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Sparing the pronator quadratus for volar plating of distal radius fractures: a comparative study of two methods

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Abstract

Objectives: The objective of this study was to compare the results of two methods for sparing the pronator quadratus in volar plating of distal radius fractures.

Methods: A total of 110 patients were randomized to volar plating with sparing of the pronator quadratus either by a transverse incision along the distal border of the pronator quadratus (Group A, 55 people) or by the brachioradialis splitting method (Group B, 55 people). The operative and radiation time, range of motion, grip strength, Disabilities of the Arm, Shoulder, and Hand (DASH) scores, Visual Analog Scale (VAS) scores, and complications were recorded.

Results: There were no significant differences in the mean operative time, radiation time, mean bone union time, or total complication rate between the groups. We found no significant differences in range of motion, grip strength, VAS scores, and DASH scores at any of the study intervals between the groups. Although neurapraxia of the superficial branch of the radial nerve was more common in Group B than in Group A (6.7% vs. 0%), the difference was not significant.

Conclusions: Both methods were efficient approaches for sparing the pronator quadratus and had similar clinical outcomes, but they had different indications.

Keywords

Distal radius fractures, wrist fractures, volar plating, pronator quadratus, muscle sparing, outcomes

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Introduction

Volar locking plate fixation has become a standard surgical method for the treatment of unstable distal radius fractures.[1–3] Although its results are encouraging, implant-related complications such as tendon injuries, and even rupture, can occur.[4] Flexor tendon rupture is a well-recognized complication after volar plating of distal radius fractures, with an incidence as high as 12%.[5,6] It is mainly caused by protrusion of the plate, such as the distal end of the plate beyond the watershed line, and different plate designs.[4] Full coverage of the plate with enough soft tissue and avoiding direct contact between the flexor tendon and the hardware is the most common solution. Studies have proposed preventing tendon rupture with early removal of the implant or with the flap of the pronator quadratus (PQ) muscle.[5,6] However, conventional incision of the PQ from its radial border make it difficult to repair owing to the contused and friable condition of the muscle[7,8] because it is a direct muscle-to-muscle repair.

In view of the uncertain effect of direct repair, some authors have proposed the pronator-sparing technique.[7–9] Typically, a transverse incision is made along the distal border of the PQ, and it involves preserving the PQ insertions and requires only minimal elevation of the undersurface of the muscle. This technique creates a pocket underneath the PQ to insert the volar plate. Good clinical results have been frequently reported.[7,9] Recently, a new pronator-sparing technique was introduced through a brachioradialis (BR) splitting approach.[10] By using the approach for release of the PQ/BR complex, the authors believed that the integrity and ease of repair of the PQ was enhanced and a good result can be expected.[10]

Although both methods had good clinical outcomes, no literature has compared the superiority of one approach over the other. The purpose of this prospective comparative study was to evaluate the clinical results of the two methods. We hypothesized that the new brachioradialis splitting technique would have a lower rate of complication and better functional outcomes compared with the common transverse incision technique for sparing the PQ.

Material and methods

Approval was obtained from our Institutional Review Board prior to performing the study and informed consent was obtained from all patients before the operation. From December 2015 to December 2017, we performed a prospective study to compare two methods for sparing the pronator quadratus for volar plating of distal radius fractures. Skeletally mature patients with displaced distal radius fractures were treated with open reduction and volar plating at our hospital. Before we performed exposure of the fracture site, we used two methods for sparing the PQ. Group A had a transverse incision along the distal border of the PQ while Group B had a brachioradialis splitting approach. The inclusion criteria were: (1) age $\geq$18 years, (2) displaced and unstable distal radius fractures, (3) fresh closed fractures (within 14 days from injury), (4) AO classification A2, A3, B3 and C. The following patients were excluded: (1) ipsilateral or contralateral upper limb fractures and/or dislocation, (2) open fractures, (3) old fractures (>14 days from injury), (4) pathological fractures or metabolic bone disease, (5) associated nerve or vascular injury requiring repair, (6) previous ipsilateral upper limb surgery, or (7) mental illness. We defined ground-level falls as low-energy injuries and traffic accidents and sports injuries as high-energy injuries. At admission, the type of treatment was chosen at random by drawing from the

box containing an equal number of envelopes with either of the two methods. Both the surgeons and the patient were unaware of the chosen surgical procedure. The patient demographics and fracture characteristics were shown in Table 1. There was no significant difference in the pre-operative variables between the two groups.

Surgical procedures

Patients were placed supine under general or regional anesthesia and operations were performed by the same group of surgeons (ZJ, ZYQ, and ZL). For patients in Group A, a standard 8- to 10-cm volar modified Henry approach was made between the flexor carpi radialis (FCR) tendon and the radial artery (Figure 1). The tendon was identified and retracted ulnarly. The radial vascular bundle was retracted radially. The PQ was exposed and a transverse incision was made along the distal edge of the PQ (Figure 2). The PQ was then elevated and a path was formed for the plate. The fracture site was accessed via gentle retraction of the PQ proximally. After the fracture was reduced and provisionally fixed with K-wires, the selected distal radius plate (Sanatmetal Orthopaedic & Traumatologic

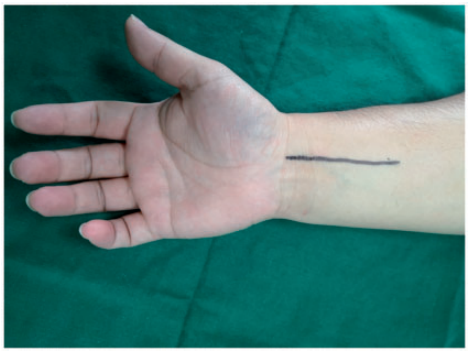

Figure 1. Modified Henry approach.

Table 1. Baseline characteristics of the two groups.

	Group A (55)	Group B (55)	*P*
Mean age (years)	44.2 ± 6.4	42.8 ± 7.6	0.298
Sex			
Male	21	18	0.550
Female	34	37	
Mean BMI	23.0 ± 2.5	23.3 ± 2.0	0.489
Dominant hand injury (n)	25	20	0.332
	30	35	
AO classification (n)			
A	18	16	0.834
B	5	4	
C	32	35	
Cause of injury (n)			
High energy	22	17	0.319
Low energy	33	38	
Mean interval from injury to surgery (days)	3.0 ± 2.6	3.5 ± 1.5	0.219
Associated ulna fracture (n)			
No ulnar fracture	20	17	0.778
Ulnar styloid fracture	33	35	
Ulnar styloid base fracture	2	3	
Mean follow-up time (months)	34.5 ± 11.3	32.2 ± 9.6	0.253

BMI, body mass index.

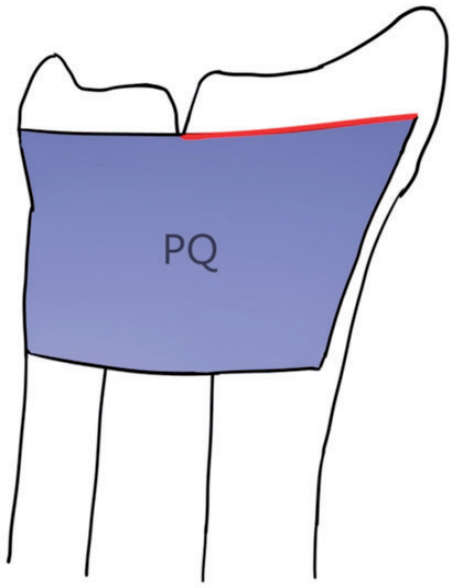

Figure 2. Diagram of the pronator quadratus muscle with a transverse incision along its distal border (Red line).

Equipment Manufacturer Ltd, Hungary) was laid on top of the PQ in estimation of its final position and fluoroscopic images were obtained to confirm satisfactory plate size and location. The plate was then slid in a retrograde direction underneath the PQ to its preferred position. A transverse stab incision was made in the PQ in the area over the oblong hole. The plate was fixed proximally with a bicortical screw through this hole, and the fracture was fixed distally with locking screws. The K-wires were removed and final x-rays confirmed satisfactory reduction and implant positioning. A simple absorbable suture was placed to repair the stab incision in the PQ before wound closure.

For patients in Group B, the brachioradialis (BR) splitting approach in this study was similar to that described by Kashir A et al.[10] From the tip of the radial styloid, an incision was made extending proximally in a longitudinal direction for about 8 to 10 cm (Figure 3). The superficial radial nerve was identified and dissected. The radial artery was also identified and protected. The surgeon used the index finger to bluntly dissect the flexor pollicis longus muscle and to retract it ulnarly and then the

Figure 3. Incision along the radial border of the wrist.

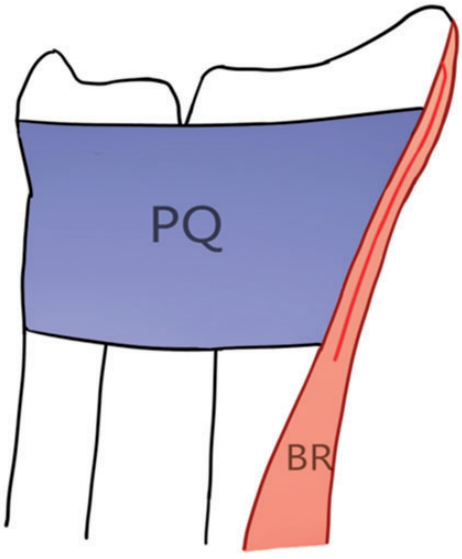

Figure 4. Diagram of the brachioradialis muscle with longitudinal splitting through the midzone of the tendon about 2–3 mm dorsal to its insertion and extending proximally a length of 3–5 cm (Red line).

PQ was exposed. The extensor retinaculum overlying the extensor pollicis brevis (EPB) and abductor pollicis longus (APL) was incised sharply with a knife, exposing the insertion of the BR into the radial styloid. EPB and APL were retracted dorsally and the BR was split longitudinally through the midzone of the tendon about 2 to 3 mm dorsal to its insertion, extending proximally a length of 3 to 5 cm (Figure 4). The PQ was then released sharply from the radius using a periosteal elevator, along with the sleeve of the BR still attached, exposing the volar surface of the distal radius. After the fracture was reduced and provisionally fixed with K-wires, a bicortical screw through the oblong hole of the selected plate was used to achieve initial fixation, then the fracture was fixed distally with locking screws. When the reduction and fixation were finished, the PQ was reattached by suturing the BR sleeve to its insertion, transferring the PQ/BR complex distally by 4 to 5 mm to cover the plate. A subcuticular 3-0 monocryl suture was used before wound closure.

All of the patients followed a similar postoperative protocol that consisted of wearing a short-arm brace for 1 week. Active range of motion of the fingers was started immediately after surgery. Wrist range of motion was started at 1 week postoperatively. At 6 weeks postoperatively, patients were advanced to progressive strengthening and resistance exercises upon evidence of sufficient interval healing on radiographs and clinical exam. At 12 weeks postoperatively, patients were advanced to a work hardening program or discharged from therapy depending on occupational needs.

Outcome assessment

Plain radiographic evaluation consisted of anteroposterior and lateral views obtained preoperatively, postoperatively and at each study interval. For data collection, the operative time was defined as the time from the skin incision to skin closure. Fluoroscopy time was obtained from the fluoroscopy log. All patients were assessed at regular intervals of 2 weeks, 6 weeks, 3 months, 6 months, and 12 months after surgery. The primary outcome measure was the Disabilities of the Arm, Shoulder, and Hand (DASH) score.[11] Secondary outcome assessments were measurements of the Visual Analog Scale (VAS) score, range of motion, and grip strength. Wrist flexion, extension, radial-ulnar deviation, and forearm rotation measurements were recorded with a goniometer. Grip strength was measured using a hand grip dynamometer with the elbow at 90° and the wrist in neutral rotation. These measurements were repeated by two blinded observers (ZYD and WJ) not involved in the patients' care. The measurement result was the average of the two. The senior surgeon (JGQ) also analyzed radiographs at the same intervals for evidence of fracture healing and maintenance of reduction. Fracture union was defined as the absence of pain and the presence of bridging callus in three of the four cortices seen on the anteroposterior and lateral radiographic views of the radius. Delayed union was defined as lack of any healing on plain radiographs within 3 months. Nonunion was defined as lack of any healing on plain radiographs within 6 months. Re-displacement was defined as radial shortening >3 mm, dorsal tilt $>10°$, or intra-articular displacement or step-off >2 mm.[12] We also recorded other complications, such as postoperative infection, extensor and flexor tendon injury, nerve or vascular injury, subluxation of the extensor pollicis brevis (EPB) and abductor pollicis longus (APL), carpal tunnel syndrome, and complex regional pain syndrome.

Statistical analysis

The distributions of data in our study were checked. Percentages were used for

categorical data, and means or medians were used for continuous data. Student's t-test was used for the comparison of continuous variables and the chi-square test was used for the comparison of categorical variables. Statistical analysis was performed using SPSS software, version 11.0 (SPSS, Inc., Chicago, IL, USA). The patient demographics (sex, dominant hand injury, cause of injury, AO classification, associated ulna fracture, postoperative complications) and fracture characteristics of the two groups were compared using the Pearson's chi-square test and Fisher's exact test for nonparametric categorical variables. An independent sample t-test was used to compare the patients' age, body mass index (BMI), interval from injury to operation, operative time, radiation time, duration of follow-up, bone union time, pain, range of motion, grip strength, and DASH scores. The level of significance was set at $P < 0.05$.

Results

One hundred and ten patients underwent volar plating for distal radius fractures in our hospital during the study period, and 55 each were placed in Groups A and B. The average follow-up time of Group A was 34.5 ± 11.3 months and Group B was 32.2 ± 9.6 months. All fractures went onto union. There were no significant differences in the mean operative time, mean radiation time, and mean bone union time between the two groups ($P = 0.391$, 0.111, and 0.329, respectively) (Table 2). At the last follow-up, 72.7% of patients in the group A had their plates taken out while 78.2% of patients in the group B had their plates taken out.

The overall complication rate was similar in both groups (8/55 vs. 8/55, $P = 0.245$) (Table 2). No intraoperative vascular injury, wound complications, postoperative re-displacement, subluxation of EPB or APL, tendon rupture, or hardware failure were observed in the two groups. Two patients (3.6%) in Group B suffered tendon irritation while four (7.3%) patients in Group A had tendon irritation ($P = 0.679$). Two patients (3.6%) in Group A complained of delayed carpal tunnel syndrome, while three patients (5.5%) in Group B complained of carpal tunnel syndrome ($P = 1.000$). Complex regional pain syndrome was diagnosed in 3.6% of patients in Group A versus 1.8% in

Table 2. Details of intra- and post-operative variables in the two groups.

	Group A (55)	Group B (55)	*P*
Mean operative time (min)	63.2 ± 12.0	65.3 ± 13.5	0.391
Mean radiation time (min)	2.4 ± 1.4	2.0 ± 1.2	0.111
Mean bone union time (weeks)	12.8 ± 3.0	12.2 ± 3.4	0.329
Total complications (n)	8	8	0.245
Nerve injury	0	2	0.495
Vascular injury	0	0	
Wound infection	0	0	
Subluxation of EPB or APL	0	0	
Re-displacement	0	0	
Extensor or flexor tendon irritation/rupture	4	2	0.679
Delayed carpal tunnel syndrome	2	3	1.000
Complex regional pain syndrome	2	1	1.000

EPB, extensor pollicis brevis; APL, abductor pollicis longus.

Table 3. Range of motion at each follow-up interval.

	6 weeks		3 months		6 months		12 months	
Group	A	B	A	B	A	B	A	B
Extension	62°	60°	75°	76°	81°	84°	85°	88°
Flexion	59°	60°	75°	80°	80°	81°	84°	85°
Pronation	80°	78°	84°	85°	86°	85°	86°	87°
Supination	77°	73°	83°	85°	85°	87°	88°	88°
Ulnar deviation	30°	27°	35°	33°	36°	36°	36°	35°
Radial deviation	15°	16°	18°	20°	20°	21°	21°	21°

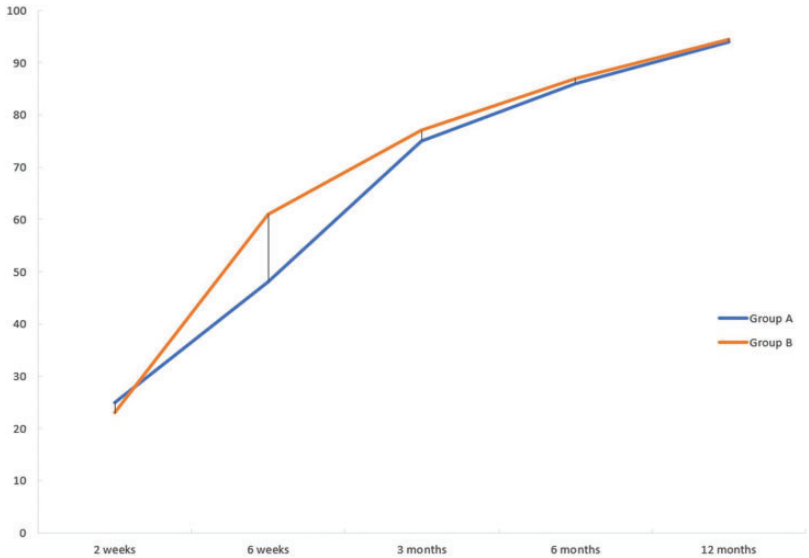

Figure 5. One-year trend of mean grip strength for Groups A and B.

Group B ($P = 1.000$). Although neurapraxia of the superficial branch radial nerve was more common in Group B than in Group A (3.6% vs. 0%), the difference was not significant ($P = 0.495$).

The range of motion measurements at each interval are shown in Table 3. Outcomes assessed at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months after surgery all demonstrated no significant differences in mean range of motion between the two groups. The mean values of all variables showed a stepwise improvement over the year as range of motion and grip strength consistently increased and DASH and VAS scores consistently decreased (Table 3 and Figures 5–7), though no significant differences were found at any of the study intervals between the 2 groups.

Discussion

This was the first clinical study to compare a transverse incision and brachioradialis splitting for sparing the pronator quadratus in volar plating of distal radius fractures. This series had the advantage being prospective and randomized in nature and

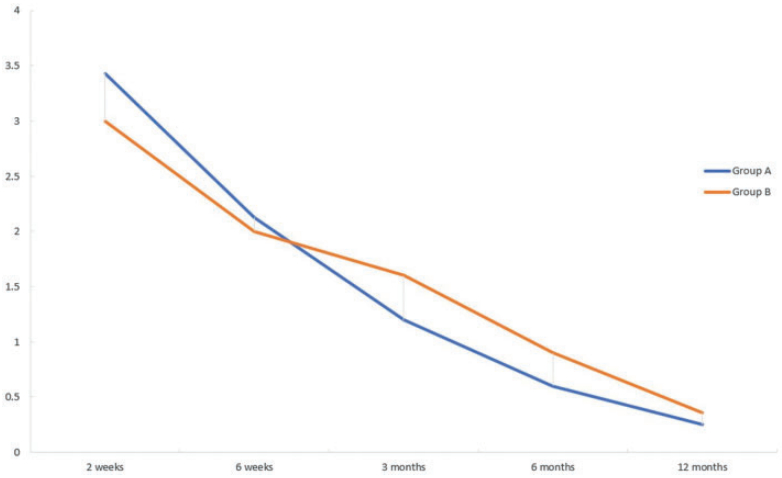

Figure 6. One-year trend of mean Visual Analog Scale scores for Groups A and B.

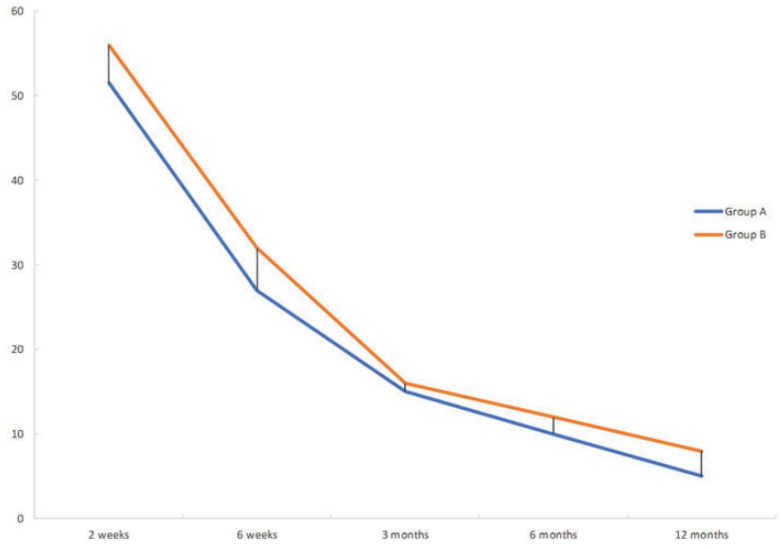

Figure 7. One-year trend of mean Disabilities of the Arm, Shoulder, and Hand scores for Groups A and B.

using validated outcome measures. We found no significant differences in the mean operative time and radiation time, and total complication rate between the two groups. Although the brachioradialis splitting approach required more time than the transverse incision method in the exposure process, it had a better exposure to the fracture site to facilitate fracture reduction and fixation, so the operative time and radiation time of the two groups were not significantly different. In addition, we found no significant differences in range of motion, grip strength, VAS scores, and DASH scores at any of the study intervals between the two groups.

Although some studies have questioned the necessity of PQ repair,[13,14] the PQ did have a role. The PQ contributes approximately 21% of the pronation torque during simultaneous pronation and gripping.[15] The PQ also contributed to the distal radioulnar joint as a dynamic stabilizer through continuous muscle contraction throughout the pronosupination arc in the absence of gripping.[9,16] Moreover, most authors believed that an intact PQ helped to reduce the irritation or rupture of the flexor tendons.[14,17,18] The total incidence of tendon irritation or rupture in our group was 5.5% (6/110), which was significantly lower than the non-PQ-sparing method.[5,6] Thus, an increasing number of studies have focused on methods of sparing the PQ.[7,9,19,20] A transverse incision along the distal border of the PQ is currently the most common sparing method used. However, some authors have argued that this method might affect fracture reduction and fixation.[15] Different from their opinions, we believe that most distal radius fractures can be reduced and fixed by gentle retraction of the PQ proximally. A recent cadaveric study also confirmed that a mean distance of 26.2 mm for the scaphoid and 23.8 mm for the lunate fossa increased following mobilization of the PQ, and this would be enough to allow for the placement of a volar plate.[8] Cannon[9] compared the postoperative results of distal radius fractures fixed through a pronator-sparing approach with those fixed through the conventional approach and revealed that the two groups did not differ significantly in most radiologic parameters postoperatively, including radial height, radial inclination, and articular step-off. Moreover, wound infections, loss of fixation, or nerve or tendon injuries did not occur after this pronator-sparing approach. The radiologic and functional outcomes and complications of this approach in our study were similar to previous findings.[9,19]

Kashir et al.[10] first described the brachioradialis splitting approach. By using this approach, they believed that the integrity of the PQ was preserved and all fractures of the distal radius requiring volar plating could be treated without requiring further incisions. They reported no nerve injury or subluxation of the first compartment. The radiologic and functional outcomes of our brachioradialis splitting approach were similar to their outcomes. However, the incidence of nerve injury in our group was higher than in their group. Numbness at the base of the thumb caused by neurapraxia of the superficial branch radial nerve was the most common complication. Fortunately, the symptoms of nerve injury in our series disappeared after approximately 8 to 12 weeks. There may be a few reasons for this. First, we only recently began to apply this technique and operative proficiency may have been inadequate. Second, this technique was more complicated than the transverse incision method and required a progressive learning curve and familiarity with regional anatomy. Third, insufficient surgical experience was also a factor. Gentle and careful retraction and intentional protection of the tendon sheath should always be emphasized to avoid the risk of nerve and tendon complications.

Although both methods of sparing the PQ achieved similar good clinical results, there were still some differences between the two methods. First, their indications were slightly different. The two methods were suitable for AO classification A2, A3, B3, and C fractures. The transverse incision method had limited exposure to the fracture site and it was not suitable for distal radius fractures with long-segment metadiaphyseal fractures. To expose the fracture site, retraction with great force might cause tearing of the PQ. Although the brachioradialis splitting approach had a wider exposure to the fracture site, it did have some limitations to

the exposure of the compressed intraarticular fractures of intermediate column as well as distal radioulnar joints. Moreover, neither method could be applied to fractures mainly with dorsal displacement, such as a dorsal articular shearing injury (B2) and a dorsal articular compression injury (dorsal die-punch fracture). Second, the brachioradialis splitting approach was more complicated and had an increased risk of neurovascular injury and tendon subluxation compared with the transverse incision method. We should pay more attention when using this approach.

Several limitations existed in our study. First, this was a single center study that enrolled only a small number of patients. To further reinforce these results, high-quality randomized controlled trials with a larger sample size are still needed. Second, although patients were allocated randomly to a surgical group, it was impossible to perform blinding of both the surgeon and patients, which might have influenced the results. Third, this study only included four cases of type C3 fractures. Thus, it was difficult to fully understand whether these results and conclusions could be extrapolated to more complex fractures. A larger sample size containing more fracture patterns would be helpful in a future study.

Conclusion

Our results indicated that both methods were efficient approaches for sparing the PQ and had similar clinical outcomes. However, defects also existed in them. We should be familiar with their respective characteristics and drawbacks and carefully select the patients requiring surgery.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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