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Reference:
Mespreuve Marc, Bosmans Frederik, Waked Karl, Vanhoenacker Filip.- Hand and wrist: a kaleidoscopic view of accessory ossicles, variants, coalitions, and others
Full text (Publisher’s DOI): https://doi.org/10.1055/S-0039-1693974
To cite this reference: https://hdl.handle.net/10067/1629470151162165141
The Hand and Wrist: a Kaleidoscopic View of Accessory Ossicles, Variants, Coalitions

Marc Mespreuve M.D., Ph.D.\textsuperscript{1,2}, Frederik Bosmans M.D.\textsuperscript{2,3}, Karl Waked M.D.\textsuperscript{4}, Filip M. Vanhoenacker, M.D., Ph.D\textsuperscript{1,2,3}.

1. Department of Radiology and Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium
2. Department of Radiology, AZ Sint-Maarten, Duffel-Mechelen, Belgium
3. Department of Radiology, Antwerp University Hospital and Antwerp University, Edegem, Belgium
4. Department of Plastic Surgery, University Hospital Brussels, Brussels, Belgium

Address for correspondence:
Marc Mespreuve M.D., Ph.D.
Department of Radiology, AZ Sint-Maarten, Duffel-Mechelen
Liersesteenweg, 435, 2800 Mechelen, Belgium E-mail: marc.mespreuve@skynet.be

E-mail addresses of other co-authors:
frederik.bosmans@student.uantwerpen.be
karl.waked@icloud.com
filip.vanhoenacker@telenet.be
Abstract
Accessory bones, variants, and coalitions are not uncommon at the hand-wrist region. They are often overlooked as they are usually asymptomatic and found incidentally on imaging. However, they may sometimes present as a (painful) swelling or mimic a (sequel of a) fracture. Other symptoms may be attributed to impingement and exercise-related pain. Thorough knowledge of the anatomy, systematic imaging analysis, and the awareness of their existence are the clues to a correct identification.

Plain radiography and MRI play a pivotal role in the correct diagnosis.

In general, signal intensity on MRI is similar to the normal bony structures. However, concomitant bone marrow oedema may indicate the presence of impingement. Therefore, MRI sequences with fat suppression should be included in case of symptomatic findings.

This article provides a kaleidoscopic overview of some of the prevalent bony anomalies of the hand-wrist region and the potential pathogenic nature.

Key-words
- Accessory Bone
- Variants
- Coalitions
- Plain Radiography
- Magnetic Resonance Imaging

Introduction
Clinical Presentation
Accessory bones, coalitions, and bony variants are distinct structures that are different from the usual bony structures described in anatomy textbooks of the human body. Most of them are incidental findings on plain radiography. However, they may become symptomatic due to impingement or altered mobility. They may cause compression on or displacement of adjacent structures or induce exercise-related pain.
Imaging Features

On plain radiography, accessory bones and bony variants are readily visible. They may cause distortion or obliteration of fat planes. Furthermore, secondary degenerative changes may be seen in some cases.

Computed Tomography (CT) may be useful to demonstrate the three-dimensional anatomy more precisely. However, due to radiation constraints, CT is rarely used for this evaluation. Moreover, the intrinsic contrast resolution of the surrounding, and possibly also altered soft tissues, is lower, compared to Magnetic Resonance Imaging (MRI). Although modern dual-energy CT equipment is able to demonstrate bone marrow oedema, CT is still regarded as the gold standard for assessment of bone marrow oedema.

The signal intensity of accessory bones and bony variants is similar to normal bone on all MRI pulse sequences. Therefore, because of their intrinsic contrast with the adjacent soft tissues, accessory bones and variants are best identified on T1-weighted images without fat suppression (FS). Isotropic 3D-GRE images will illustrate the three-dimensional anatomy in detail. T2-weighted images with FS or short tau inversion recovery (STIR) images may eventually show bone marrow oedema and are useful sequences to evaluate the potential symptomatic nature of accessory bones. MRI may also evaluate the mass effect on adjacent soft tissue structures.

Accessory bones, variants, and coalitions of the hand-wrist region

Carpal Boss (CB)

- Definition: osseous, sometimes painful mass at the quadrangular joint.

- Prevalence: common, but exact prevalence is unknown. In general, the prevalence of an os styloideum is estimated between 1-4%. However, the incidence in the symptomatic CB population is 8-26% and a ganglion is present in up to 30%.
- Potential symptoms: local swelling and/or pain (CB syndrome)\(^7\) due to a palpable dorsal mass at the second or third carpometacarpal (CMC) joint, mimicking an arthrosynovial cyst or soft tissue tumor.

- Diagnosis: clinical examination and plain radiography will usually reveal the diagnosis. Radiography, and in particular CT, allow for an evaluation of the bony morphology or detection of an accessory bone (os styloideum) (\(\text{Fig. 1, 2 B}\)), but fail to correlate with the experienced pain. The absence of bony anomalies, however, does not allow for the exclusion of carpal boss syndrome. Ultrasound (US) and colour Doppler may add information about tendinopathy, arthrosynovial cyst, and synovial proliferation. MRI may illustrate a variable bony morphology and additional bony and soft tissue pathologies (old fracture, degeneration with osteophytes, soft tissue oedema, tendinopathy, dorsal ligamentous tears, synovitis) (\(\text{Fig. 1, 2}\)). Bone marrow oedema (BMO) shows a significant correlation with a painful carpal boss.\(^8\) MRI may be of additional diagnostic value in patients with persistent pain and in a preoperative setting. The exact location and morphology of the carpal boss may allow for a more limited resection or shaving in order to reduce the risk of post-operative instability due to ligamentous injury (\(\text{Fig. 2 C}\)). Contrast may be administered in case of synovial proliferation (\(\text{Fig. 2 D}\)). MR arthrography to illustrate ligamentous anomalies is rarely needed (\(\text{Fig. 2 E}\)).

- Treatment: in case of pain, treatment is usually conservative and involved activity modification, anti-inflammatory analgesics, and eventually a wrist splint. If the pain persists, a long acting steroid may be injected at the level of the CMC-joint. When conservative treatment fails, excision of the bony abnormality and/or the soft tissue swelling may be considered.
**Carpal coalition (CC)**

- Definition: coalition between two or more adjacent bones in almost any combination. The carpal bones on the ulnar side are more commonly involved.\(^9\)
- Prevalence: fusion of carpal bones is hereditary and the trait is transmitted as a dominant factor which is not sex-linked.\(^10\) Lunotriquetral coalition (LTC) is the most frequent type of carpal coalition, representing 90 % of all carpal fusions.\(^11\) The general prevalence of LTC is about 0.1 % in the Caucasian population and the congenital variant is often bilateral.
- Potential symptoms: although usually considered as an asymptomatic normal variant, CC may become symptomatic due to the pseudarthrosis or in case of a fracture. A weaker fibrocartilaginous coalition appears to be more susceptible to stress or trauma.
- Diagnosis: from the moment their ossification centers occur the fusion may become visible on *plain radiography*. Most CC occur between carpals within the same carpal row.\(^8\) CC between carpals from different rows are quite rare\(^12\) (\(\text{Fig. 3}\)). Complicated CC (\(\text{Fig. 3 E, F}\)) are likely to be associated with more widespread anomalies. The coalition may be fibrous (syndesmosis), cartilaginous (synchondrosis), or osseous. Frequently, it is a mixture of the former two variants. de Villiers Minnaar\(^13\) classified the carpal coalitions into four types (\(\text{Fig. 4}\)). Minnaar type 1 resembles a pseudarthrosis with irregular sclerotic margins and a narrowed joint space (due to its incomplete fibrocartilaginous coalition). In case of progression, subcortical cysts may be seen. This non-osseous coalition may result in degenerative osteoarthritis due to abnormal joint mechanics and the thin cartilage between the affected carpals.\(^14\)

*MRI* in CC type 1 shows far better the subchondral cysts and may additionally show bone marrow edema on fluid-sensitive sequences adjacent to the joint in symptomatic cases (\(\text{Fig. 5}\)). After contrast administration, the edema and fibrovascular tissue in the
synovium and subcortical cysts will enhance, although this does not add any clear
diagnostic information. MRI may also exclude concomitant pathology of the wrist, which
certainly needs to be evaluated in case that any operative treatment is considered. Due to
the absence of osseous superposition, MRI allows for a more accurate evaluation and
classification, compared to plain radiography. In type 4 CC, additional soft tissue
anomalies are eventually illustrated as well.

- Treatment: after resection of the pseudarthrosis, surgical fusion\textsuperscript{12} may be performed in
  symptomatic cases (i.e. type 1) using a Herbert screw\textsuperscript{15} and/or a cortico-cancellous
  wedge.

\textit{Congenital syndromes (CS)} These are numerous and of complex nature. As an example, we
consider briefly a patient with Ellis-van Creveld Syndrome (EvC)

- Definition: chondroectodermal dysplasia, six-fingered dwarfism.

- Prevalence: very rare genetic disorder of the skeletal dysplasia type, classified as a type of
  mesomelic limb shortening in the group of the short rib-polydactyly dysplasias (OMIM
  #225500). The reported incidence is 1/1,500,000 births with an equal sex ratio. EvC is
  caused by loss-of-function mutations in the genes EVC or EVC2, the phenotype
  associated with these gene mutations being indistinguishable. The inheritance pattern is
  autosomal recessive.\textsuperscript{16}

- Potential symptoms: bilateral postaxial polydactyly is a constant finding\textsuperscript{17}. There are two
types: type A (well-formed digit) and type B (rudimentary skin tag, designated as a
  vestigial digit).

- Diagnosis: one or more accessory carpal bones may be noticed, mostly on the ulnar side
  of the hamate bone (the so called fifth distal carpal bone (FDCB)).\textsuperscript{17,18} The abnormalities
tend to be symmetrical. MRI shows, as well as plain radiography, a postaxial hexadactyly
Axial T1-SE, coronal T1-SE and T2-FS sequences are mandatory to evaluate bones and soft tissues. There is a partial segmentation of the 5th and 6th metacarpal and the extra digit has only two phalanges (hypertrophic proximal and distal). Moreover, MRI showed that the tendons of the flexor digit minimi (DM) and opponens DM ran adjacent to the 5th finger, whereas the tendon of the abductor DM was located adjacent to the 6th finger. In patients experiencing painful motion, more sensitive STIR sequences may be added - only for diagnostic reasons - in order to demonstrate dysfunctional bone marrow oedema due to a defective bony configuration.

- Treatment: when reconstruction of a type A is considered (non-functional digit or for cosmetic reasons), MRI may precise pre-operative anatomy, in order to allow for a maximal preservation of the muscle(s).

**Pisiform bone ossification variant**

- Definition: irregular ossification of the pisiform bone at the age of 8 to 12.
- Prevalence: often occurs in the carpal bones during development. The pisiform is the most common carpal bone to demonstrate this irregular ossification.19
- Potential symptoms: none.
- Diagnosis: on lateral *plain radiography* the appearance with multiple ossification centers sometimes is most confusing (Fig. 7A). Occasionally, other carpal bones may also show ossification variants (Fig. 7C-D).
- Treatment: none
**Nora lesion (NL)**

- **Definition:** bizarre parosteal osteochondromatous proliferation (BPOP)\(^{30}\) is a reactive lesion, defined as a well-marginated mass of heterotopic mineralization arising from the periosteal aspect of an intact cortex. There are no medullary changes and it is predominantly located in the diaphysis or metaphysis of the phalanges, mostly posterolateral on the friction site.

- **Prevalence:** rare benign lesion occurring at any age, most frequently during the second or third decade. Mostly in the (right) hand or foot, which may be an indicator of a traumatic etiology, and less frequently in the long bones.\(^{21}\)

- **Potential symptoms:** non-characteristic, occasionally fast-growing soft tissue or bony swelling. Discomfort or pain unrelated to activity may be present. A history of trauma is frequent. No malignant transformation has ever been described.

- **Diagnosis:** *plain radiography* may show a periosteal soft tissue thickening (\(\text{Fig. 8A}\)) or mass, without alterations of the cortex and eventually with some tiny calcifications in a first stage. Later, the flamelike parosteal calcifications become more prominent in the calcified periosteal mass. A completely ossified, cortical-based sessile osteophytic lesion (\(\text{Fig. 8B}\)) is considered as the mature end stage presentation. Consecutive radiographies are mandatory as this maturation process is achieved within a period of six months for diagnostic and differential diagnostic reasons. There is no continuity with the medullary canal. Recurrences are usually asymptomatic and difficult to differentiate from a primary lesion. They may present as a partially, more irregularly calcified or completely ossified lesion. BPOP is part of a spectrum of reactive lesions\(^{22}\), presenting as florid reactive periostitis and acquired osteochondroma (Turret exostosis). This Turret subungual exostosis occurs specifically in the distal phalanges beneath the nail bed as a subperiosteal
bone formation which develops beneath the extensor apparatus of the toes. It may be a source of pain and nail deformity.

There are no specific MRI characteristics. The cortex, bone marrow and surrounding soft tissues have a normal signal intensity. Marked enhancement of the lesion is noted. Scintigraphy shows an abnormal uptake of the radioactive markers.

Differential diagnosis includes a benign juxtacortical chondroma, but malignant tumors, such as periosteal or parosteal chondrosarcoma and osteosarcoma (rarely in the hand or foot) should be considered in the initial phase.

- Treatment: immediate biopsy is not required, unless there is an atypical evolution. Total excision of the completely ossified lesion is the treatment of choice. Recurrence rate is frequent (up to 50%), usually within six months.

**Ulnar styloid bone (USB)**

- Definition: os (ulno)styloideum is a persistent ulnar styloid ossicle.
- Prevalence: probably around 1-2%.
- Potential symptoms: none, but mainly a differential diagnostic problem if focal pain at the ulnar styloid persists after trauma.
- Diagnosis: theoretical differentiation from other normal variants, such as an os triangulare (also known as os intermedium antebrachii or os triquetrum secundarium, which is more radially located between the ulnar styloid, lunate bone and triquetral bone) and a lunula (which lies at the tip of a normal ulnar styloid process). Mainly, the differentiation between an USB and a non-union of an ulnar styloid process fracture is important as the latter may be symptomatic due to collision with the triquetral bone during ulnar deviation.

On plain radiography, the borders of ossicles are smooth and corticated. A lunula may be
fused with the styloid process, giving it an elongated appearance. Recent fractures have irregular or ragged margins. The cortical line at the proximal pole of the USB is rounded. A non-union fragment may be more flattened or even concave ( signer. Specific attention should be given to the peristyloidal fat line, which may be blurred in a traumatic setting. MRI highlights neo-articulation and BMO ( signer. The triangular fibrocartilage complex (TFCC) ulnar insertion (fovea and tip) in relation to these bone fragments is depicted ( signer. The ulnar stability of the TFCC may be evaluated.

- Treatment: none.

**Ulnar styloid length**

- Definition: the ulnar styloid length may vary considerably. The Garcia-Elias index may indicate the risk of developing a stylo-triquetral abutment.
- Prevalence: more in Asians and more in positive ulnar variance.
- Potential symptoms: stylo-triquetral abutment.
- Diagnosis: Plain radiography will illustrate the styloid process length increase. The Garcia-Elias index may indicate a risk of developing a stylo-triquetral abutment. An overall styloid length greater than 6 mm is considered abnormal. Impaction with the triquetral bone may appear with flattening of the tip of the styloid process ( signer. MRI may show bone marrow oedema, degenerative subcortical cysts and synovitis with contrast enhancement of the marrow oedema and the surrounding synovitis (prestyloidal synovitis) ( signer. The treatment: resection of the distal part of the styloid process if conservative treatment fails.
**Positive ulnar variance (PUV)**

- **Definition:** the ulnar variance refers to the relative lengths of the distal articular surfaces of the radius and ulna. Positive variance means that the ulna is (> 2 mm) longer.
- **Prevalence:** the frequency is lower in males and increases with age.  
25
- **Potential symptoms:** ulnar impaction syndrome, a painful condition of excessive contact and wear between the ulna and the carpus, which may be associated with a degenerative tear of the TFCC. Often, the patient will present with significant loss of pronation and supination. Significant positive ulnar variance will contribute to the limitation of the radiocarpal mobility of the wrist (Fig. 10A).
- **Diagnosis:** on plain radiography, the ulnar length is evaluated on a strict postero-anterior radiograph using the Hulten criteria.  
26 Ulnar variance changes considerably with changing wrist position and increases with pronation and during a firm grip. In ulnar impaction syndrome, plain radiography may reveal bony alterations (subchondral cyst(s), sclerosis), observed at the proximal-ulnar side of the lunate bone, but only in a late phase of ulnar impaction. Early diagnosis will be revealed by MRI. Chondral lesions and BMO typically appear at the proximal-ulnar corner of the lunate bone.
- **Treatment:** ulnar shortening if conservative treatment fails.

**Negative ulnar variance (NUV)**

- **Definition:** the ulnar variance refers to the relative lengths of the distal articular surfaces of the radius and ulna. Negative variance means that the ulna is (> 1 mm) shorter.
- **Prevalence:** unknown. Young adolescent boys demonstrate a greater degree of negative ulnar variance compared to young adolescent girls.  
27
• Potential symptoms: ulnar impingement syndrome, a painful condition of excessive contact and wear between the head of the ulna and the distal radius. The precise role of ulna minus in the development of Kienböck disease remains uncertain.\textsuperscript{28}

• Diagnosis: on \textit{plain radiography}, the ulnar length is evaluated on a strict postero-anterior radiograph (\textsuperscript{4} Fig. 10B) using the Hulten criteria. In ulnar impingement syndrome, plain radiography may reveal bony alterations (subchondral cyst(s), sclerosis), observed at the distal radius, proximal to the distal radioulnar joint. Early diagnosis will be revealed by MRI. BMO typically appears at the contact zone.

• Treatment: decompression with shortening of the radius, lengthening of the ulna or distal ulnar resection if conservative treatment fails.

\textit{Dense Epiphysis (DE)}

• Definition: also called ivory epiphysis.
• Prevalence: unknown. Normal variant, but DE may be caused by\textsuperscript{29}

  \textbf{Common causes:}
  \begin{itemize}
  \item Hypopituitarism
  \item Multiple epiphyseal dysplasia
  \item Retarded skeletal maturation
  \item Thiemann disease
  \item Trichorhinophalangeal dysplasia type 1
  \item Trichorhinophalangeal dysplasia type 2
  \end{itemize}

  \textbf{Uncommon causes:}
  \begin{itemize}
  \item Coffin-Lowry syndrome
  \item Coffin-Siris syndrome
  \item Connective tissue disease
  \item Deprivation dwarfism
  \item Dyggve-Melchior-Clausen dysplasia
  \item Homocystinuria
  \item Hypothyroidism
  \item Lesch-Nyhan syndrome
  \item Morquio syndrome
  \item Mucolipidosis type 3
  \item Renal osteodystrophy
  \item Robinow syndrome
  \end{itemize}
Scleroderma  
Seckel syndrome  
Silver-Russell syndrome  
Spondyloepiphyseal dysplasia congenita  
Stickler syndrome  
Systemic lupus erythematosus  
Trisomy 21  
Turner syndrome  
Williams syndrome  

- Potential symptoms: none.  
- Diagnosis: the even increase in density of the normal epiphysis as an isolated finding in DE is clear on plain radiography († Fig. 11).  
- Treatment: none.

**Tuft sclerosis (TS)**  
- Definition: sclerosis due to a localized form of endosteal bone formation at the distal phalanx.  
- Prevalence: common, more than 50% of the population over the last 44 years.  
- Potential symptoms: none.  
- Diagnosis: typically striking dense aspect of the tuft of the distal phalanx on plain radiography († Fig. 12). A similar appearance as in TS may be found with superimposed calcinosis over the terminal phalanx, as may be seen in connective tissue disease. The typical location differentiates it from a more generalized reactive endosteal new bone formation (metastasis, Paget, osteomyelitis, fracture, ivory sclerosis in psoriasis).  
- Treatment: none.
**Trevor Disease (dysplasia epiphysealis hemimelica) (DEH)**

- **Definition:** uncommon developmental bone disorder during childhood, characterized by an abnormal overgrowth of cartilage from the epiphysis of the long bones, particularly at the lower limbs and mainly at the knee, ankle, as well as the tarsal bones.

- **Prevalence:** usually affects children between 1 and 15 years. Males are affected three times as often as females. The incidence has been estimated at 1/1,000,000 people. Involvement of carpal bones is extremely rare.

- **Potential symptoms:** painless mass or swelling on one side of the affected joint. Pain usually occurs at a later stage of the disease. The specific symptoms present in each child vary and depend on the size and location of the cartilage mass. Decreased range of motion of the affected joint, joint deformity, and discrepancy in limb length are possible additional symptoms.

- **Diagnosis:** *plain radiographies* (Fig. 13) are mandatory to illustrate the abnormal osteocartilaginous mass(es). Initially an irregular and often multicentric calcific mass appears at one side of the epiphysis or carpal bone. A premature ossification of the affected bone usually occurs. The multiple ossification centers increase in size and coalescence. The hemimelic cartilage overgrowth occurs mostly at the medial, sometimes at the lateral side of the long bones. In the localized form, DEH affects only a single bone. Multiple bones in a single limb are affected in the classical form. In the generalized form the entire limb is involved. Approximately two-thirds of the patients have multiple lesions. *MRI* may demonstrate DEH lesions at an earlier stage. The extent of epiphyseal and joint involvement is evaluated well. A cleavage plane between the mass and the normal epiphyseal cartilage may be illustrated, which is a useful in case of surgery.

- **Treatment:** surgical resection of the abnormal osteocartilaginous mass.
Osteochondroma (OC)

- **Definition:** Osteocartilaginous exostosis is a benign outgrowth on the surface of the bone, made up of both bone and cartilage at the level of the growth plate. Osteochondroma(ta) may develop as a single tumor (osteocartilaginous exostosis) or as many tumors (multiple osteochondromatosis).

- **Prevalence:** Mostly during childhood or adolescence osteochondromas occur in 3% of the general population. They represent up to 40% of all benign bone tumors and are equally distributed between men and women. OC are thought to be associated with the EXT1 gene. Mutations in this gene cause the type I form of multiple OC, or occur as a result of previous trauma to a growth plate, including previous irradiation.

- **Potential symptoms:** A painless growing hard “bony” mass. They are commonly found at the end of long bones, mainly the shoulder, knee, and hip. The hand is less commonly involved. Once the skeleton has reached maturity, the osteochondroma will stop growing. It may disappear spontaneously as well. Pain and snapping with activity may be present if an OC is located under a tendon. Numbness may occur when localized near a nerve. Exceptionally, the stalk of a pedunculated osteochondroma may break and cause severe local pain and swelling. Formation of a pseudoaneurysm and venous thrombosis may lead to claudication, pain, acute ischemia, and symptoms of phlebitis. Reactive myositis and bursal formation with bursitis may occur. Malignant transformation takes place in the cartilage cap, but is uncommon in solitary OC (~1%).

- **Diagnosis:** On plain radiography, the OC is seen in the metaphyseal region typically growing away from the epiphysis, with often an associated broadening of the metaphysis. It may be pedunculated (with a stalk) or sessile (with a broad base on the long bone) (Fig. 14). In OC, the medullary cavity is usually continuous with the parent bone. The cartilage cap - if visible - may show ring and/or arc shaped calcifications and an irregular
subchondral bone. Cortical irregularity or continued growth after skeletal maturity, as well as aggressive features such as bony destruction, and a large soft tissue component are suspicious for malignant transformation. CT is more able to demonstrate the medullary continuity, as well as the cartilage cap. MRI is the best imaging modality to assess the thickness of the cartilage cap. The presence of BMO or oedema in the adjacent soft tissues, and compression on neural or vascular structures near the tumor will be highlighted on MRI. A cartilage cap of 1.5 - 2 cm is borderline and over 2 cm in thickness is suspicious for malignant transformation. After intravenous (IV) gadolinium, an enhancement is normally seen in the fibrovascular tissue that covers the cartilaginous cap. However, the cartilaginous cap itself should never enhance at all. Trevor's disease and metachondromatosis are considered in the differential diagnosis.

- Treatment: most patients are not treated. Careful observation over time with regular plain radiography and sometimes MRI to keep track of any changes in the tumor is recommended. Surgical excision is considered if the OC causes pain, puts pressure on a nerve or vessel, or has a thick cartilage cap.

**Hereditary Multiple Exostosis (HME)**

- Definition: multiple osteochondromata (Fig. 15).

- Prevalence: approximately 15% of the osteochondromas occur as hereditary multiple osteochondromas. They usually present during childhood, but the majority only manifest clinically at the time of adolescence. It is an autosomal dominant inherited disease. Mutations in EXT1 and EXT2 genes located on chromosomes 8 and 11 have been associated with HMO.38,39

- Potential symptoms: in HMO, the rate of malignant transformation is higher (up to 5%)40,41 than in solitary OC.
- **Diagnosis:** Trevor's disease and metachondromatosis are considered in the differential diagnosis of hereditary osteochondromas.

- **Treatment:** In HME, the surgical indications\(^2\) are based on the patient's age, tumor location and number, accompanying symptomatology, aesthetic concerns, family history and underlying gene mutation. However, the best evidence for each of the currently practiced surgical procedures is lacking.

**Conclusion**

Although most accessory bones, coalitions and bony variants are asymptomatic, they may mimic a soft tissue swelling, cause pain, and become symptomatic due to compression on adjacent structures or impingement.

Thorough knowledge of the anatomy, systematic imaging analysis and awareness of their existence are the clues to a correct identification.
References

42. EL-Sobky TA, Shady Samir S, Naeem S. et al. Current paediatric orthopaedic practice in hereditary multiple osteochondromas of the forearm: a systematic review. SICOT-J 2018;4:10
Figures

Fig. 1 CB presenting with pain after repetitive stress at the CMC-joint in a professional piano player. (A) Plain radiography PA view, (B) Coronal SE PD-WI FS and (C) SE T2-WI FS (A) Presence of an os styloideum (arrow). (B-C) Focal bone marrow edema at the os styloideum (arrows) and the base of MC-III (C) (arrow). The pain disappeared after resection of the os styloideum.

Fig. 2 (A, B and C) Sagittal 3D-GRE (D) Coronal SE T1-WI FS with gadolinium contrast, and (E) MR midcarpal arthrography sagittal SE T1-WI FS. (A) Osteophytes (arrows) resembling a volcano, with a subchondral cyst (oblique arrow) and irregular narrowing of the dorsal joint space. (B) CB due to an os styloideum (horizontal arrow) interfering with the normal path of the ECRB tendon (vertical arrow). (C) Rupture of the dorsal CMC-III ligament (arrow) with surrounding soft tissue edema. (D) Contrast enhancement in CB due to rheumatoid arthritis. Dorsal prominent synovitis (arrows) at the CMC-III joint. (E) Trapezoid-MC-II joint showing the close relationship (oval) of the dorsal CMC-ligament and the more superficial tendon of the ECRL.
Fig. 3 Isolated and combined coalitions. (A), (B), (E) and (F) plain radiography, (B) Coronal SE T1-WI and (D) Coronal SE T2-WI.

(A) and (B) trapezoid-capitate coalition (arrows).
(C) and (D) capitate-hamate (long arrows) and trapezoid-capitate (short arrows).
(E) scapho-trapezium (long arrow) and capitate-hamate (short arrow).
(F) trapezo-trapezoideum (long arrow), capitate-hamate (short arrow) and LTC (double short arrow).
Fig. 4 Minnaar types 1 to 4. Schematic view.
Type 1: narrowed LTJ with irregular sclerotic margins (arrow).
Type 2: incomplete osseous fusion with (small) mostly distal remnant of the joint space (arrow).
Type 3: complete osseous fusion between the lunate and triquetral bone (arrow).
Type 4: same as Type 3, but with other carpal congenital bony abnormalities.
Fig. 5 Symptomatic patient with lunotriquetral coalition Minnaar type 1. (A) plain radiography and (B) Coronal SE T1-WI, (C) SE proton density and (D) SE T2-WI. Type 1 coalition with subchondral cysts (A) and surrounding edema (B-D) in a patient with ulnar sided wrist pain.
Fig. 6 Ellis-van Creveld Syndrome. (A) Plain radiography and (B) Axial SE T1-WI. (A) Postaxial polydactyly with proximal partial synmetacarpalism (V-VI). Relative hypertrophy of the proximal phalanx (PPh) in the 6th digit. Absence of the middle phalanx. Presence of a fifth distal carpal bone (FDCB) articulating with the synmetacarpal. (B) Dorsal position MC-V. Digit minimi tendons: flexor (F) (large vertical arrow) and opponens (O) (large horizontal arrow) adjacent to the 5th finger and abductor (A) (small arrow) adjacent to the 6th finger.
Fig. 7 Ossification variants. Plain radiography lateral (A, C) and PA (B, D) -view.
(A) Appearance with multiple ossification centers in the pisiform bone.
(B) Double ossification center in the trapezium bone.
(C-D) Lunate bifid ossification center.
Fig. 8  NORA lesion. Plain radiography – lateral view.
(A) 2006: periosteal soft tissue thickening, (B) 2018: completely ossified sessile osteophytic lesion.
Fig. 9 Ulnar (intra)styloid and stylotriquetral abutment. (A) Plain radiography – PA view; (B) FS T2-WI; (C) Sagittal 3D-GRE; (D) PA plain radiograph; (E) Coronal SE T1-WI; (F) Coronal SE PD-WI FS and (G) Coronal SE T1-WI FS with gadolinium
(A) neo-articulation in the center of the ulnar styloid process (arrow) with a flattened cortical line at the proximal border of the bone.
(B-C) bone marrow oedema and degenerative subcortical cysts.
(D-F) Stylotriquetral abutment with flattening of the tip of the styloid process (D), bone marrow oedema and synovitis (E-F), and contrast enhancement of the marrow oedema and the synovitis (G).
Fig. 10 Ulnar variance. Plain radiography – PA view (A) positive and negative ulnar variance.

Fig. 11 Dense epiphysis of the distal phalanx. Plain radiography (A) PA and (B) lateral view.
Fig. 12 Tuft sclerosis of the distal phalanx of the fifth finger. Plain radiography – PA view.

Fig. 13 Dysplasia epiphysealis hemimelica. Plain radiography (A) PA and (B) lateral view. Four irregular ossification centers of different size of an enlarged scaphoid bone.
Fig. 14 Sessile osteochondroma. Plain radiography (A) PA and (B) lateral view. At the distal radius a small sessile osteochondroma was a coincidental finding in trauma in a mature skeleton. Typically, the medullary cavity is continuous with the parent bone.
Fig. 15 Hereditary Multiple Exostosis in a 15-y-old male. Plain radiography – PA view.