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The effectiveness of CBCT systems and other image modalities in the diagnosis and treatment of oral maxillofacial disorders: a systemic review

Abstract

Background: A lot of advancements happened recently in the field of medical technologies, including the Cone Beam Computed Tomography (CBCT). When it was first introduced it has shown that it can accomplish rapid volumetric image with its cone-shaped beam. The aim of this study was to examine the success of this imaging method and how safe it is in the dental field.

Materials and methods: A Regular systematic review was accomplished. Different sources were searched to investigate the evidence about the performance (sensitivity, specificity and safety) of CBCT in comparison to different standard diagnostic methods.

Results: 31 articles were included in the study; most of them had shown diagnostic studies with a sample size of (n<9.9). Limitations about the performance of this technology and the shown evidence were vague and controversial. In the meantime, CBCT technology has vastly advanced and with image quality higher than that of MDCT. But still, it has a lower contrast resolution than that of MDCT. Consequently, MDCT is a better choice with soft tissue imaging. As for the evaluation of hard tissue in the maxillofacial area, CBCT has the clearer image resolution.

Conclusion: CBCT devices are now mainly used to get detailed information of the OMFS region and would vastly help in diagnosing and treating maxillofacial disorders.

Keywords: tumor, cyst, swelling, benign, malignant, x-ray, diagnosis, inflammation, CBCT, MDCT, image modalities

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Introduction

Tumors is a swelling part of the body usually accompanied by an inflammation in the area, caused by abnormal growth of tissue, could be in a benign form or a malignant form. On the other hand, the definition of cyst according to the National Cancer Institute (NCI) is: A closed, sac-like pocket of tissue that can form anywhere in the body. The space created could be filled with any material.

Types of tumors could be discussed as follows:

I. Benign tumors, which has two different forms (a) Solid (b) Cystic.

II. Premalignant lesions.

III. Malignant lesions.

Some medical technologies have shown great improvement in the last decade for the diagnosis and treatment of oral diseases. Using these technologies nowadays could help in diagnosis and treatment. In different circumstances, uncontrolled and unlimited use of these advancements may lead to high demand by service providers and unselective use. Usually this problem grows mainly in many developing countries leading to an increased cost. CBCT was first launched two decades ago and has also been used recently in radiotherapy and ENT. In compared to CT, CBCT uses different technology to help 3D CT volumetric scanning of the examined area. Images are not taken in slices, but it happens to show an entire object with a cone-shaped beam. With the beam going around and taking multiple images in multiple angulations, the examined object would be shown from different directions. With the recent advancements of imaging technologies, taking images using 3D technology has a high Resolution when used on hard tissue.

Classifications

As for the classification of tumors of the oral cavity, it is based on the tissue of origin; they are divided into five types:

1. Tumors of Epithelial tissue origin.
2. Tumors of Connective tissue origin.
3. Tumors of Muscle tissue origin.
4. Tumors of Nerve tissue origin.
5. Metastatic tumors of jaws.

Coming to the types of cysts, it also has different forms and origins,

(i) Odontogenic Cyst; which is tooth related.

(ii) Non-Odontogenic Cyst; which is non-tooth related.

To get a precise detection of tumors or cystic lesions is an important step in the process of computer-aided diagnosis systems. Radiologists are important in the diagnosing team; however, usually manual detection becomes tiresome in the presence of small sized lesions and consumes time due to the presence of large amount in data collecting. Therefore, developing an automatic or semi-automatic method can save a lot of time for the radiologists.

Three-dimensional imaging can be obtained using the Cone Beam CT (CBCT), which is rapidly advancing, in the area of the

maxillofacial diagnosis, as well as the sensitive tissues and organs in the head and neck. Abdulali et.al. Concluded that CBCT is a reliable tool for preoperative radiological assessment of cyst and tumors when compared with conventional CT. The two most common types of cyst maxillofacially are the periapical and radicular cyst. Radicular cysts account for more than 50% of all inflammatory cysts and they are the main reason of chronic swelling in mandible. In addition, the dentegerous cyst is the 2nd most prevalent, it is associated with the crown of an unerupted tooth. While the 3rd and the most recurrent is the keratocyst. Algorithm designing for maxillofacial cysts could have its challenges due to several reasons. First starting with the sizes and shapes of the detected cysts, when diagnosed with conventional methods might lead to inaccurate and poor diagnosis. It could be the reason of getting precision in diagnosing the size and shape of the cyst is important aspect. Secondly, a 2D slice of cysts is time consuming for the radiologists, that's why getting better software to diagnose will help in time consumption as well as getting an accurate diagnosis. Dental CBCT technology has been used since the late 1990s. Three-dimensional (3D) images of the neck and chin area can be obtained using this technology (2 D. Sarment et al. 2013). CBCT devices are useful in implant planning (2 W. De Vos, J. Casselman, et al. 2009), teeth segmentation (2 D.X. Ji 2014), jaw tissue segmentation (2 R. Lloréns, et al. 2012), detection of facial traumas of the jaw (2 W.C. Scarfe et al.[1]), and obtaining 3D images of lesions and other pathologies (2 S. Kayipmaz et al. 2011).

Materials and methods

In this systematic review, articles were taken from 1990 to 2012. They were searched using:

1. Pubmed
2. Readcube application
3. Google Scholar

"CBCT" (key word) was appropriately searched in the mentioned databases.

In consideration of the objectives of our study, some irrelevant studies were excluded; full texts of the remaining articles were retrieved; as some articles were chosen based on the inclusion and exclusion criteria as the following:

Study population

Studies had to be performed on humans or phantom models. Experimental studies were preferred with high sample sizes. In human studies, they had to be conducted on living patients.

Intervention:

Studies that used CBCT in their examination.

Studies with and without a control group entered the study

Diagnostic studies that compare CBCT results with a control group were included.

Outcome

Within the diagnostic studies, one specific inclusion was the comparison of CBCT with a similar imaging technique. Some articles containing information on application of CBCT mentioning its safety, accuracy, positive and negative aspects, predicting changes in the course of treatment and in patient status (the Quality Adjusted Life Years: QALYs and Disability Adjusted Life Years: DALY) were all included.

Study design

Specific diagnostic, interventional and systematic reviews were chosen. Considering the diversity within some of the articles, a meta-analysis was not possible and data were analyzed using meta-synthesis.

Results

Looking in a total of 31 articles we divided them into two groups:

Review articles, notes and reports regarding the setting up and operating CBCT devices

11 articles were collected in this group. Some articles were used for the preparation of a report and haven't been used to compare the diagnostic values. Lagravere et al.[2] indicated that the location of the object in CBCT had no effect at all on CT Number. While Veyre-Goulet et al.[3] said that CBCT images are important for controlling the shape of alveolar bone before any implant therapy.

In another study done by Scarfe et al.[1] indicated that CBCT has the capability in providing diagnostic images in high resolution in a short period of scan time (10 to 70s) and has a radiation dose of 15 times less than that of the conventional CT scans. As for Florian et al. it was showed that NewTom9000 has less value in displaying the spongy bone grafts than the cortical bone grafts. Lagravere et al.[4] also indicated that CBCT is an important tool for the determination of CT count (Hounsfield Unit). Adding to that Schulze et al.[5] showed that CBCT is also capable of detecting trauma and osteomyelitis to spongy and cortical bone. Lascala et al.[6] indicated that actual images are always much larger than those shown by CBCT; but these differences are only possible in intracranial measurements. CBCT images undervalue the intracranial distances but are appropriate for linear measurement of other areas and surfaces in close to oral and maxillofacial region and shows more accurate images. Araki et al.[7] discovered that the new CBCT system that provides a 3D volumetric high-resolution images are better for evaluating any oral and maxillofacial disorders. Walker et al.[8] conclude that 3D imaging of canine impaction can detect any presence or absence of canine tooth during the size of dental follicle, changing of the longitudinal tooth axis, related buccal and lingual positioning, the structure of bone that covers the tooth surface and detecting any abnormalities from the surrounding surfaces of the targeted tooth area. Stratemann et al. implied that the any data collected from the two CT scan systems (Mercuray and NewTom) were absolutely accurate in comparison to to the physical measurements of the skull (gold standard) as it showed that the collective error rate was less than 1%. Pinsky et al. reported that CBCT has the possibility to be a noninvasive, accurate, practical technique of discovering the measurement of the injury and trauma to bone.

Comparing CBCT devices with other imaging modalities

With a total of 20 articles were placed and distributed in 5 major subgroups. Subgroup 1 articles with the comparison of different CBCT systems (NewTom3G, NewTom9000, CB Mercuray, i-CAT). 2 articles were in this subgroup. Subgroup 2 had 13 articles that compare

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CBCT with other CT devices (Table 1 & 2). Going to Subgroup 3, it compared CBCT with regular radiography. 3 articles were in this subgroup. While subgroup 4 has included 1 article that compares CBMCT with laser scanning. Subgroup 5 has included also 1 article that compares CBCT and biopsy.

Table 1 The list of review articles about CBCT

Effect of object location on the density measurement and Hounsfield conversion in a NewTom 3G cone beam computed tomography unit.
Accuracy of linear measurement provided by cone beam computed tomography to assess bone quantity in the posterior maxilla: a human cadaver study.
Clinical applications of cone-beam computed tomography in dental practice.
Imaging of bone transplants in the maxillofacial area by NewTom 9000 cone-beam computed tomography: a quality assessment.
Density conversion factor determined using a cone-beam computed tomography unit NewTom QR-DVT 9000.
Diagnostic criteria for the detection of mandibular osteomyelitis using cone-beam computed tomography.
Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom).
Characteristics of a newly developed dentomaxillofacial X-ray cone beam CT scanner (CB MercuRay): system configuration and physical properties.
Three-dimensional localization of maxillary canines with cone-beam computed tomography.
Comparison of cone beam computed tomography imaging with physical measures.
Accuracy of three-dimensional measurements using cone-beam CT.

Table 2 The list of articles comparing with other imaging modalities

No	Title	Author	Year Published	Compared Modality
1	Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions	Haiter-Neto et al.[9]	2007	Comparison of CBCT and two intraoral receptors namely digital and film sensors
2	Value of two cone-beam computed tomography systems from an orthodontic point of view	Korbmacher et al.[10]	2007	Comparison of two CBCT systems (New Tom 9000 and Mobile Arcadis 3D)
3	Cone beam CT and conventional tomography for the detection of morphological temporomandibular joint changes	Hintze et al.[11]	2006	Comparison of CBCT (NewTom3G) with conventional tomography
4	In vitro cone beam computed tomography imaging of periodontal bone	Mol et al.[12]	2007	Comparison of New Tom 9000 with conventional radiography
5	Radiation exposure during midfacial imaging using 4-and 16-slice computed tomography, cone beam computed tomography systems and conventional radiography	Schulze et al.[13]	2004	Comparison of CBCT with MDCT and conventional radiography
6	Image quality vs radiation dose of four cone beam computed tomography scanners	Loubele et al.[14]	2007	Comparison of 4 CBCT systems (Accuitomo 3D, Mercuray, New Tom 3G, i-CAT with MDCT sensation 16)
7	Beam hardening artefacts occur in dental implant scans with the New Tom cone beam CT but not with the dental 4-row multidetector CT	Draenert et al.[15]	2006	Comparison of CBCT (NewTom 9000) with MDCT (Philips MX 8000)
8	Dosimetry of 3 CBCT devices for Oral and Maxillofac Radiology: CB Mercury, New Tom 3G and i-CAT	Ludlow et al.[16]	2006	Comparison of three CBCT systems (Mercuray, NewTom3G and i-CAT) and comparison of CBCT and MDCT
9	Comparison of three radiographic methods for detection of morphological temporomandibular joint changes: panoramic, scanographic and tomographic examination	Hintze et al.[17]	2007	Comparison of CBCT (NewTom3G) with conventional tomography
10	Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images	Lagravere et al.[18]	2006	Comparison of CBCT and CMM
11	Comparison of image performance between cone-beam computed tomography for dental use and four row multidetector helical CT	Hashimoto et al.[19]	2006	Comparison of CBCT with MDCT
12	Quantitative measurements obtained by micro-computed tomography and confocal laser scanning microscopy	Kamburoglu et al.	2008	Comparison of CBCT with laser scanning microscopy
13	Differential diagnosis of large periapical lesions using cone-beam computed tomography measurements and biopsy	Simon et al.	2006	Comparison of CBCT (NewTom3G) with biopsy

Table Continued...

No	Title	Author	Year Published	Compared Modality
14	Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography	Suomalainen et al.	2008	Comparison of CBCT with MDCT
15	Cone-beam computed tomography in assessment of periodontal ligament space: in vitro study on artificial tooth model	Özmeric et al.[20]	2008	Comparison of CBCT with conventional radiography
16	Radiation absorbed in maxillofacial imaging with a new dental computed tomography device	Mah et al.[21]	2003	Comparison of CBCT with other CT systems
17	A comparative evaluation of cone beam computed tomography (CBCT) and multislice CT (MSCT): Part I. On subjective image quality	Liang et al.	2009	Comparison of CBCT with MDCT
18	Acomparative evaluation of cone beam computed tomography (CBCT) and multislice CT (MSCT). Part II: On 3D model accuracy	Liang et al.	2009	Comparison of CBCT with MDCT
19	Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications	Loubele et al.[14]	2008	Comparison of CBCT with MDCT
20	Radiological diagnosis of periapical bone tissue lesions in endodontics: a systematic review	Petersson et al.	2012	Comparison of CBCT with other CT systems

Comparison of CBCT with other CTs

Looking at the study done by Liang et al, they used a high-resolution laser scanner as the gold-standard in their comparison of accuracy of the 3D model acquired by CBCT as well as multi-slice computed tomography (MSCT) they reported that the mean deviation from the gold-standard was 0.131 mm for MSCT, 0.282 for CBCT, 0.227 for i-CAT, 0.169 for Accuitomo, 0.388 for New Tom and 0.2 for Scanora and Galileos. Liang et al., again reported that Accuitomo was better than MSCT and other CBCT systems in displaying the anatomical landmarks; whereas MSCT is greater in reducing image noise. Some studies showed the absorbed dose of tissues by the New Tom 9000 and other CTs. They found that the successful dose for maxillofacial imaging with New Tom 9000 was 50.24 muSv; which was less than that of conventional CTs. On the other hand, some studies compared the imaging artefacts of New Tom and MDCT and indicated that scans with NewTom9000 showed stronger artefacts than MDCT. Lagravere et al. had a comparison of the accuracy of linear measurements made on CBCT and coordinate measuring machine (CMM) and reported that t-test found no notable difference in angular and linear measurements between the CMM and New Tom 3G and the difference was less than 1degree and 1mm, respectively. Other studies had a comparison in the image performance between CBCT and a (MDCT). They evaluated the CBCT images using a 5-level scale. It was revealed that CBCT images had the greater quality than MDCT images and that CBCT is considered as a useful imaging modality in dentistry. In another study, Loubele et al.[14] Reported that on the most favorable radiation dose versus image quality belonged to i-CAT in comparison 4 different CBCT Systems (i-CAT, NewTom3G, CB Mercuray, Accuitomo). Mercuray had the lowest image quality while the highest went to Mercuray as well as Somatom Sensation. As for the lowest belonged to Accuitomo 3D. Hintze et al.[11] copmpared image accuracy of CBCT and conventional CT, and reported that there is no significant differences between the two systems when used for the detection of any skeletal abnormalities. While when used in detecting sensitivity and specificity, CBCT was compared for investigating the flattening, osteophytes and defects. Starting with the sagittal dimension, it was shown that sensitivity's mean value was 0.14 for CBCT and 0.13 for the conventional CTs. While using the cross-sectional dimension, sensitivity's mean was 0.29 for CBCT and 0.18 for regular CTs. As was the mean in the sagittal dimension 0.92 for CBCT and 0.97 for conventional CTs. The cross-sectional value dimension shown was almost the same CT and CBCT. To put it differently, sensitivity's mean for different changes was mostly low and around 0.112 for flattening in conventional CTs to 0.41 for defects on cross-sectional CBCT. In a comparison done by Schulze et al.[13] showed that the radiation of multi-slice CT had a much higher exposure volume than conventional CBCT, resulting that CBCT is much safer that many other systems. Hintze et al.[17] reported that there is no difference in the detection of skeletal changes in and articular or condyle bone within two CBCT systems (NewTom3G and conventional tomography). In a systematic review done by Petersson et al. in 2012 reported that the equal diagnostic accuracy of the conventional film technique and digital intraoral radiography is inadequate. They couldn't finalize to any conclusion regarding the radiological examination in detecting the periapical bone tissue changes or condition of the pulp of the tooth.

Comparison of different CBCT systems

In a comparison done by Haiter-Neto et al.[9] between NewTom3G and Accuitomo CBCT systems it was shown that NewTom3G had less diagnostic accuracy in detection of caries than Accuitomo. NewTom3G was considered the first product of this company as the newer and advanced systems have a better image quality; especially the latest product New Tom VG that uses advanced flat panel technology and has a relatively high image resolution. Korbmacher et al.[10] had a comparison between NewTom9000 and Mobile Arcadis 3D CBCT system as well as conventional radiography in relation of image quality for orthodontic diagnosis and reported that CBCT has the superiority compared to conventional radiography in this respect.

Comparison of CBCT with conventional radiography

Özmeric et al.[20] did a comparison between the NewTom9000 and a regular radiography device (RG) in regards to image quality and

reported that the CBCT device NewTom9000 showed a lower quality results than RG. Mol et al.[12] had a similar comparison between the same devices (NewTom9000) and a regular radiography device (RG), but their focus was on the quantitative and diagnostic information. It was agreed that NewTom9000 was better to RG for that manner. In terms of radiation exposure, Schulze et al.[13] did a comparison between CBCT, MDCT and a regular radiotherapy device, the results showed that MDCT, CBCT and RG in a decreasing order, had the highest radiation exposure.

Comparison of CBCT with laser scanning microscopy

Kamburoglu et al. did a comparison between the CBCT and a laser scanning microscopy, regardless of the strong correlation of the two, it was shown that CBCT had underestimated the volumes and diameters.

Comparison of CBCT with biopsy

Simon et al. had a differential diagnosis of periapical lesions using both CBCT and biopsy and reported that the CBCT gives an accurate diagnosis in comparison to biopsy, which will help prevent any invasive approach or to wait for a long time to see the results if went to a non-invasive approach.

Discussion

There are many studies that are related to CBCT and mostly they have a diagnostic or descriptive aspect. These studies target understanding the application of CBCT, regarding its accuracy and diagnostic properties e.g. radiation exposure, quality, dose etc. Little evidence shown regarding the activity of CBCT in treatment. The CBCT devices usually have different designs and results differ for system to system. Lots of studies had different results in relation to the system compared. Some studies are comparing older devices with MSCT which resulted in showing the advancement of MSCT in comparison to the older system. While more recent comparisons of newer CBCT systems to MSCT have shown reverse results. Easier in application, better image quality, lower radiation, giving a 3D volumetric and higher speed, are all considered to be advantages of newer CBCT systems. Some evidence-based studies showed that CBCT systems have less sensitivity and higher specificity. We can consider that the CBCT has a non-invasive advanced technique in estimation of the skeletal or dental trauma in the maxillofacial region. Considering the different technical abilities of this automation, it should be used for specific purposes specialists. Currently, CBCT has in increase usage in dentistry and maxillofacial surgery and is mostly used by dentists (not radiologists). Technically it is suggested that oral and maxillofacial radiologists should use CBCT. However, it should not be considered as the only imaging option in different trauma patients, because using its technique alone, it cannot accurately help with some of the intracranial assessments.[22–25]

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Conflicts of interest

The author declares that there is no conflict of interest.

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