The experience of CBCT application in detection of bone fractures by the example of the anthropological material

Poster No.:	C-1379
Congress:	ECR 2015
Type:	Scientific Exhibit
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Keywords:	Comparative studies, Digital radiography, CT, Cone beam CT, Trauma, Bones
DOI:	10.1594/ecr2015/C-1379

Aims and objectives

Allusions of #-rays application in anthropology are known from publications since the beginning of the XX-th century. Nowadays modern visualization techniques are used increasingly for the remains examinations. However, information about an assessment of anthropological material using such #-ray techniques, as digital microfocus radiography with direct multiple images magnification (DMFR) or multislice computed tomography (MSCT) is limited by a few publications [1-5, 8-11].

With the advent of cone beam computed tomography (CBCT) systems of a new generation it has become possible to conduct researches of remains with high-quality images production, but capabilities of CBCT-technique application in detection of signs of various pathological intravital or postmortal processes is not studied enough [6, 7, 9, 11]. Currently, CBCT-images obtaining is based on scanning of an interest area with pulsed X-ray beam, collimated in such a way that the radiation is distributed in the form of a cone. It strikes subsequently a flat panel detector weakened by tissues. Just one circular rotation of a gantry around the examined area is resulted in a primary three-dimensional image that is ready for further processing. CB-system allows avoiding a loss of graphic information, which is an important factor while studying the bone structure. Despite the obvious advantages, CBCT still does not have a wide application in researches of anthropological material. In the framework of our research CBCT application capabilities in detection of bone fractures by the example of the anthropological finds have been analyzed.

Methods and materials

All the anthropological materials were provided by Research Institute and Museum of Anthropology named after D. N. Anuchin of Lomonosov Moscow State University (fig. 1). In total, 24 skeleton fragments, which were introduced by the soldiers' remains bone material of the Imperial Napoleon Bonaparte`s army who died in 1812 war, have been examined on modern CBCT-scanner - NewTom 5G (QR S.r.l., Italy). There were a number of indisputable advantages that were applied when cone beam unit had been selected: its modification and technical parameters, first of all (fig. 2). CBCT of the anthropological finds were conducted with the individual scanning settings: positioning, technical parameters and modes, according to its anatomical origin and size (fig. 3, 4). The obtained results were compared with the data of DMFR with direct multiple images magnification (#3,2), which have been carried out on X-ray unit Pardus (Russia), and MSCT, which have been conducted on Brilliance 64 (Philips, Holland) in 100 % (n = 24) of the samples. All the objects were with various posttraumatic changes of different anatomical segments. Visual inspection of each skeleton fragment had been executed to determine their anatomical origin, size and condition of its exterior surfaces before the radiation researches. In addition, we have made a database of digital photographs of all the presented bones.

Images for this section:

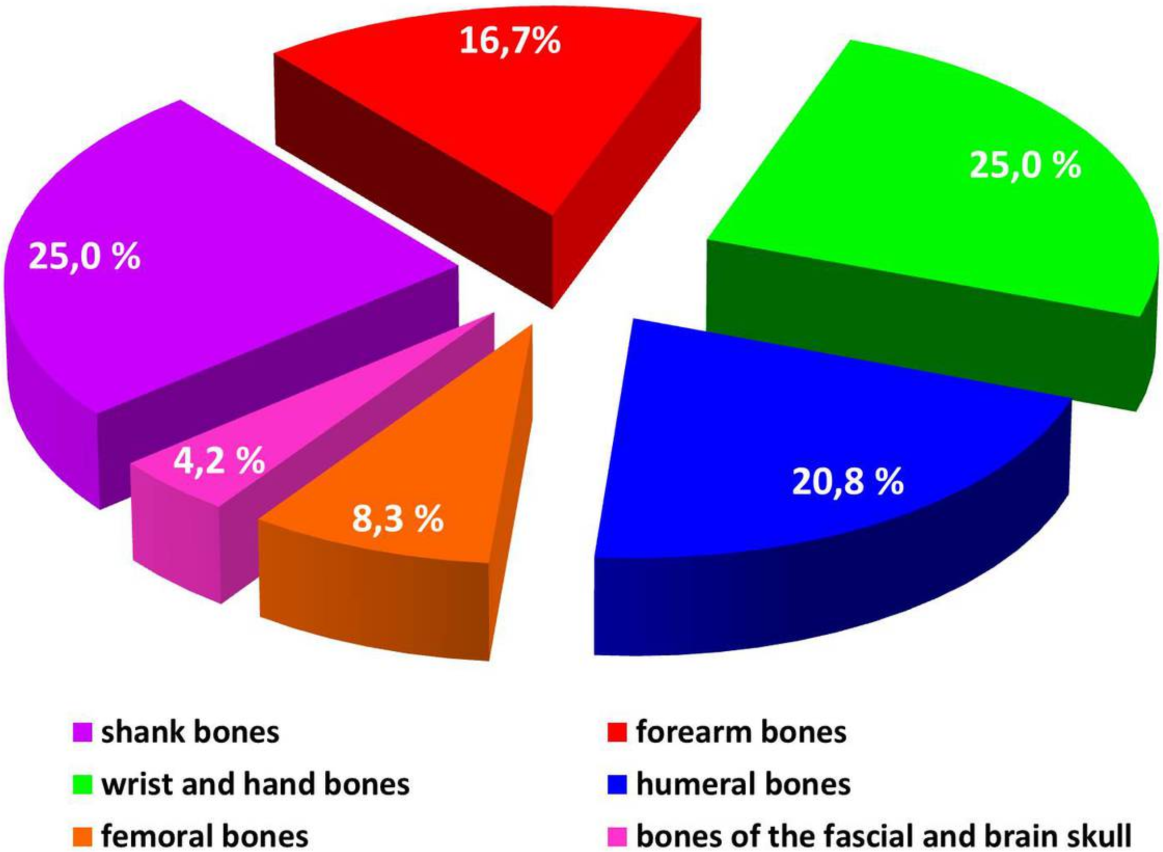

Fig. 1: the distribution of the bone fragments in accordance with its anatomical origin

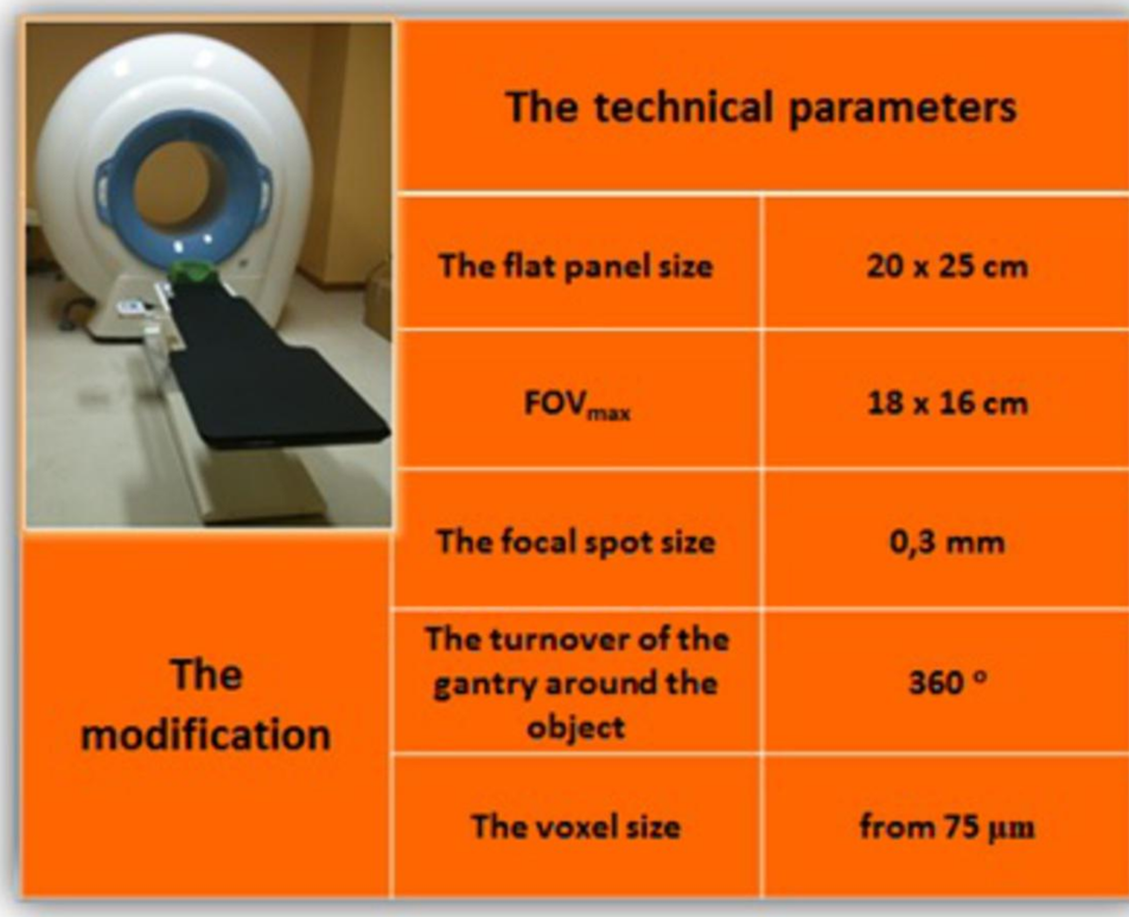

Fig. 2: the modification and the technical parameters of the CBCT unit

Scan parameters of the phalangeal bones	
Scan mode	Patient Scan
Scan type	Regular Scan or High Resolution
FOV	6 x 6 or 8 x 8 cm
Scan time	18 s
Exposure time	3,6 – 4,8 s
X-ray tube voltage	110 kV
Current	0,6 – 0,8 mA

Fig. 3: the photo of the wrist finger distal phalanges and the CBCT scanning settings for the phalangeal bones

Scan parameters of the facial and brain skull bones	
Scan mode	Dental Scan
Scan type	Regular Scan
FOV	16 x 18 cm
Scan time	24 s
Exposure time	4,8 s
X-ray tube voltage	110 kV
Current	6,6 – 7,7 mA

Fig. 4: the photo of the skull and the CBCT scanning settings for the facial and brain skull bones

Results

Received CBCT-images of all the anthropological finds were distinguished by high-resolution with a detailed mapping of bone structure: accurate differentiation and direction of bone trabeculae (fig. 5). It became possible to measure the thickness of the cortical bone, even if it was less than 1 mm and the length of the defects in those places where it was destroyed. During the comparative analysis it was found that visualization of bone structure on CBCT-images was comparable or even exceeded MSCT and digital microfocus X-ray images. In addition, small bone fragments and areas of pathological alteration of bone tissue (even under 1 mm) were observed reliably on CBCT-images. It became possible to specify its localization and spatial location.

In the framework of the x-ray expert examination the signs of various types of fractures were identified reliably in 79,2 % (n = 19) of the samples on the CBCT-images with subsequent building of multiplanar and 3D-reconstructions, 41,6 % (n = 10) among them - malunion and ununited. In cases with the malunion fractures consolidation was presented by the "bone bridges" due to coalescence of intermediate fragments and periosteal component of callus on the images with signs of comminuted fractures in 29,1 % (n = 7) of the objects (fig. 6, *a - c*).

One of the most representative examples with the similar changes was the femoral bone with the signs of the malunion comminuted fracture at the level of the proximal and distal fragments in the middle third of its diaphysis. The displacement of the former bone fragments has not been repaired. It was noted that the outward width shift of them was more than the width of the diaphysis (almost 2 diaphysis width). The overriding of the former bone fragments for each other was at the medially opened angle. The consolidation was presented by the "bone bridges" due to coalescence of the intermediate fragments, which lengthwise reaches 45,6 mm, and the periosteal component. Under the fragments there was the pathological cavity with the uneven outline, which spread from the medullary canal. The bone sequestrums and high-density inclusions (most likely shots) were visualized reliably inside of the cavity. The both fragments medullary cavities were narrowed appreciably or not traced at all at the level of the fracture. The cortical bone was thickened due to the endosteal and periosteal components (fig. 7, *a - c*). The laminar periosteal reaction was determined reliably only on MSCT and CBCT-tomograms.

During the evaluation of the CBCT and MSCT images results it became possible to identify the presence, to determine the size and spatial location of the intermediate fragments (less than 2 mm), which were not visualized significantly by DMFR. The ununited fractures were characterized by an absence of signs of fragments consolidation with clear, smooth contours of its edges, irregular narrowing of lumen of the bone medullary canal, thickening of the cortical plates due to the endosteal and periosteal component on the changes level in 25 % (n = 6) of the objects (fig. 8).

The comprehensive X-ray study of the skeleton fragments allowed to reveal the signs of fractures complications in the form of osteoreparation abnormality process in 16,6 % (n = 4) of the samples. The obtained data argued that there were signs of ununited transverse fracture of the left ulnar bone at the lower third of its diaphysis. The edges of the fragments had smoothed, curve contours. The medullary cavity at this level was narrowed unevenly. The fragments lumens were closed with the compact closure plates - the signs of the false joint formation - were revealed convincing on MSCT and CBCT. (fig. 9, a - c).

It is worth noting that an absence of the callus, smoothing and rounding of the bone fragments ends, the compact closure plates presence at the fragments ends were visualized on the all the received x-ray images. But the presence of the closure plates at the edges of the fragments was determined with CBCT and MDCT most convincingly (fig. 10, a - c).

Images for this section:

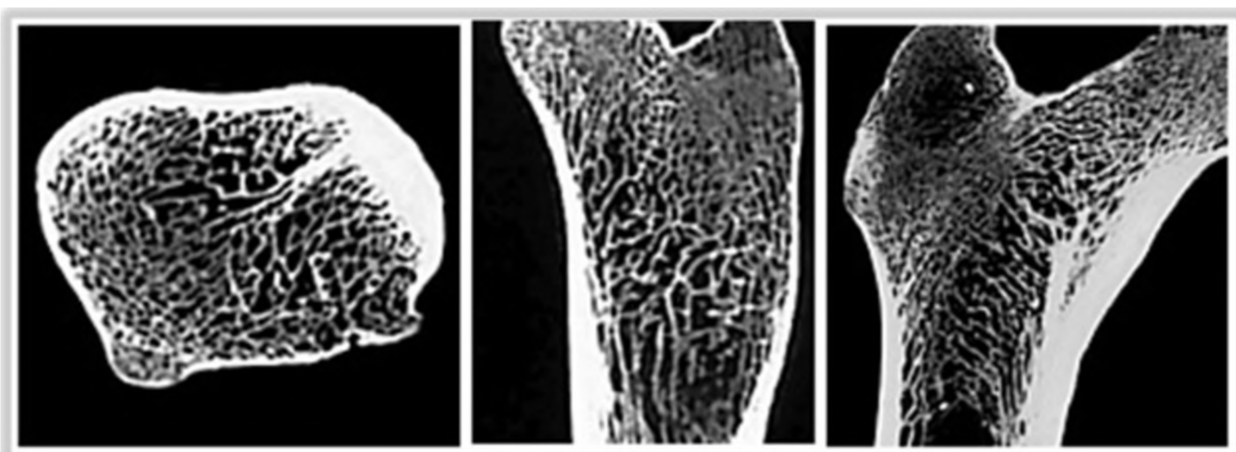

Fig. 5: the CBCT-images of the right femoral bone`s proximal metaphysis with the detailed mapping of the bone structure

Fig. 6: the photo (a), the CBCT-image (b) and the DMFR with the 3,2 direct images magnification (c) of the right humeral bone with the signs of the malunion comminuted fracture at the level of the lower third of the diaphysis and distal epiphysis

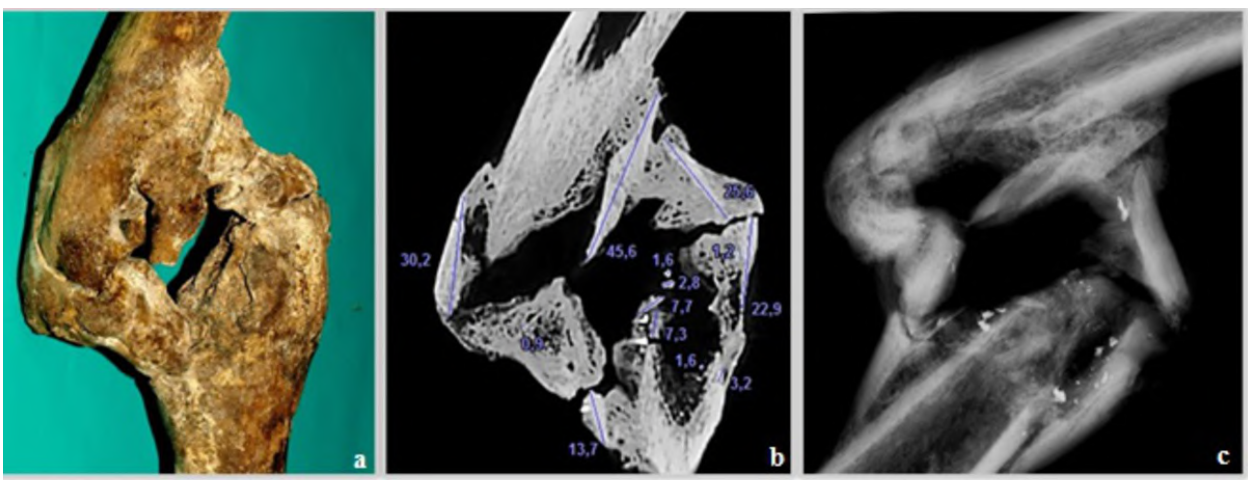

Fig. 7: the photo (a), the CBCT-image (b) and the DMFR with the 3,2 direct images magnification (c) of the right femoral bone with the signs of the malunion comminuted fracture at the level the middle third of its diaphysis

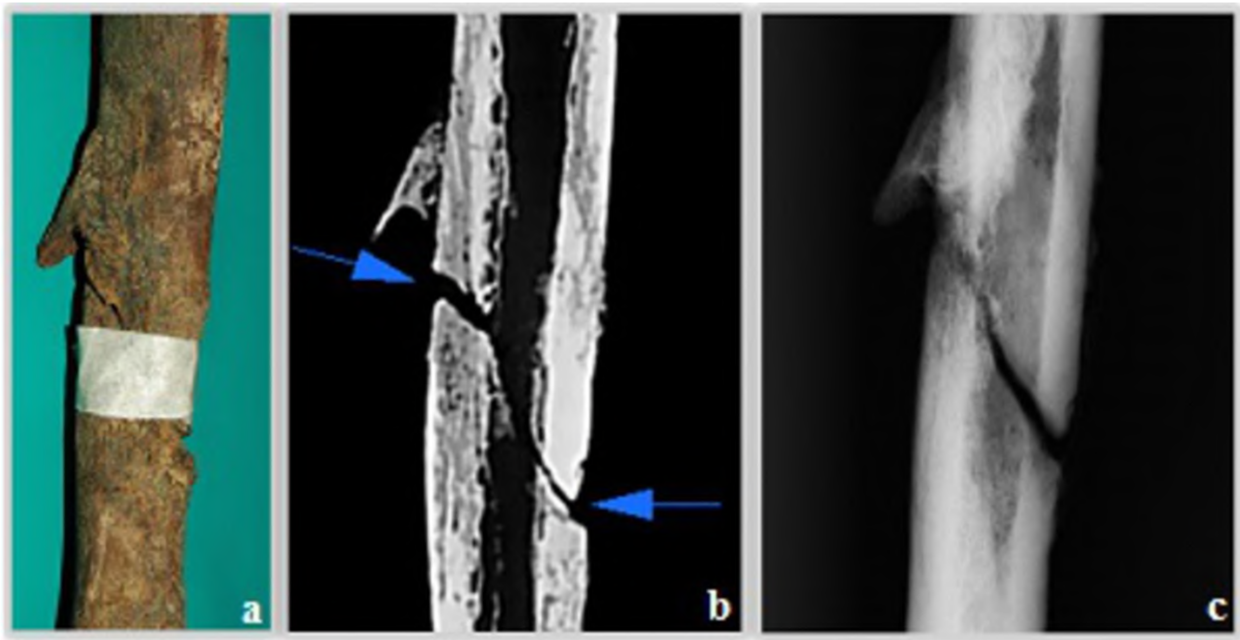

Fig. 8: the photo (a), the CBCT-image (b) and the DMFR with the 3,2 direct images magnification (c) of the left humeral bone with the signs of the ununited comminuted fracture at the level the middle and lower thirds of its diaphysis

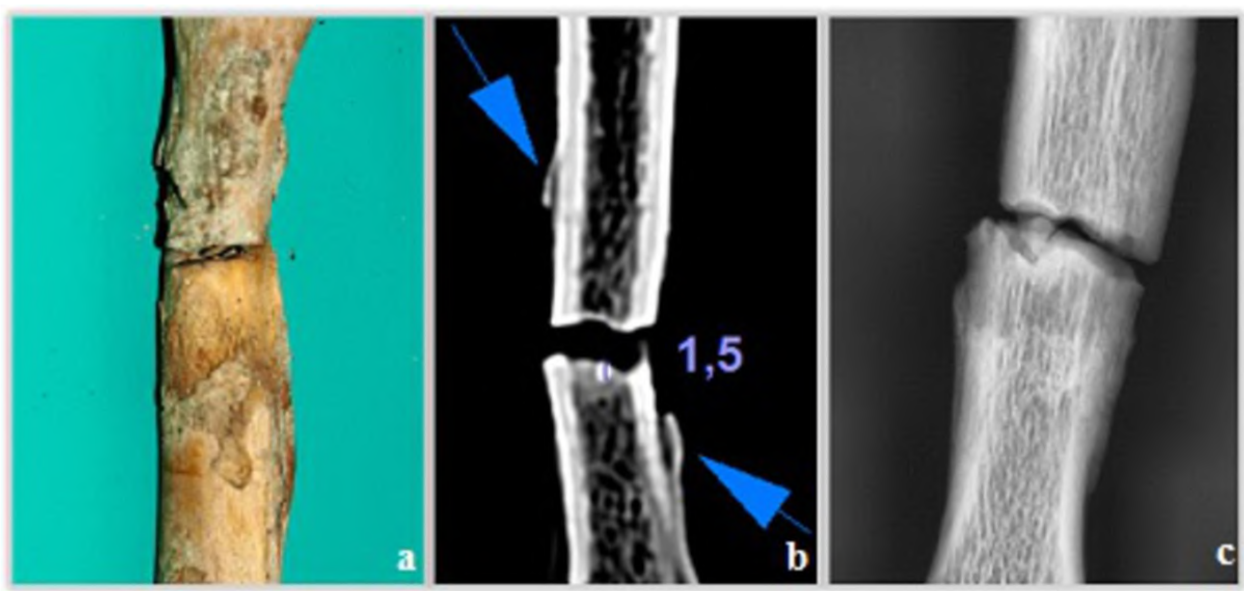

Fig. 9: the photo (a), the CBCT-image (b) and the DMFR with the 3,2 direct images magnification (c) of the left ulnar bone with the signs of ununited transverse fracture and the false joint formation at the lower third of its diaphysis

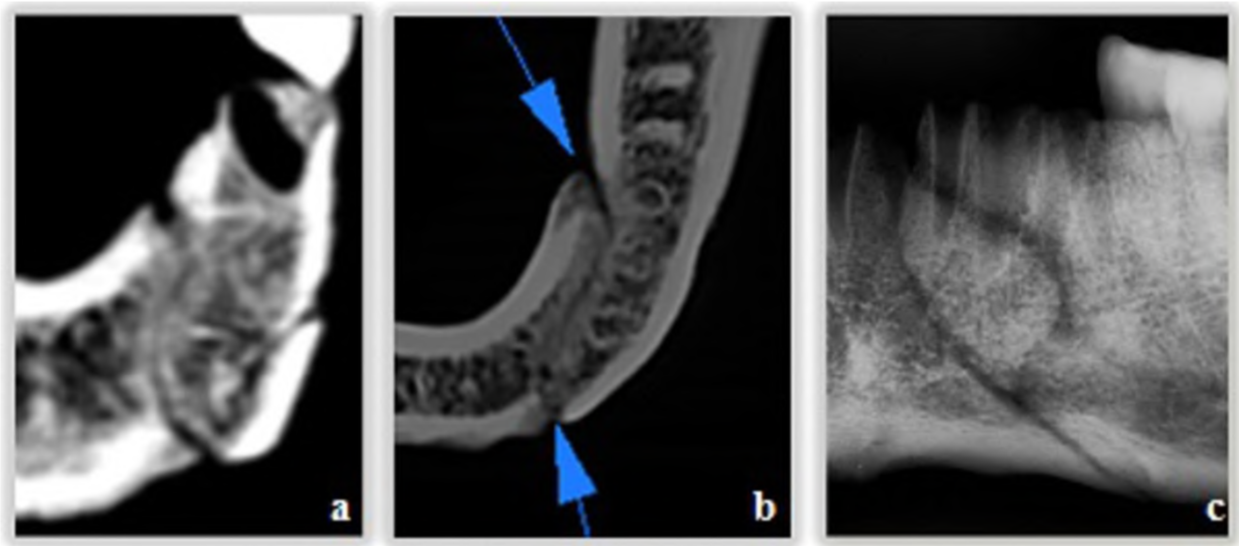

Fig. 10: the MSCT-image (a), the CBCT-image (b) and the DMFR with the 3,2 direct images magnification (c) of the mandible frontal area - false joint. The fracture line was spread from the level of the interdental alveolar septum, between absent teeth 3.1 and 3.2, through the tooth 3.1 alveolar socket, to the bottom of the mandible body at the level of the 3.6 tooth. There are fragments of periosteal layers on the bone vestibular surface at this level

Conclusion

The obtained data during the comparative analysis proves the necessity of using modern X-ray techniques with a wide range of the image processing capabilities to detect various types of the bone fractures in anthropological finds. CBCT-images are comparable with MSCT and it could be recommended as a specific X-ray method of the bone structure posttraumatic intravital and postmortem changes visualization, which size is even less than 1 - 2 mm.

Personal information

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