SCIENTIFIC ARTICLE

Rotational Corrective Osteotomy for Malunited Distal Diaphyseal Radius Fractures in Children and Adolescents

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Purpose To report our method of computer-planned rotational corrective osteotomy for malunited distal diaphyseal radius fractures in children and adolescents using a custom jig and to review the results of 4 cases.

Methods Four patients (mean age, 13 years; range, 11−16 years) underwent computer-planned rotational corrective osteotomy for malunited distal diaphyseal radius fracture using a custom jig. We retrospectively evaluated their radiographic and clinical data.

Results In patients who had marked restriction of forearm supination before osteotomy, the mean arc of forearm supination improved from 5° before surgery to 79° after surgery. Angular deformity on x-ray, range of forearm rotation, and grip strength all improved after surgery. Mild and moderate pain reported by 1 and 2 patients, respectively, was resolved after surgery.

Conclusions Computer-planned rotational corrective osteotomy for malunited distal diaphyseal radius fracture in children and adolescents using a custom jig is a strategy that facilitates the surgical procedure by accurately correcting both rotational and angular deformities on 1 plane in a single procedure. *(J Hand Surg Am. 2017;■(■):1.e1-e8. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic V.

Key words Corrective osteotomy, patient-matched instrument, computer simulation, rotational deformity, malunited distal diaphyseal radius fracture.

Online Exclusive

Corrective osteotomy for malunited distal diaphyseal radius fractures in children and adolescents is not usually undertaken, despite the existence of a deformity.[1] In children aged 9 years or younger, a diaphyseal radius malunion of 15° to 20° usually remodels spontaneously.[1,2] In addition, distal diaphyseal radius deformity is less likely to cause loss of forearm rotation than is deformity of the middle diaphyseal region.[3] However, angular deformity is less likely to remodel in older children,[3] and it is not clear whether rotational deformities undergo spontaneous remodeling.

Rotational deformities of the radius cause loss of forearm rotation equal to the degree of the deformity.[4–6] However, considering that forearm malunion is usually associated with a combination of angular and rotational deformity, plus length discrepancy between the radius and the ulna, forearm rotation is likely to be more affected than the actual amount of rotational deformity. Anatomically accurate correction is highly desirable to achieve a good

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outcome,[7,8] although it is difficult to quantify 3-dimensional malalignment with only plain x-rays. With advances in computer technology, bone deformity can be accurately evaluated using 3-dimensional computer bone models.

We have developed a computer-aided corrective osteotomy using a custom jig.[8–11] In this technique, preoperative computer simulation suggests the most appropriate method of correction by comparing the affected bone and contralateral normal bone. When the main element of deformity is rotation, rotational corrective osteotomy is indicated even when the x-ray suggests a simple angular deformity.[11] Rotational correction with use of an oblique osteotomy plane can help achieve both angular and rotational correction.[8,11]

This study aimed to evaluate our method of computer-aided rotational corrective osteotomy for malunited distal diaphyseal radius fracture, in children and adolescents, using a custom jig.

MATERIALS AND METHODS

Between January 2011 and December 2012, 4 patients (3 boys and 1 girl; mean age, 13 years [range, 11–16 years]) with malunited distal diaphyseal radius fractures underwent corrective osteotomy using a custom jig. Our institutional review board approved this study. All patients had presented with pain and/or loss of motion attributed to the distal diaphyseal radius deformity. The mean time from injury to osteotomy was 6.3 months (range, 5–7 months). Mechanism of injury included a fall from heights in 2 patients and sports-related injuries in the other 2. Three patients had previously undergone percutaneous pin fixation, and 1 patient was initially treated nonsurgically with cast immobilization. All patients were initially treated at other hospitals. The mean time between undergoing computed tomography (CT) and osteotomy was 42 days (range, 28–48 days). This period reflected the time required to complete these preparations for the osteotomy. The mean follow-up duration was 22 months (range, 19–25 months).

SIMULATION TECHNIQUE

We attempted to simulate 3-dimensional correction of the deformity using a computer model of the bone.[8–13] The affected and contralateral forearms were scanned using a CT scanner (LightSpeed Ultra 16; GE Medical Systems, Waukesha, WI) with a low-radiation dose technique.[14] Three-dimensional surface bone models of bilateral radius and ulna were created from the 1.25-mm-sliced digital data using a commercially available software (Bone Viewer Bone Simulator; Orthree, Osaka, Japan). The degree of deformity was evaluated by superimposing the affected bone onto the mirrored contralateral (normal) bone; the deformity was determined in terms of rotation around, and translation along, a 3-dimensional deformity axis (Fig. 1). The 3-dimensional deformity angle, which was defined as the angle between the affected bone and the mirrored contralateral bone around the 3-dimensional deformity axis, was measured using the computer software. Because the 3-dimensional deformity axis was nearly parallel to the longitudinal axis of the affected bone in all these patients, the affected bone was simulated to be cut on the plane perpendicular to the 3-dimensional deformity axis on the computer.[11] Both angular and rotational corrections were achieved by rotational correction on an oblique plane. Shortening or lengthening of the radius was also simulated to correct the length discrepancy between the distal radius and the distal ulna.

To reproduce the preoperative simulation during the surgery, we used a custom jig and correction guide (Fig. 2), which are described elsewhere in detail.[11,12] The custom jig is a patient-specific osteotomy guide that incorporates guide holes for insertion of 2 sets of Kirschner wires, which indicate the angle of deformity. After cutting the bone through the slit on the custom jig, the custom jig was removed while the Kirschner wires were left in the bone. The Kirschner wires were then brought into alignment with each other to achieve the planned correction. A correction guide was used to maintain the correction by holding the Kirschner wires in alignment. Plastic models of the custom jig, correction guide, and real-sized 3-dimensional corrected bone model were constructed using a rapid prototyping machine (Eden250; Objet Geometries, Rehovot, Israel) with medical-grade resin at our institution (Fig. 3). Before the surgery, we manually bent an osteosynthesis metal plate of the appropriate size to fit the contours of the corrected bone model at the target site for internal fixation.

Operative technique

During the surgery, the custom jig was securely placed on the bone surface (Fig. 4). After confirming that all its edges were in precise contact with the bone surface, the guide was held in place with 2.0-mm Kirschner wires inserted through metal drill sleeves mounted on the guide, and the bone was osteotomized through the slit using a bone saw. The deformity