Lateral Humeral Condyle Fractures in Pediatric Patients

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Lateral humeral condyle fractures are frequently seen in pediatric patients and have a high risk of unfavorable outcomes. A fall on the outstretched arm with supination of the forearm is the most common trauma mechanism. A physical examination combined with additional imaging will confirm the diagnosis. Several classifications have been described to categorize these fractures based on location and comminution. Treatment options depend on the severity of the fracture and consist of immobilization in a cast, closed reduction with percutaneous fixation, and open reduction with fixation. These fractures can lead to notable complications such as lateral condyle overgrowth, surgical site infection, pin tract infections, stiffness resulting in decreased range of motion, cubitus valgus deformities, 'fishtail' deformities, malunion, non-union, avascular necrosis, and premature epiphyseal fusion. Adequate follow-up is therefore warranted.

lateral humeral condyle fracture children diagnosis treatment surgery

1. Treatment Options

Non-operative treatment is the preferred option for fractures with a minor (<2 mm) displacement and no other additional injuries [1]. Closely regulated follow-up is mandatory to rule out secondary displacement in the cast. Follow-up should be performed within one week after trauma in the outpatient clinic and should include conventional X-rays in AP and lateral and oblique views. If the fracture is >2 mm displaced, with a disruption of the articular surface, reduction and fixation of the fracture are recommended [1][2]. The authors of each classification system for lateral humeral condyle fractures have made recommendations concerning treatment options based on the severity of the fractures; these recommendations can be found in **Table 1**. In cases with a successful fracture union and without complications, the success rate for non-operative and operative lateral humeral condyle fracture, as described in meta-analyses, is between 89.8–91.5% [1][3][4][5]. A delayed diagnosis of these fractures (>3 weeks after injury) should initially be given based on the time between the injury and presentation and the amount of displacement, in accordance with the above-described options [6][7]. Unfortunately, a malunion or nonunion of these fractures with a delayed diagnosis is quite common after 3 months [6]. Treatment of these complications requires a different approach depending on displacement, elbow alignment, and a stable condylar fragment.

Table 1. Classification of lateral humeral condyle fractures and their respective preferred treatment options for the pediatric patient.

	1 (A)	2 (B)	3 (C)	4	5
Milch [8]	Cast/CRPP	CRPP/ORIF	-	-	-
Jakobs [9]	Cast/CRPP	CRPP	ORIF	-	-
Finnbogason [10]	Cast/CRPP	CRPP	CRPP/ORIF	-	-
Weiss [11]	Cast/CRPP	CRPP	ORIF	-	-
Song [12]	Cast	Cast/CRPP	CRPP	CRPP	ORIF

Cast = above elbow cast, CRPP = closed reduction and percutaneous pinning with Kirschner wires, ORIF = open reduction internal fixation with Kirschner wires and/or cannulated screw.

The non-operative treatment option for lateral humeral condyle fractures in children is an above-elbow cast. This applies to a fracture with no displacement, an intact articular surface, and no additional injury [1][2][8][9][13][14]. The elbow should be positioned in a 90-degree flexion, and the wrist and hands should be in a neutral position (**Figure 1**). Patients will return after 4 weeks for cast removal if non-operative treatment shows no secondary fracture displacement on the X-ray in a long arm cast within the first week after injury [1][2][3][13][15][16][17]. If the physician, after removal, doubts whether cast therapy for 4 weeks has been enough, an additional X-ray should be made. If the X-ray shows no callus around the fracture, treatment with plastered cast therapy should be continued for another 2 weeks [1][2][3][13][15][16][17]. Secondary fracture displacement, which warrants an operative treatment [2][18] (unstable fracture, see classifications **Table 1**), occurs most frequently between three and seven days after injury [1][18]. Secondary displacement of lateral humeral condyle fractures treated with a cast occurs in 4.8–29.4% of all pediatric cases [1][2][4][15][16][18][19][20].



Figure 1. Digital picture of a left arm in an above-elbow cast in the recommended position (90-degree flexion and neutral rotation).

Plastered cast therapy for a patient with a malunion or nonunion after >3 months and after an initial delayed diagnosis is only viable if the displacement is less than 5 mm, shows a stable condylar fragment, and shows evidence of bony bridging on a CT scan [6].

1.2. Surgical/Operative Treatment Options

1.2.1. Closed Reduction and Internal Fixation

The minimally invasive surgical technique to reduce and stabilize the lateral humeral condyle fracture is called closed reduction and internal fixation (CRIF), or closed reduction and percutaneous pinning (CRPP). This technique is generally used for unstable/displaced fractures with 2 mm–4 mm displacement [21]. Most fractures that do not show signs of rotation of the fragment and/or additional fractures of the elbow are treated with CRPP. Fracture reduction through CRPP is achieved by flexing the elbow and supinating the wrist while applying pressure to the lateral side of the elbow. Simultaneous imaging should be performed to deduce the effects of the closed reduction. Successful reduction shows an anatomical articular surface during imaging. Fluoroscopy and ultrasound-guided reduction are suitable options to provide basic imaging during surgery.

Ultrasound-assisted reduction creates the opportunity to provide basic imaging of good quality while negating the negative effects of fluoroscopy radiation [22]. The image quality and ability to perform the surgery is linked to the imaging capabilities of the surgeon when using ultrasound. Ultrasound-assisted closed reduction is a relatively new technique with a learning curve for the surgeon. Nevertheless, recent results show comparable complication rates to closed reduction with fluoroscopy and/or ORIF [22].

Through simultaneous fluoroscopy, one can deduce the effects of the reduction. However, the diagnostic accuracy of joint reduction appreciated on two-dimensional fluoroscopy used in the operating theater shows inferior results compared to a CT scan [23]. The subjective image quality of fluoroscopy is the main contributing factor toward inferior diagnostic accuracy. The imaging quality is affected by the degree of image focus achieved during surgery. The most notable factor which directly impacts the quality of the image is the presence of osteosynthesis material, which results in scattering and artifacts. A secondary factor influencing the image quality is the relative thickness of the cartilage, which is more prominent in children than adults, compared to bone thickness. The cartilage and articular surface of the elbow in children are not as visible using fluoroscopy as they would be through arthrotomy since fluoroscopy does not show cartilaginous tissue as clearly as bone. Considering these factors, and combined with the over-estimation in the measurement of displacement seen in radiography prior to surgery, it is best to visualize a joint reduction through arthrography, arthroscopy, or arthrotomy.

Next, the surgeon performs a percutaneous fixation of the reduced fracture by placing two smooth Kirschner wires perpendicular to the fracture line. Crossed Kirschner wires may reduce fracture stability [24]. A third Kirschner wire can be placed through the condyles, parallel to the joint, to increase fracture stability and minimize rotation. Kirschner wires can be buried underneath the skin or exposed for easy removal. Both methods show similarly low complication rates, low infection rates, and high successful union rates. Kirschner wires are left in place for 4 weeks after surgery. In addition, the patient receives a long arm cast with elbow back slab support for 4 weeks.

CRPP for a patient with a malunion or nonunion after >3 months and after an initial delayed diagnosis is only viable if the displacement is less than 5 mm, shows an unstable condylar fragment, and shows no evidence of bony bridging on a CT scan [6].

1.2.2. Open Reduction and Internal Fixation

Open reduction and internal fixation (**Figure 2**) is the preferred surgical treatment option for a fracture showing more than 4-mm displacement and/or rotation of the fragment. It is also the next step-up surgical option when CRPP fails to reduce the fracture to an anatomic situation. A small incision is made on the anterolateral side of the elbow. Subsequent careful dissection of the subcutaneous tissue, fascia, and articular capsule is performed. The malrotation of the fracture's fragment and size warrants careful dissection not to disrupt the distal humerus's blood supply and/or harm the radial nerve bundle. Like with CRPP, the surgeon will fix the fracture by placing two smooth Kirschner wires perpendicular to the fracture line. The postoperative treatment is similar to that of the CRPP. Surgeons can opt for screw fixation with a small AO bone screw combined with K-wires for rotational stability of the fragment. However, studies show screw fixation results in comparable quality of life and range of motion postoperatively while having disadvantages such as second surgery to remove the screw, impairment of the range of motion, delayed union, and wound infections [5][21].

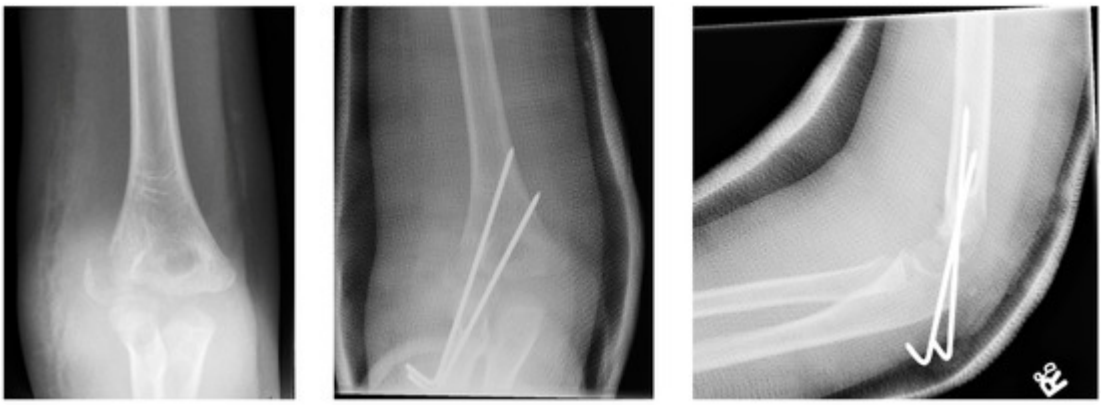


Figure 2. (**Left**) Anterior–posterior view of a lateral humeral condyle fracture. (**Middle**) Anterior–posterior and (**right**) lateral radiographic view of the elbow after open reduction and internal k-wire fixation.

ORIF for a patient with a malunion or nonunion after >3 months and after an initial delayed diagnosis is viable if the displacement is greater than 5 mm or is less than 5 mm with a normal elbow alignment [6][7]. If the patient has an elbow malalignment, a corrective osteotomy with simultaneous anterior transposition of the ulnar nerves can be performed [6][7].

2. Complications

Complications can occur during and after treatment. One in ten patients with lateral humeral condyle fractures has severe complications of the fracture and/or treatment [1][3][5]. Unsuccessful treatment of this complicated and menacing fracture may lead to a long-term loss in quality of life for pediatric patients. To minimize the risk of

complications during treatment, the attending physician benefits from consulting an experienced pediatric elbow surgeon when discussing treatment options. The most notable complications are lateral condyle overgrowth, surgical site infection, pin tract infections, stiffness resulting in decreased range of motion, cubitus valgus deformities, 'fishtail' deformities, malunion, non-union, avascular necrosis, and premature epiphyseal fusion.

2.1. Lateral Overgrowth

Lateral overgrowth or lateral 'spurring' is a hypertrophic bony overgrowth on the lateral side of the elbow due to overstimulation of osteoblasts during the normal bone healing process [25][26]. Lateral overgrowth can be appreciated on conventional radiographs and felt during a physical examination of the elbow [12][15]. The occurrence rate of this complication is comparable between both treatment groups (non-surgical, 4.5–74%; and surgical, 4.5–73.7%) and between surgical techniques (CRPP, 4.5–73.7%; ORIF K-wires, 22.1–73.7%; and ORIF cannulated screw, 10.1–74%) [2][5][12][19][20][27][28][29].

2.2. Infections

Infections are an infrequent complication of surgical interventions and can be divided into two groups: superficial surgical site infections and deep infections of the osteosynthesis material. Treatment options for these infections can differ, ranging from local topical (antibiotic) treatment to extensive revision surgery. The occurrence rate of infections as a complication of lateral humeral condyle elbow surgery is 0.01–19.3% [5][15][16][20][21][28][29].

2.3. Malunion and Non-Union

A malunion of the bone describes the situation in which a patient's bone does not heal properly and creates an abnormally shaped joint with possible impaired function of the extremity as a result. A delayed or even non-union of the bone is a failure of a fracture to heal properly after three to nine months [30]. Malunion can cause structural deformities with a cubitus varus or, more commonly, cubitus valgus or impairment in the range of motion. Non-union or malunion of lateral humeral condyle fractures often require revision surgery to attempt to repair shortcomings and improve clinical outcomes for the patient [7][31][32][33][34][35]. Non-union or malunion, as a complication after revision surgery, occurred between 0–13% [32][33][34]. The physical performance score of the elbow, measured using the mayo performance score, increased in more than 80% of patients [32][33][34]. Non-union and malunion of the fracture occur more frequently in the cast therapy group [1][15][20]. The occurrence rate of non-union and malunion of the fracture is between 0–11.8% and 1.3–11.8%, respectively [3][5][15][16][17][19][20][21][27][28][29][31][36]. This rate of occurrence is exceptionally high, demonstrating the unforgiving nature of fracture healing for lateral humeral condyle fractures.

2.4. Avascular Necrosis

Avascular necrosis, or osteonecrosis, is a complication that causes ischemic damage to bone cells and, eventually, necrosis of bone due to the loss of blood supply. This can occur to bones after trauma because of the increased swelling, decreased range of motion of the elbow, and rotation of the broken fragment with subsequent tearing of

the arteries [17]. The capitulum and lateral condyle are supplied solely with blood from a couple of small end arteries on the lateral side of the elbow. Hence, the capitulum and lateral condyle are considered to be relatively avascular. Therefore, one can appreciate how a slight traumatic injury or surgical operation through a posterior dissection approach can cause permanent damage to the small arteries supplying the lateral side, causing avascular necrosis [37]. The occurrence rate of avascular necrosis after lateral condyle fractures is 0.9–3.1% [3][16][17][27][29][36]. No study has reported the difference in occurrence rates of avascular necrosis between a non-operative and surgical treatment option. The elbow's functionality, stability, and range of motion are highly impeded after avascular necrosis. As a result, the patient will have a long-term disability when it comes to daily function.

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