.*

Methods: *Twenty-seven patients with malunited distal radius fractures were operated on in Lerdsin General Hospital, Bangkok. The inclusion criteria were–symptomatic malunited distal radius and unacceptable radiographic parameters. We divided patients into IBG and BPBG groups. We collected radiologic parameters at preoperative, postoperative (4th week), and the last visit. We compared radiographic parameters from both groups by unpaired t-test and calculated radiographic parameters by time sequence in each group by paired t-test. The reoperation rate in both groups was also compared by chi-squared (Fisher exact test).*

Results: *The study did not show a statistical difference in any of the radiographic parameters between the two groups. The union rate was 91.67%, 11 in 12 cases, in the IBG group while the union rate was 80%, 12 in 15 cases, in the BPBG group (p>0.05). The failure correction rate was 8.33%, 1 in 12 cases, in the IBG group while the failure correction rate was 26.67%, 4 in 15 cases, in the BPBG group (p>0.05). Six patients, 1 in the IBG and 5 in the BPBG groups, needed re-operation due to pain or failure to improve functional outcomes. The re-operation rate was 8.33% and 33% in the IBG and BPBG groups, respectively (p>0.05).*

Conclusion: *Radiographic parameters in the BPBG group were not significantly different from the IBG group. Regarding the union and re-operation rate, even though there was no statistically significant difference, there was a tendency of a lower union rate and higher re-operation rate in the BPBG group.*

Keywords: *Osteotomy, malunion distal radius fracture, beta-tricalcium phosphate bone graft, autogenous iliac bone graft*

The Thai Journal of Orthopaedic Surgery: 40 No.3-4: 11-17
Full text. e journal: *http://www.rcost.or.th, http://thailand.digitaljournals.org/index.php/JRCOST*

Introduction

Fracture of the distal radius is the most common fracture in the upper extremities. One of the most frequent complications is malunion which results in wrist weakness, pain, limited range of motion, numbness, tingling sensation, arthritis, and carpal malalignment and instability. Asymptomatic malunion of distal radius can be left untreated especially in patients with low daily activity. However, symptomatic malunion is usually subjected to corrective osteotomy. Corrective osteotomy with bone grafting and fixation is still the mainstay operation used to restore normal anatomy. Various types of osteotomy have been reported. Closing wedge osteotomy offers the advantage of bone to bone contact and more stable construction, but with the major disadvantage of shortening the radius relative to the ulna.(1) Opening wedge is the most popular technique with successful results. However, its disadvantages are potentially increased instability, risk of nonunion, and fixation failure.(1,2) Various methods of fixation in corrective osteotomy have been described such as external fixation, radio-radial fixation, standard T-plates, and fixed angle plates. The volar locking plate, one type of the fixed angle plates, is biomechanically and clinically accepted to be the best method for both dorsal and volar angulations. In general, the volar locking plate is commonly used in the treatment of acute distal radius fractures, however it can also be utilized in the treatment of malunited distal radius.(1, 3) Open wedge osteotomy can be performed on the dorsal side or volar side to create a bone defect that requires replacement of the bone-graft. Both autogenous bone graft and bone graft substitute can be used as the replacement bone graft; its advantage is load bearing capacity and stability.(4)

The iliac crest has been reported to be the most common site for bone grafting. However, the harvesting of autogenous bone grafts is associated with increased operative time and chance of complications (postoperative donor site pain, hematoma, fracture, and infection). The purpose of this study was to compare the radiographic outcomes of patients after placement of beta-tricalcium phosphate bone graft substitute and autogenous bone grafts in corrective osteotomies of malunited distal radius fractures with volar locking plates.

Materials and methods

Twenty-seven patients with malunited distal radius fractures were operated on in Lerdsin General Hospital, Bangkok. They were 13 males and 14 females. The average age was 50.53 years, range 16 to 75 years. The inclusion criteria included: (1) symptoms with pain, stiffness, grip weakness, malfunction, median nerve compression, and cosmesis (2) unacceptable radiographic parameters such as radial height <5mm, radial inclination <15°, dorsal tilt ≥15° or volar tilt ≥20°, and articular incongruity >2mm.[1,5,6] The exclusion criteria included: (1) malunion fracture associated with other conditions e.g. distal ulna fracture, scaphoid nonunion, and chronic osteomyelitis (2) incomplete data collection (3) follow-up period of less than 3 months.

All patients were operated on by the same senior staff in May 2007- December 2009. Thirteen patients were operated on the left and 14 on the right side. We divided the patients into two groups. The first group was the patients who underwent corrective osteotomy with volar locking plates and autogenous iliac bone grafts (IBG), and the second group included the patients with volar locking plates and beta-tricalcium phosphate bone grafts (BPBG). The operation was performed using the standard extra-articular osteotomy technique as suggested by Fernandez DL. However, we had modified the technique to use the volar approach since we had selected the volar locking plate as a fixation method.

After surgery, the wrist was placed in the short arm slab for 6 weeks. Gentle passive and active ranges of motion exercise were started after removal of the slab. All patients were followed up for at least 3 months. The radiographic examinations were obtained immediately, at 4 weeks, and at the final follow-up period with a mean follow-up time of 9.38 months, range 3 to 27 months.

We reviewed medical and standard anteroposterior and lateral radiographic records to collect demographic data and radiologic parameters at preoperative, postoperative (4^{th} week), and the last visit. On the antero-posterior radiographs, 3 parameters were used to evaluate the malunion: radial inclination, ulnar variance, and radial height. On the lateral radiographs, we measured 5 parameters: volar tilt, radioscaphoid angle, scapholunate angle, radiolunate angle, and capitolunate angle.[1,5,6] We used standard techniques of measurement as shown in Figures 1A and 1B. Each of the radiographic parameters was measured 3 times with an interval of 5 minutes and its average was recorded.

Statistical analysis

We compared radiographic parameters from both groups by unpaired t-test and calculated radiographic parameters by time sequence in each group by paired *t*-test. The reoperation rate in both groups was also compared by chi-squared (Fisher exact test).

Results

The study did not show a statistical difference in any radiographic parameters between the IBG group and BPBG group, as shown in Tables 1-4. We collected both clinical and radiographic results after corrective osteotomy and most of the cases showed improved symptoms. Eleven cases n the IBG group achieved union and showed satisfactory ranges of motion and cosmetic results as seen in figures 2A-2F. One of the re-operation cases in the BPBG group is demonstrated in Figure 1A-1F.

Fig. 1 Radiographs of one case in the BPBG group (A), (B) Preoperative anteroposterior view (C), (D) The 1st day postoperative anteroposterior and lateral, (E), (F) One year after operation

Table 1 Demographic data

	BPBG (N=15)	**IBG (N=12)**
Age	50.06(16-69) years	50.45(34-75) years
Male : Female	7 : 8	6 : 6
Right : Left	8 : 7	6 : 6
Year of operation		
2007	6	3
2008	9	4
2009	0	5
Follow up time	8 (3-15) months	11.27 (3-27) months

Table 2 Results of corrective osteotomy

	BPBG (N=15)	**IBG (N=12)**	***P*-Value**
Union	12	11	0.396
Failure correction	4	1	0.223
Re-operation	5	1	0.182

Table 3 Radiographic parameters for autogenous bone graft group at postoperative and last visit

Parameter	Postoperative mean (±SD)	Follow up mean (±SD)	*P*-Value
Volar tilt	4.75 (±12.19°)	-2.08 (±10.30°)	0.07
Radial inclination	15.58 (±17.07°)	23.17 (±8.96°)	0.13
Radial height (mm)	10.92 (±3.34)	11.08 (±3.63)	0.78
Ulnar variance (mm)	1.67 (±3.73)	1.75 (±3.16)	0.80
Scapholunate angle	59.25 (±9.18°)	62.92 (±4.85°)	0.32
Radiolunate angle	-3.33 (±6.21°)	-6.83 (±6.90°)	0.09
Capitolunate angle	-6.67 (±7.38°)	-10.67 (±9.88°)	0.12
Radioscaphoid angle	55.58 (±11.52°)	56.75 (± 6.92°)	0.78

Table 4 Radiographic parameters for beta-tricalcium phosphate group at postoperative and last visit

Parameters	Postoperative mean (±SD)	Follow up mean (±SD)	*P*-Value
Volar tilt	6.13 (±9.60°)	-0.13 (±17.76°)	0.11
Radial inclination	23.47 (±7.3°)	22.27 (±9.47°)	0.55
Radial height (mm)	12.34 (±3.92)	10.73 (±4.57)	0.16
Ulnar variance (mm)	1.27 (±1.87)	2.4 (±3.14)	0.14
Scapholunate angle	53.60 (±16.44°)	58.07 (±14.18°)	0.18
Radiolunate angle	1.46 (±14.06°)	2.00 (±11.66°)	0.88
Capitolunate angle	-16.80 (±16.62°)	-19.40 (±13.03°)	0.33
Radioscaphoid angle	56.67 (±10.30°)	57.73 (±15.26°)	0.81

Table 5 Comparison of mean difference of radiographic parameter

Parameters	Postoperative mean difference (95% confidence interval)	Follow up mean difference (95% confidence interval)
Volar tilt	-1.38 (-10.00,7.24)	-1.95 (-13.86,9.96)
Radial inclination	-7.88(-17.91,2.15)	-0.90(-6.40,8.28)
Radial height	-1.42(-4.35,1.52)	0.35(-2.99,3.69)
Ulnar variance	0.40(-1.87,2.67)	-0.65(-3.16,1.86)
Scapholunate angle	5.65(-5.30,16.60)	4.85(-3.99,13.69)
Radiolunate angle	-4.8(-13.81,4.21)	-8.83(-16.69,-0.97)
Capitolunate angle	10.13(-0.53,20.80)	8.73(-0.64,18.10)
Radioscaphoid angle	-1.08(-9.74,7.57)	-0.98(-10.80,8.84)

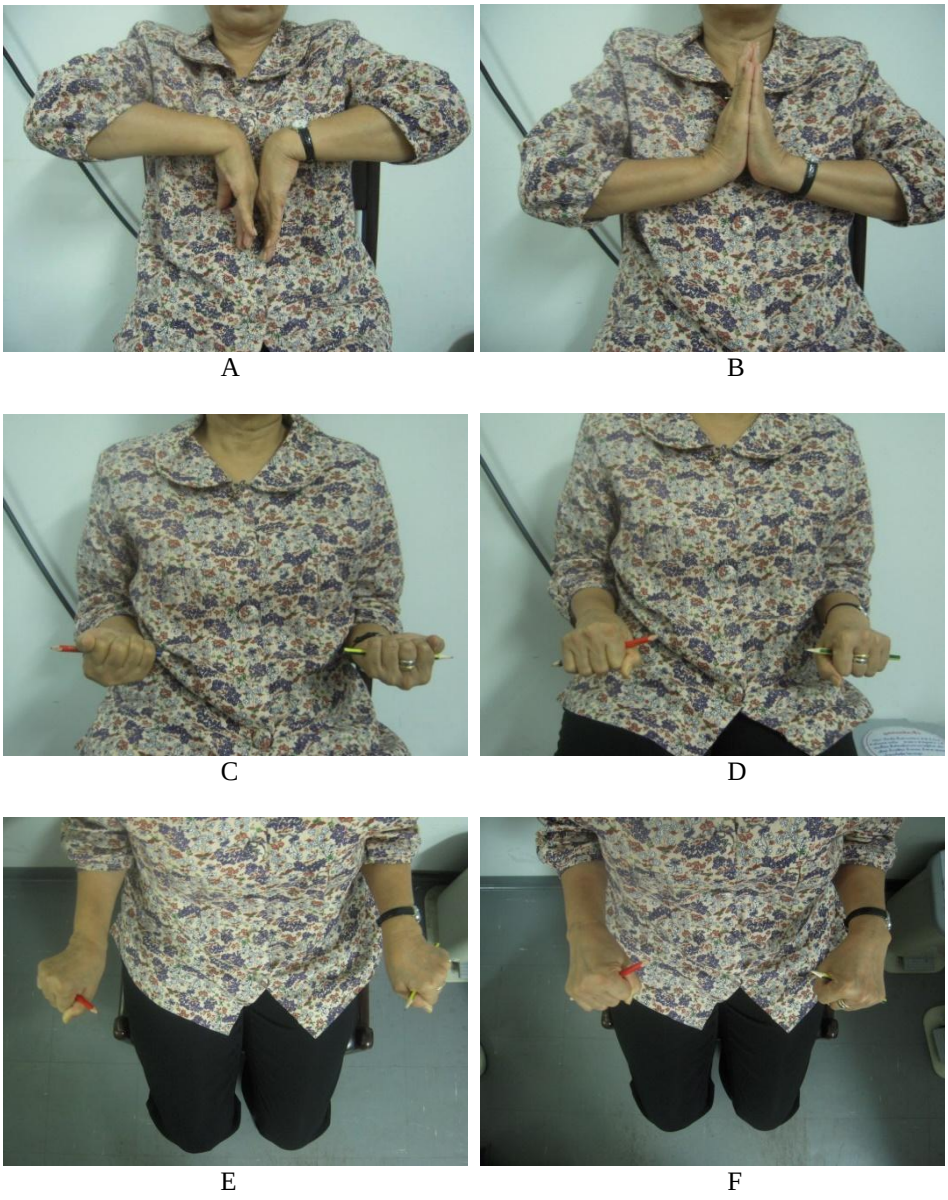

Fig. 2 Ranges of motion of one case in the autogenous bone graft group (A) Volarflexion (B) Dorsiflexion (C) Supination (D) Pronation (E) Ulnar deviation (F) Radial deviation

Discussion

Our study did not show a statistical difference in any of the radiographic parameters between the IBG group and the BPBG group. Therefore, we cannot conclude any correlation between radiographic parameter change and dorsal radiocarpal subluxation, or carpal malalignment or instability. In the previous clinical observation and biomechanical studies, it has been demonstrated that dorsal angulations of the distal radius cause wrist instability in two patterns. The first pattern is dorsal radiocarpal subluxation with maintenance of midcarpal alignment, and the second pattern is adaptive midcarpal dorsal intercalated segment instability deformity.[1]

The union rate in the BPBG group was 80% (12 in 15) while it was 91.67% (11 in 12) in the IBG group (P = 0.396). The failure correction rate in the BPBG group was 26.67% (4 in 15) while it was 8.33% (1 in 12) in the IBG group (P = 0.223). The re-operation rate in the BPBG group was 33% (5 in 15) while it was 1 in 12 (8.33%) in the IBG group (P = 0.182). Luchetti *et al.* reported successful results in a series of patients treated with carbonated hydroxyapatite instead of autogenous bone graft in the osteotomy gap.[7] Yasuda *et al.* reported a case involving the use of calcium phosphate bone cement with osteotomy and volar plating that resulted in complete radiographic union and improvement of symptoms[8]. However, some reports described the unsuccessful results. Ekrol *et*

al. reported a series of patients treated with RhBMP-7 in osteotomy and non-bridging external fixator or pi-plates that resulted in a slower bone healing rate than autogenous bone grafts.[9] Compared to the previous reports, the result of BPBG usage in our study was different from carbonated hydroxyapatite and calcium phosphate bone cement usage, but gave the same result as RhBMP-7 and BPBG usage in another study. Jakubietz *et al*. reported no difference in both clinical and radiographic results between internal fixation only and additional beta-tricalcium phosphate in comminuted intraarticular distal radius fractures.[10]

Prior to conducting the study, we had performed osteotomy using BPBG for bone graft substitute in most of the cases. After 2 years of follow-up we found, however, that there was a higher re-operation rate in patients who were operated on with BPBG as compared to those with IBG. We also collected both clinical and radiographic results after corrective osteotomy, which in most of the cases showed improvements in symptoms. However, 6 cases had to be re-operated due to pain and failure to achieve good functional outcomes. Even though there is no statistical difference of clinical and radiographic results between the two groups, the study has revealed the tendency towards a higher rate of failure in the BPBG group. The limitations of this study are that it was of retrospective design and the sample size was small in number. It is worth noting that a prospective study is beneficial and, by collecting more of both radiographic parameters and clinical outcomes, including range of motion and major symptoms, future studies will provide more conclusive results. Furthermore, as for the union time, our study is a retrospective review of the radiographs of the operated wrist. Therefore, it might be difficult to define the exact time of union at the osteotomy in association with the use of the two types of graft.

Conclusion

Radiographic parameters in the BPBG group were not significantly different from the IBG group. Compare to the previous reports, the result of BPBG usage in our study was different from carbonated hydroxyapatite and calcium phosphate bone cement usage, but gave the same result as RhBMP-7 and BPBG usage in another study. The union rate in the BPBG group was lower than the IBG group. The failure correction rate and re-operation rate in BPBG group was higher than the IBG group, however this difference in rates was not statistically significant.

References

1. Bushnell, B.D. and D.K. Bynum, Malunion of the distal radius. J Am Acad Orthop Surg, 2007. 15(1): p. 27-40.
2. Shea, K., et al., Corrective osteotomy for malunited, volarly displaced fractures of the distal end of the radius. J Bone Joint Surg Am, 1997. 79(12): p. 1816-26.
3. Smith, D.W. and M.H. Henry, Volar fixed-angle plating of the distal radius. J Am Acad Orthop Surg, 2005. 13(1): p. 28-36.
4. Khan, S.N., et al., The biology of bone grafting. J Am Acad Orthop Surg, 2005. 13(1): p. 77-86.
5. Verhaegen, F., I. Degreef, and L. De Smet, Evaluation of corrective osteotomy of the malunited distal radius on midcarpal and radiocarpal malalignment. J Hand Surg Am. 35(1): p. 57-61.
6. Graham, T.J., Surgical Correction of Malunited Fractures of the Distal Radius. J Am Acad Orthop Surg, 1997. 5(5): p. 270-281.
7. Luchetti, R., Corrective osteotomy of malunited distal radius fractures using carbonated hydroxyapatite as an alternative to autogenous bone grafting. J Hand Surg Am, 2004. 29(5): p. 825-34.
8. Yasuda, M., et al., Early corrective osteotomy for a malunited Colles' fracture using volar approach and calcium phosphate bone cement: a case report. J Hand Surg Am, 2004. 29(6): p. 1139-42.
9. Ekrol, I., et al., A comparison of RhBMP-7 (OP-1) and autogenous graft for metaphyseal defects after osteotomy of the distal radius. Injury, 2008. 39 Suppl 2: p. S73-82.
10. Jakubietz, M.G., J.G. Gruenert, and R.G. Jakubietz, The use of beta-tricalcium phosphate bone graft substitute in dorsally plated, comminuted distal radius fractures. J Orthop Surg Res. 6: p. 24.

ผลภาพถ่ายรังสีของการผ่าตัดแก้ไขกระดูก distal radius ผิดรูปโดยการใช้ beta-tricalcium phosphate เปรียบเทียบกับการใช้กระดูกเชิงกราน

ณัฐธร ดาราพงศ์สถาพร, พบ, ชัยโรจน์ เอื้อไพโรจน์กิจ, พบ

วัตถุประสงค์: *เพื่อศึกษาเปรียบเทียบภาพถ่ายรังสีที่เป็นผลจากการผ่าตัดแก้ไขกระดูก distal radius ผิดรูปโดยการใช้กระดูกเทียมชนิด beta-tricalcium phosphate เปรียบเทียบกับการใช้กระดูกเชิงกราน*

วิธีการศึกษา: *ผู้ป่วยที่มีกระดูก distal radius ผิดรูปจำนวน 27 รายในโรงพยาบาลเลิดสิน ที่มีอาการจากกระดูกผิดรูป และมีค่า parameters จากภาพถ่ายรังสีที่ผิดปกติ ที่เข้ารับการผ่าตัดแก้ไขโดยใช้กระดูกเทียมชนิด beta-tricalcium phosphate และกระดูกจากเชิงกราน โดยทำการติดตามค่า parameters จากภาพรังสีทั้งก่อนผ่าตัด หลังผ่าตัด 4 สัปดาห์ และครั้งสุดท้ายที่มาตรวจติดตามผล โดยรวบรวมผลและคำนวณโดยใช้ unpaired t-test, paired t-test และ chi-squared (Fisher exact test)*

ผลการศึกษา: *ค่า parameters จากภาพถ่ายรังสี ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติของทั้งสองวิธี แต่พบว่าในกลุ่มที่ใช้กระดูกเทียมชนิด beta-tricalcium phosphate มีการติดของกระดูกหลังผ่าตัดเพียงร้อยละ 80 และในกลุ่มที่ใช้กระดูกจากเชิงกราน มีการติดของกระดูกหลังผ่าตัดถึงร้อยละ 91.67 และยังพบว่าในกลุ่มที่ใช้กระดูกเทียมชนิด beta-tricalcium phosphate มีอาการปวด และมีปัญหาจากการใช้งาน มีการสูญเสียมุมที่แก้ไขถึงร้อยละ 26.67 และต้องกลับมารับการผ่าตัดซ้ำถึงร้อยละ 33 ส่วนในกลุ่มที่ใช้กระดูกจากเชิงกราน มีการสูญเสียมุมที่แก้ไข และต้องกลับมารับการผ่าตัดซ้ำร้อยละ 8.33*

สรุป: *ค่า parameters จากภาพรังสี ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติของทั้งสองวิธี แต่พบว่าในกลุ่มที่ใช้กระดูกเทียมชนิด beta-tricalcium phosphate มีอัตราการติดของกระดูกน้อยกว่า มีการสูญเสียมุมที่แก้ไขและต้องกลับมารับการผ่าตัดซ้ำมากกว่ากลุ่มที่ใช้กระดูกจากเชิงกราน แต่ก็ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติ*