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Cuboid nutcracker fracture in children: Management and results

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ABSTRACT

Introduction: Compression fractures of the cuboid bone in children and adolescents are rare. Fracture morphology, associated lesions, treatment options and long-term outcomes of this very rare injury are published in a few case reports. This study with review of the literature aims to support the understanding of fracture pattern and optimize pathways of decision making.
Material and Methods: A retrospective two-center study was performed in a patient cohort treated between 2001 and 2016. All patients aged less than 18 years who sustained a cuboid fracture were included. Age, gender, mechanism of injury, fracture morphology, amount of displacement, associated injuries, and therapy were analyzed. In the follow-up (FU), the AOFAS Midfoot Scale was investigated.
Results: Fractures of the cuboid bone were diagnosed in 7 boys and 9 girls. The mean age of the patients was 10 years (range: 2.2–16.1 years). According to the classification of Fenton we detected 11 (69%) type 2, 2 (12%) type 3 and 3 (19%) type 5b fractures. Other fracture types according to Fenton were not observed. All children under 10 years sustained a type 2 fracture. Open reduction and internal fixation was performed in 5 (31%) patients. Bone grafting was not necessary. FU was performed in 14/16 patients on average after 9 years (mean; range: 1.4–16.2 years). The mean AOFAS Midfoot Scale at FU for extra-articular type 2 fractures was 100 points, whereas in intra-articular fractures (Type 3) and fractures associated with mid-tarsal disruption (type 5b) worse results were found (95 and 66 points, accordingly).
Conclusion: This rare injury shows inhomogenous morphologies and offers different treatment approaches. Extra-articular Fenton type 2 lesions are the most common type of cuboid fracture in children (69%). A potential loss of length of the lateral column must be considered. In contrast to adults, type 1, 4, and 5a fractures were not found in our cohort of children and adolescents. Lower scores of the AOFAS Midfoot Scale were found with either intra-articular involvement or associated midfoot lesions.

Introduction

Compression fractures of the cuboid bone in children are rare and often missed during the initial consultation. They can be difficult to manage and pose a high risk for long-term pain and osteoarthritis in the foot. Hermel and Gershon-Cohen described this type of injury and used the term “nutcracker fracture” for the first time because of the mechanism and fracture pattern [1]. These fractures occur when the cuboid is compressed between the bases of the fourth and fifth metatarsals and the calcaneus. Combined injuries involving other midfoot bones and/or fracture dislocations have also been described. It is a different fracture pattern than in adults, where no “nutcracker” mechanism is seen due to the bone’s quality after conclusion of growth. In this study, we investigated the morphology, associated lesions, type of treatment, operative strategies, and long-term outcomes of these rare fractures in children and adolescents.

Material and methods

A retrospective study was performed in a cohort treated between 2001 and 2016 in two level-I trauma hospitals. All children and adolescents included in the study were younger than 18 years and sustained a traumatic fracture of the cuboid bone.

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Table 1
Summary of the cuboid fracture types, the total numbers and outcome scores [2].

Type	Description	Frequency (%)	Mean AOFAS at FU
1	Avulsion	–	–
2	Extra-articular	69% (11/16 children)	100 (9 children/14 FU)
3	Intra-articular	12% (2/16)	95 (2/14)
4	Tarsometatarsal	–	–
5a	Lateral column	–	–
5b	Bi-columnar	19% (3/16)	66 (3/14)

Age, gender, mechanism of injury, fracture side, amount of displacement, imaging methods, and therapy were assessed. The fractures were classified according to Fenton et al. [2] Table 1 shows avulsion fractures (type 1), extra-articular fractures (type 2), intra-articular fractures (type 3), fractures associated with disruption of the tarso-metatarsal complex (type 4), and fractures associated with mid-tarsal disruption (lateral column: type 5a; bi-columnar: type 5b). In the follow-up, the AOFAS Midfoot Scale was routinely assessed and documented in the charts to evaluate pain, function, footwear requirements, maximum walking distance, walking surfaces, gait abnormalities, and alignment [3]. According to Kitaoka et al., the results were rated as excellent with 90–100 points, good with 80–89 points, fair with 70–79 points, or poor with <70 points [3].

Results

In the study period, a fracture of the cuboid bone was diagnosed in 7 boys and 9 girls which is shown in Table 2. The mean age of the patients was 10 years (range: 2.2–16.1 years). The left side was affected in 9 patients and the right side in 7 patients. All patients presented with an acute onset of foot pain after trauma. There were no pre-existing conditions related to the symptoms. According to the classification of Fenton et al., we observed 11 (69%) type 2, 2 (12%) type 3, and 3 (19%) type 5b fractures, demonstrated in Figs. 1–3. Type 1, 4, and 5a fractures were not found in our cohort. All children younger than 10 years suffered a type 2 fracture.

Plain radiographs were performed in 94%, computed tomography (CT) in 56% and magnetic resonance imaging (MRI) in 13% of patients. In 13 patients, the fracture was visible in plain radiographs. In our two youngest patients, the cuboid fracture was not evident in plain radiographs but in MRI. In one patient, the fracture was diagnosed in the whole-body trauma scan, which was performed according to our polytrauma protocol. Associated fractures were found in 44% (7/16) of patients.

Surgical treatment with open reduction and internal fixation (ORIF; 4x plate, 1x screws) was performed in 5 (31%) patients as shown in Figs. 1 and 3. Bone grafting was necessary in none of the patients. The indications were a shortening of the lateral column, steps or gaps in the calcaneo-cuboid joint of more than 3 mm, and open fractures. The follow-up examination (FU) was performed on average after 6.7 years (range: 1.4–16.2 years) in 14 out of 16 (88%) patients. Two patients were not available for the follow-up. The mean AOFAS Midfoot Scale at FU in extra-articular type 2 fractures was 100 points (excellent), in intra-articular type 3 fractures 95 points (excellent), and in fractures associated with mid-tarsal disruption type 5b only 66 points (poor).

Discussion

Traumatic fractures of the cuboid bone are rare in adults and are very uncommon in children and adolescents. Treatment of these fractures can be done operatively or non-operatively, according to fracture pattern and associated injuries. This might determine the outcome regardless the pathway of treatment.

Hermel and Gershon-Cohen described the compression fracture of the cuboid bone caused by indirect compression and used the term "nutcracker fracture" [1]. In this injury, the cuboid bone is compressed between the bases of the fourth and the fifth metatarsals and the calcaneus. In their publication, Hermel and Gershon-Cohen described 5 cases: 4 of these were detected in adults and 1 in a 12-year-old boy. Van Raaij et al. described four displaced cuboid fractures treated operatively [4].

These traumatic fractures in children must be clearly distinguished from stress fractures of the cuboid bone in early childhood which are referred to as “toddlers` cuboid fracture” [5–9]. Toddlers walk in plantar-flexed and everted foot, jump from heights and trip

Table 2
Demographic data, fracture characteristics and outcome scores.

Name	Age (y)	Type	Mechanism	Displacement	OP	FU (y)	AOFAS
L. H.	2.2	2	Displaced fracture while walking	No	–	3.6	100
P. L.	4.6	2	Heavy piece of wood rolled over the foot	No	–	6.9	100
C. K.	4.7	2	Jump from 1.5 m	1.9 mm shortening	–	1.4	100
J. S.	6.9	2	Displaced fracture in tube slide	2.2 mm shortening	–	3.5	100
L. S.	7.4	2	Unclear	2.7 mm shortening	–	n.a.	n.a.
N. L.	8.7	2	Displaced fracture in tube slide	No	–	13.8	100
D. T.	9.0	2	Fall from a bunk bed (1.8 m)	2.8 mm shortening	–	3.0	100
V. J.	9.5	2	Unclear	1.9 mm shortening	–	n.a.	n.a.
A. E.	9.8	2	Fall from a tree (2 m)	3 mm shortening	+	8.9	100
A. B.	10.9	5b	Displaced fracture on stairway	1.2 mm shortening	–	5.5	68
T. F.	11.9	2	Stepped in a hole	3 mm shortening	+	5.3	100
M. A.	14.2	5b	Car crash	1 mm gap articular surface calcaneocuboid (open comminuted fracture)	+	10.4	62
N. G.	14.5	5b	Bicycle crash	5 mm gap articular surface calcaneocuboid	+	7.4	68
A. H.	14.7	2	Displaced fracture while running	No	–	16.2	100
A. S.	14.8	3	Jump from 0.5 m with distortion of the foot	No	–	5.6	100
E. Ö.	16.1	3	Displaced fracture while playing soccer	4 mm impression/Step articular surface calcaneocuboid	+	4.3	90

n.a. = not available; y= years.

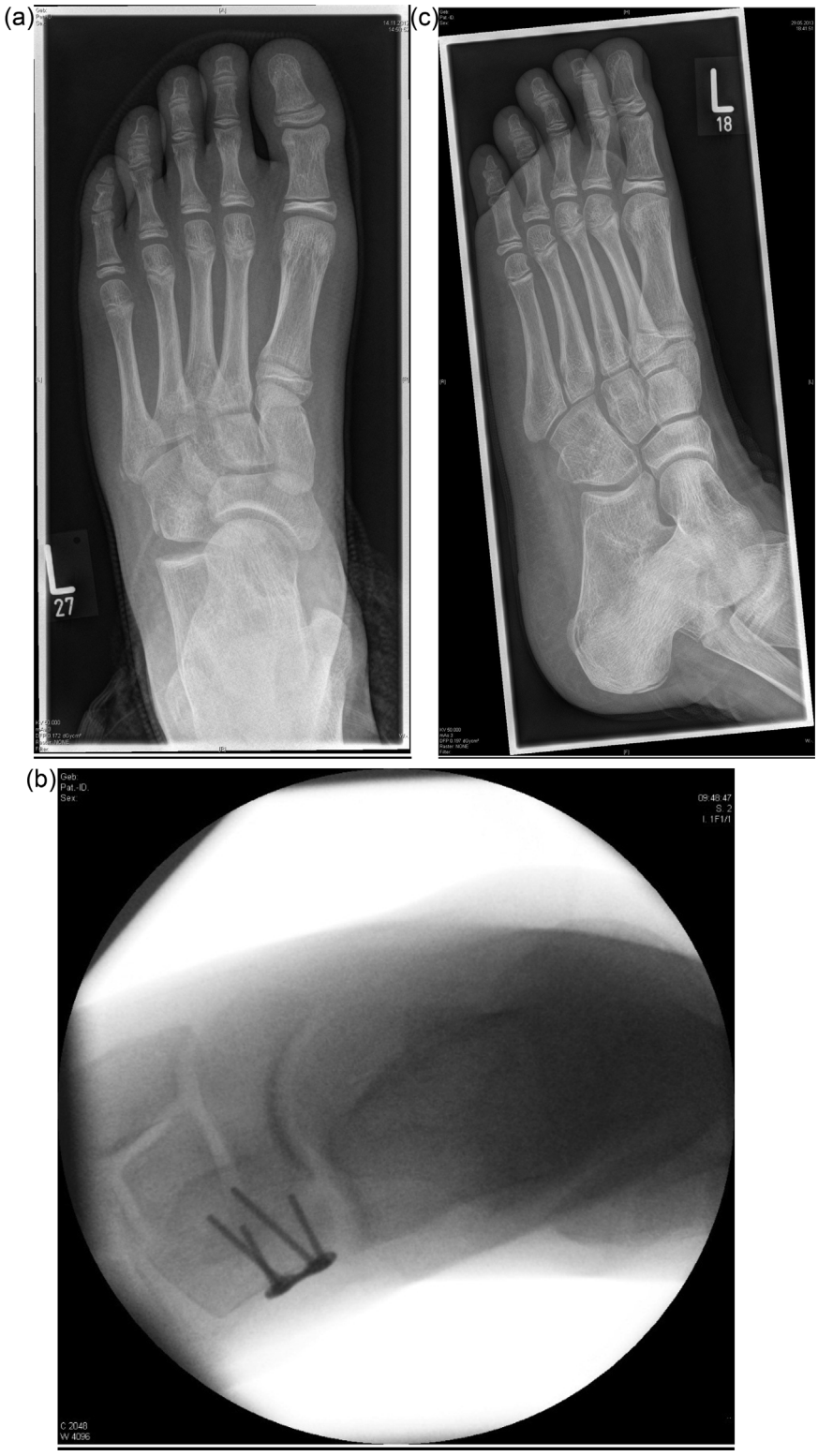

Fig. 1. (a)Patient with an extraarticular Type 2 cuboid fracture showing a shortening of the lateral column and deep depression of the calcaneo-cuboidal joint surface. (b) the fracture was treated with ORIF using an angle-stable plate. (c) Plane radiograph after removal of the plate 6 months later. At FU (5.3 years) the patient achieved an AOFAS score of 100 points.

and stumble frequently. Parents or caregivers may not see these events as sufficient to cause an injury. Furthermore, toddlers` fractures of the cuboid may also be caused by chronic stress due to abnormal gait of the child learning to walk. Conventional plain radiographs are often negative at the initial presentation. In these cases, follow-up radiographs have been recommended after 10–14 days to visualize the callus and confirm the diagnosis [8].

In contrast to the toddlers` fractures, little has been published about the traumatic nutcracker fractures of the cuboid bone in children and adolescents. The nutcracker fracture often results

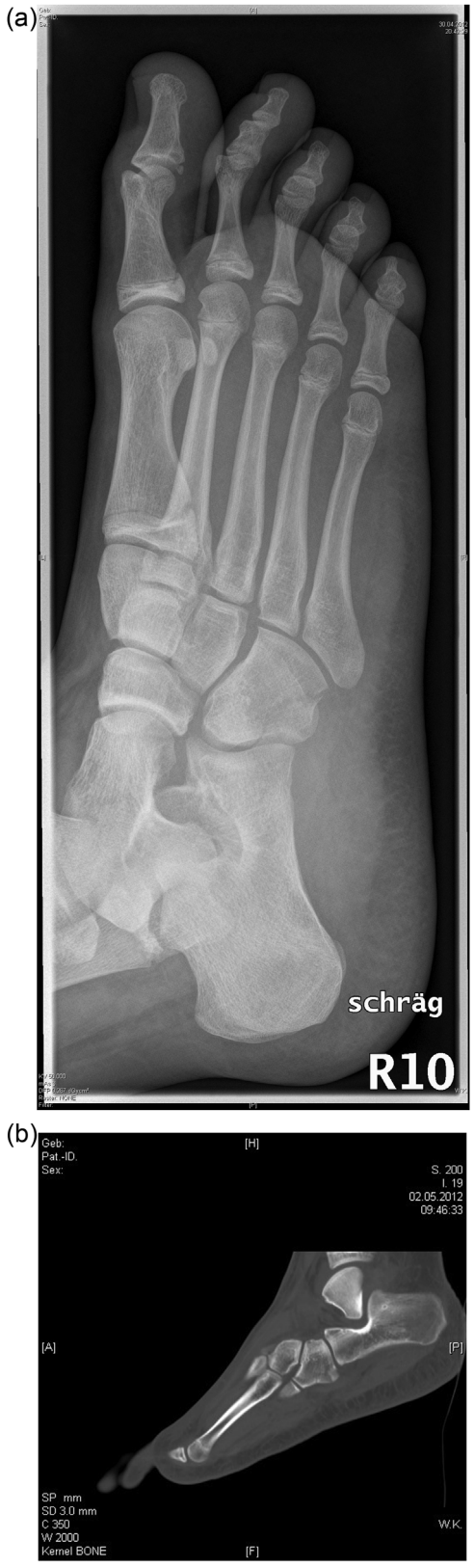

Fig. 2. (a)Plain radiograph and (b) CT-scan showing an intraarticular Type 3 fracture. Non–operative treatment has been performed because of non-displaced fracture. At FU (5.8 years) the patient achieved an AOFAS score of 100 points.

from a forced abduction of the forefoot, which is mostly combined with axial force. Ceroni et al. reported about 4 children with nutcracker fractures that occurred in horse riders sustaining a forced hyper-abduction of the forefoot. The horse fell, and the child`s foot was entrapped in the stirrup [10]. In our study, we found another hazardous leisure activity: two children suffered a cuboid fracture caused by forced hyper-abduction at the bottom of a tube slide. Particular attention should be paid to children presenting with such a medical history. Cuboid fractures also occur after a fall from height as a result of an axial load. A direct trauma is another possible cause of a nutcracker fracture [11].

The cuboid bone articulates with the calcaneus, the lateral cuneiform, the navicular, and the fourth and fifth metatarsals. It is the key bone in the rigid lateral column of the foot. The static and dynamic functions of the foot are influenced by the integrity of the cuboid. Reconstruction of both the anatomy and the length of the lateral column are cornerstones of the treatment concept. Untreated articular disruption can cause a posttraumatic osteoarthritis and stiffness. Loss of length of the lateral column results in abduction of the forefoot and planus deformity with compensatory eversion of the hindfoot. Although fractures of the cuboid can occur in isolation, they may form a component of a more complex injury involving the midfoot and/or the hindfoot. Therefore, we used the classification system published by Fenton et al., as this recognizes that some cuboid bone fractures occur as part of associated injuries and require careful radiological investigation and complex management [2]. For cuboid fractures, the AO/OTA classification system distinguishes between comminuted and simple extra-articular or intra-articular fractures [12] and might be less useful as Fentoń s classification. In our patient cohort, type 1, 4, and 5a fractures were not found. One possible explanation is the very high stability of childreń s ligaments. In contrast to adults (only 13% [2]), extra-articular fractures (type 2) were the most common injury pattern in our study (69%). In children under 10 years, this fracture type was the only one observed: the mechanical characteristics of the bone with high subchondral bone stiffness explain why there was no intra-articular involvement. In type 2 injuries, the fracture occurs within the cancellous bone of the body of the cuboid showing a lateral extrusion of the wall in X-rays. A potential loss of length of the lateral column should be anticipated. Intra-articular type 3 fractures were found in 2 patients only (boys aged 14 and 16 years) and were due to the changing characteristics of the bone with increasing age. Nineteen percent of our patients sustained a type 5b lesion with a crush fracture of the cuboid with disruptions of both the lateral and medial columns. Associated fractures were found in 44% patients. Ceroni et al. found similar results. Therefore, when a cuboid nutcracker fracture is diagnosed, other associated midfoot or hindfoot injuries should be sought and excluded using plain X-rays and if necessary computed tomography or MRI [10].

Operative reconstruction is recommended in all cases with lateral column shortening or intraarticular fracture displacement. Due to the limited data available concerning outcomes of these fractures in children, no clear recommendation can be made regarding the amount of intra-articular step-off and gap sizes that can be tolerated. Using other indications for treatment of pediatric joint fractures, we established articular disruptions and/or lateral column shortening of more than 2–3 mm as indications for surgical treatment. A precise measurement of the intra-articular fracture displacement is a limitation of this study, as measurements can be performed precisely in CT, but are very difficult to provide in plain radiographs.

The technical aspects of the operative reconstruction of the cuboid bone in children differ according to the fracture morphology and the size of the bone defect, which may occur due to the compression mechanism. Bone defects are filled with autograft or allograft bone blocks [10,11,13]. Some authors fixed the fractures using Kirschner wires as temporary transfixation of the calcaneo-cuboid joint [11,13]. The hardware is accordingly

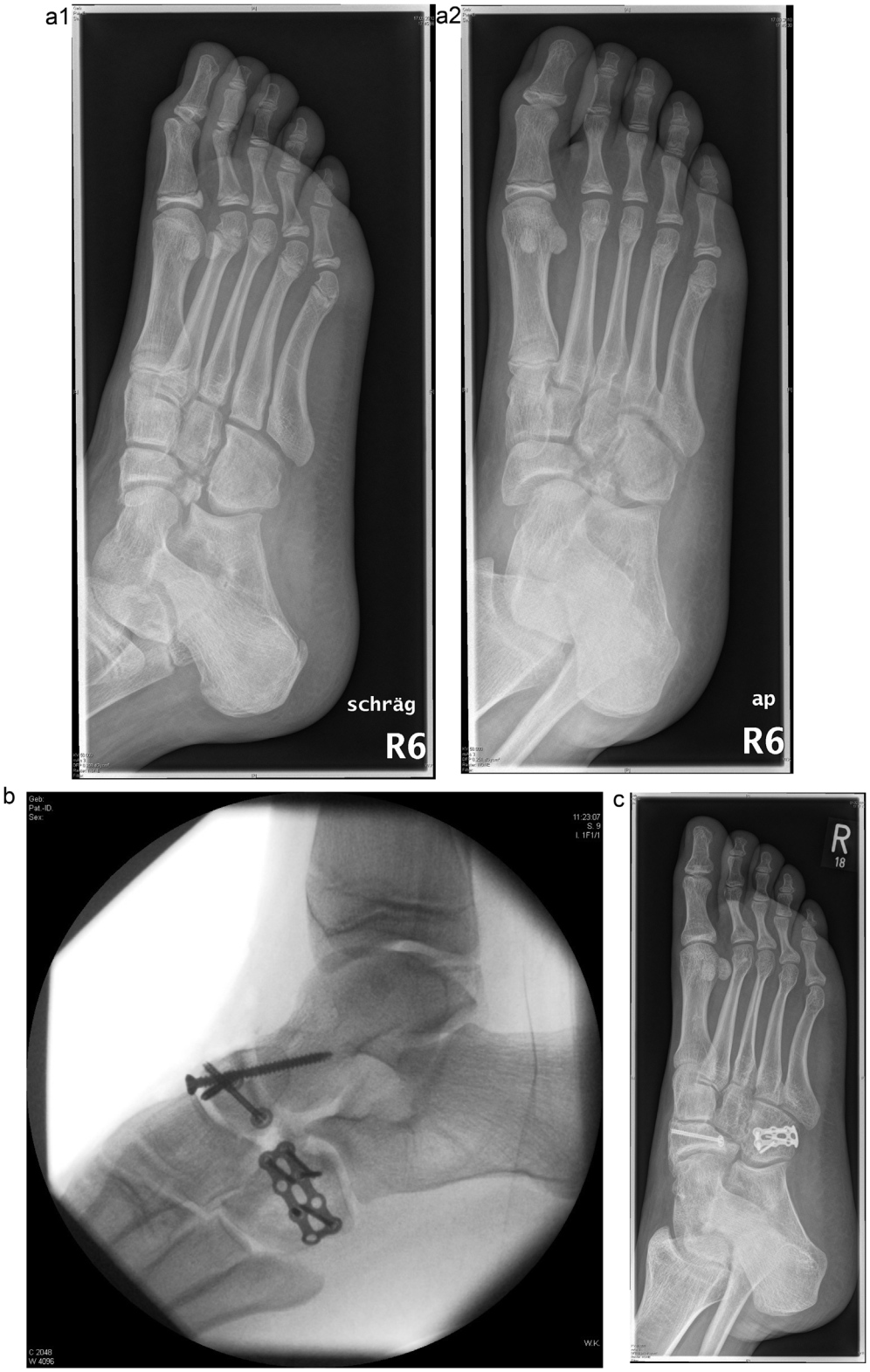

Fig. 3. (a) A.p. and lateral plane radiographs showing a multi-fragmentary Type 5b cuboid fracture associated with a mid-tarsal disruption and navicular bone fracture. (b) The fracture was treated with ORIF using screws and plate osteosynthesis. (c) The FU was performed at 7.8 years, the patient achieved an AOFAS score of 68 points.

removed within 6–8 weeks. Ruffing et al. used a fixed-angle plate to reconstruct and maintain the length of the lateral column [14]. As the subchondral bone stock was sufficient to achieve stable fixation, bone grafting was not necessary in this case of angle-stable plate osteosynthesis.

In our study, the AOFAS midfoot scale reflected the severity of the fracture type classification developed by Fenton et al. Despite the limited number of patients for an in-depth correlation analysis, we observed that AOFAS midfoot scale values were poorer with higher fracture types.

Conclusions

Despite optimal restoration of the anatomy, poorer outcome results may occur in more complex fracture types. Clear indications for treatment of these fractures should be established in prospective studies with higher numbers of patients.

Conflicts of interest

All authors have no conflicts of interest

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