The capabilities of cone-beam computed tomography application in assessment of knee joint pathological changes

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Aims and objectives

Injuries and diseases of musculoskeletal system occupy the 4th place in the overall structure of morbidity in the world. They are located on the 2nd place among all the causes of temporary disability [1]. To characterize a bone structure or to detect its changes the diagnosis algorithm is limited mostly by a standard radiography, as a technique of the «first step» in such cases. Along with this the main trend in the development of modern radiology in osteology is a new class of a contemporary digital technologies elaboration (equipment and techniques) for musculoskeletal system researches with low radiation dose and bone structure detailed mapping. There are also several reasons which conditioning the requirement of specialized visualization techniques for bones and joints of upper and lower limb studies. The optimization of spatial resolution and signal / noise ratio, improved tissue contrast, reducing the number of artifacts from metal, and functional information obtaining (studies of a lower limb under load are of particular relevance) are among them [2, 5, 6-8].

For potential clinical use cone-beam computed tomography (CBCT) was first proposed in 1982 in Mayo Clinic Biodinamics Reserch Laboratory (USA). Application capabilities of cone-beam computed unit, which was intended for the maxillofacial region researches were presented by P. Mozzo et al. for the first time in 1998. However CBCT became widely adopted in diagnosis of maxillofacial region in 2001 only. X-ray electro-optical transducer and circular detector were used in first cone-beam computed scanners. X-ray beam was spread in the form of a cone and that was behind the name of the technique. However, there is no entire coincidence in terminology till now. It could be termed variously, for example, «digital volume tomography». 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 the gantry around the examined area is resulted in a primary three-dimensional image that is ready for further processing (fig. 1). CB-system allows avoiding a loss of graphic information, which is an important factor when studying the bone structure. Despite the obvious advantages, CBCT still does not have a wide application in everyday clinical practice for the knee joint researches, the obtained information about it among the available publications is scanty, that`s why in the framework of our research CBCT capabilities in assessment of knee joint pathological changes have been analyzed [3, 4, 6].

Images for this section:

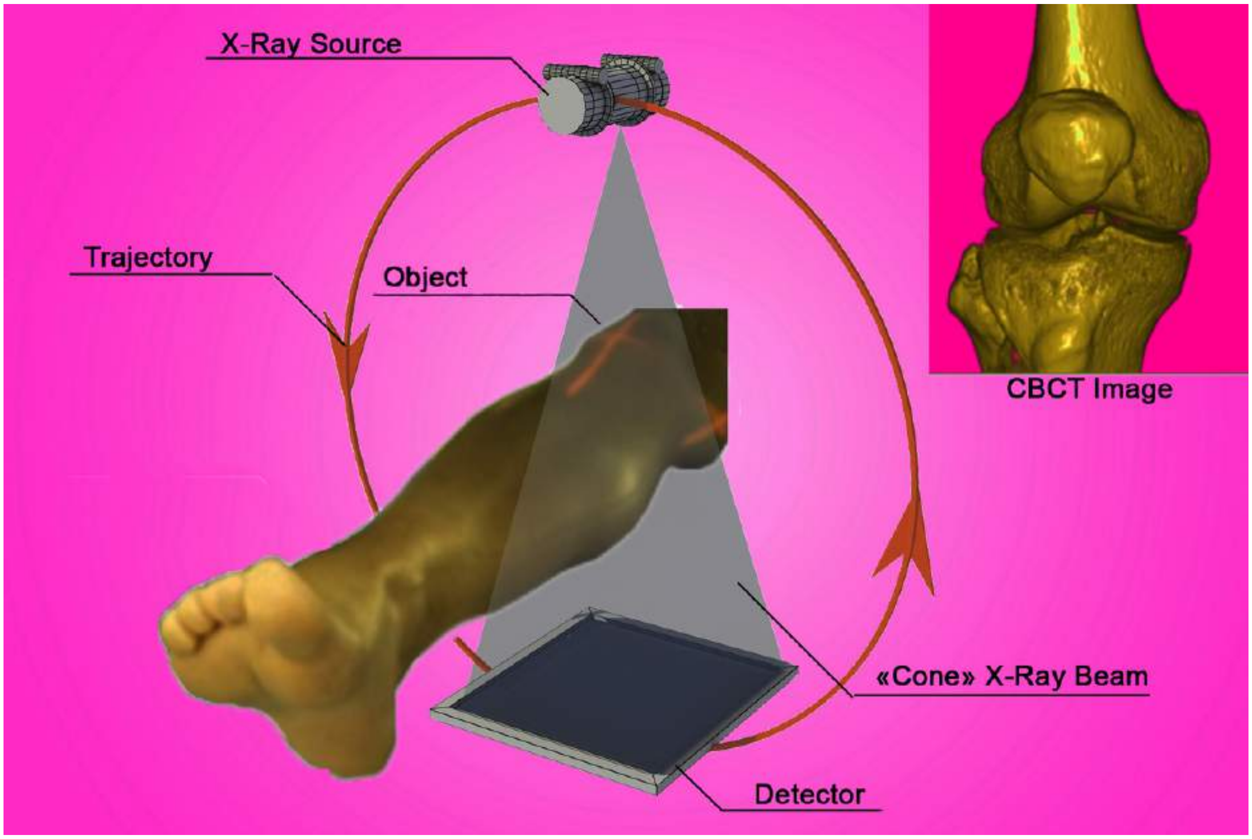

Fig. 1: the principle of CBCT-images obtaining

Methods and materials

In total, 30 patients, among them 8 men and 2 women, at the age from 14 to 46 years old with posttraumatic changes (n = 14) and some kinds of diseases (n = 16) of knee joint were examined on modern specialized CBCT-scanner - NewTom 5G (QR S.r.l., Italy), completed with tomographic table (fig. 2). The CBCT-methodology (the individual scanning settings) of the knee joint study has been elaborated for the study unification: the most comfortable positioning of the patient with special nonopaque tools, technical parameters and modes (fig. 3).

The CBCT evidence were compared with the data of magnetic resonance tomography (MRI) which has been performed on Centauri MPF 3000 (XinAO MDT, China), digital microfocus radiography (DMFR) with direct multiple images magnification (#3), which has been carried out on X-ray unit Pardus (Russia) and standard radiography (SR) - on X-ray unit KRD-SM 50/125-1 (Spektrup, Italy, Japan, France) - of the knee joints in 40 % (n = 12), 50 % (n = 15) and 50 % (n = 15) of the cases respectively. The CBCT data were correlated also with the findings of multislice computed tomography (MSCT), which have been conducted on Brilliance 64 (Philips, Holland), to 30 patients with the similar pathology (fig. 4).

Images for this section:

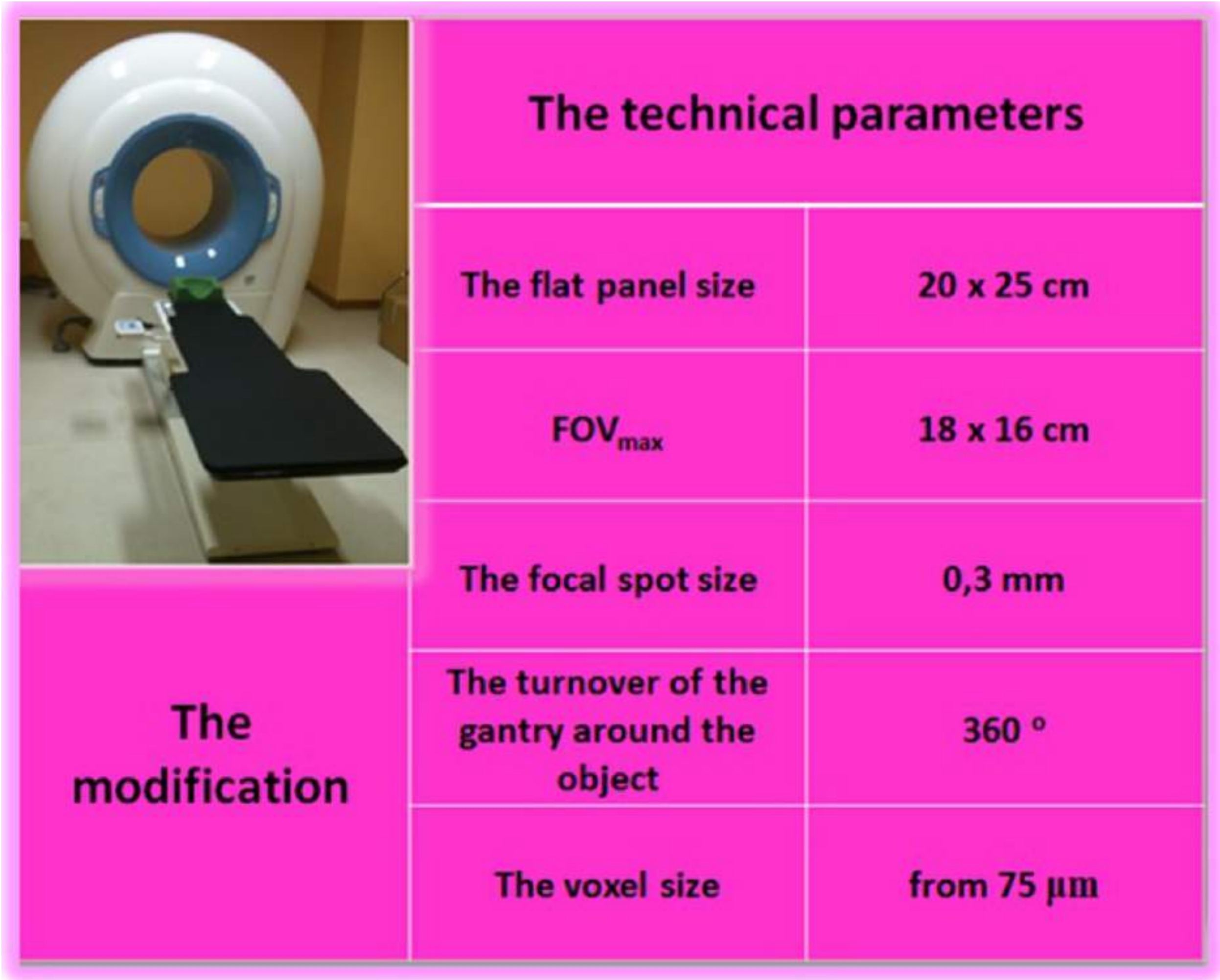

Fig. 2: the modification and the technical parameters of the CBCT unit

Scan parameters of the knee joint

Scan mode	Patient Scan
Scan type	Regular scan or High resolution
FOV	18 x 16 cm or 12 x 8 cm
Scan time	24 s or 36 s
Exposure time	6,6 – 7,3 s
X-ray tube voltage	110 kV
Current	7,6 mA

Fig. 3: the methodology of the CBCT knee joint study

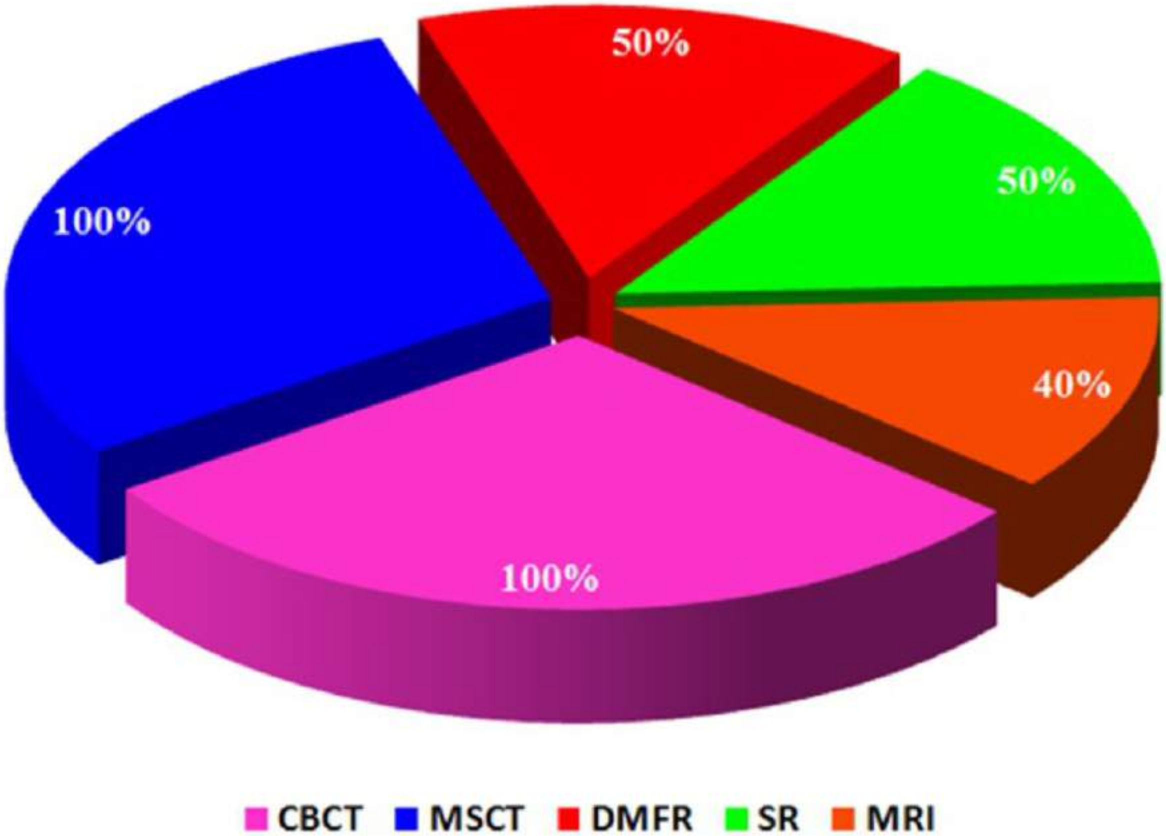

Fig. 4: the CBCT examinations data was conducted with the results of MSCT, MRI, DMFR and SR

Results

The received CBCT-images of the knee joints were characterized by the detailed mapping of the bone structure with the accurate differentiation and direction of bone trabeculae. It has become possible to trace its orientation (fig. 5). During the comparative analysis it has been found that visualization of the bone structure on the CBCT-images was comparable or even exceeded MSCT and DMFR with direct multiple images magnification (#3), but it was not defined on SR. In addition, small bone fragments and areas of pathological alteration of bone tissue (even under 1 mm) were observed reliably on the CBCT-tomograms (fig. 6). The similar changes were visualized on MSCT, but were not detected on DMFR and on SR.

The 14 years old patient has been applied to the hospital with the suspected knee joint injury. To exclude any pathological changes of the bone structure CBCT-examination has been performed. During processing of the derived images we were managed not only to characterize the articular surfaces and the underlying bone structure, but to assess the bone growth plates condition also (fig. 7).

When scanning the patients with metal constructions or high density materials, our attention was attracted also by the lack of significant artifacts from it on CBCT-images as distinct from MSCT (fig. 8).

CBCT-images of the knee joints were distinguished by high spatial resolution, optimal signal-to-noise ratio, uniform accuracy and dynamic range grayscale, which allowed estimating not only of bone structure, but dense soft tissue formations as well: muscles, ligaments and tendons (fig. 9). The obtained information during CBCT-examinations about soft tissues injuries has been confirmed by MRI (n = 12).

Images for this section:

Fig. 5: the CBCT-images (axial - a, coronal - b and sagittal - c) of the right knee joint with the detailed mapping of the bone structure

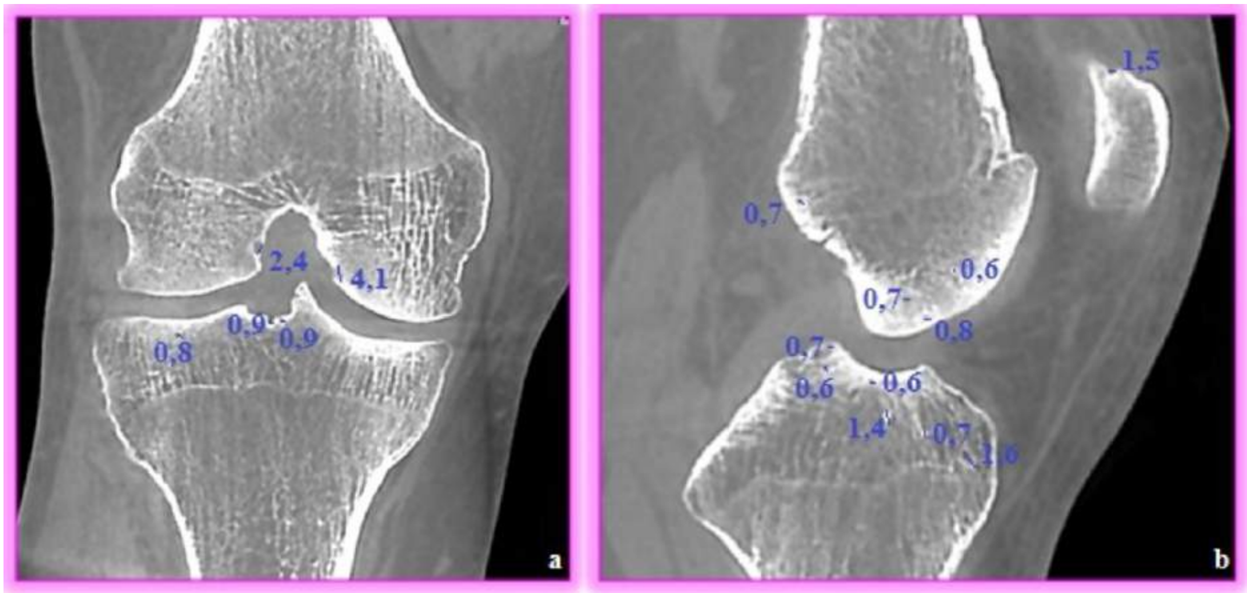

Fig. 6: the CBCT-images of the left knee joint with the accurate differentiation of the cystic and osteosclerosis lesions even under 1 mm

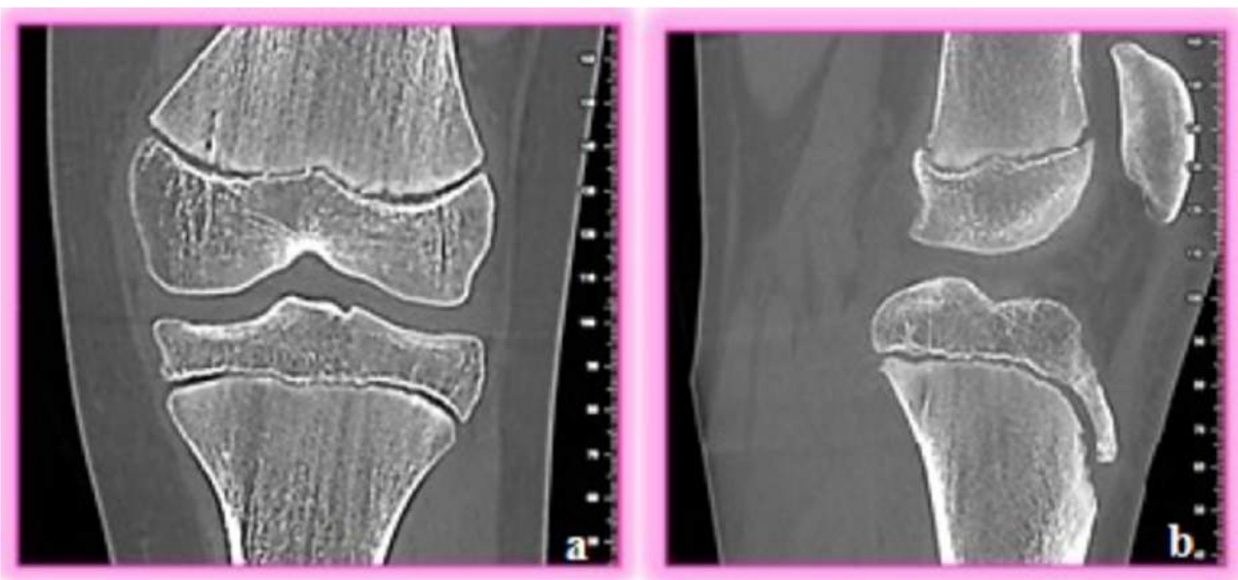

Fig. 7: the CBCT-images of the left knee without signs of traumatic and destructive changes of the bone structure on the scanning level

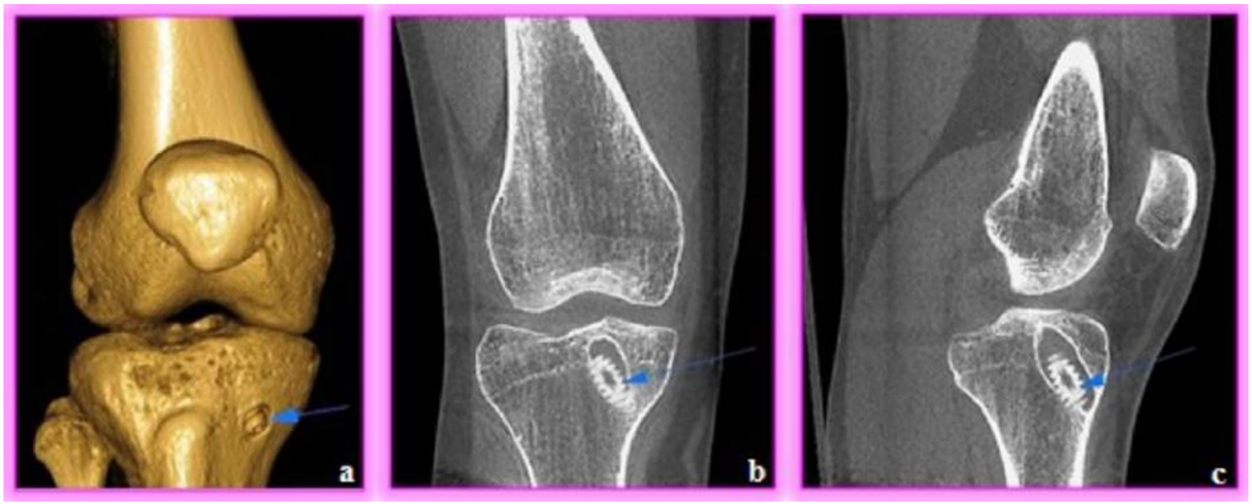

Fig. 8: the CBCT-images of the right knee joint. There is no significant artifacts from the external screw (blue arrows)

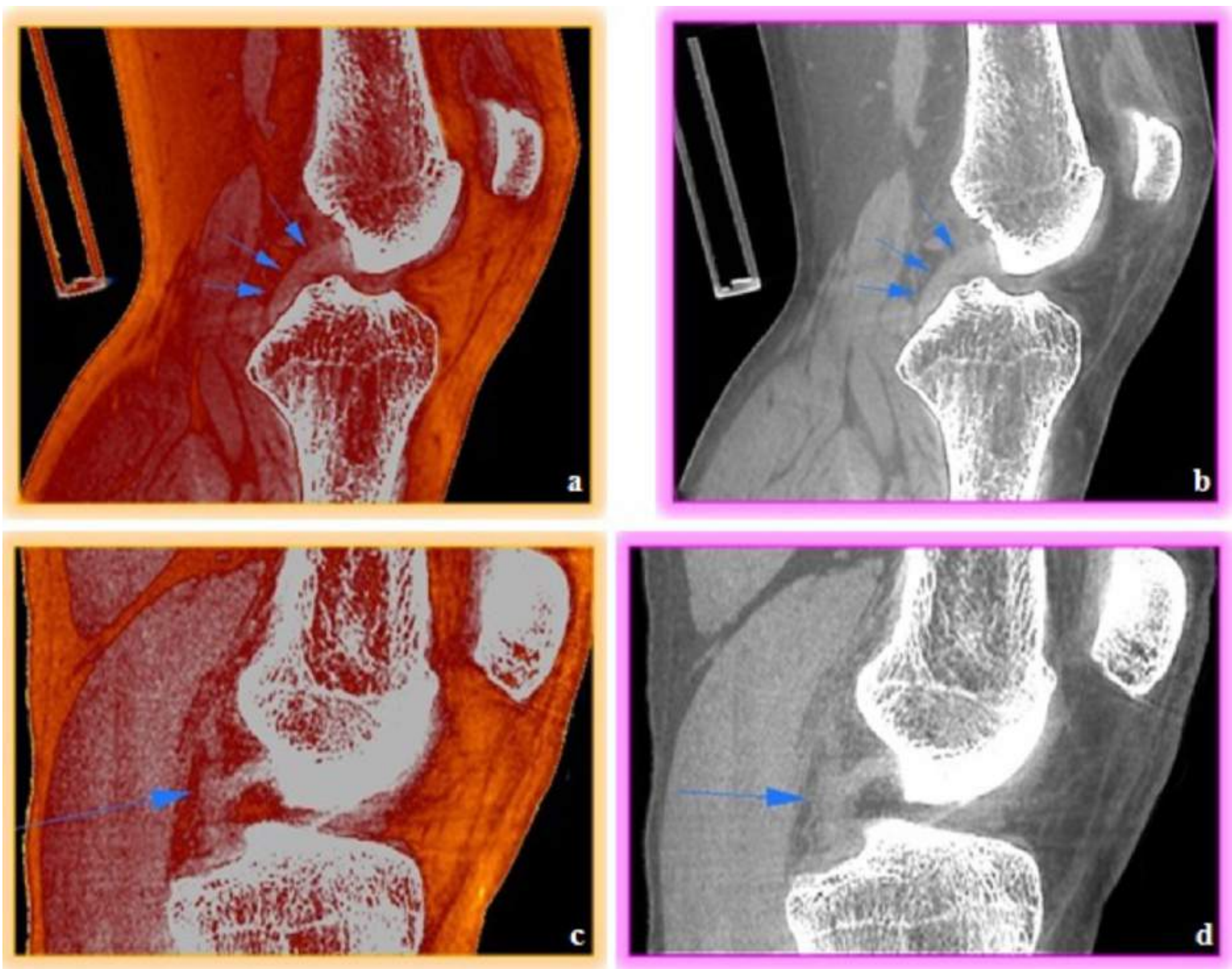

Fig. 9: the CBCT-images: of the right knee joint with without signs of posterior cruciate ligament pathological changes (blue arrows) - a, b; of the right knee joint with the

signs of posterior cruciate ligament partial rupture in the form of its focal thickening and pronounced bend (blue arrow) - c, d

Conclusion

During the detailed analysis of the knee joints CBCT-images the following capabilities of the technique were identified:

- CBCT could be applied as a priority method when evaluating small (less than 1 mm) areas of bone tissue pathological rearranging and posttraumatic changes, where summational effects pronounced mostly on SR;

- CBCT allows assessing a state of dense soft tissue structures;

- CBCT-images stand out with the lack of significant artifacts from high density materials. It does not reduce the quality of CBCT-tomograms and do not complicate the study results analysis during the treatment results control;

- high quality of CBCT-images with relatively low radiation dose.

Taking into consideration all the significant advantages CBCT could be recommended as a priority method of the first stage for some kinds of knee joint injuries and diseases diagnostics and dynamic researches, replacing gradually SR. It is necessary to revise an examination algorithm for such patients.

Personal information

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