Post-traumatic diaphyseal bone defects in the upper extremity of children

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Abstract

Introduction: The aim of this study was to evaluate whether or not the combination of osteosynthesis and bone autograft represents an effective and reliable therapeutic method in children with chronic dyaphiseal segmental bone defects in humerus or forearm bones.
Materials and Methods: We evaluated retrospectively nine children, treated between 2005 and 2015, with fractures in long bones in upper limbs that got infected and resulted in segmental bone defects; all of them had a ≥6-month history since the initial traumatism. We included 7 boys and 2 girls who averaged 9.9 years of age. Four bone defects were in the humerus; three, in the ulna, and two, in the radius. All of them had been subject to surgical treatment (3.7 on average), which originated bone defects of average 4.5 cm in length. The average time between the initial traumatism and the definite surgery was 21.8 months.
Results: The average follow-up was 2.2 years. We got bone healing in all cases. In one patient we used cement spacer and, in another one, fibular free graft. Two patients with lesions in their humerus showed significant shortening. All the children returned to sport and recreational activities with no limitations.
Conclusions: By combining different types of bone autograft, diverse plates bridging the lesion and the technique of the induced membrane we got healing, and the nine children with segmental dyaphiseal bone defects in humerus, ulna or radius returned to their normal activities.

Key words: Bone defects; posttraumatic; upper limb; children.
Level of Evidence: IV

Defectos óseos diafisarios postraumáticos en la extremidad superior de niños

Resumen

Introducción: El objetivo de este estudio fue evaluar si la combinación de osteosíntesis asociadas a autoinjerto óseo representa un método terapéutico eficaz y confiable en niños con defectos óseos segmentarios diafisarios crónicos en el húmero o los huesos del antebrazo.
Materiales y Métodos: Se evaluó retrospectivamente a nueve niños, tratados entre 2005 y 2015, con fracturas en huesos largos de la extremidad superior que se infectaron y resultaron en defectos óseos segmentarios; todas con ≥6 meses de evolución desde el trauma inicial. Se incluyó a 7 niños y 2 niñas, con una edad promedio de 9.9 años. Cuatro defectos óseos se localizaban en el húmero; tres, en el cúbito y dos, en el radio. Todos habían sido sometidos a intervenciones quirúrgicas (promedio 3,7) que originaron defectos óseos de 4,5 cm en promedio. El tiempo entre el trauma inicial y la cirugía definitiva promedió los 21.8 meses.

Conflict of interests: The authors have reported none.

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Resultados: El seguimiento promedio fue de 2.2 años. Se obtuvo la consolidación en todos los casos. En un paciente, se utilizó espaciador de cemento y, en otro, injerto libre de peroné. Dos pacientes con lesión en el húmero presentaron un acortamiento significativo. Todos los niños retomaron sus actividades deportivas y recreativas sin limitaciones.
Conclusiones: Mediante la combinación de diferentes tipos de autoinjerto óseo, diversas placas colocadas puenteando la lesión y la técnica de la membrana inducida, se logró la consolidación y los nueve niños con defectos óseos diafisarios segmentarios en húmero, cúbito o radio retornaron a sus actividades normales.

Palabras clave: Defectos óseos; postraumático; extremidad superior; niños.
Nivel de Evidencia: IV

Introduction

Posttraumatic segmental bone defects in long bones can be secondary to infection due to open fractures. In association with absolute bone defects at the level of the fracture we can find relative bone defects which spread various centimeters proximal and distally; reconstruction comes as a challenge.[1] Posttraumatic segmental bone defects in children are hardly frequent;[2] their incidence increases after infections in children subject to surgical treatment. There are few publications studying these injuries in Pediatrics; most of them describe isolated cases or include lesions in both lower and upper limbs, or injuries in adults and children in the same series, or acute and chronic bone defects.[3-5]

The treatment of these injuries has the aim of giving the bone stability and restoring adequate biological environment to allow the bone to grow and to add bone tissue, as well as recovering continuity in the affected bone.

Open reduction and internal fixation (ORIF) with plates, associated with bone autograft has allowed surgeons to get good results in the treatment of diaphyseal bone defects in long bones in adults' upper limbs.[16] In this study, we present nine children with chronic diaphyseal segmental bone defects, in humeral or forearm bones, secondary to infection after surgical treatment.

Materials and Methods

Our aim was to evaluate whether or not the combination of osteosynthesis with wave or bridge plate and bone autograft represents an effective and reliable therapeutic method in children with posttraumatic segmental bone defects in upper limbs.

We evaluated retrospectively nine children, treated between 2005 and 2015, with long bone fractures in the upper limb which got infected and resulted in segmental bone defects; all lesions had a ≥6-month history since the initial traumatism. We evaluated seven boys and two girls who averaged 9.9 years of age (ranging from 7 to 14). Four bone defects were in the humerus; three, in the ulna and two, in the radius (Table). We excluded patients with bone defects secondary to oncologic resections, as well as aseptic and congenital non-unions.

All the patients had been subject to surgery (3.7 on average, ranging from 1 to 11) which originated bone defects of average 4.5 cm in length (ranging from 2 to 12). The average time between the initial traumatism and the definite surgery was 21.8 months (ranging from 4 to 62).

The definite treatment in seven cases consisted of ORIF with plates (LCP in 3 cases, LC-DCP in 2 cases and plane bones reconstructive plates in 2 cases), inserted so as to bridge bone defects and associated with cancellous bone graft from the iliac crest (Figure 1). One of these seven cases was that of 9-year old boy who suffered limb amputation at arm level and had an infection in the humeral osteosynthesis seven months after the limb replantation.

Regarding the two remaining patients in the series, one of them consulted six months after ORIF with humeral one-third tubular plate had been given, with active infection and a 2-cm bone defect. We removed the implant and carried out debridement of necrotic and infected tissues, and we inserted a cement spacer with antibiotic parallel to the humerus, where previously the plate had been.

The ninth patient in the series was an 8-year old boy with 11 previous surgeries and a 12-cm bone defect (Figure 2); in this case, we carried out two-time reconstruction; in the first surgery we used a non-vascularized free double fibular graft in the bone defect, stabilizing bone with a Kirschner wire (both proximal and distal bone ends looked highly atrophic and were small; therefore, we could not use internal fixation with plate); during the second procedure, eight months afterwards (once bone ends had undergone enough hypertrophy so as to bear a plate), we associated an LCP wave plate plus cancellous bone autograft from the iliac crest.

Whenever we used bone autograft, we applied 1 g-vancomycin powder.

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Table. Patients, treatment and results

Patient	Age	Sex	Bone	History (months)	Previous surgeries	Bone defect (cm)	Treatment	Follow-up (years)	Results
1	8	M	Humerus	62	11	12	1. Non-vascularized free double fibula. 2. Wave LCP plate. Cancellous bone autograft	4	Healing. Complete mobility No pain, 7-cm shortening 35%-loss in elbow flexion strength.
2	11	M	Humerus	18	2	5	Bridge LCP plate. Cancellous bone autograft	1.5	Normal mobility and strength 2-cm shortening
3	9	M	Humerus (replantation)	7	1	3	Bridge LC-DCP plate. Cancellous bone autograft	5	Healing. Functional limitation in elbow, hand and wrist. No pain, 6-cm shortening
4	14	M	Humerus	6	2	2	Cement with antibiotic	1.5	Healing. Normal mobility and strength. No pain
5	7	M	Ulna	31	4	6	Plane bones reconstructive plate. Cancellous bone autograft	2.5	Healing, 45º-loss in elbow pronation Neither pain nor shortening
6	10	M	Ulna	12	3	4	Bridge LCP plate. Cancellous bone autograft	1	Healing. Normal mobility and strength Neither pain nor shortening
7	13	M	Ulna	34	5	3,5	Bridge LCP plate. Cancellous bone graft	1	Healing. 20º-loss in elbow extension/20º-loss in elbow pronation. Neither pain nor shortening
8	9	F	Radius	14	3	2,5	Bridge LC-DCP plate. Cancellous bone autograft	2	Healing. Normal mobility and strength. Neither pain nor shortening.
9	8	F	Radius	12	2	3	Plane bones reconstructive plate. Cancellous bone autograft	1.5	Healing. Normal mobility and strength. Neither pain nor shortening.

M = male, F = female.

Results

The average follow-up was 2.2 years (ranging from 1 to 5) (Table). We got bone healing and continuity in all cases. All the children were able to return to school, sports and recreational activities with no limitations. The humeral infected bone defect in which we inserted a cement spacer with gentamicin and vancomycin parallel to the defect healed with no need of a second surgery (the cement was removed six months later, once the defect had filled with mature bone callus).

In the child with the most significant bone defect, the one we used fibular free graft in, we got healing and the patient recovered normal limb function with neither pain nor instability, but with a 7-cm shortening. The patient who received replantation of the upper limb at humeral level got bone healing, he suffered neither pain nor instability either, but he underwent a 6-cm shortening and functional limitations in the limb—which are typical of these kinds of injuries, with high levels of satisfaction anyway.

In the three cases of ulnar injury, reconstruction was successful and with no shortening; none of these patients suffered pain, but the three of them presented some degree of functional limitation (two with 40º and 20º-elbow pronation limitations respectively, and one with 25º-elbow extension limitations). The patients with radial bone defects recovered limb function and length without pain.

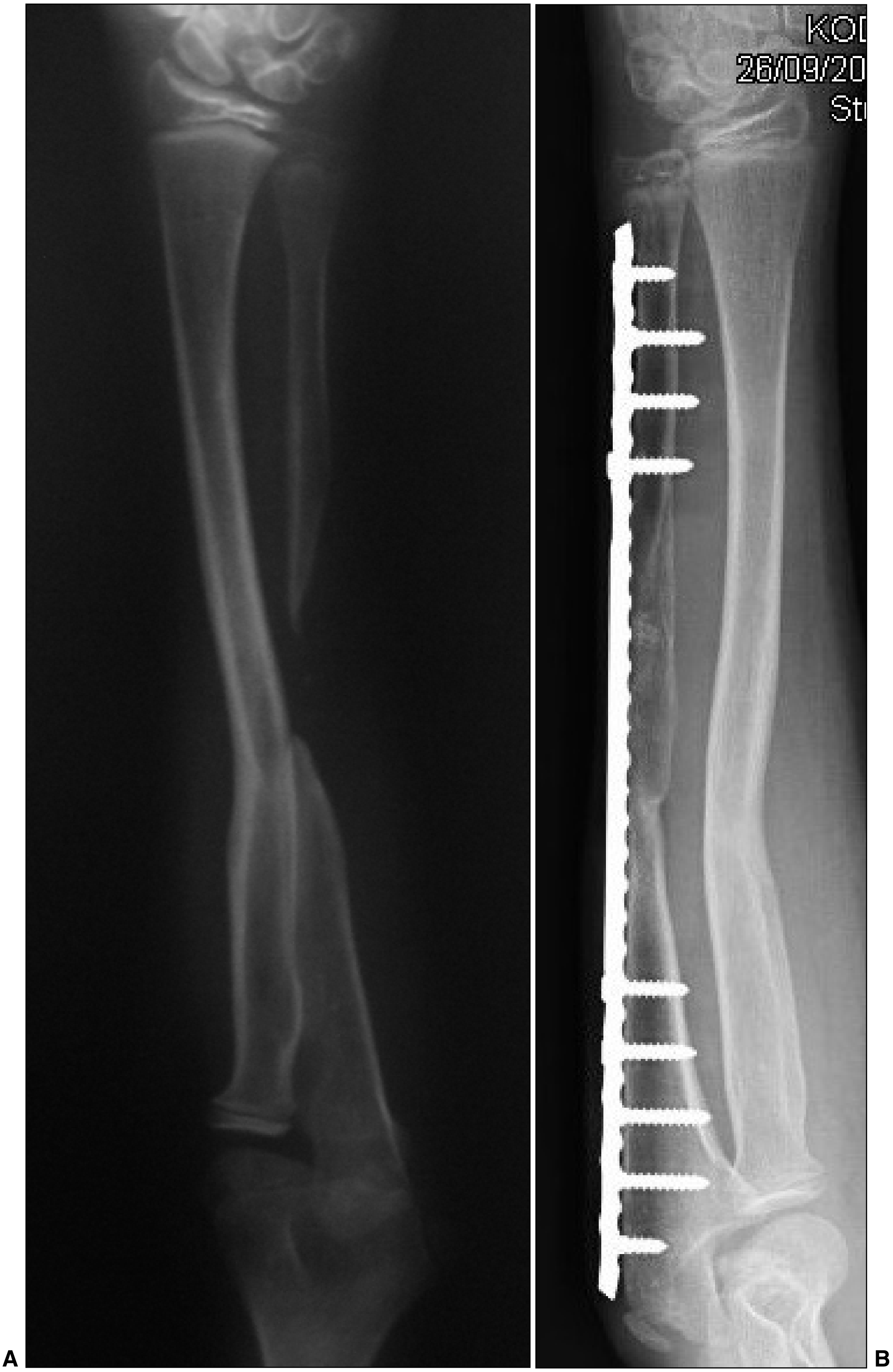

Figure 1. A. Seven-year old patient, 6-cm defect in ulnar diaphysis. **B.** X-ray showing bone healing and restoration of the ulnar length after treatment with 3.5 mm long LCP plate bridging the defect plus cancellous bone autograft from iliac crest.

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A B

Figure 2. A. Humeral 12-cm bone defect with atrophic bone ends. Non-vascularized free double fibular graft stabilized with wire. **B.** Eight months later, bone ends have hypertrophied and the wire was replaced with wave LCP plate and cancellous bone autograft in the distal bone end, with which bone continuity, stability and progressive remodeling were achieved.

Discussion

Posttraumatic diaphyseal bone defects are rare in children;[2,4,5] in general, they result from complex lesions or from complications in the treatment of fractures.[6] Consequently, most of them are clear-cut bone defects. If bone defects are in the forearm, surgical reconstruction has the aim of restoring a normal radio-ulnar relationship (length, alignment, and curvature); however when bone defects are in the humerus, some degree of shortening is well tolerated.[3,7]

In our series, we present nine children with segmental diaphyseal bone defects in humerus, ulna and radius; in eight cases, we resorted to bone autograft with plate bridging the defect (the ninth case healed after giving debridement and cement spacer with antibiotic), with healing, stability and absence of pain in all cases.

Reconstructive options in posttraumatic diaphyseal bone defects in the upper limb include the use of bone graft and plates, vascularized bone grafts, the technique of membranes induced by cement described by Masquelet, techniques of bone transportation and the creation of a one-bone forearm.[8-11]

Papakostidis et al.,[12] in a review of 37 articles, arrived at the conclusion that distraction osteogenesis using the Ilizarov method is an effective procedure to overcome bone defects in long bones in lower limbs; although there is high risk of undergoing refracture, especially in the cases with bone defects of 8 cm or more, and the authors recommend that patients are carefully selected due to the high percentages of intolerance associated with this therapeutic method. In the cases in our series, we believe that, given the patients' age (9.9 years old on average) and the location of the lesions (humerus, ulna, and radius), the Ilizaror method is associated with important limitations in terms of tolerance and complications. Ring et al. reported that the combination of osteosynthesis with wave or bridge plate and bone autograft represents a reliable method in the treatment of non-union with bone defect in upper limbs.[8,10]

The type of implant we used in our series varied as the bone diameter and the affected limb did, because, although from the biomechanical point of view LCP and LC-DCP plates bridging bone defects are methods of choice in the cases with bone defect, there were two cases in which we used plane bones reconstruction plates (due to their smaller and lower profiles and diameters as compared to the other plates); the two cases were lesions that affected forearm bones in children of 7 and 8 years of age, respectively.

In spite of the fact that vascularized free autografts of fibular bone are recommended for >6-cm bone defects in adults,[13] mainly due to the lower incidence of stress fractures they are associated with as compared to the use of non-vascularized fibular free grafts, there is no reported evidence for their superiority in children; on the other hand, both surgical time and infrastructure plus surgical skills needed are significantly less when non-vascularized fibular autografts are used.

Our series included a child with a 12-cm humeral bone defect, whose reconstruction was carried out by non-vascularized double fibular autograft, with good results and return to activities with neither limitations nor pain (Figure 2). The technique of induced membrane, introduced by Masquelet in 1986, has shown to be effective to treat bone defects, even large ones, and provides the surgeon with a successful treatment in case of infection.[10,14] Its use in the reconstruction of infected non-unions in adults' upper limbs has been successful.[15] In children, the periosteum is wider, more vascularized and more active, rich in growth factors and stem cells, and it is less adhered to the cortical bone; therefore, it might be total or partially preserved in segmental bone defects; when periosteum is preserved in children, and the infection is resolved, bone healing can occur spontaneously.[16-19]

We present a child with humeral infected non-union, in which the removal of the implant, the debridement of necrotic and infected tissues, and the insertion of a cement spacer with antibiotic lateral to the lesion (where previously the plate had been) allowed us to restore bone continuity and the patient's limb normal function with no need of reoperation.

Conclusions

The treatment of posttraumatic diaphyseal bone defects in upper limbs represents a challenge for surgeons. There are different techniques or a combination of techniques for reconstruction depending on the localization (affected bone, bone size and quality of bone in the remaining bone ends) and the characteristics of the lesion (degree of bone deficit, vascularization, associated injuries, and presence/absence of infection); bearing all this in mind, the surgeon should decide if he or she will carry out reconstruction in one or two surgical times, as well as the type of bone graft and the stabilization method of choice for every case. In our series, the combination of different techniques: different types of bone autograft (iliac crest and non-vascularized fibular bone graft), diverse plates (LCP, LC-DCP and plane bones reconstructive plates) bridging the lesion, and the use of the technique of the induced membrane allowed us to get bone healing and return to normal activities in the nine children with segmental diaphyseal bone defects in humerus, ulna and radius.

When the soft tissues background is adequate, bone grafts incorporate soon in children, and fixation with plates allows them early movement while protecting the incor-

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poration of the bone graft, thus accelerating the functional recovery of the limb. Although our series has the limitations typical of retrospective studies, it is the most important one about posttraumatic bone deficits in children's upper limbs that have been published so far, and we believe that it allows us to arrive at significant conclusions.

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