Systematic Review

The Efficacy of CBCT for Diagnosis and Treatment of Oral and Maxillofacial Disorders: A Systematic Review

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Abstract

Background and Aim: Cone Beam Computed Tomography (CBCT) has the ability to accomplish rapid volumetric image acquisition by its cone-shaped beam. The aim of this study was to evaluate the safety and efficacy of this imaging modality.

Materials and Methods: A standard systematic review was performed. Medline (December 2012) and The Cochrane Library (Issue 3 2012) were searched to identify evidence about the performance (sensitivity, specificity and safety) of CBCT compared with other standard diagnostic methods. The results of the included studies were analyzed using a qualitative method.

Results: Thirty-one articles were included in the study; the majority of them were diagnostic studies with a small sample size (n<10) .There was limited evidence about the effectiveness of this technology and the available evidence was scattered and sometimes controversial. At present, CBCT technology has greatly advanced and its image quality in terms of resolution is higher than that of MDCT. However, its contrast resolution is still lower than that of MDCT. Therefore, MDCT is preferred for soft tissue imaging. For evaluation of hard tissue in the maxillofacial region, a more clear image with higher resolution can be obtained by CBCT.

Conclusion: CBCT technology is now commonly used in developed countries for obtaining detailed information regarding the oral and maxillofacial region and can greatly help clinicians in diagnosis and treatment of maxillofacial disorders.

Key Words: CBCT , Imaging , Cone beam computed tomography , Dentistry

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Introduction

In the recent years, medical technology has witnessed great advancements in diagnosis and treatment of diseases. Adequate use of these technologies can greatly help diagnosis and treatment of diseases [1]. On the other hand, unlimited and uncontrolled use of these technologies may lead to an induced demand by the service providers and indiscriminate use. This problem is growing in many developed and developing countries leading to a significant increase in costs. Thus, in many countries, systematic assessment of health technology is done before allowing import and usage of new technologies [2]. CBCT was introduced in 1990 and has recently been used in radiotherapy and ENT as well. Compared with the conventional CT, CBCT scanners use flat panel technology to enable 3D CT volumetric scanning of the head and neck. Thus, images are not captured as slices. Instead, it shows the entire volume of object with its cone-shaped beam. By rotation of the beam around the object and imaging at different angulations, the respective area is displayed and observed from different directions. Due to the advanced image reconstruction algorithms, 3D images have high resolution and contrast for bone and hard tissue assessment.

Its rapid rotation and low radiation dose produces high quality diagnostic data [3]. At present, demand for using this technology in Iran has increased. Thus, this systematic review was conducted upon request of the Health Technology Assessment Department of the Ministry of Health to evaluate the efficacy of CBCT for diagnosis and treatment of oral and maxillofacial diseases.

Materials and Methods

In this systematic review, first articles published in the following databases from 1990 to October 2012 were searched:

1.Cochrane library (HTA Database, DARE reviews, NHS EEDs, Central)
2.Medline, UK HTA Website
3.BMJ Clinical Evidence
4.TRIP
5.Google Scholar

"CBCT" (key word) was searched in the aforementioned databases. Appropriate search strategy was applied for each database. In the first step, 98 articles were found. In the next step, a systematic review was found published in 2012. The references of the searched articles were also evaluated; which helped us find another 25 articles. Title and abstract of these articles (124) were thoroughly reviewed. Considering the objectives of our study, irrelevant studies were excluded; full texts of the remaining 63 articles were retrieved and studied; 31 articles were chosen based on the inclusion and exclusion criteria as follows:

1.Study population: Study had to be performed on human or phantom. The study had to be experimental and sample size over 10 subjects. Human studies had to be conducted on patients.
2.Intervention: Studies using CBCT for diagnosis or treatment of disease
3.Studies with and without a control group entered the study. Diagnostic and therapeutic studies comparing CBCT with a control group were included
4.Outcome: In diagnostic studies, one inclusion criterion was comparison of CBCT with a similar imaging technique. Articles containing information on application of CBCT, its safety, accuracy, positive and negative predictive values, change in the course of treatment and change in patient status (increasing the Quality Adjusted Life Years: QALYs and Disability Adjusted Life Years: DALY) were included.
5.Study design: Diagnostic, experimental (interventional) and systematic reviews were chosen. In order to assess the quality of articles, the available standard lists (Center for Review and Dissemination: CRD 2009) were used. Articles included in our study were assessed by one researcher in terms of adherence to the criteria and reviewed by another researcher. If disagreement existed between the two, opinion of a third party was sought. All three were oral and maxillofacial radiologists. Considering the significant heterogeneity among the articles, a meta-analysis was not feasible and data were analyzed using meta-synthesis.

Table 1: List of articles chosen for the study

Number	Article	Authors	Publication year	Country	Study design
1	Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions [4]	Haiter-Neto et al,	2007	Brazil	Comparative
2	Value of two cone-beam computed tomography systems from an orthodontic point of view [5]	Korbmacher et al,	2007	Germany	Comparative

3	Effect of object location on the density measurement and Hounsfield conversion in a New Tom 3G cone beam computed tomography unit [6]	Lagravère et al,	2008	Canada	Technical
4	Accuracy of linear measurement provided by cone beam computed tomography to assess bone quantity in the posterior maxilla: a human cadaver study [7]	Veyre_Goulet et al,	2008	France	Technical
5	Cone-beam computed tomography in assessment of periodontal ligament space: in vitro study on artificial tooth model [8]	Özmeric et al,	2008	Turkey	Technical
6	Cone beam CT and conventional tomography for the detection of morphological temporomandibular joint changes [9]	Hintze et al,	2006	Denmark	Comparative
7	In vitro cone beam computed tomography imaging of periodontal bone [10]	Mol et al,	2007	USA	Comparative
8	Radiation absorbed in maxillofacial imaging with a new dental computed tomography device [11]	Mah et al,	2003	USA	Technical
9	Radiation exposure during midfacial imaging using 4-and 16-slicecomputed tomography, cone beam computed tomography systems and conventional radiography [12]	Schulze et al,	2004	Germany	Comparative
10	Image quality vs. radiation dose of four cone beam computed tomography scanners [13]	Loubele et al,	2007	Belgium	Comparative
11	Beam hardening artefacts occur in dental implant scans with the New Tom® cone beam CT but not with the dental 4-row multi detector CT [14]	Draenert et al,	2006	Germany	Comparative
12	Clinical applications of cone-beam computed tomography in dental practice [15]	Scarfe et al,	2006	USA	Technical
13	Imaging of bone transplants in the maxillofacial area by New Tom 9000 cone-beam computed tomography: A quality assessment [16]	Draenert et al,	2008	Germany	Technical
14	Density conversion factor determined using a cone-beam computed tomography unit New Tom QR-DVT9000 [17]	Lagravere et al,	2006	Canada	Technical
15	Diagnostic criteria for the detection of mandibular osteomyelitis using cone-beam computed tomography [18]	Schulze et al,	2006	Germany	Technical
16	Dosimetry of 3 CBCT devices for Oral and Maxillofacial Radiology: CB Mercuray, New Tom 3G and i-CAT [19]	Ludlow et al,	2006	USA	Comparative
17	Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-New Tom) [20]	Lascala et al,	2004	Brazil	Technical
18	Characteristics of a newly developed dentomaxillofacial X-ray cone beam CT scanner (CB MercuRay): system configuration and physical properties [21]	Araki et al,	2004	Japan	Technical
19	Comparison of three radiographic methods for detection of morphological temporomandibular joint changes: panoramic, scanographic and tomographic examination [22]	Hintze et al,	2009	Denmark	Comparative
20	Three-dimensional accuracy of meas-	Lagravere et al,	2006	Canada	Comparative

	urements made with software on cone-beam computed tomography images [23]				
21	Comparison of image performance between cone-beam computed tomography for dental use and four rowmultidetector helical CT [24]	Hashimoto et al,	2006	Japan	Comparative
22	Three-dimensional localization of maxillary canines with cone-beam computed tomography [25]	Walker et al,	2004	USA	Technical
23	Quantitative measurements obtained by micro-computed tomography and confocal laser scanning microscopy [26]	KamburoLlu et al,	2008	Turkey	Comparative
24	Comparison of cone beam computed tomography imaging with physical measures [27]	Stratemann et al,	2008	USA	Technical
25	Differential diagnosis of large periapical lesionsusing cone-beam computed tomography measurements andbiopsy [28]	Simon et al,	2006	USA	Comparative
26	Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography [29]	Suomalainen et al,	2008	Finland	Comparative
27	Accuracy of three-dimensional measurements using cone-beam CT [30]	Pinsky et al,	2006	USA	Technical
28	A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT): Part I. On subjective image quality [31]	Liang et al,	2009	Belgium	Comparative
29	A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT). Part II: On 3D model accuracy [32]	Liang et al,	2009	Belgium	Comparative
30	Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications [33]	Loubele et al,	2008	Belgium	Comparative
31	Radiological diagnosis of periapical bone tissue lesions in endodontics: a systematic review [34]	Petersson et al,	2012	Sweden	Comparative

Table 2: List of excluded articles and the reason for their exclusion

Number	Author/Publication year	Reason for exclusion
1	Andreas Staveopoulos/2006	Study was conducted on animal model (pig)
2	Dee Zoo/2009	Only one patient was evaluated
3	Eggers/2009	Study was done on a plastic skull
4	AlexiouKe/2009	Study emphasized on NewTom3G,9000 findings and characteristics of this device namely safety, sensitivity, specificity and accuracy were not mentioned
5	R0, Der, Zel/2008	Study design was not experimental
6	Liu, Deng-gao/2008	Study emphasized on NewTom3G,9000 findings and characteristics of this device namely safety, sensitivity, specificity and accuracy were not mentioned
7	King, Keith S/2007	Description of a specific technology in New Tom 9000
8	LimEugene Y/2007	Introduction of a side technology using NewTom3G
9	King, Keith S/2006	Study emphasized on NewTom3G,9000 findings and characteristics of this device namely safety, sensitivity, specificity and accuracy were not mentioned
10	Loube, Meit/2006	Study was done on a jaw plastic model
11	Ogawa/2007	Study emphasized on NewTom3G,9000 findings and characteristics of this device namely safety, sensitivity, specificity and accuracy were not mentioned
12	Sirin Y/2010	Study was conducted on an animal model (sheep)
13	Sirin Y/2010	Study was conducted on an animal model (sheep)
14	Gracco A/2010	Study was done on healthy individuals
15	Makris N/2010	Study emphasized on NewTom3G,9000 findings and characteristics of this device

		namely safety, sensitivity, specificity and accuracy were not mentioned
16	Van Elslande D/2010	Study was done on a plastic model
17	Chung RR/2010	Description of a specific technology in NewTom3G
18	Stumpel LJ/2010	Observational case report
19	Kamburoglu K/2010	Study was done on an autopsy corpse
20	Kamburoglu K/2010	Description of a specific technology in NewTom3G
21	Christiansen R/2009	Description of a specific technology in NewTom3G
22	Lagravere MO/2009	Description of a specific technology in NewTom3G
23	Hassan B/2009	Study emphasized on NewTom3G,9000 findings and characteristics of this device namely safety, sensitivity, specificity and accuracy were not mentioned
24	Hassan B/2008	Introduction of a side technology using NewTom3G
25	Loubele M/2008	Study was done on a phantom
26	Lagravere MO/2008	Introduction of a side technology using NewTom3G
27	Lagravere MO/2008	Study emphasized on NewTom3G,9000 findings and characteristics of this device namely safety, sensitivity, specificity and accuracy were not mentioned
28	Van der Zel JM/2008	Description of a specific technology in NewTom3G
29	Haiter-Neto F/2008	Study was done on laboratory models

Results

A total of 31 articles were divided into two groups:

1. Review articles, technical notes and reports regarding the setup and operation of CBCT

A total of 11 articles were in this group. A list of articles in this group that were used for preparation of a report and did not compare the diagnostic value is shown in Table 3.

Lagravere et al. showed that the position of the object in CBCT device had no effect on CT Number [6].

Veyre-Goulet et al. confirmed that CBCT images are valuable for determining the shape of alveolar bone before implant therapy [7].

According to a study by Scarfe et al, CBCT is capable of providing diagnostic images of high resolution and quality in a short scan time (10 to 70s) and radiation dose of 15 times less than that of conventional CT scans [15].

Florian et al. showed that NewTom9000 has less value in displaying spongy bone grafts than cortical bone grafts [16].

Lagravere et al, also concluded that CBCT is a valuable tool for determination of CT number (Hounsfield Unit) [17]. Schulze et al. showed that CBCT is capable of detecting osteomyelitis and trauma to spongy and cortical bone [18]. Lascala et al. found that actual images are always larger than those obtained by CBCT; but these differences are only detectable in intracranial measurements. CBCT images underestimate the intracranial distances but are suitable for linear measurement of other structures in close vicinity to oral and maxillofacial region and provide more accurate images [20]. Araki et al. found the new CBCT system to provide 3D volumetric images of high resolution that are suitable for evaluation of oral and maxillofacial disorders [21].

Walker et al. concluded that 3D volumetric imaging of impacted canine teeth can detect the presence or absence of canine tooth, size of dental follicle, deviation of the longitudinal tooth axis, relative buccal and lingual position, the amount of bone covering the tooth, status of adjacent teeth, adjacent anatomical landmarks, and a view of tooth development [25]. Stratemann et al. reported that the volumetric data obtained by the two CT scan systems (Mercuray and NewTom) were completely accurate compared to the physical measurements of the skull (gold standard) and the relative error rate was less than 1% [27]. Pinsky et al. showed that CBCT has the potential to be an accurate, non-invasive, practical and reliable technique for determining the magnitude of the injury and trauma to bone [30].

2. Articles comparing different CBCT systems (NewTom9000, NewTom3G, CB Mercuray, i-CAT) with one another and with other imaging modalities

A total of 20 articles were placed in this group and evaluated in 5 major subgroups. Subgroup 1 articles compared different CBCT systems (NewTom3G, NewTom9000, CB Mercuray, i-CAT). Two articles were assigned to this subgroup (4, 5). Subgroup 2 contained articles comparing CBCT with other CT systems; 13 articles were assigned to this subgroup [9, 11, 13, 14, 19, 22-24, 29, 31-34].

Table 3: The list of review articles about CBCT

Number	Title
1	Effect of object location on the density measurement and Hounsfield conversion in a New Tom 3G cone beam computed tomography unit [6]
2	Accuracy of linear measurement provided by cone beam computed tomography to assess bone quantity in the posterior maxilla: a human cadaver study [7]
3	Clinical applications of cone-beam computed tomography in dental practice [15]
4	Imaging of bone transplants in the maxillofacial area by New Tom 9000 cone-beam computed tomography: A quality assessment [16]
5	Density conversion factor determined using a cone-beam computed tomography unit New Tom QR-DVT 9000 [17]
6	Diagnostic criteria for the detection of mandibular osteomyelitis using cone-beam computed tomography [18]
7	Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-New Tom) [20]
8	Characteristics of a newly developed dentomaxillofacial X-ray cone beam CT scanner (CB MercuRay): system configuration and physical properties [21]
9	Three-dimensional localization of maxillary canines with cone-beam computed tomography [25]
10	Comparison of cone beam computed tomography imaging with physical measures [27]
11	Accuracy of three-dimensional measurements using cone-beam CT [30]

Table 4: The list of articles comparing CBCT with other imaging modalities

Number	Title	Author	Publication year	Compared modality
1	Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions [4]	Haiter-Neto et al,	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 [5]	Korbmacher et al,	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 [9]	Hintze et al,	2006	Comparison of CBCT (NewTom3G) with conventional tomography
4	In vitro cone beam computed tomography imaging of periodontal bone [10]	Mol et al,	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 [12]	Schulze et al,	2004	Comparison of CBCT with MDCT and conventional radiography
6	Image quality vs radiation dose of four cone beam computed tomography scanners [13]	Loubele et al,	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 [14]	Draenert et al,	2006	Comparison of CBCT (NewTom 9000) with MDCT (Philips MX 8000)
8	Dosimetry of 3 CBCT devices for Oral and Maxillofac Radiology: CB Mercuray, New Tom 3G and i-CAT [19]	Ludlow et al,	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 [22]	Hintze et al,	2007	Comparison of CBCT (NewTom3G) with conventional tomography
10	Three-dimensional accuracy of measurements made with software on cone-beam computed tography images [23]	Lagravere et al,	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 [24]	Hashimoto et al,	2006	Comparison of CBCT with MDCT

12	Quantitative measurements obtained by micro-computed tomography and confocal laser scanning microscopy [26]	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 [28]	Simon et al,	2006	Comparison of CBCT (NewTom3G) with biopsy
14	Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography [29]	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 [8]	Özmeric et al,	2008	Comparison of CBCT with conventional radiography
16	Radiation absorbed in maxillofacial imaging with a new dental computed tomography device [11]	Mah et al,	2003	Comparison of CBCT with other CT systems
17	A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT): Part I. On subjective image quality [31]	Liang et al,	2009	Comparison of CBCT with MDCT
18	A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT). Part II: On 3D model accuracy [32]	Liang et al,	2009	Comparison of CBCT with MDCT
19	Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications [33]	Loubele et al,	2008	Comparison of CBCT with MDCT
20	Radiological diagnosis of periapical bone tissue lesions in endodontics: a systematic review [34]	Petersson et al,	2012	Comparison of CBCT with other CT systems

Subgroup 3 compared CBCT with conventional radiography. Three articles fell into this subgroup [8, 10, 12]. Subgroup 4 included articles comparing CBMCT with laser scanning. One article was included in this subgroup [26]. Subgroup 5 included one article comparing CBCT and biopsy [28]. Characteristics of these articles are demonstrated in Table 4. It should be mentioned that the new systems have different features. For example, New Tom VG uses flat panel and provides clearer images than NewTom9000 and New Tom.

2A. Comparison of CBCT with other CTs

Liang et al, in their study used a high-resolution laser scanner as the gold standard for comparison of the accuracy of the 3D model obtained by CBCT and multi-slice computed tomography (MSCT) and reported that the mean deviation from the gold standard was 0.137 mm for MSCT, 0.282 for CBCT, 0.225 for i-CAT, 0.165 for Accuitomo, 0.386 for New Tom and 0.206 for Scanora and Galileos [32]. Liang et al, also reported that Accuitomo was superior to MSCT and other CBCT systems in displaying anatomical landmarks; whereas MSCT is superior to other CBCT systems in reducing image noise [31]. Loubele et al. compared the efficacy of CBCT and MSCT and the following results were obtained: the effective dose was in the range of 13-82 μSv for CBCT and 474-1160 μSv for MSCT. These rates were lower than those of Accuitomo and higher than those of i-CAT [33]. Suomalainen et al. compared the accuracy of linear measurements obtained using CBCT and MSCT and reported that the mean measurement error was 4.7% for CBCT and 8.8% for MSCT in a dry mandible. This rate was 6.6% for CBCT and 5.4% for MSCT for mandible immersed in sucrose solution [30]. Mah et al. compared the absorbed dose of tissues by New Tom 9000 and other CTs and found that the effective dose for maxillofacial imaging with New Tom 9000 was 50.3 muSv; which was significantly less than that of conventional CTs [11]. Draenert et al. compared imaging artefacts of New Tom and MDCT and reported that scans with NewTom9000 showed stronger artefacts than MDCT [14]. Lagravere et al. compared the accuracy of linear measurements made on CBCT and coordinate measuring machine (CMM) and reported that t-test found no significant difference in linear and angular measurements between the CMM and New Tom 3G and the difference in this respect was less than 1 mm and 1degree, respectively [23]. Ludlow et al. in dosimetry of 3 CBCT devices reported the calculated dose (in mSv, E1990, E2005) to be (45, 59) for New Tom 3G, (135, 193) for i-CAT and (477, 558) for CB Mercuray. These values were 4 to 42 times greater than the panoramic examination doses (6.3 mSv, 13.3 mSv) [19]. Hashimoto et al. compared the image performance between CBCT and four-row multi-detector helical computed tomography (MDCT). MDCT images were used as the standard. CBCT images were evaluated using a 5-level scale. Assessment of imaging performance revealed that CBCT images had higher quality than MDCT images and that CBCT is a useful imaging modality in dentistry [24]. Loubele et al, in another study on image quality and radiation dose of 4 different CBCT systems (i-CAT, NewTom3G, CB Mercuray, Accuitomo) reported that the most favorable radiation dose versus image quality belonged to i-CAT. The lowest image quality belonged to Mercuray. The highest radiation dose belonged to Mercuray and Somatom Sensation and the lowest belonged to Accuitomo 3D [13]. In another study done by Hintze et al, image accuracy of CBCT and conventional CT was compared and the results found no significant differences between the two systems for detection of skeletal changes. Sensitivity and specificity of CBCT were compared for detection of flattening, defects and osteophytes. In the sagittal (lateral) dimension, the mean sensitivity value was 0.14 for CBCT and 0.13 for conventional CTs. In the cross-sectional dimension, the mean sensitivity was 0.3 for CBCT and 0.2 for conventional CTs. The mean specificity in the sagittal (lateral) dimension was 0.92 for CBCT and 0.97 for conventional CTs. This value for the cross-sectional dimension was 0.93 in CBCT and 0.94 in conventional CTs.

In other words, the mean sensitivity for various changes was usually low and varied from 0.11 for flattening in conventional CTs to 0.4 for defects on cross-sectionalCBCT images. The mean specificity was high for various changes ranging from 0.87 for CBCT cross-sectional views of the flattening to 0.99 for CT images of osteophytes [22].

Schulze et al. compared the radiation exposure of CBCT and conventional CTs and found that multislice CT had higher exposure values than CBCT and thus, CBCT is safer that multislice CT systems [12].

Hintze et al. failed to find a significant difference for detection of skeletal changes in condyle and articular bone between two CBCT systems namely NewTom3G and conventional tomography [9].

Petersson et al, in their systematic review in 2012 concluded that evidence regarding the equal diagnostic accuracy of the digital intraoral radiography and the conventional film technique is insufficient. The same goes for CBCT. They failed to draw any conclusion about the accuracy of radiological examination for detection of periapical bone tissue changes or condition of tooth pulp [34].

2B. Comparison of different CBCT systems

Haiter-Neto et al. compared NewTom3G and Accuitomo CBCT systems and reported that NewTom3G had lower diagnostic accuracy for detection of caries than intraoral imaging system and Accuitomo [4]. It should be noted that NewTom3G was among the first products of this company and the newer systems have higher image quality; particularly the latest product New Tom VG that uses flat panel technology and has a very high image resolution. Korbmacher et al. compared NewTom9000 and Mobile Arcadis 3D CBCT systems and conventional radiography in terms of image quality for orthodontic purposes and concluded that CBCT systems are superior to conventional radiography in this respect [5].

2C. Comparison of CBCT with conventional radiography

Özmeric et al. compared CBCT (NewTom9000) and conventional radiography (RG) in terms of image quality and showed that CBCT had a lower quality than RG [8].

Mol et al. compared CBCT (NewTom9000) and conventional radiography in terms of quantitative and diagnostic information and found that NewTom9000 was superior to RG in this respect (10).

Schulze et al. compared CBCT with MDCT and RG in terms of radiation exposure and showed that

MDCT, CBCT and RG had the highest radiation exposure in a decreasing order [12].

2D. Comparison of CBCT with laser scanningmicroscopy

Kamburoglu et al. compared CBCT with laser scanning microscopy and despite the strong correlation between the two, it was shown that CBCT significantly underestimated the diameters and volumes [26].

2E. Comparison of CBCT with biopsy

Simon et al. performed differential diagnosis of periapical lesions using CBCT and biopsy and concluded that CBCT provides an accurate diagnosis compared with biopsy and histology without the need for an invasive surgery or waiting for a year to see the results of non-surgical therapy [28].

Discussion

Numerous studies are available on CBCT and the majority of them have a diagnostic or descriptive design. These studies aimed at assessing the application of CBCT, its diagnostic accuracy and technical properties namely the radiation dose, resolution, contrast and etc. Limited evidence exists regarding the efficacy of CBCT in the course and outcome of treatment and the existing ones are mostly controversial. These factors seem to change over time by the advances in technology. The CBCT system is produced in different designs and the results are different based on the type of system used. However, these differences are mostly insignificant. Studies comparing older CBCT systems with MSCT have shown that the image quality in MSCT is higher than that of CBCT. More recent studies comparing newer CBCT systems with MSCT have reported reverse results. CBCT has some advantages over similar systems namely higher image quality, high speed, easy application, low radiation dose and providing a 3D volumetric image by one time radiation. Based on the available evidence, CBCT has low sensitivity and high specificity. It seems that CBCT can be an accurate, non-invasive and practical technique for estimation of the magnitude of dental and skeletal trauma especially in the oral and maxillofacial region. Considering the various technical characteristics of this technology, it should be used for specific purposes by expert individuals. At present, CBCT has the highest application in dentistry and maxillofacial surgery and is mostly purchased by dentists and maxillofacial surgeons (not radiologists). Considering its technical aspects, it is suggested that CBCT be used by the oral and maxillofacial radiologists. CBCT should not be used as the only imaging modality in poly-trauma patients because the intracranial assessments cannot be done accurately by this technique alone. Based on the available literature, this system is suitable for import and use in Iran. However, number of imported systems, their location of use, indications for use and related tariffs have to be precisely controlled.

Conclusion

CBCT technology is now commonly used in developed countries for obtaining detailed information regarding the oral and maxillofacial region and can greatly help clinicians in diagnosis and treatment of maxillofacial disorders.

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REFERENCES

1- Bridges JF, Jones C. Patient-based health technology assessment: A vision of the future. Inter J Tech Assess in Health Care. 2007 Winter; 23(1):30-5.

2- Garber AM. Can technology assessment control health spending? Health Aff. 1994 Summer;13(3):115-26.

3- De Vos W, Casselman J, Swennen G. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Inter J Oral and Maxillofac Surg. 2009 Jun;38(6):609-25.

4- Haiter-Neto F, Wenzel A, Gotfredsen E. Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions. Dentomaxillofac Radiol. 2008 Jan;37(1):18-22.

5- Korbmacher PDH, Kahl-Nieke B, Schöllchen M, Heiland M. Value of two cone-beam computed tomography systems from an orthodontic point of view. J Orofacial Orthopedics/ Fortschritte der Kieferorthopädie. 2007 Jul; 68(4):278-89.

6- Lagravère M, Carey J, Ben-Zvi M, Packota G, Major P. Effect of object location on the density measurement and Hounsfield conversion in a NewTom 3G cone beam computed tomography unit. Dentomaxillofac Radiol. 2008 Sep; 37(6): 305-8.

7- Veyre-Goulet S, Fortin T, Thierry A. Accuracy of linear measurement provided by cone beam computed tomography to assess bone quantity in the posterior maxilla: a human cadaver study. Clini Imp Dent & Related Res. 2008 Dec; 10(4):226-30.

8- Özmeric N, Kostioutchenko I, Hägler G, Frentzen M, Jervøe-Storm P-M. Cone-beam computed tomography in assessment of periodontal ligament space: in vitro study on artificial tooth model. Clin Oral Invest. 2008 Sept; 12(3):233-9.

9- Hintze H, Wiese M, Wenzel A. Cone beam CT and conventional tomography for the detection of morphological temporomandibular joint changes. Dentomaxillofac Radiol. 2007 May; 36(4):192-7.

10- Mol A, Balasundaram A. In vitro cone beam computed tomography imaging of periodontal bone. Dentomaxillofac Radiol. 2008 Sept;37(6):319-24.

11- Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. Oral Surg Oral Med Oral Path Oral Radiol and Endod. 2003 Oct;96(4):508-13.

12- Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4-and 16-slice computed tomography, cone beam computed tomography systems and conventional radiography. Dentomaxillofac Radiol. 2004 Mar;33(2):83-6.

13- Loubele M, Jacobs R, Maes F, Denis K, White S, Coudyzer W, et al. Image quality vs radiation dose of four cone beam computed tomography scanners. Dentomaxillofac Radiol. 2008 Sept;37(6):309-19.

14- Draenert F, Coppenrath E, Herzog P, Müller S, Mueller-Lisse U. Beam hardening artefacts occur in dental implant scans with the NewTom® cone beam CT but not with the dental 4-row multidetector CT. Dentomaxillofac Radiol. 2007 May;36(4):198-203.

15- Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J-Can Dent Ass. 2006 Feb; 72 (1):75.

16- Draenert FG, Gebhart F, Neugebauer C, Coppenrath E, Mueller-Lisse U. Imaging of bone transplants in the maxillofacial area by NewTom 9000 cone-beam computed tomography: A quality assessment. Oral Surg Oral Med Oral Path Oral Radiol and Endod. 2008 Jul; 106(1): e31-e5.

17- Lagravere MO, Fang Y, Carey J, Toogood RW, Packota GV, Major PW. Density conversion factor determined using a cone-beam computed tomography unit NewTom QR-DVT 9000. Dento Maxillofac Radiol. 2006 Nov; 35 (6):407-9.

18- Schulze D, Blessmann M, Pohlenz P, Wagner KW, Heiland M. Diagnostic criteria for the detection of mandibular osteomyelitis using cone-beam computed tomography. Dento Maxillofac Radiol. 2006 Jul; 35(4):232-5.

19-Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for Oral and Maxillofac Radiology: CB Mercuray, NewTom 3G and i-CAT. Dento Maxillofac Radiol. 2006 Jul;35(4):219-26.

20-Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dento Maxillofac Radiol. 2004 Sept;33(5):291-4.

21-Araki K, Maki K, Seki K, Sakamaki K, Harata Y, Sakaino R, et al. Characteristics of a newly developed dentomaxillofacial X-ray cone beam CT scanner (CB MercuRay): system configuration and physical properties. Dento Maxillofac Radiol. 2004 Jan;33(1):51-9.

22-Hintze H, Wiese M, Wenzel A. Comparison of three radiographic methods for detection of morphological temporomandibular joint changes: panoramic, scanographic and tomographic examination. Dento Maxillofac Radiol. 2009 Mar; 38(3):134-40.

23-Lagravere MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. Am J Orthod and Dentofac Orthoped. 2008 Jul;134(1):112-6.

24-Hashimoto K, Kawashima S, Araki M, Iwai K, Sawada K, Akiyama Y. Comparison of image performance between cone-beam computed tomography for dental use and four-row multidetector helical CT. J Oral Sci. 2006 Mar; 48(1):27-34.
25-Walker L, Enciso R, Mah J. Three-dimensional localization of maxillary canines with cone-beam computed tomography. Am J Orthod & Dentofac Orthoped. 2005 Oct; 128 (4):418-23.
Kamburoğlu K, Barenboim S, Arıtürk T, Kaffe I. Quantitative measurements obtained by micro-computed tomography and confocal laser scanning microscopy.
26-Dentomaxillo Radiol. 2008 Oct;37(7):385-91.
27-Stratemann S, Huang J, Maki K, Miller A, Hatcher D. Comparison of cone beam computed tomography imaging with physical measures. Dentomaxillofac Radiol. 2008; 37(2):80-93.
28-Simon JH, Enciso R, Malfaz J-M, Roges R, Bailey-Perry M, Patel A. Differential diagnosis of large periapical lesions using cone-beam computed tomography measurements and biopsy. J Endod. 2006 Feb;32(9):833-7.
29-Suomalainen A, Vehmas T, Kortesniemi M, Robinson S, Peltola J. Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography. Dentomaxillofac Radiol. 2008 Jan;37(1):10-7.
30-Pinsky H, Dyda S, Pinsky R, Misch K, Sarment D. Accuracy of three-dimensional measurements using cone-beam CT. Dentomaxillofac Radiol. 2006 Nov;35(6):410-6.
31-Liang X, Jacobs R, Hassan B, Li L, Pauwels R, Corpas L, et al. A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT): Part I. On subjective image quality. Eur J of Radiol. 2010 Aug; 75(2): 265-9.
32-Liang X, Lambrichts I, Sun Y, Denis K, Hassan B, Li L, et al. A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT). Part II: On 3D model accuracy. Eur J Radiol. 2010 Aug; 75(2): 270-4.
33-Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol. 2009 Sept; 71 (3):461-8.
34-Petersson A, Axelsson S, Davidson T, Frisk F, Hakeberg M, Kvist T, et al. Radiological diagnosis of periapical bone tissue lesions in endodontics: a systematic review. Inter Endod J. 2012 Sept;45(9):783-801.