LUIZ CARLOS ANGELINI1, WALTER MANNA ALBERTONI2, FLÁVIO FALOPPA3

Treatment of radius distal third fracture through external fixation and bone graft

SUMMARY
The author presents a prospective study in which he uses the external fixation method associated with the autogenous bone graft for the management of articular and metacarpal distal radius fractures. Thirty-six patients with a mean age of 52.2 years were treated. The follow-up had an average duration of 36.2 months. The stability of the reduction and its maintenance were assured by the external fixation with the autogenous bone graft. In the patients who underwent a densitometric analysis of the bone mass, the presence of the autogenous mass showed statistically steady in the long run. With this technique the rehabilitation could be anticipated and began in the immediate postoperative period, thus favoring the mobilization. In the fourth week the external fixation device is removed, this restoring the free movement of the wrist, except for the extension which is hampered by a splint of dorsal situation for two additional weeks. In the review of the data resulting from the treatment the anatomical and functional features were considered. The anatomical findings were obtained from radiographic examinations on the patients. The analysis of these outcomes were based on the Scheck method (1962) and were graded excellent in 72% of the cases, and good in 28%, satisfactory as a whole. The data related to the function obtained were evaluated based on the Green And O’Brien system (1978) modified by Cooney et al.(1987). In the 24th week, 14% were considered unsatisfactory and 86% satisfactory. At 12 months and in December, 1999, they were considerate satisfactory as a whole. The complications detected during the treatment were: pin site infections in 8,31% of the cases, and transient symptoms of post-traumatic sympathetic dystrophy in 8,33%, all of them thoroughly resolved with appropriate therapy. In 33% of the patients there were also identified signs of post-traumatic pseudoarthrosis of the ulnar styloid process which however evolved asymptomatically in all cases under review.

Keywords: Distal fractures; External fixator; Bone Transplantation; Densitometry.

INTRODUCTION
Among the fractures occurring on upper limb, those of distal radius are the most frequent, estimated as accounting for 16% of all skeletal fractures. An epidemiologic study stated that distal radius fracture accounts for up to 74.5% of the forearm fractures, with an incidence of approximately 1:10.000 individuals(6). Today, radius distal end fracture is seen as a complex lesion, with a variable prognosis, depending on the kind of treatment adopted. This can be divided into conservative methods - or non-surgical methods – and surgical reduction methods. Within conservative methods, some deviation degrees on fractures alignment are acceptable, emphasizing the functional outcome. In the surgical reduction, the importance of the anatomical outcome is highlighted, correlating it to the functional outcome.

The bloodless reduction, which consists on a forced manipulation of the distal fragment, followed by immobilization with plastered devices or splints, with wrist strongly flexed and ulnar shift (Cotton-Loder position)(2), has been the most common treatment for this kind of fracture for a long time. However, if this is reasonably easy for obtaining a fracture alignment, the same does not happen with reduction maintenance. There is a high incidence of fracture shift recurrence and unsatisfactory results with this kind of treatment.

In order to obtain fragments reduction and to keep them aligned until they are united, many methods have been proposed: wedges on plaster(3), percutaneous fixation introduced at the ulnar distal third, followed by plaster(4); immobilization with forearm in supine position(5); percutaneous fixation(6,7); repeated plaster replacements(8); immobilization with extended wrist(9), among others. Böhler n(10) described a technique in which transfixed pins

Study conducted at the Hand Surgery Clinic of the Hospital do Servidor Público Municipal de São Paulo (HSPM) and at Hospital São Paulo from the Federal University of São Paulo (HSP-UNIFESP).

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Received in: 10/19/04; approved in 11/22/04

ACTA ORTOP BRAS 13(2) - 2005
on bones were built in a plastered device. The basic principle was to provide a fixed traction, preventing radius shortening. The method was widely accepted, and, overtime, some authors such as Anderson and O’Neil(11); Scheck(12); Green(13); Carrozella and Stern(14), introduced some modifications.

In the last few years, studies on wrist biomechanics(15,16) and on the instability of complex fractures conceptually established the advantages of the treatment with an external fixation. Nevertheless, we think that an extended fixation time and the metaphyseal comminution were problems which, in our point of view, have not been solved, which led us to probe the use of a bone graft and early mobilization.

The purpose of this study was to evaluate the treatment of 36 patients with joint and metaphyseal fractures of the distal radius submitted to external fixation associated with autogenous bone graft.

MATERIALS AND METHODS

Within the period between July 1993 and December 1999, 36 patients with distal radius fractures have been treated at the Hospital São Paulo of the Federal University of São Paulo (UNIFESP) and at the Hospital do Servidor Público Municipal de São Paulo (HSPM-SP). They were categorized according to the method by the Association for the Study of Internal Fixation (AO/ASIF).

The sample comprised 28 women, ages ranging from 31 to 73 years old (average 51 years); and eight aged 25 – 67 years old (average 46 years), all of them were Caucasians.

Patients’ occupations had a non-uniform distribution, except for the housewives and retirees, totaling 13 (36.1%) of patients.

The incidence of lesions in upper body’s dominant limbs prevails over the non-dominant ones: 19 (52.7%) being dominant and 17 (47.2%) non-dominant.

Diagnosis was provided by physical examination and by radiographic investigation in posteroanterior and lateral incidences, performed at baseline.

Time interval between trauma and surgery date varied from three to five days, with an average of four days, and the follow-up ranged from 12 to 77 months, with an average of 36.2 months.

The thirty-six patients participating in this study were selected because of their similar characteristics, i.e., radius distal fractures, simple or comminutive, articular, with metaphyseal comminution, treated by employing the external fixation method associated to bone graft. None of those lesions presented bilaterally or with bone exposure. This was a prospective study, complying with a protocol developed in our medical service and applied to each patient (Table 01).

In a surgical setting, and with the patient under general anesthesia, new radiographic images are taken on frontal and lateral planes. Osseous mass evaluation was made with duomagnetic osseous densitometry.

SURGICAL TECHNIQUE

A pneumatic garrote is routinely used which is placed on the arm medium third. Contralateral hip region is prepared for bone graft removal.

After ten minutes with the upper limb rose, the pneumatic garrote is insufflated with 100 – 150 mmHg above patient’s systolic pressure(17) and a 3-cm longitudinal incision is performed just above the dorsoradial base of the second metacarpal bone. Radial sensitive nerve ramifications are visualized and protected. The retraction of the 1st dorsal interosseous muscle is performed, which allows a thorough access of the radial portion of the second metacarpal bone base. Under direct view, with the aid of two Bennett’s retractors, the 2.5-mm self-screwing Schanz’ pins are inserted by means of a guide, motored by an electric perforator with controllable speed. The first pin is inserted in the second metacarpal bone and fixed on the third metacarpal bone, in an inclination of 30-45 degrees related to the sagittal plane with the purpose of enabling thumb extension and a good visualization of the radiographic images.

Thus, the transverse metacarpal arch is also manually maintained and the thumb abducted in order to prevent interdigital contractures. A second 2.5-mm Schanz’ pin is then transfixed in a parallel orientation to the other, targeting only the radial and ulnar corticals of the second metacarpal bone, avoiding the violation of the second interosseous compartment. Skin and subcutaneous cellular tissue are sutured with nylon monofilament 5-0, trying not to transmit pins tension to the skin.

Proximal pins are similarly inserted through a 3-cm longitudinal incision, 10 – 12 cm away from radius styloid process, under the dorsoradial edge of its diaphysis, 3 – 5 cm proximal from fracture site (with the forearm in neutral rotation). In this region, the radial sensitive nerve is dissected between the brachioradial and the carpus radial long extensor muscles, and carefully isolated for pins insertion, which is performed within the interval between carpus radial extensor long and radial short. The skin is sutured by employing the same directions previously described.

After Schanz’ pins insertion, the external fixation device is assembled, by fitting connectors to the pins and these to the main tube, which is formed by two segments articulated to each other by an universal joint (Figure 2 A,B,C).

For fractures reduction, we made use of the effects of ligationotaxis, which is obtained by longitudinal traction applied to the wrist, through straps fixed at the 2nd and 3rd fingers of the hand, followed by a careful handling of the fracture core. A radiographic control showing a good reduction determines the blockage of connectors, stabilizing the frame. By this moment, a 4.0-cm incision is performed in the region of the contralateral iliac crest. The anterior flap is elevated with the aid of an osteotome and the spongy graft of the ileum bone is removed, at a sufficient amount to fill the osseous gap on distal radius. For placing the bone graft on distal radius, a dorsal and longitudinal 3-cm incision at the level of the third compartment close to the dorsal tuberculum is performed. A Freyer’s retractor is used to raise impacted fragments under fluoroscopic visualization. Then, bone graft is placed. A final radiographic control on PA and lateral positions, previously described, is crucial for assessing the reduction and for checking fractured metaphysis filling (Figure 3 A, B).
Then, a plastered splint for volar, antebrachial support is prepared leaving fingers’ metacarpophalangeal and interphalangeal and the thumb loose for two weeks. Upper limb is supported by a fabric sling extending from the shoulder to the hand.

Postoperatively, patients remain with the external fixation device for four weeks, followed by two weeks with an antebrachial dorsal “orthosis” (Figure 4 A,B), blocking only wrist extension. Rehabilitation starts on the 7th day postoperatively. All patients in this study were assessed on the 24th week, at month 12, and by the end of the study (December 1999) for anatomic and functional aspects.

RESULTS

Information regarding treatment was divided into two groups: an anatomic group, with radiology and osseous densitometry data, and a functional group, with data regarding range of motion, palmar prehension strength, functional performance (return to work), sensitiveness and pain.

We used the radiographic evaluation described by Scheck(12) which analyzes the ulnar inclination angle averaged 21 degrees, radial length with final average of 11 mm, on the PA radiograph and the volar inclination angle on lateral plane, scoring and grading the results. Those parameters were established at the 24th week, on month 12, and by the end of this study (December/1999) (Figure 5 A,B,C,D).

Regarding bone densitometry, all patients have been submitted to bone mass investigations on forearms. The research was performed at the proximal and distal portions of the radius and ulna by means of a densitometer provided with specifications for quantifying bone mineral content (at the regions mentioned above). Statistical analysis of the comparison of data obtained from involved and non-involved sides, at each time and for each region, showed no statistically significant differences on percentage variations (%) between regions on the 6th week, as well as on the 24th week and on months 12 and 36. Although there is no reference data in literature regarding osseous mass staging on individuals suffering a distal radius fracture, we believe that the results achieved are promising (Figure 6).

For the functional evaluation we used the Green and O’Brien(18) System, modified by Cooney et al.(19). Those achieving excellent, good and regular grades were considered as satisfactory, totaling 86% of the patients, and those with poor grades (total: 14% of patients) were considered as unsatisfactory. (Data collected by the end of the study, in December 1999) (Figure 7).

The charts show the mean progression of ranges of motion for the involved limb compared to those for the non-involved limb on the 24th week, on month 12 and in December 1999, when this study was completed, as well as the mean progression of the prehension strength of the involved limb compared to the non-involved limb on the 24th week, by month 12 and in December, when the study was completed (December 1999).

Minimum follow-up time for patients’ outcomes analysis was 12 months and the maximum follow-up time was 77 months, with an average of 36.2 months. All patients were re-assessed in December 1999 (Chart 01).

Table 1 - Patients listed by number (patient #), name initials (name), gender, age (in years), occupation, involved side, dominant side, AO/ASIF classification, date of surgery (surgery date), time interval (days) between fracture and surgery (Time interval fract/surg), follow-up time in months (follow-up).

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COMPLICATIONS

During the time the fixation device was used, the following complications were seen: 3 (8.33%) patients presented with an inflammatory response around the pins, with heat, flush, and a slight serous fluid. All cases progressed to infection cure.

Sympathetic-reflexive dystrophy occurred in 3 (8.33%) patients, two were moderate and one severe, progressing to symptoms remission.

Regarding fractures of the ulnar styloid process, those occurred in all cases, with 12 (33.33%) patients developing a pseudoarthrosis, but not asymptomatic.

DISCUSSION

Radius distal fracture occurring in an anatomic site is relatively small. Even if some of those lesions reach bone diaphysis, the majority is concentrated on metaphyseal and joint regions of the distal radius.

From fresh cadavers to laboratory reproduction of lesions and their mechanical behavior, the advent of imaging diagnosis improvement, through computer systems and new materials used on the reduction and maintenance of those lesions have modified concepts related to the therapeutic approach of distal radius fracture, which, in literature, is marked by frequent doubts and by multiple techniques described for treating such fracture(10,11,04,20,,21,22,23,24,25,26,27,28,29,30). This has led us to a retrospective review of the patients treated up to 1991, not only regarding anatomic and functional aspects, but also concerning the care involved on the treatment of such lesions.

A fact that called our attention was that the reduction of the metaphyseal comminution could not be well resolved simply by using an external fixation device, which led us to investigate the use of bone graft to fill this gap, concluding, then, that the autogenous graft might be the most favorable option.

Thus, we selected adult patients with distal radius fractures and assessed them in a prospective study, projected to a sample as much homogenous as possible. The 36 patients represent a 9% fraction of an universe of 397 fractures of the distal radius, which, for many different reasons were excluded from this sample. Fractures associated with soft parts lesions have not been included in the sample, as well as open fractures and carpal ligament lesions and/or those with any association to other fracture of the upper limb.

AO/ASIF classification (31), which strictly notes the morphological aspects of the lesion, is organized in an increasing order of severity for bone involvement (Figure 1 A).

For treatment purposes, we chose those from type C, groups 2 and 3 and subgroups 1 and 2, i.e., those involving joint surface in a simple or comminutive manner, associated with metaphyseal comminution, resulting from impacts due to compression forces (Figure 1 B). Patients selected for the proposed treatment were submitted to surgery approximately four days after trauma. We preferred the general anesthesia due to both surgical steps: bloody reduction of fracture and bone graft removal.

Under a technical point of view, we developed an external fixation device, Moldaço brand, patent number MU 6801401-Brazil, with good stiffness conditions(32), light-weighted, low profile, radiotransparent, multiplanar, with affordable price, patented by SPI Marcas & Patentes S/C Ltda (Figure 2 A).

The majority of complications and criticisms mentioned regarding external fixation is related to pins, their insertion and theoretical low stability provided by the frame, and due to its long time of use(33,34). We tried to control or prevent those issues by introducing the pins through a minimally opened access, preserving vessels, nerves, muscles and tendons. In order to reduce micromovements in the pin-bone interface, directly related to loosening and infections situations(35), we applied a curving load slightly convergent on pins through the connector and through bone holes perforations achieved with the aid of a specifically-configured guide(36).
About the pins fixation in the bone, we agree with Seitz et al., who have fixed four pins: two proximal, passing through four radius cortical and two distal, with the first traversing the second and third metacarpal bones, transfixing four corticals. The second pin passes through the second metacarpal bone and through two corticals. We kept the index finger’s metacarpo-phalangeal joint in a 90-degree flexion position at the moment those pins were inserted, since a shift to the ulnar side of extensor tendons and peritenodesis structures occurs.

Once the device is fixed, reduction is achieved because of the effects of ligamentotaxis, i.e., the reorganizing effect of the intact radiocarpal extra-articular ligaments on shifted fragments, which reconstruct radius compartment and the radial inclination angle, but fails on restoring volar inclination angle, since volar radiocarpal ligaments are shorter.

With the use of the safety measures above mentioned, the surgical technique for inserting pins did not result in any complications regarding nervous, tendinous and osseous lesions. Regarding the use of an external fixation device in patients with osteoporosis, we agree with the authors Cooney and Hass and De La Caffiniere, being used only in patients up to 73 years old.

Fractures severely involving joint and metaphysis not only lose the reduction of joint inclination angles, but also the maintenance support of radius facets, resulting in radius shortening. Many authors have proposed the primary use of spongy bone graft, whether associated to the osteosynthesis or not, as a treatment alternative for such cases, in which good anatomic and functional outcomes are reported. They noted that when the fixation device was used without a graft, a collapse of the fracture zone occurred. They considered that a spongy bone graft produces both a mechanical stabilizing effect and a biologic osteoinductor or osteogenic effect, while increasing fracture stability and union speed. Indeed, biomechanical models demonstrated that fracture spaces filling tend to absorb part of axial forces that are distributed between the radius and the external fixation device, decreasing frame tension, pin-bone interfaces and enhancing system stability, and also promoting an important increase of mineral density, as demonstrated by Carter Dr, Hayes WC50.

On the other hand, we are aware of the occurrence of direct spongy union with cell proliferation in metaphyseal fractures, accompanied with a quantitative increase of bone mass, provided a close and steady contact is maintained between fragments. In such conditions, the spongy layer consolidates sooner than the cortical layer.

As for the location of bone graft removal we had no complications such as those found by Cockin, who mentioned a 10% complication rate in his 118 review cases, and by Youger and Chapman, who found a complication rate of up to 20%.

Functional rehabilitation plays an important role in our methodology through the early wrist mobilization, we remove the external fixation device in all patients on the 4th week replacing it by a dorsal “orthosis” which allows wrist flexion, but prevents its extension for two weeks; this was made possible due to a strict control during the fracture period, with no cases of reduction loss. The difference regarding the shorter period of time in which the fixation device is used is probably due to the bone graft allowing its earlier removal.

Bone metabolism goes through two physiological stimuli by the moment of fracture and during its treatment: one stimulus is osteogenic, for repairing lesion, and the other is osteopenic, as a result of disuse. The results showed a match with the non-involved side, demonstrating that at least there was no change on bone mass at the studied site, which corroborates to the biomechanical idea that the stability strengthening due to the graft promotes an initial outcome in six weeks and definitely establishes the cure. Further studies will certainly be required for establishing the real advantages of this investigation, which, however, presents a less invasive method due to the use of lower amounts of x-ray loads.

In this study, the final radiographic result was graded as satisfactory in 100% of the cases, both on the 24th week and to date (December/ 1999).

Regarding functional results, our patients achieved an average of 44.7 degrees of wrist movement. Regarding the prehension force, corresponding to 75.15% of the non-involved side, with non-involved wrist average being 25.1 kgf.

In our opinion, the treatment for this kind of fracture should be surgically-based due to the fact that this is a lesion presenting clear characteristics of instability. Such approach should be extended to elderly active patients, who, due to their life expectation rates today, also expect better outcomes and a shorter treatment.

We achieved fractures reduction and kept them with the external fixation device and with the bone graft until patients could start their
rehabilitation. The time spent until this point should be as shortest as possible. As opposed to other methods, at the immediate postoperative period, some rehabilitation measures are already taken, as well as during the period of wrist extension restraining. Average time for starting rehabilitation has decreased and the total time for returning to occupational activities was approximately three and a half months. In addition, there was a gradual increase of the prehension force over time, especially for those patients who practiced strong activities with the involved limb. It was clear that the reduction enhancement is reflected to a function enhancement. Our functional and anatomic results, however, do not allow us to conclude that this method is superior to other reported methods. Many of them have achieved a high percentage of excellent and good results, such as these achieved in this study. However, we cannot lose sight of certain disturbing questions: should we shorten treatment length? How to do this safely?

**CONCLUSION**

1) External fixation associated with autogenous bone graft assured the reduction and stabilization of joint and metaphysis fractures of the distal radius classified by AO/ASIF method, types C, groups 2 and 3 and subgroups 1 and 2.

2) Bone graft was kept in place over time and allowed for the removal of the external fixation device within four weeks.

3) After the removal of the external fixation device in four weeks, there were no changes on radiographic parameters.

4) Functional results were satisfactory in all cases.
REFERENCES