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Original article

The role of vascularized flaps in the treatment of proximal pole avascular necrosis in scaphoid non-unions

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Summary. *Objectives:* The purpose of this study is to evaluate the clinical and radiological outcomes of scaphoid non unions surgically treated with bone graft versus medial condyle corticoperiosteal free flaps. *Materials and Methods:* 32 patients were divided in 2 groups. Group A (17 patients 12male, 5 females, mean age 35 years old) treated with bone grafts; Group B (15patients 11 male, 4 females, mean age 33 years old) treated with medial condyle cortico periosteal free flap. A radiological follow up was performed about every 30 days after surgery until the complete healing and at 12-month follow-up. The clinical follow up was performed at 6 and 12 months from surgery. Functional assessment was provided by Mayo wrist score and Visual Analogic Scale (VAS). *Results:* The average length of follow up was 12.52 months ± 1.36. In group A 60% of patients healed in 4.4 ± 1months with a reduction of 28.4% of healing times in group B ($p<0.05$).In Group B all nonunion sites healed primarily at an average time period of 3.2 ± 1 months. Statistical analysis showed a significant difference ($p<0.001$) about the preoperative and the postoperative VAS and Mayo Wrist Score evaluation in both groups at 6 and 12-month follow-up, moreover we recorded a statistical difference between groups at the 6-month and 12-month follow-up ($p<0.05$). *Conclusion:* The present study showed that the free flaps showed better clinical and radiographic results for the surgical treatment of scaphoid nonunions. In fact, despite the good results of the bone graft, the flaps seems to be preferable in the treatment of these nonunions. (www.actabiomedica.it)

Key words: scaphoid nonunion, corticoperiosteal flap, microsurgery

Introduction

Acute scaphoid fractures account for 2% to 3% of all fractures, approximately 10% of all hand fractures and between 60% and 80% of all carpal fractures (1). The incidence of scaphoid fractures quoted in the literature is inconsistent with a range from 1.5to 29 fractures per 100,000 persons per year (1-4).

Scaphoid fractures usually occur after a fall on to the outstretched hand or during sports (1, 2) but is also documented that a low-energy fall from standing height occurred more frequently in females, with males more likely to sustain their fracture afterahigh-energy injury such as sports or a motor vehicle collision (2).

The natural history of scaphoid fracture nonunion is unknown as the majority of patients represent due to new or on-going symptoms. The quoted rate of nonunion is variable due to a lack of agreement regarding the criteria for union and the imaging modality that should be used. Nonunion is said to occur in approximately 10% of all scaphoid fractures, but the rate is much lower for nondisplaced fractures and approaches zero when a nondisplaced fracture is adequately treated and protected (5, 6). Displaced fractures have a 50% nonunion rate, with an increased rate also seen with

proximal pole fractures (7). Other proposed risk factors for nonunion of scaphoid waist fractures include delayed diagnosis or treatment (8, 9).

Scaphoid nonunion with avascular necrosis of the proximal fragment represents a challenge. Surgical options include nonunion repair using both bone grafts or free vascularized cortico periosteal grafts including the medial femoral condyle flap (10, 11). The rationale of this technique was based on the evidences suggesting that superior healing rates are achieved with medial femoral condyle free flaps over pedicled bone grafts (10-12).

The aim of this retrospective study is to evaluate the clinical and radiological outcomes of proximal pole avascular necrosis in scaphoid nonunions surgically treated with bone graft versus medial condyle corticoperiosteal free flaps.

Materials and Methods

From April 2013 to April 2015 37 patients with scaphoid non union were enrolled in the present study. All the patients gave the informed consent prior being included into the study.

The study was authorized by the local ethical committee and was performed in accordance with the Ethical standards of the 1975 Declaration of Helsinki as revised in 2000.

From the original 37 patients 32 met the inclusion criteria and were available for the follow up. These 32 patients were divided in 2 groups. Group A (17 patients 12 male, 5 females, mean age 35 years old) treated with bone grafts; Group B (15 patients 11 male, 4 females, mean age 33 years old) treated with medial condyle cortico periosteal free flap according to Bishop (13).

Inclusion criteria: age >18 years old, bone gap >3 mm, time from injury >6 months,no evidence of fracture consolidation on three consecutive radiographs in two projections more than 6 months after the fracture, no infections, initial conservative treatment of scaphoid fracture,no previous surgery on the index wrist or contralateral wrist, small defect, high grade avascular necrosis of the proximal pole of the scaphoid.

Follow-up

A radiological follow up was performed about every 30 days after surgery until the complete healing and at 12-month follow-up. The clinical follow up was performed at 6 and 12 months from surgery. Functional assessment was provided by Mayo wrist scorewith 0 reflecting majordisability and 100 reflecting complete recovery of the wrist. Pain was quantified using the Visual Analogic Scale (VAS), with 0 indicating absence of pain and 10 indicating maximum pain. Focusing on the donor site, postoperative X-rays were taken until bone healing. The pain using the Visual Analogic Scale (VAS) and the range of motion (ROM) were evaluated.

Postoperative Rehabilitation

Immediately after surgery, all patients were encouraged to elevate the hand and begin early finger motion. A short arm plaster splinting was maintained for 5 weeks. At that 2 weeks follow-up the dressings and sutures were removed; at the 5 weeks follow-up the therapy was started under the supervision of a certified physiotherapist. During weeks 2 through 6, an anti-edema protocol was started along with tendon gliding and range of motion exercises.

Statistical Analysis

One-way Analysis of Variance (ANOVA) with a post hoc Tukey test was used to compare Mayo Wrist score, VAS scores between groups. In the donor site the ROM pre op and the ROM post op data were compared using the Student *t-test*. Statistical significance was set at p-value of 0.05. All tests were performed using SPSS (version 20, IBM, UK).

Results

The average length of follow up was 12.52 months ± 1.36.

In group A 60% of patients healed in 4.4 ± 1 months with a reduction of 28.4% of healing times

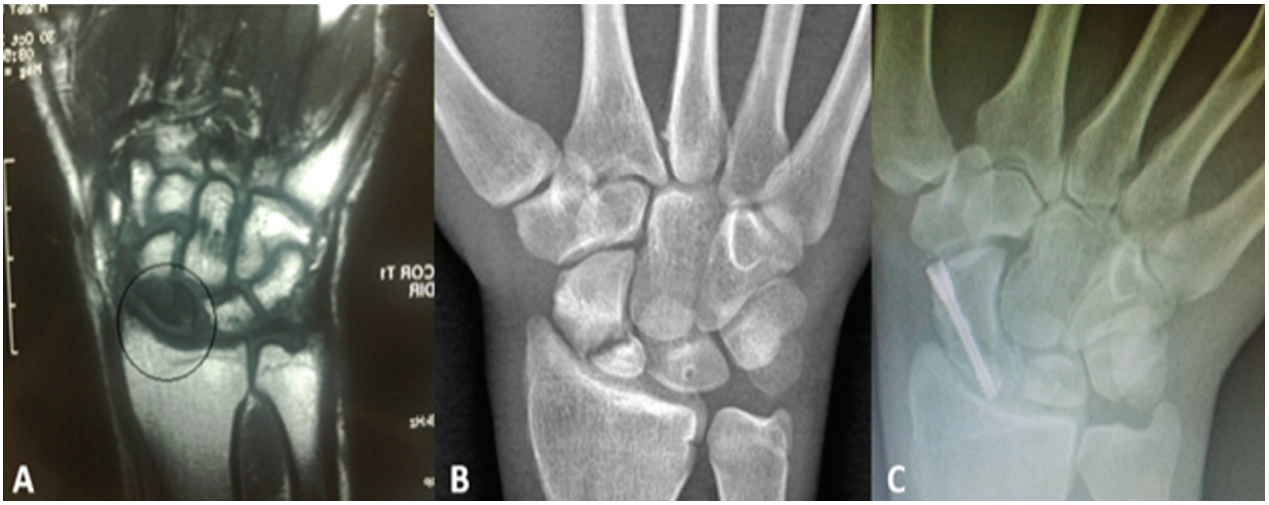

Figure 1. This figure shows: A) Pre operative MRI of a patient of Group B; B) Pre operative AP X-Ray of a patient of Group B; C) Post operative (5 months) X-Ray of a patient of Group B

in group B ($p<0.05$). In Group B all nonunion sites healed primarily at an average time period of 3.2 ± 1 months (Figure 1).

Statistical analysis showed a significant difference ($p<0.001$) about the preoperative and the postoperative VAS and Mayo Wrist Score evaluation in both groups at 6 and 12-month follow-up, moreover we recorded a statistical difference between groups at the 6-month and 12-month follow-up ($p<0.05$) (Table 1). At the donor site, the mean VAS score was 2 ± 2.1 at seven days post operatively. The time to return to normal walking activity was 2 days (range 1-4).All patients restore the full ROM at 7 days post surgery.

Table 1. Statistical analysis showed a significant difference ($p<0.001$) about the preoperative and the postoperative VAS and Mayo Wrist Score evaluation in both groups at 6 and 12-month follow-up, moreover we recorded a statistical difference between groups at the 6-month and 12-month follow-up ($p<0.05$)

	Group A	Group B
Preoperative Mayo Wrist Score	33±8.6	30±5.6
6 Months Mayo Wrist Score	70.51±3.7	79.51±3.63
12 Months Mayo Wrist Score	79.65±3.5	90.47±2.9
Preoperative VAS	7.2±1.5	7.05±2
6 Months VAS	4.1±1	2.11±2
12 Months VAS	2.9±1	1.5±1.16

Discussion and Conclusion

The most important finding of the present study is that the free flaps showed better clinical and radiographic results for the surgical treatment of proximal pole necrosis in scaphoid nonunions.

In fact despite the good results of the bone graft, the flaps seems to be preferable in the treatment of these nonunions.

The corticoperiosteal flap is a microsurgical technique that can be performed only by expert microsurgeons. The traditional grafts like the free fibular can be used to treat larger defect, for this reason their use in case of minimal bone loss is still discussed. The medial femoral condyle flap provides a source of corticoperiosteal vascularized bone that does not require the harvest of a major vessel. Because of its thickness (0.5-1 mm), it seems that the flap can be rapidly harvested and tailored to numerous shapes and configurations as required for various osseous defects. The great osteogenic capacity of this flap has been frequently demonstrated by different authors: Sakai has shown that the periosteum is osteogenic, however when harvested as an isolate layer it failed (14). The proposed reason for this unreliability is the injury of the to the cambium layer, which lies between the periosteum and cortex of the bone (14, 15). The preservation of this layer increases local bone mass within the recipient

site, enhancing graft incorporation. This fine layer is easily injured when the periosteum is separated from the cortex. Doi and Sakai (14) described elevating the periosteum along with a thin strip of cortex, thus protecting the delicate and vital cambium layer. We believe that the cortico-periosteal is the only microsurgical bone flap with those proprieties. After their introduction different Authors described the clinical implications of the corticoperiosteal flap: Fuchs et al. (13) reported bone healing in 3 patients with atrophic nonunion of the clavicle that were healed by free vascularized corticoperiosteal bone grafts. More recently, Choudry et al. (16) reported excellent results in the treatment of 12 bone nonunions. In that series 75% of the nonunion sites healed primarily without complication, 25% healed secondarily following implant modification. Similar success rates have been reported by Muramatsu et al. (17) in their treatment of 10 humeral nonunions. In our study 100% of unions were achieved at a mean length of 3.2 months. Patients showed a remission of functional pain and disability at the previous nonunion site with return to normal daily activities. In fact, the clinical evaluation showed a significant improvement of pain and disability of the upper limb starting on the 6-month follow-up compared to the preoperative clinical condition and compared with the control group. The 12-month follow-up revealed a substantial maintenance of pain and functional improvements. These clinical data are very interesting if combined with the radiographic results, in fact, in our study, the unions occurred after an average time of 3.2 months after surgery, highlighting a correlation between the bone healing and the pain and clinical scale improvements. Although reports are still limited, the corticoperiosteal flap is the only surgical treatment with a success rate close to 100% and a limited donor defect. One of the possible explanations of the minimal morbidity of the donor site is related to the surgical technique. In fact the surgical access to the medial condyle is between the natural cleavage of the vastusmedialis and the adductor longus. Moreover, thanks to the intrinsic features of the bloody supply of the medial condyle, the graft harvesting does not cause ischemia, in fact in the condyle the flow is centrifugal from the medullary to the cortex (18-22). An other important advantage of this technique is that the anatomy and biomechanics of the donor site are not compromised. Katz et al. (21) in 2012 ssessed the axial stability of the femur after harvesting corticocancellous flaps. Authors demonstrated that, when stressed with supraphysiologic forces, the femur retains its axial stability even after harvesting of large corticocancellous flaps (up to 24 cm) from its medial aspect. In our study, no postoperative radiographic changes at the donor site were documented; there were no cases of ROM limitations and patients return to normal walking activity in 2 days. We do not report cases of persistent knee pain. Compared to other bone graft the corticoperiosteal flap showed less complications at the donor site: chronic (> 6 months) donor site pain, dysesthesias around the incision area, iatrogenic nerve injuries, superior gluteal artery injuries, iliac fractures and hernias, are reported in case of iliac crest bone graft (23,24). While, chronic pain, dysesthesias around the incision area, instability and limited range of motion in the ankle, sensory deficit, claw toe, dorsiflexion of the great toe are reported in case of vascularized fibula graft (24). In fact, compared with traditional grafts the corticoperiosteal graft allows a faster healing of fractures with a minimal morbidity at the donor site. At our knowledge this flap is the only microsurgical procedure, in orthopaedic surgery, that can be performed not only as a rescue technique but also as a treatment of first choice in case of scaphoid nonunions.

At our knowledge, these flaps are a valid surgical technique for the treatment of proximal pole necrosis in scaphoid nonunions.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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