



3D-corrective osteotomy using surgical guides for posttraumatic distal humeral deformity

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An original technique was developed to correct distal humerus malunion using a three-dimensional computer-assisted planning and a custom-made surgical guide. The technique was used in three cases (two with cubitus varus and one with cubitus valgus). A CT-scan of the distal humerus was obtained. The correction was simulated by software. A three-dimensional model of the patient's affected humerus was created by rapid prototyping, allowing creation of a surgical guide and premoulding of the osteosynthesis plate. At the time of surgery, the sterilised guide was placed on the surface of the bone to guide the saw blade. Osteosynthesis was performed using the moulded plate.

At the latest follow-up, all three patients were asymptomatic and had regained full elbow mobility. Satisfying correction was obtained in all three cases. One complication was encountered : a postoperative infection that healed with plate removal and systemic antibiotic administration.

Using an osteotomy guide facilitates three-dimensional humeral correction. This technique presents several benefits : it decreases the operating time and minimizes the surgical incision. Fluoroscopy is unnecessary during the procedure and accuracy is increased. Disadvantages are the time for planning and guide confection, the need of a CT-scanner and the increased cost.

Keywords : cubitus varus ; cubitus valgus ; corrective osteotomy ; surgical guide.

INTRODUCTION

Cubitus valgus and cubitus varus are common complications of supracondylar elbow fractures in

children, giving both aesthetic and functional loss (7,9,10). Surgical treatment is only recommended in case of important deformities (7,9,10). Many surgical techniques have been proposed. Accurate correction is the key to obtain good aesthetic and functional outcomes after corrective osteotomy (7). One of the most popular methods is a closing wedge osteotomy, by placing K-wires under fluoroscopy to simulate the correction angle and by following the K-wires with an oscillating saw. This kind of planning is based on two 2D-plain radiographs (anteroposterior and lateral view) and it is sometimes difficult to accurately reproduce at the time of surgery the exact desired amount of correction as preoperatively planned.

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We have developed a new technique consisting of tri-dimensional calculation of the osteotomy angle on a CT-scanner and preparation a surgical guide. A premoulded osteosynthesis plate is obtained thanks to a prototyped model of the humerus. Osteotomy and internal fixation are realised through a single small incision. Parents were informed, and consent was obtained for participation in the study.

MATERIALS AND METHODS

Patient series

Three children with humeral deformity consecutive to malunited supracondylar humeral fracture were included. Clinical data for the 3 patients are summarized in Table I.

Preoperative radiographic carrying angle measurement

Two mid points were marked on the distal humerus (mid diaphysis and mid distal metaphysis) and two others on the ulna (at the level of the radial tuberosity and at the most proximal ossification of the ulna). Two lines were drawn through these points giving the carrying angle (Fig. 1) (1,2,6,8).

Preoperative planning for osteotomy

A preoperative humerus CT-scan was obtained using a Brilliance 40 CT-scanner (Philips, the Netherlands) with 1-mm spacing between slices and 2-mm slice



Fig. 1. — Measurement of the radiographic carrying angle. Antero-posterior view of the lower end of the humerus and upper end of radius and ulna. Line A–B is drawn through two mid points on the humerus, one at the distal metaphysis and the other in the distal third of the diaphysis. Line C–D is drawn through two mid points on the ulna, one at the level of the radial tuberosity and the other at the most proximal end of the ulna.

Table I. — Clinical and radiographical data of the patients

Case	Sex	Age at time of surgery (years)	Humeral deformity	Pre-operative carrying angle	Planned resected angle	Post-operative carrying angle	Pre-operative elbow ROM	Post-operative elbow ROM	Pre-operative pain	Post-operative pain
Case 1	M	10	Cubitus varus	-9°	+27°	+16°	140/10	140/0	During sport	none
Case 2	M	13	Cubitus varus	-7°	+17°	+11°	145/10	160 /0	none	none
Case 3	F	8	Cubitus valgus	+33°	-23°	+1°	110/30	130/10	During effort	none

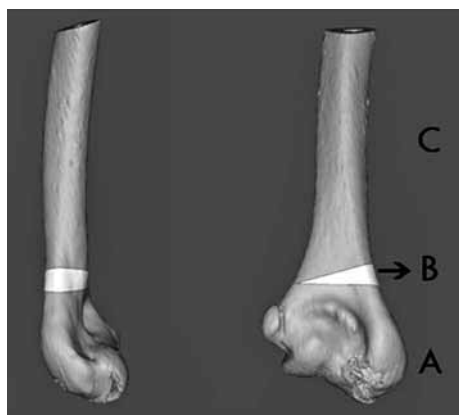


Fig. 2. — 3D-reconstruction of the patient's humerus. The wedge osteotomy is planned (B).

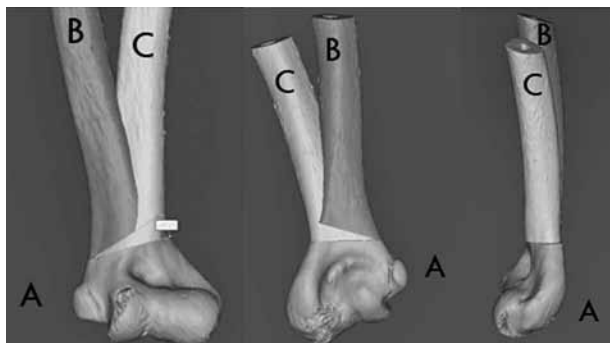


Fig. 3. — Distal end of the humerus with : epiphysis (A), humerus with cubitus varus deformity (B) and the correction obtained after lateral closing wedge osteotomy (C). Left : anterior view. Middle : posterior view. Right : lateral view.

thickness. A 3D-reconstruction was made with Mimics software (Materialise, Leuven, Belgium) (Fig. 2 & 3). The closing wedge was planned, leaving a small bony hinge at the opposite side for stability.

Creation of osteotomy guide

A model of the patient's humerus was created by rapid prototyping using a 3D-plaster printing based on the CT-scanner data (3). The guides were created by the contact of the prototypes with one unique possible position (Fig. 4 & 5). A model of the corrected humerus was also obtained, permitting preoperative moulding of the osteosynthesis plate. The guides and the moulded plate were sterilised to be available in the operating room.

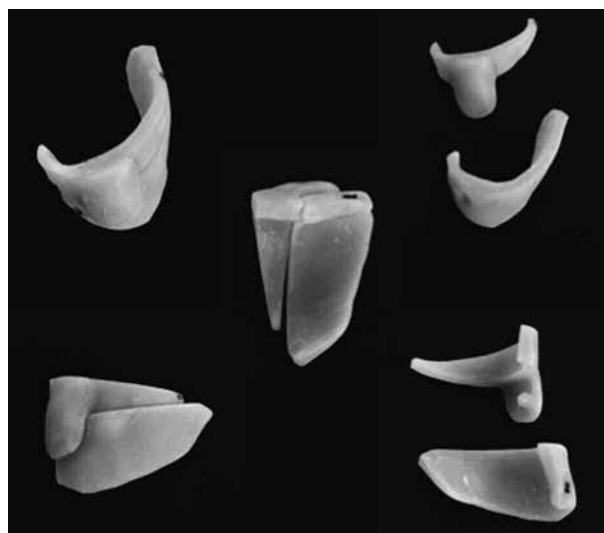


Fig. 4. — The osteotomy template (real acrylic model)

Corrective osteotomy using the guide

The patient was placed in the supine position with the arm on an arm board and with a tourniquet (Fig. 6). A lateral approach was used for the cubitus varus deformity, and a medial approach for the cubitus valgus deformity. A 4-5 cm incision was used. After soft-tissue dissection, the periosteum was incised longitudinally and the distal humeral metaphysis was exposed subperiosteally. For the medial approach, the ulnar nerve was dissected and protected during the procedure. The guide was displaced until the unique position was reached. By following the surgical guide with the oscillating saw a closing wedge osteotomy was performed (4,5,11). The opposite cortex (hinge) was gently weakened with a small osteotome, and the bony wedge was resected. By closing the wedge, the planned correction was directly obtained and internal fixation was performed with the moulded plate (Fig. 7).

Post-operative period

All children were immobilized in a long-arm posterior splint with the elbow flexed at 90° for three weeks, with a change after 1 week. At 3 weeks postoperatively, the radiograph showed consolidation of the osteotomy and mobilization was allowed.

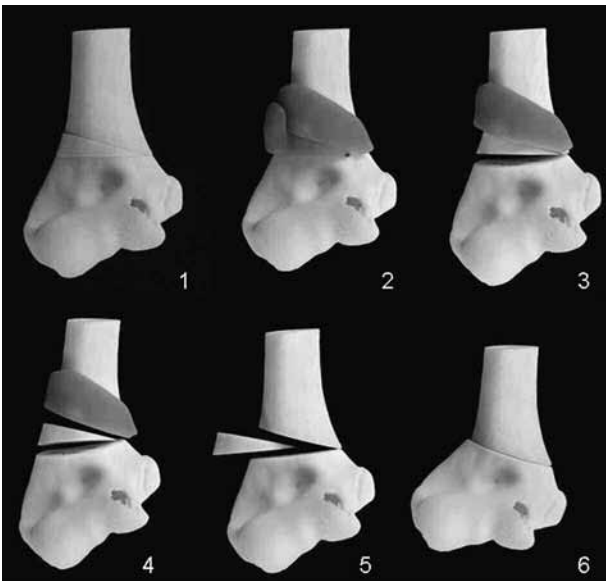


Fig. 5. — A model of the patient's distal humerus is created by rapid prototyping (1). The osteotomy template is placed on the bone (2). The first cut is made and the small part of the guide is removed (3). The second cut is made (4). The large part of the guide is removed and the bone wedge is removed (5). The distal humerus is realigned as planned (6).

RESULTS

The results obtained for the three patients are summarized in Table I. The postoperative radiographic evaluation was performed 6 months postoperatively (Fig. 8). A postoperative complication was encountered in one case: an infection that required removal of the plate and antibiotherapy. Final evolution was favourable. The desired correction was obtained in all cases. The correction obtained (measured on the postoperative radiograph) was the one planned with an error of 2°, 1° and 9° respectively (Table I). At the latest follow-up, all patients were asymptomatic and had regained full elbow mobility.

DISCUSSION

In case of distal humeral deformity, we usually wait until the patient has reached the age of ten years, in order to minimize the risk of recurrence, considering that remaining growth is negligible.



Fig. 6. — The patient is placed in the supine position with the arm on an arm board. Preoperative picture of the cubitus varus.

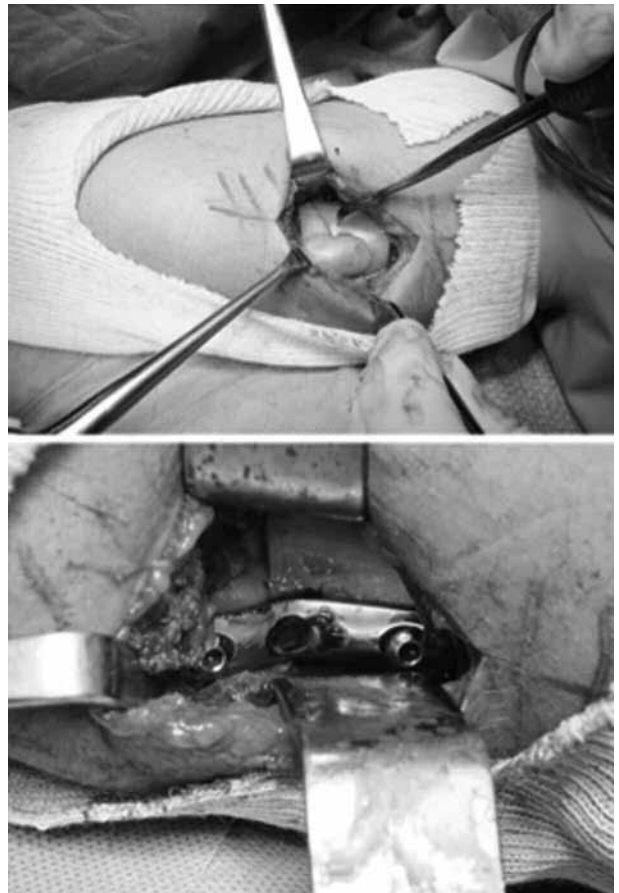


Fig. 7. — The osteotomy guide is placed on the anterolateral surface of the humerus through a lateral approach. Internal fixation is performed with a premoulded plate after bone wedge resection.



Fig. 8. — Preoperative (left) and postoperative (right) radiograph of the elbow showing the cubitus varus and the correction obtained.

For this female patient, who was 8 years old, we had to perform the correction earlier because of significant pain and functional impairment.

It is not easy to correct a tri-dimensional deformity based on two-dimensional radiographs. Most of the studies have suggested using frontal and sagittal radiographs to plan the corrective osteotomy (5). It is very difficult to find the correct orientation during surgery and most of the complex osteotomy techniques require extensive surgical exposure.

One of the advantages of this original technique is that the surgical guide is custom-made and fits perfectly the patient's deformed bone. The guide is placed at the bone surface and moved until its unique position is found. The planning is made to obtain good contact of both cortices after bony wedge resection.

Other benefits include achieving precise three-dimensional correction, saving time, minimizing surgical incision and avoiding fluoroscopy.

Disadvantages of the technique include radiation exposure during CT-scanning and the additional cost for the patient (700 euros on average). In our series, the patients payed no fees, as they were included in the study.

Further improvement of our technique will include the use of a medial approach for its cosmetic advantage in all cases (also for cubitus varus) (4), and the calculation of a translation to perfectly align the distal humerus with the diaphyseal axis.

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