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Tomosynthesis for diagnosis of musculoskeletal injuries and diseases: a systematic review

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Digital tomosynthesis is a radiological method having an intermediate position between x-ray and computed tomography (CT). Benefits with the imaging technology include improved image quality, post-processing (reconstructed to 1 mm thick slices), minimal tissue overlap in the projection image and a lower X-ray dose as compared to CT. Tomosynthesis is most commonly used in breast, chest (pulmonary tuberculosis), musculoskeletal and intraoral screening examinations. There is disagreement among professionals on feasibility and clinical effectiveness of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases. Our goal was to summarize evidence relating to efficacy and feasibility of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases. Russian and foreign literature was reviewed based on methodological principles of the PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions. The review included 34 articles in English and in Russian (referenced 16 to 49) describing an original study with focus on phantom, diagnostic, clinical studies. We considered articles which investigated use of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases including rheumatoid arthritis affecting the hands and feet, specific and nonspecific spine lesions and injuries, nonspecific lesions and injuries to the joints; subtle fractures and dislocations. With the advantages of tomosynthesis in clinical practice, the imaging modality can be recommended for the diagnosis of the above conditions.
Keywords: tomosynthesis, musculoskeletal system, trauma, joint, spine, bone tissue, bone, arthritis

INTRODUCTION

Digital tomosynthesis (a combination of two Greek words “tomos” – a section, slice or a cutting – and “synthesis” – a process, resulting in formation of something new) is a radiological method having an intermediate position between x-ray and computed tomography (CT). Benefits with the imaging technology include improved image quality, post-processing (reconstructed to 1 mm thick slices), minimal superposition (e.g., overlay) problems in the projection image and a lower X-ray dose as compared to CT [1, 2]. With reconstruction algorithms, tomosynthesis is most commonly used in breast, chest (pulmonary tuberculosis), musculoskeletal and intraoral screening examinations. Digital breast tomosynthesis can be used as an effective diagnostic tool to evaluate non-palpable breast masses and specific areas of abnormality. Over recent years, there have been a significant increase in publications reporting the use of tomosynthesis for screening musculoskeletal system. Tomosynthesis is employed for postoperative monitoring of the healing process of long bone and olecranon fractures, identification of delayed union and severe complications (refractures) [3, 4, 5, 6]. The clinical use of digital tomosynthesis in the depiction of labral and chondral pathology in the setting of postoperative femoroacetabular impingement of the hip following intraarticular administration of contrast has been demonstrated [7]. Tomosynthesis can be used to confirm the diagnosis of a suspected scaphoid fracture excluding the need in other imaging modalities [8]. Tomosynthesis plays a role in the early diagnosis of sacroiliitis in adults [9], different bone and joint diseases and injuries in children [10, 11]. Tomosynthesis was shown to have a sensitivity of 54.0 % and a specificity of 80.0 % in traumatic injuries to the spine while standard radiography had a sensitivity of 25.0 % and a specificity of 67.0 %. Tomosynthesis generates nearly identical resolution images as computed tomography (CT) scans, and the radiation dose with digital tomosynthesis is less compared to that with CT (1.2 mGy and 12 mGy, respectively) [12]. Tomosynthesis is good at demonstrating subtle fractures and at imaging metallic implants that would be difficult to image with CT with better noise properties [13]. Some data do not support the usefulness of digital tomosynthesis in the quantification of bone erosion in gout [14]. There is disagreement among professionals on feasibility and clinical effectiveness of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases.This review

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aims at analyzing tomosynthesis in clinical practice and providing an overview of published studies on clinical experience with the imaging modality. Our goal was to summarize evidence relating to efficacy and feasibility of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases.

MATERIAL AND METHODS

The study design is a systematic review of Russian and foreign literature based on methodological principles of the PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions [15]. The original literature search was conducted on key resources including Scientific Electronic Library (www.elibrary.ru) and the National Library of Medicine (www.pubmed.org). Literature searches included both Russian and English studies. The search strategy was comprised of both controlled vocabulary, such as the National Library of Medicine's MeSH (Medical Subject Headings), and keywords: tomosynthesis, musculoskeletal, bone, joint, spine, arthritis (and same in the Russian language). The search strategy is presented in Figure 1.

Inclusion criteria were as follows: (1) research findings related to the topic of systematic review, (2) original research (phantom, diagnostic, clinical), (3) publication in a peer reviewed journal, (4) available objective data on methods and efficacy of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases. Then the following data were retrieved from the articles: author(s)'s name, year of publication, country of origin; objective; study design; statistical hypothesis; nosology, localization; description of the method, application, diagnostic value; efficacy; results; the data summarized and reviewed. The review is relevant as of 01.08.2019.

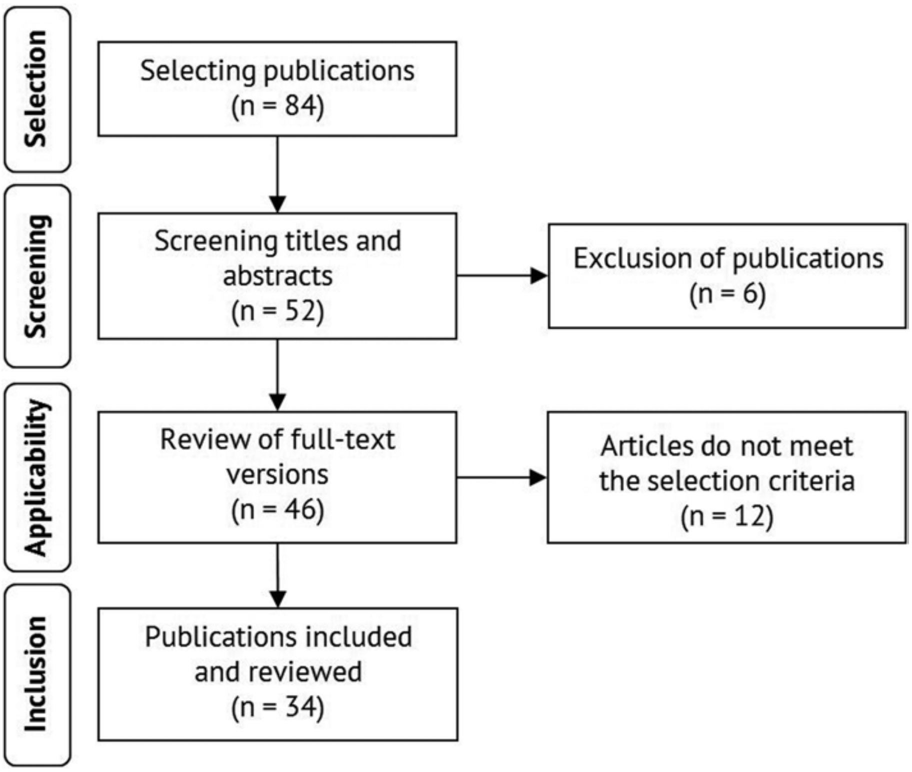

Fig. 1 Strategy for selecting publications for systematic review

RESULTS AND DISCUSSION

The review included 34 articles in English and in Russia (referenced numbers 16 through 49). We identified four major trends in the use of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases: (1) rheumatoid arthritis affecting the hands and feet, (2) specific and nonspecific spine lesions and injuries, (3) nonspecific lesions and injuries to the joints, (4) subtle fractures and dislocations.

1. Rheumatoid arthritis affecting the hands and feet

Tomosynthesis is a powerful technique for detecting disease progression in rheumatoid arthritis. Several studies compared tomosynthesis with radiography for the detection of bone erosions in patients with established rheumatoid arthritis with CT or MRI used as a reference standard. The principles of the Sharp–van der Heijde scoring method were applied for the assessment of images that were read by two or three independent readers. The data are presented in Table 1. The positive predictive value was 77.0 % for radiography and 76.0 % for tomosynthesis; the negative predictive value was 71.0 % for radiography and 80.0 % for tomosynthesis [16].

All studies indicated to the overall sensitivity, specificity, and accuracy of radiography being significantly lower than those with tomosynthesis and CT or MRI. The false-positive findings with tomosynthesis may be explained by the fact that on thin slices, the subchondral bone plate might be, in some instances, barely visible and that the radiologist might make the diagnosis of bone erosion in interphalangeal and metacarpophalangeal joints, in particular. The false-positive erosion score was similar for tomosynthesis and radiography [16, 17]. False-negative erosion score was associated with interpretation of metacarpal joints [18]. Digital tomosynthesis provided diagnostic information superior to that of radiography in patients with rheumatoid arthritis, and postoperative evaluation of wrist fractures being nearly identical to CT and MRI. The mean Sharp–van der Heijde score was significantly lower for radiography as compared to tomosynthesis or MRI [16, 17]; and significantly lower for tomosynthesis as compared to CT [17]. Tomosynthesis and CT have been shown to be comparators in detecting bone erosion in patients with established rheumatoid arthritis and both modalities are superior to conventional radiography of hands and feet.

The mean total dose per patient is minimum with radiography and maximum with CT. Tomosynthesis insignificantly increases radiation dose and significantly improves diagnostic quality approximating to CT and MRI. Radiology decision making in diagnostic imaging of erosion in the joints features higher level of consensus with the use of tomosynthesis and MRI (Cohen kappa of 0.65–1.00 and 0.680–1.00, respectively) and lower consensus with conventional radiography (Cohen kappa of 0.22–0.56). MRI can directly visualize and assess detect synovitis and bone marrow edema, however, rheumatoid arthritis can be difficult to diagnose with the modality due to costs and technical challenge [18]. No comparative chronometry of investigations has been performed. Subjectively, the time needed for interpretation of CT scan or MRI image are nearly identical for tomosynthesis and CT or MRI, and radiological interpretation requires less time [16, 18]. Expertise of a reader interpreting tomosynthesis has no role for cyst detection as opposed to osteophyte detection [19]. A phantom research performed in 2003 demonstrated reliable measurements of the joint space width using tomosynthesis images of the hand. Image processing with the choice of filters and reconstructions has been investigated in phantom series with no clinical application in arthritic cases [20, 21].

Tomosynthesis is a promising imaging modality for the detection of bone erosions in rheumatoid arthritis and can be used to assess the progression of disease and the efficacy of treatment by antirheumatic drugs [17]. The impact of tomosynthesis as a follow-up technique for patients with established rheumatoid arthritis should be evaluated in a large clinical study. Further study is necessary to evaluate the use of tomosynthesis for the small joints of the hand and foot and to compare this technique to ultrasonography [16, 18]. Conventional radiography is to be the preferred modality before such clinical findings become available [16]. The effective doses administered with tomosynthesis of the hand are exceedingly low. Image quality with scan settings 50 kV and 40 mA was found to be significantly identical to that with exposures 60 kV and 80 mA [22]. The use of tomosynthesis has shown a high diagnostic value in the detection and monitoring progression of rheumatoid arthritis being associated with a fairly small increase in radiation dose compared with radiography. Clinical relevance requires further investigations.

Table 1

Diagnostic performance of tomosynthesis and radiography of hands and feet in patients with rheumatoid arthritis

	Radiography	Tomosynthesis	Radiography	Tomosynthesis	Radiography	Tomosynthesis
Author	Simoni P. et al., 2015		Canella C. et al., 2011		Aoki T. et al., 2014*	
Number of patients	18		30		20	
Sensitivity, %	66.0	80.0	53.9	77.6	68.1	94.8
Specificity, %	81.0	75.0	92.0	89.9	97.5	97.8
Accuracy, %	74.0	78.0	70.9	83.1	86.7	96.7
Mean Sharp–van der Heijde score	16.4 ± 18.0	18.8 ± 16.8	86.7	17.4 ± 16.2	–	–
Dose, mGy	0.42	0.56	0.13	0.25	0.070	0.185

* – MRI as the gold standard

2. Specific and nonspecific spine lesions and injuries

Tomosynthesis is common in the diagnosis of spine injuries and diseases. An experimental study demonstrated the ability to measure topography of the entire vertebral endplate surface using clinical imaging modalities [23]. Tomosynthesis was shown to facilitate evaluation of osteoporotic spinal compression fractures. Significantly more vertebrae and significantly more fractures were seen with the modality at the mean effective dose of 0.11 mSv. Observer agreement for thoracic spine tomosynthesis was substantial (mean $\kappa = 0.73$) [24].

Surmounting summation effects of overlying shadows allow adequate visualization of the area C1–C2, small erosions and cones in the thoracic spine, spondylolysis of the vertebral arches in the lumbosacral spine. Osteochondropathies of the thoracic spine, spondylolysis and spondylolisthesis in the lumbar spine were demonstrated with the use of digital tomosynthesis with superb anatomic detail. Neural arches can be visualized bilaterally from a single pass of the x-ray tube at a low exposure dose avoiding additional examinations [25]. Tomosynthesis could depict more subtle damage of spinal vertebrea in patients with ankylosing spondylitis detecting small erosions, sclerosis of facet joints and being more sensitive for the identification of ankylosis characteristics. A cross-sectional diagnostic study compared digital tomosynthesis with radiography for the assessment of spinal damage using Stoke Ankylosing Spondylitis Spinal Score (mSASSS) [26]. The results of the study showed low homogeneity and relatively weak statistical analysis. The value of digital tomosynthesis applied in diagnosing spinal tuberculosis was explored on a higher quality level.

In 2015-2016, Iu.A.Tsybulskaia hypothesized that technical characteristics of tomosynthesis has the potential for better visualization of disk destruction, sequesters of the spine in patients with tuberculous spondylitis including certain vertebral sites (spinous procesess, transverse process, cervical vertebral bodies) where it is difficult to appreciate bony changes on conventional X-ray. The hypothesis was confirmed in a complex study of diagnostic imaging of spinal tuberculosis. Imaging modalities are used to identify location, the extent of bony destruction and paravertebral abscess in patients with tuberculous spondylitis. The possibilities with conventional radiography for detection of tuberculous spondylitis are limited due to difficulties in visualization of small sequestrum and sometimes technical challenges (summation of bowel loops). CT can help to address the problems and tomosynthesis is a serious alternative with lower exposure dose and cost of investigation [1, 27, 28].

Conventional radiography, CT and tomosynthesis were compared in a diagnostic study (Table 2). Three types of vertebral body destruction identified included subchondral, focal and combined patterns. The most indicative signs of spinal tuberculosis seen with tomosynthesis were combined vertebral body destruction ($p < 0.04$), severe anterior wedging of the vertebral body ($p = 0,05$), uncommon involvement of the transverse process and the spinous process ($p = 0.05$). The reported effective dose with tomosynthesis was about 2 to 12 times that of standard radiography but about 2 to 11 times lower than that for CT depending on the body site examined [1, 27, 28]. With CT used as the reference, the diagnostic accuracy of tomosynthesis was substantially superior compared with that of conventional radiography. The causes of false-positive and false-negative results were identified. False-positive findings were shown to be associated with tuberculous abscess localizing in the sacrum at the SIII–SIV level and poor visualization with interfered bowel loops and diffuse thickening of iliopsoas muscle. False-negative findings were seen in smaller (up to 2-3 cm) paravertebral abscesses over the cervical spine and in abscesses localizing in the thoracic spine [1, 27, 28].

Table 2

Diagnostic performance of different imaging modalities in detection of tuberculous spondylitis and paravertebral abscess [1, 27]

Description, %	Radiography		CT		Tomosynthesis	
Sensitivity, %	82.2	79.6	89.7	94.1	84.6	86.7
Specificity, %	76.1	82.5	84.0	89.1	79.3	84.0
Prognostic value of positive result, %	69.1	–	76.5	–	78.6	–
Prognostic value of negative result, %	87.1	–	91.3	–	85.2	–
Accuracy, %	78.4	89.7	85.0	91.3	81.8	85.5

Tomosynthesis would be inferior to CT in visualization of soft tissues, and 10 % of tuberculous involvement can be detected with CT scans but can be seen neither on radiograph nor tomosynthesis scan. For this, the authors suggested using combined approach with lower exposure dose employing tomosynthesis in detection of bone destruction and ultrasonography in the diagnosis of paravertebral abscesses. No statistically significant differences in evaluation of osteoporosis grading were found between CT, conventional radiography and tomosynthesis [1, 27, 28]. Similar results were reported in 2016 by D. Jiao et al. who retrospectively analyzed images of digital radiology and tomosynthesis in 55 patients with spinal tuberculosis, and tomosynthesis was more efficacious in detecting destruction, sequestration and paravertebral abscesses. The two modalities showed no differences in accuracy detecting changes in the intervertebral space [29].

Therefore, tomosynthesis has been shown to be superior to conventional radiography in visualization of sequestration and bone lesions in patients with spinal tuberculosis. Data on accuracy of detecting paravertebral abscesses are dubious. Tomosynthesis appears to have less efficacious diagnostic value than CT being more safe and less costly [1, 27–29]. Tomosynthesis can be a method of choice in the diagnosis and monitoring progression of spinal tuberculosis. Its role in screening osteoporotic compression fractures of the spine requires further investigation.

3. Nonspecific lesions and injuries to the joints

Tomosynthesis is applied for the diagnosis and monitoring of the course of knee osteoarthritis, injuries and postraumatic instability of the foot joints. Tomosynthesis has a significantly higher sensitivity for osteophyte detection in knee osteoarthritis than radiography (94.0–100.0 % and 71.0–75.0 %, respectively) with specificity being similar for both modalities. Diagnostic accuracy for tomosynthesis is higher than that for radiography (93.0–100.0 % vs 83.0–93.0 %). Tomosynthesis allows more accurate detection of osteophytes scored as grade 1 according to the Osteoarthritis Research Society International grading system that are more likely to be missed at radiography. Such meticulousness can provide better characterization of pain, however, there is no solid evidence for that. There is no significant difference between tomosynthesis and radiography with regard to their diagnostic performance [19].

Automated method using tomosynthesis images was offered for the assessment of knee joint space narrowing in a standing and weight-bearing upright position with experimental validation using a knee phantom and priliminary clinical evaluation [30]. The results suggested that the method might be beneficial for diagnosing and monitoring disease progression or treatment of osteoarthritis (at early stages, in particular) but required comprehensive study.

Diseases and injuries to subtalar, talocalcaneonavicular joints, posttraumatic instability of the foot joints are difficult to diagnose. The role of radiography is insignificant, and CT allows static examination only. Tomosynthesis facilitates anatomical structures visualization with functional tests or weight-bearing and represents an important alternative to CT in foot evaluation. Tomosynthesis also provides specific quantifications in the subtalar range of motion measuring 15 degrees in the normal foot [31]. Tomosynthesis can be used for imaging joints under weight-bearing and functional tests that is crucial for traumatology and orthopaedics [30, 31] providing better quality of diagnostic images as compared to conventional radiology although no comparative analysis has been performed. Tomosynthesis can be portrayed as a more accurate diagnostic tool for osteochondropathy of the femoral head/Legg-Calve-Perthes disease (Table 3).

Table 3

Comparative radiological semiotics of Legg-Calve-Perthes disease with standard digital radiography and tomosynthesis [25]

Stage of the disease	Standard digital radiography	Tomosynthesis
I	No pathological changes revealed in the bone tissue	Minimal solidification of bone structure at the involved side (100.0 %); cyst-like restructuring of bone-trabecular structure of the subchondral bone of the femoral head (75.0 %); flattening of the medial epiphyseal pole (17.0 %)
II	Impaction of the femoral head and widening of the articular space (80.0 %); absence of subchondral translucence (60.0 %); solidified structure of the femoral head (40.0 %)	Intra-articular effusion (100.0 %); incongruent rim of the femoral head and the acetabulum (80.0 %); areas of osteonecrosis (60.0 %)
III	Femoral head homogeneously shadowed with bone pattern being absent (100.0 %); short femoral neck (60.0 %)	Intra-articular effusion (100.0 %); fragmentation of the femoral head (90.0 %); shortening and thickening of the femoral neck (70.0 %)
IV–V	Lateral subluxation of the femoral head (63.6 %)	Lateral subluxation of the femoral head (81.8 %)
	Rate of detection of other manifestation is similar	

The accuracy, sensitivity and specificity of standard radiography have been reported to be 73.3 %, 70.3 % and 71.2 % in patients with suspected osteochondropathy of the femoral head, and those of tomosynthesis, 91.8 %, 92.4 % and 93.1 %, respectively [10, 32]. Tomosynthesis allows sharper structural visualization of the femoral head and evaluation of its anterior and posterior aspects [25]. Tomosynthesis appears to be superior to conventional radiography in accuracy, sensitivity and specificity and can be recommended as a method of choice for the diagnosis of osteochondropathy of the femoral head.

Total hip/knee replacement is an increasingly common surgical approach for the management of injuries and chronic conditions. Every patient undergoing a joint arthroplasty would incur routine lifetime follow-up that would involve diagnostic imaging. Phantom series report improved visualization as compared to standard radiography with fewer artifacts from metallic components of arthroplasty devices; exposure dose can be reduced by 20 % due to iterative reconstruction and reverse transform of the filtered data. Limitations with the method are associated with demineralization and osteolysis being better detected on anteroposterior view; lateral radiographic view provides sharper images [33–35].

Potential role of tomosynthesis is associated with globally increasing knee arthroplasties as well as revision surgeries. Bone defects developing around primary implants due to osteolysis result in instability creating considerable difficulties for revision surgery. Early and accurate detection of the defects is a primary clinical goal. Accuracy of conventional radiography is dubious in the scenario, CT and MRI can be problematic or targeted at detection of larger defects and preoperative planning, so screening and early detection of osteolysis and instability do not occur.

Minoda Y. et al. explored in vitro tomosynthesis for early detection of small areas of osteolysis and instability. Zirconia ceramic (n = 6) and cobalt-chrome alloy (n = 6) femoral components were used. Different bone defects and instability were simulated (linear defects of up to 2 mm, cysts of up to 0.7 cm^3). The efficacy of the detection of small bone defects between fluoroscopically guided plain radiography, CT, MRI, and tomosynthesis was compared in two experiments. Summarized data are presented in Table 4.

Early diagnosis of implant instability cannot be fully made with radiography. Noise also contributes to metal artifacts in CT. Therefore, it is difficult for radiologists to interpret CT images with metallic implants due to the artifacts problem. This situation hampers the diagnostic interpretability of the implants themselves, peri-implant bone loss and adjacent soft tissue itself. MR images can be practically useless for interpretation for a cobalt-chrome implants. However, due to the occurrence of metal artefacts or small condylar defects are concealed by implant, the diagnosis on radiographic and MR images remains challenging with many cases rendered uninterpretable. The low role of tomosynthesis is caused by the large atomic number of zirconium as compared to other materials the implants made of that have direct effect on the degree of x-ray beam attenuation. The detectability of tomosynthesis findings is largely dependent on the implant material. Tomosynthesis may also be invaluable as an alternative to other imaging modalities in detecting small defects.

Making decision for the timing of revision total joint arthroplasty remains questionable. With the progression of periprosthetic osteolysis, revision surgery has been shown to be costlier, technically more difficult, and associated with higher rates of complications. The potential benefits of using tomosynthesis for more accurate detection and monitoring of osteolysis can be used to increase diagnostic confidence and facilitate a reliable decision making. Moreover, when compared to CT, the advantages of tomosynthesis consist in a pronounced reduced radiation dose to patients by 94.4 %. In addition to tomosynthesis, the need of carrying out CT scans must be justified as indispensable for preoperative planning with the decision on revision procedure made [36–37].

Table 4

Diagnostic performance of different modalities in depicting early signs of osteolysis around femoral component [36, 37]

		Component material	
		Zirconia ceramic	cobalt-chrome alloy
Radiography	sensitivity, %	0	0
	specificity, %	0	0
Tomosynthesis	sensitivity, %	21.9	85.4**
	specificity, %	36.8	87.2**
CT	sensitivity, %	15.1	61.5
	specificity, %	33.0	64.1
MRI	sensitivity, %	84.4*	0
	specificity, %	86.6*	0

* – values for MRI being significantly higher than those for tomosynthesis; ** – values for tomosynthesis being significantly higher than those for CT.

The role of tomosynthesis has been demonstrated experimentally for screening of osteolysis and aseptic loosening of the knee prostheses made of cobalt-chrome alloys. However, it appears to be ineffective for zirconia implantation. These are preliminary findings and need firther investigations. Scietific substantiation of clinical aspects of tomosynthesis would be important for medical, social and economic implications of revision total joint arthroplasty.

4. Subtle fractures and dislocations

Diagnosis of injuries to the bones and joints that appear to be subtle with classical radiography can be improved with minimal tissue overlap provided by tomosynthesis to avoid CT scanning.

Comparative studies of digital tomosynthesis and computed tomography or classical radiography performed for hundreds of patients with injuires to the limbs, femoral neck, knee, glenohumeral and ankle joints, paranasal sinuses, orbital floor, mandibula, spine, clavicle, thorax, pelvis and sacrum, wrist (scaphoid), atlantoaxial joint were reported [24, 38–42]. Diagnostic performance of the modalities is presented in Table 5. There were no statistically significant differences in tomosynthesis and CT. Compared with conventional radiograpgy, tomosynthesis could significantly improve detection sensitivity, specificity and accuracy. Diagnostic accuracy in detection of hip injuries (suspected femoral neck fracture) was 90.0 % for radiography and 95.8 % for tomosynthesis in positive predictive value; 36.6 % and 76.0 % in negative predictive value, respectively [41]. Diagnostic accuracy in detection of wrist and hand injuries (suspected femoral neck fracture) was 94.0-97.0 % for radiography and 90.0-97.0 % for tomosynthesis in positive predictive value; 57.0–76.0 % and 90.0–93.0 % in negative predictive value, respectively [40].

Tomosynthesis provided diagnostic information superior to that of radiography in postoperative evaluation of wrist fractures with clear visualization of bone structure due to multiple images, thin slices and absence of summation. The superior performance of tomosynthesis compared with radiography was found in the evaluation of fracture healing and identification of risks factors for nonunion. [25]. Tomosynthesis was characterized by much lower radiation dose per patient with the mean 0.07 mGy measuring 1.5 % of that in CT [42]. The effective dose was reported to measure 0.36 mGy examining the hip joint (a suspected femoral neck fracture) [38].

The role of tomosynthesis was experimentally demonstrated in evaluation of the temporomandibular joint more than 25 years ago. The modality allowed better visualization of condylar process fractures verified arthroscopically but not detected by digital subtration radiography [43]. The studies have limitations and require further exploration. Tomosynthesis is also advantageous in a variety of clinical contexts, including orthopedic and emergency imaging. In emergency imaging, tomosynthesis radiography is useful for enabling easy and swift access to tomographic diagnostic imaging for detecting subtle fractrures and dislocations at a lower exposure dose compared with CT. Tomosynthesis can reduce demand in CT and MRI for the diagnosis of suspected femoral neck fractures by 51.0 % [38]. Possibilities with tomosynthesis in emergency imaging require further investigations.

Tomosynthesis showed the superior performance compared with conventional radiography in the effective follow-up of fracture healing including evaluation of dynamics in callosity to prevent nonunions. AUC (area under curve) was 0.84 for tomosynthesis and 0.76 for radiography with differences being statistically significant.

Table 5

Diagnostic performance of different imaging modalities in depicting subtle musculoskeletal injuries

		Authors			
		Xia W. et al., 2013	Tuerdi B. et al., 2015*	Al-Mokhtar N. et al., 2015	Ottenin MA et al., 2012
Radiography	sensitivity, %	–	73.5	–	61.0–80.0
	specificity, %	–	65.2	–	65.0–83.0
	accuracy, %	–	71.9	–	63.0–78.0
CT	sensitivity, %	84.62	–	–	77.0–87.0
	specificity, %	78.57	–	–	76.0–82.0
	accuracy, %	–	–	–	78.0–82.0
Tomosynthesis	sensitivity, %	91.67	93.9	67.0–100.0**	93.0–95.0
	specificity, %	84.62	82.6	100.0	86.0–95.0
	accuracy, %	–	91.7	–	90.0–95.0

* – significant differences; ** – depending on available physical examination findings.

The cortex was found to be less obsured by internal metal constructs in tomosynthesis than in classical radiography [44]. With reduced radiation dose, lower cost (compared to CT), greater significance and relatively easy interpretation (compared to radiography) tomosynthesis appears to be an effective modality for evaluation of bone healing following osteosynthesis, bone plasty and total joint arthroplasty [44]. Nevertheless, the studies have serious limitations in evident inhomogeneity of samples; parameters of diagnostic performance and clinical aspects require further thorough studying.

Several original publications reported results of tomosynthesis in the diagnosis of musculoskeletal conditions that can be evaluated as preliminary findings showing potential applications that require larger scale exploration. Authors report on the use of tomosynthesis in the detection of avascular osteonecrosis of the knee joint (subchondral insufficiency fractures) [45]; measurements of bone mineral density [46, 47]. Tomosynthesis is a reliable tool for evaluating musculoskeletal conditions being superior to conventional radiology by diagnostic performance. One of the recent studies identified the prevalence and distribution of sesamoid bones and accessory ossicles of the foot using digital tomosynthesis [48, 49]. Characterization of sesamoid bones is important as an anatomical variation that can be helpful in interpretation of degenerative changes.

CONCLUSION

Currently, application of tomosynthesis in the diagnosis of musculoskeletal injuries and diseases is focused on rheumatoid arthritis affecting the hands and feet, specific and nonspecific spine lesions and injuries, nonspecific lesions and injuries to the joints, subtle fractures and dislocations. For majority of the cases, tomosynthesis is significantly superior to conventional radiography being close to CT in diagnostic performance providing reduced radiation dose, lower cost, easier accessibility and enhanced interpretation. Tomosynthesis can be used for imaging joints under weight-bearing and functional tests that is crucial for traumatology and orthopaedics. Tomosynthesis is a method of choice in rheumatoid arthritis, spinal tuberculosis, osteochondropathy of the femoral head, injuries to joints, hand and foot with limited access to CT/MRI. Evidence for significant efficacy of tomosynthesis in the diagnosis of musculoskeletal conditions is rather low. Primary data showing a potential role of the modality are available and larger scale studies are required. The use of tomosynthesis for the detection of chronic processes (degenerative, rheumatoid) in major joints, long bone healing requires clinical approval. The role and possibilities with tomosynthesis are to be accurately identified in emergency settings with focus on a fracture pattern. Based on tomosynthesis there are potentials for developing screening of aseptic loosening of total joint arthroplasty (with limitation to zirconia implants), monitoring of drug therapy for osteoarthritis, rheumatoid arthritis, and screening of reparative bone regeneration.

The authors declare that there is no conflict of interest.

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