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APPLICATION OF THE CONE BEAM COMPUTED TOMOGRAPHY (CBCT) MODALITY WITH WEIGHT BEARING TECHNIQUE TO IDENTIFY OSTEOARTHRITIS (OA) IN THE KNEE JOINT

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ABSTRACT

Background : Osteoarthritis (OA) is a degenerative joint disease that causes inflammation of the cartilage due to the load that is often received by the joints. The knee joint is a part that is often affected by OA. Radiographic and CT examinations can be used to check for OA of the knee. Radiographic examination has the advantage of optimally displaying OA because the examination is carried out under weight bearing conditions, and CT is superior in displaying anatomical details due to cross sectional and 3D reconstruction. Technological developments present Cone Beam Computed Tomography (CBCT) weight bearings that combine the advantages of radiographic and CT examinations. The purpose of this study is to determine the role and benefits of CBCT weight bearing on knee joint image information in cases of OA. **Method :** This type of research is literature review research with a narrative review approach. The databases used in the review articles include Science Direct, ProQuest, PubMed, DOAJ, Google Scholar, Wiley Online Library, ISI Web of Knowledge, and the Oxford Journal. The articles that have been obtained will be processed in tabulated form for later extraction. **Result :** The results of this study indicate that weight bearing is able to assess degeneration causing internal rotation in the range of ± 2.8-3.1^{o}, lateral patellar shift up to ± 0.4 mm, joint space width (JSW) up to ± 0.5 mm, meniscal extrusion (ME) up to ± 10.2 mm. **Conclusion :** CBCT is used to obtain volumetric and cross sectional 3D knee images, in order to obtain images with high spatial resolution with low doses, detailed bone structure images, short scan times, visualization of narrowing and progression of OA in JSW clearly, visualization of OA in the menisci, as well as visualizing the complexity of the joint and soft tissue images so that OA is easily identified.

Keyword : Weight Bearing; Lower Extremity; Knee; Cone Beam

Introduction

The lower extremities are a series of bones in the lower part of the human body that function to support the body's weight when standing, walking, running, and jumping. Therefore, the lower extremities have a stronger shape than the upper extremities. Parts of the lower extremities include the upper and lower limbs which are composed of the tibia and fibula bones, as well as joint parts such as the knee joint (genu), ankle joint, and foot (pedis) (Marieb et al., 2012).

One of the abnormalities or pathologies that exist in the lower extremities is osteoarthritis (OA). OA is defined as a degenerative joint disease and is a type of arthritis that causes inflammation of the cartilage in the joints. The inflammation causes joint wear and tear and changes in bone structure. The causes of OA are ranging from age, genetics, and the burden that is often received by the joints. The joints in the lower extremities, especially the knee joints, are the most frequently affected parts of OA, because of their role in supporting the body's weight. As a result of OA can damage joints that have a role in supporting the weight of the human body (weight bearing joints) (Mann, 2012).

The modality that has become the gold standard for examining OA is radiographic examination. The price for this modality is quite affordable and with a low dose. Besides, this modality is easily available and has been the benchmark in the examination of OA in the joints for centuries. This modality is able to distinguish the density of tissues, organs, fluids, fat, air and the skeleton of the human body quite well. Pathologies such as OA can also be well assessed, along with the classification of OA in certain joints (Kapoor et al., 2015). Measurement of OA from radiographic examination is also well known as KL (Kellgren and Lawrence). These measurements can assess and measure the classification of OA in the joints, especially the knee joint by using OA grade two as a reference for the presence or absence of OA in the joints being examined. The KL method can also assess the presence or absence of osteophytes in the joints and the narrowing that occurs in the joint space (Doherty et al., 2016).

Other modalities such as CT (Computed Tomography) are an alternative in examining OA. CT is able to reconstruct the scanned images to display anatomical images from various fields such as axial, coronal, and sagittal as needed to assess OA. CT can provide images with complex density ranges, and provide more detailed soft tissue images. This makes CT quite superior in displaying bone images, especially the knee joint coupled with 3D reconstruction (Kapoor et al., 2015).

Examination with radiographs in which the patient is usually positioned standing can optimally display OA conditions (Frank et al., 2013), while the CT modality also has the advantage of non-superpositioned bone image results and can display anatomical details better, and allows 3D reconstruction of the patient. post-processing to optimally assess pathology (Romans, 2018) and cross-sectional reconstruction that can display images from the axial, coronal, and sagittal planes, thus making CT more flexible than radiographic examination (Kapoor et al., 2015).

CT knee can display OA condition and knee joint anatomical information, but with the patient's supine position, the OA is displayed less than optimally for examination (Romans, 2018). The supine position makes the knee joint in a relaxed state because it is not in a state of supporting the body's weight. This makes the distance between the bones at the knee joint look normal or close to normal, so that clinical features such as OA will look mild (Richter et al., 2020).

Conventional CT in the supine position has several shortcomings in the clinical evaluation of the knee joint. Some of the shortcomings of conventional CT are the lack of accuracy in assessing OA in the joints (Hirschmann et al., 2014), the complexity of the resulting data is limited so that clinical information is reduced (Malhotra et al., 2019), and the lack of accuracy in assessing bone alignment and joint space width (JSW) due to the supine position (Hirschmann et al., 2015).

The growing technology allows CT knee joint to be performed in an erect (standing position) with the term weight bearing which can assess the condition of the knee joint. The weight bearing condition puts pressure on the knee joint so that OA can be assessed optimally (Hirschmann et al., 2014), and can minimize rotation due to patient movement (Lintz et al., 2018). Cone beam computed tomography (CBCT) technology is a solution for the application of weight bearing conditions. CBCT with weight bearing is able to evaluate the condition of the knee joint better than conventional CT and with lower radiation (Richter et al., 2020).

Weight bearing with cone beam computed tomography (Weight Bearing CBCT) was introduced in 2012 for the examination of lower extremity joints as a new technology that allows 3D imaging with full weight bearing (standing position). 3D Imaging with Weight Bearing CBCT allows precise interpretation of data in 3D volume without the influence of projection or foot orientation due to standing position. Another advantage that is obtained is that the image shows the original condition of the anatomy of the lower extremities, especially the knee joint with various pressures received from the body. Therefore, if there is narrowing or OA in the knee joint, it can be known more optimally (Richter et al., 2020).

This study aims to determine the application and benefits of CBCT weight bearing on CT knee joint image information with clinical OA.

Method

This study uses a literature review method with a narrative review approach to collect, identify, evaluate and interpret the use of CBCT weight bearing in the knee joint, especially the joint area (knee, ankle, foot) with clinical osteoarthritis. The data collection period in this study starts from January to March 2021. The data sources in this study were obtained through Science Direct, ProQuest, PubMed, DOAJ, Google Scholar, Wiley Online Library, ISI Web of Knowledge, and Oxford Journal with search engines. Google is used to find relevant articles. Searching for relevant articles on the journal site immediately starts by typing the sentence cone beam CT knee weight bearing, or cone beam CT lower extremity weight bearing in order to get article results that are specific to the author's topic. The articles obtained will be selected based on inclusion and exclusion criteria.

1. Inclusion Criteria
   a. Research articles published in 2011-2020.
   b. Articles published in international journals.
   c. Articles with experimental and/or non-experimental research results.
   d. An article that discusses the use of CBCT with weight bearing method in knee joint with indication of OA.
2. Exclusion Criteria
   a. Articles displayed are not full text.
   b. Articles that do not include a DOI.
   c. Articles that are not in English.

The results of the literature review will be explained based on the article data collected from the inclusion criteria, then a synthesis is carried out by extracting data from the articles that have been found. The collection of data extraction results that have been put together to obtain new results is then referred to as the synthesis of results which aims to answer the formulation of the problem. The following is a synthesis of the results obtained :

1. Application of clinical OA weight bearing knee joint CBCT examination which discusses when CBCT is needed in OA knee examination based on the type and grade of OA.
2. The benefits of CBCT weight bearing on knee joint CT image information with clinical OA in visualizing the anatomy of the knee joint well and the pathology of OA clearly.

Result and Discussion

The collected articles amounted to 9 (nine) articles after going through the selection process and will be arranged in the form of a table for extraction, so that the findings of each article and in-depth studies are obtained to answer the problems in the research. The following is data from the nine articles :

Table 1 Research article data

Num.	Author, Year of publication, Title of article
1.	Berger et al., (2016), Marker-Free Motion Correction in Weight Bearing Cone Beam CT of the Knee Joint
2.	Qian et al., (2017), Modeling and Evaluation of a High-Resolution CMOS Detector for Cone-Beam CT of the Extremities
3.	Choi et al., (2016), Over-Exposure Correction in Knee Cone-Beam CT Imaging with Automatic Exposure Control Using a Partial Low Dose Scan
4.	Hirschmann et al., (2015), Upright CT of the Knee: The Effect of Weight Bearing on Joint Alignment
5.	Kothari et al., (2020), The Relationship of Three-Dimensional Joint Space Width on Weight-Bearing CT With Pain and Physical Function
6.	Mezlini-Gharsallah et al., (2018), Three Dimensional Mapping of The Joint Space for the Diagnosis of Knee Osteoarthritis Based on High Resolution Computed Tomography: Comparison With Radiographic, Outerbridge, and Meniscal Classifications
7.	Segal et al., (2017), Comparison of Tibiofemoral Joint Space Width Measurements from Standing CT and Fixed Flexion Radiography
8.	Sisniega et al., (2016), Image-Based Motion Compensation for High Resolution Extremities Cone-Beam CT
9.	Thawait et al., (2015), Extremity Cone-Beam CT for Evaluation of Medial Tibiofemoral Osteoarthritis: Initial Experience in Imaging of the Weight Bearing and Non-Weight Bearing Knee

A. Result

1. Application of CBCT weight bearing knee joint examination with clinical OA

a. Nine articles obtained by the author used CBCT to obtain volumetric images that could be reconstructed in cross sectional and 3D.

b. Good anatomical structures and details can be obtained from the weight bearing CBCT method, so that OA that causes JSW narrowing can and ME can be visualized clearly (Thawait et al., 2015).

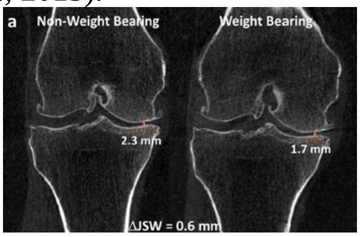


Figure 1 Measurement of JSW knee OA on the coronal bone window with a narrowing of the JSW medial femorotibial condyle area of 1.7 mm under load-bearing conditions (Thawait et al., 2015)

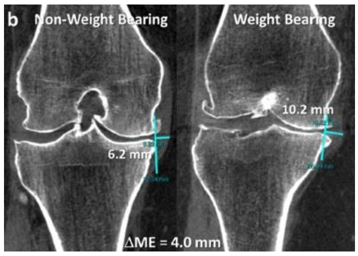


Figure 2 Measurement of ME knee OA on the coronal soft tissue window and the pressure on ME under weight bearing conditions with a length of 10.2 mm (Thawait et al., 2015)

c. Narrowing of the JSW was measured by cross sectional reconstruction of the medial and lateral femorotibial JSW using a coronal section as a reference by measuring the midpoint area (Hirschmann et al., 2015), and for 3D analysis carried out with a radiolucent positioning system that serves to maintain the position of the foot from possible rotation. externally and to keep the knee-flexion angle in place (Kothari et al., 2020).

d. The detectors on the CBCT are FPD and CMOS. FPD provides high-resolution contrast at low-dose knee scanning. The CMOS detector is able to capture high-frequency trabecular tissue (0.06 mm trabecular size consistency), this ability is four times better than FPD (Qian et al., 2017).

e. CBCT provides reconstruction after scanning to minimize artifacts with AEC and motion correction. AEC reconstruction was able to minimize artifacts due to over exposure, while motion correction reconstruction was able to minimize streak artifacts and motion artifacts up to 35° (or 10-15% improvement in 2-4 mm of patient-generated movement (Berger et al., 2016; Sisniega et al., 2016).

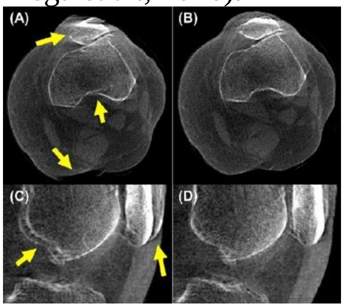


Figure 3 Reconstruction of motion artifacts with motion correction to minimize artifacts in images (A) and (C) as shown by yellow arrows to make them better as in images (B) and (D) (Sisniega et al.,2016)

f. Image results were analyzed by statistical ICC (Intra-class Correlation Coefficient) guidelines and WOMAC guidelines (Western Ontario and McMaster Universities Osteoarthritis Index) to assess knee OA. The ICC guidelines have a rating range: >0.75 = very good, 0.4-0.75 = moderately good, and <0.4 = poor, p-values less than 0.05 are significant. The WOMAC guidelines can assess OA progression in the range 0-4 with a total score of 20 (Hirschmann et al., 2015; Kothari et al., 2020).

2. Benefits of CBCT weight bearing on CT knee joint image information with clinical OA

a. The weight bearing method in CBCT is optimal in producing informative anatomical images and degeneration or OA affecting the knee area such as the patella, femorotibial or tibiofemoral JSW, as well as visualizing the condition of the meniscus to assess the presence or absence of ME due to narrowing of the JSW (Hirschmann et al., 2015; Kothari et al., 2020; Segal et al., 2017; Thawait et al., 2015).

b. Anatomical information that can be visualized from CBCT modalities includes the patella, patellar tendon, cartilage, menisci, distal femoral, proximal tibia and fibula, patellofemoral, and femorotibial joints (Hirschmann et al., 2015; Qian et al., 2017; Segal et al., 2017; Thawait et al., 2015).

c. The weight bearing method in CBCT can display the anatomical structure of the knee clearly and the degeneration that causes joint narrowing and displacement accurately (Hirschmann et al., 2015).

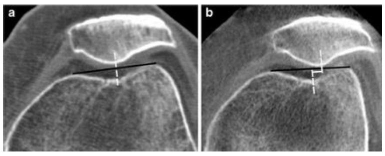


Figure 4 Comparison between the application of weight bearing (b) and non-weight bearing (a) where in Figure (a) there is no visible change in position (0 mm), while Figure (b) shows a shift in the position of the patella as far as 0.4 mm from the deepest trochlear groove (Hirschmann et al., 2015)

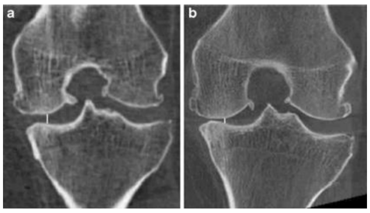


Figure 5 Comparison between the application of wieght bearing (b) and non-weight bearing (a) where the image (a) shows the length of the JSW on the medial femorotibial 4 mm, while in the image (b) it is 0.5 mm (Hirschmann et al., 2015)

d. Measurement of OA on CBCT can be done using the KL method, 3D map (color coding), and 3D joint space mask (Mezlini-Gharsallah et al., 2018).

Figure 6 Method of measuring KL in OA with CBCT weight bearing mid-knee coronal section. Scoring in KL starts from 0 (normal), 1 (early OA), 2 (moderate OA), 3-4 (severe OA) (Mezlini-Gharsallah et al., 2018)

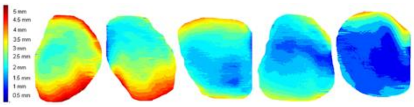


Figure 7 Measurement of knee OA with a 3D map uses a color code, where the dark blue color indicates a narrowing of the JSW (Mezlini-Gharsallah et al., 2018)

Figure 8 Measurement of knee OA with a 3D joint space mask that works like wrapping the JSW space on the knee (Mezlini-Gharsallah et al., 2018)

B. Discussion

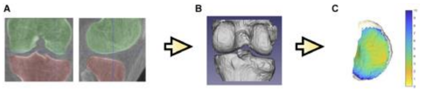
1. Application of CBCT weight bearing knee joint examination with clinical OA

The use of CBCT in examining OA in the knee with the weight bearing method is carried out to obtain a volumetric image with a 360^{o} scanning process that can be reconstructed in cross sectional and 3D to see the condition of the knee and joint degeneration (OA) which generally affects the tibiofemoral joint area of the knee. CBCT is used to obtain cross sectional and 3D images of the knee, especially JSW, in assessing symptoms of OA, osteophytes, subchondral cysts, cartilage pathology, and evaluation of meniscal morphology in order to obtain more accurate results. This is similar to the statement from Kothari et al., (2020).

Cross sectional and 3D images can be generated due to the combination of X-rays and computational technology (Hendee, 2014). It can be used to identify early knee joint OA, osteophytes, subchondral cysts, evaluate meniscal morphology, assess trabecular bone density, as well as bone microarchitecture and cortical bone density.

This statement is also in line with several articles reviewed by the authors such as the article Qian et al., (2017) who described CBCT used to obtain volumetric images for the evaluation of bone trabeculation (bone morphometry examination), identify degeneration in the trabecular microarchitecture area of the subchondral bone, and evaluate the patella. malformation. As well as the articles of Hirschmann et al., (2015) and Segal et al., (2017) which describe the use of CBCT for evaluation of patellofemoral, femorotibial alignment, assessing the condition of cartilage and menisci, rotation of the femorotibial, distance of the tibial tuberosity-trochlear groove (TTTG), severe OA valgus of the knee, measuring OA of the JSW and menisci, and complete visualization of bone structures from various planes/sides in 360^{o} isotropic 3D.

Narrowing in JSW can be measured by cross sectional and 3D reconstruction. The geometry of the tibiofemoral was obtained by semi-automated segmentation on CBCT. The segmentation produces the surface of the tibia and femur, then the image enters the smoothing process with the Geomagic Studio software (3D system). Parts of the subchondral femoral and tibial surfaces that have been smoothed with the 3D system were used to determine other parts (elements) around using MATLAB. Each distance in the area around the subchondral will display a color code. The color code of each area (element) will be calculated to generate distance-surface area data. This is in accordance with the explanation of Segal et al., (2017) where color coding in 3D reconstruction can improve bone detail and facilitate the identification of OA.



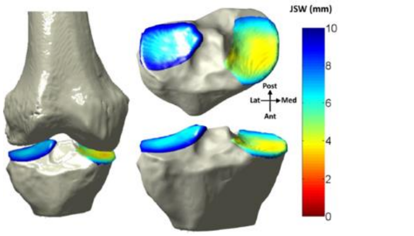


Figure 9 The process of reconstructing knee CBCT weight bearing images with 3D JSW in detecting OA (Kothari et al., 2020; Segal et al., 2017)

The image results obtained can be analyzed in the form of measurements as explained by Hirschmann et al., (2015) to assess the pathology of the knee area. Femorotibial rotation angle measurements were performed on an axial section parallel to the posterior femoral condyles and on a parallel line leading to the posterior osseous contour of the tibial plateau. The TTTG distance was measured from a parallel line leading to the posterior femoral condyle (3 cm above the femorotibial JSW which was used to draw the perpendicular line perpendicular to the midpoint of the trochlea). Measurements of the lateral patellar tilt angle and lateral patellar shift use an axial section and the measurement refers to the widest patella.

Mezlini-Gharsallah et al., (2018) stated that CBCT can be used to obtain high-resolution images of complex structures of the knee and to examine OA, assess trabecular bone density, as well as bone microarchitecture and cortical bone density more clearly through MPR and 3D. This argument is supported by Sisniega et al., (2016) with the aim of using CBCT, among others, to obtain images of trabecular, cortical bone areas, morphological conditions with cuts from various fields, as well as for OA identification and early OA detection. Not only that, the explanation from Thawait et al., (2015) also adds another role of CBCT, namely to obtain volumetric and efficient knee images for visualizing the 3D orientation of the osseous structure, measuring meniscal extrusion (ME) that occurs due to narrowing of the joint space. width (JSW) which refers to cartilage loss, measurement of JSW, assessment of OA progression in the femorotibial joint, and evaluation of cartilage pathology and structural damage to the knee area due to OA.

The ability of CBCT to manage image results with cross sectional and 3D reconstruction is also supported by a built-in detector that can increase the resolution of the resulting image, as well as reconstruction that can be used to minimize certain artifacts. This statement is in line with the article written by Qian et al., (2017) which states that CMOS and FPD detectors with specifications of 0.139 pixel pitch, 0.7 mm scintillator, and 0.5 focal spot, an average dose of 5-15 mGy, FOV 20x20x20 cm3, scan time 30 s3, spatial resolution 0.25-0.35 mm, capable of low-dose and high-resolution knee scanning. CMOS with a thickness of 0.4 mm can display the trabecular knee area well and with high resolution, while 0.7 mm is superior in imaging soft tissues.

This is in line with Hendee's (2014) explanation because FPD has a fairly large dynamic range and a flat X-ray absorption layer so that it can provide sufficient resolution, making it effective in displaying images of OA, fracture, ACL abnormalities, malformation, deformity. Unlike the CMOS detector, which is able to capture high-frequency trabecular tissue (0.06 mm trabecular consistency), this capability is four times better than FPD. CMOS with 0.4 mm thickness 10-20% is better in imaging bone conditions up to knee trabeculation, trabecular microarchitecture of subchondral bone, OA pathology, and evaluation of patellar malformation with high resolution, while thickness 0.7 mm is superior in soft tissue imaging because it is able to capture more frequency. CMOS has high sensitivity with an extension of the amplification circuit at each pixel and with three transistors.

Reconstructions that can be used to minimize artifacts such as the explanations of Choi et al., (2016), Berger et al., (2016), and Sisniega et al., (2016) are AEC reconstruction and motion correction reconstruction (NGI, MB, GC). AEC reconstruction is able to handle over exposure and minimize artifacts due to overdosage and improve knee image quality. The image generated from the low dose scan with AEC reconstruction is close to the high dose scan. Low-dose scans only provide about 2.8% of the total annual average effective dose of 2.95 mSv.

As well as motion correction reconstruction with NGI (normalized gradient information), MB (marker-based), and GC (gradient correlation) types, it is also able to improve image quality by minimizing streak artifacts (especially at bone boundaries), improving bone outline, and improving image quality. minimized motion artifact by 35^{o} (or 10-15% improvement in 2-4 mm of patient-generated motion during examination in SSIM data) with UQI (universal quality index) 53.3, 56.1, and 53.7, for GC, NGI, and MB, where UQI below 18.4

indicates no improvement in image quality (no motion correction) (Berger et al., 2016; Sisniega et al., 2016).

Both methods of reconstruction are supported by the explanations of Hendee, (2014) and Maier et al., (2020) because the reconstruction uses a built-in algorithm that is able to subtract motion estimates from the latest frame to the previous frame (before the movement causes artifacts) or 2D / algorithm. 3D registration which has a working method such as tracking the initial condition to the final condition (translation) to estimate the anatomical shape of the image before the appearance of artifacts due to movement. The reconstructed image shows the condition of bone, trabeculation, fluid, and especially the clinical pathology of OA in the knee, then the image results will be assessed and analyzed by a radiologist (Thawait et al., 2015).

Segal et al., (2017), Mezlini-Gharsallah et al., (2018), and Kothari et al., (2020), explain that OA identification can be done in several ways such as assessment and measurement through cross sectional imagery with KL in the mid coronal plane. and 3D high resolution with color coding so that the OA grading can be determined accurately. The measurement results can be analyzed with the ICC and WOMAC guidelines (Hirschmann et al., 2015; Kothari et al., 2020).

Statistical analysis was used to strengthen the results of observations and measurements such as the Wilcoxon and Cohort Study which then used specific references in assessing OA with ICC or WOMAC as guidelines (Hirschmann et al., 2015; Kothari et al., 2020). These guidelines are in line with those used by the theory of Richter et al., (2020)and the research article Collins et al., (2011) where the ICC is used as a reference for calculating OA by grouping varus, valgus, and normal. WOMAC which is used to assess knee OA and chondral defects combined with ICC gives a range of values: >0.75 = very good, 0.4-0.75 = quite good, and <0.4 = poor, p-values less than 0.05 are significant. WOMAC guidelines can assess OA progression in the range 0-4 with a total score of 20. Like the statistical analysis conducted by Kothari et al., (2020) in their research to process data results using a cohort study and combined with WOMAC guidelines with a sample of 528 knee joints, more of the half got a score of 0 in the indication of knee pain, the remaining third got a score below 2. Few of the volunteers experienced severe pain but according to the calculation the score did not reach statistical significance (p = 0.07). The image results that have gone through a series of evaluation, measurement, and analysis processes with qualitative and quantitative (statistical) assessments are then calculated. Calculation of the results of the analysis aims to assess the condition of the knee starting from bone trabeculation, details of bone structure, ligaments, joint fluid, joint condition, and to determine the presence or absence of OA pathology around the knee (Demehri et al., 2015).

2. Benefits of CBCT weight bearing on CT knee joint image information with clinical OA

The results of CBCT weight bearing images can provide an informative anatomical description and pathology of OA that affects the knee area, as well as visualization of the condition of the meniscus to assess the presence or absence of ME due to degeneration in JSW. Anatomical information that can be visualized includes the patella, patellar tendon, cartilage, menisci, distal femoral, proximal tibia and fibula, patellofemoral, and femorotibial joints. This statement is in line with Maier et al., (2017) and Demehri et al., (2015) who in their articles stated the same thing and with the support of color coding on 3D reconstruction it can make it easier to identify JSW narrowing, OA grading, and menisci conditions.

The weight bearing method in CBCT is effective in showing degeneration or OA that affects the knee area such as patella, femorotibial or tibiofemoral JSW, as well as visualizing the condition of the meniscus to assess the presence or absence of ME due to narrowing of the JSW. The anatomical information seen includes the patella, patellar tendon, cartilage, menisci, distal femoral, proximal tibia and fibula, patellofemoral, and femorotibial joints.

According to the authors, CBCT is able to provide an anatomical image of the knee with high spatial resolution, shows OA clearly, shows joint space narrowing and soft tissue (cartilage, ligament, and meniscus) of the knee area clearly, shows narrowing of the tibiofemoral JSW and patellofemoral joint clearly. OA of the menisci, as well as evaluation of OA of the knee area with a short scan time. The resulting isotropic data also provides details of JSW and from the coronal aspect so that the visualization of OA is better. This is in line with articles from Mezlini-Gharsallah et al., (2018) and Kothari et al., (2020).

Thawait et al., (2015) and Segal et al., (2017) add that narrowing of the JSW due to OA can lead to meniscal extrusion (ME), and CBCT can evaluate this optimally at high spatial resolution. JSW which can be visualized from various fields makes it easier to measure OA with the KL method to determine the severity of OA because in conditions of weight bearing articular cartilage in the knee with OA it will be more sensitive.

OA measurement on CBCT can be done using semi-automatic methods, namely KL, 3D map (color coding), and 3D joint space mask, so that OA grading on OA can be identified optimally. The KL method in CBCT is like a radiographic examination, which is to facilitate the classification of OA, but in CBCT these measurements are carried out simultaneously to obtain a picture with a wide density range, so that other abnormalities can be seen. The semi-automatic KL method, 3D map (color coding), and 3D joint space mask make it possible to measure the knee JSW from the 3D CBCT aspect with high resolution and the distribution of the JSW value in real terms so as to produce isotropic data. According to Mezlini-Gharsallah et al., (2018), the resulting isotropic data makes JSW visualization more detailed and from the coronal aspect so that OA conditions can look optimal.

The previous statement is also supported by statements from articles written by Choi et al., (2016) and Hirschmann et al., (2015) which state that CBCT is able to provide a detailed description of bone structure, soft tissue around the knee clearly, can visualize joint space narrowing. femorotibial width (JSW) due to OA and optimal lateral patellar joint displacement. The density of the exterior of the patella and patellar tendon on the knee can be visualized well so that clinical features such as OA can be optimally diagnosed. Weight bearing in a standing position can illustrate a potential method and can become a basic need for a natural and more physiological knee examination (because it is in a standing position) so that a more optimal evaluation can be carried out for biomechanical needs and appropriate surgical planning. Especially in OA pathology and OA valgus (from mild to severe), the narrowing will be more visible on the lateral JSW image.

This is in line with the theory of Richter et al., (2020) and a research article from Tuominen et al., (2013) who added another benefit of CBCT weight bearing in clinical knee examination of OA that weight bearing conditions contribute to optimal visualization of OA at a low dose. low. Optimal image results are also supported by the ability of the built-in CBCT detector that can provide high-resolution contrast and the application of reconstruction that can minimize artifacts so that image quality increases. AEC reconstruction and motion correction can minimize several artifacts such as over exposure artifacts, motion artifacts, and streak artifacts, so that anatomical images and especially pathology are not disturbed.

Conclusion

The studies and discussions that have been carried out have reached the following conclusions:

1. CBCT weight bearing method can produce 3D volumetric and cross sectional (axial, sagittal, coronal) images of the knee with a 360^o isotropic scanning process to check for degeneration of the tibiofemoral joint area, degeneration of the trabecular microarchitecture area of the subchondral bone, identification of early OA, assessing rotation of the subchondral bone. femorotibial, measuring the distance in the tibial tuberosity-trochlear groove (TTTG), evaluating severe OA valgus, evaluating osteophytes, assessing trabecular bone density, assessing the density of cortical bone, and evaluating pathology in cartilage and structural damage to the knee area due to OA.
2. CBCT weight bearing method provides a number of benefits from the resulting image with high spatial resolution and low dose so that the picture of bone structure is more detailed without large losses due to dose, short scan time, showing narrowing and progression of OA at joint space width (JSW). femorotibial and patellofemoral joints clearly showed optimal lateral patellar joint displacement, well demonstrated OA of the menisci, showed joint space narrowing and soft tissue area of the knee. Weight bearing conditions can provide a physiological picture of the knee so that OA is clearly visible.

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