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THE USE OF CONE-BEAM COMPUTED TOMOGRAPHY IN AN ORTHODONTIC DEPARTMENT IN BETWEEN RESEARCH AND DAILY CLINIC

A correct orthodontic diagnosis needs to be based on accurate images of the craniofacial region and is crucial for the development of a valid treatment plan. A cone-beam computed tomography (CBCT) scanner allows 3D imaging of the craniofacial complex. CBCT scanners represent a significant advantage in imaging capabilities for dentistry and orthodontics, replacing conventional 2D radiographic images with 3D data sets and only a small increase in radiation. The present study surveys the rationale, advantages, and disadvantages of the available CBCT appliances and presents answers to questions often asked in relation to this technology. World J Orthod 2008;9: 269–282.

Cone-beam computed tomography (CBCT) was introduced to the dental community in 1998[1]; since then, CBCT scanners have been used in a growing number of specialties within dentistry. Traditionally, orthodontists have applied a combination of panoramic and lateral cephlometric radiography as the key diagnostic records in treatment planning. The errors implicit in both types of examinations have repeatedly been addressed,[2] and supplements to the standard exposures, such as 45-degree images of frontal and axial exposures, have been recommended to obtain more precise information.[3] Various methods that make use of 2D images have been implemented to get 3D information if it was considered necessary for diagnosis and treatment planning.[4]

Although computed tomography (CT) was introduced in 1971,[5] its application within dentistry has been restricted to very specific cases due to the high levels of radiation given to the patient and high cost of the scanning. On the other hand, CBCT scanning is superior cost-wise to the 2D radiographic images with respect to increased information and to medical CTs with respect to radiation dose and cost. The replacement of conventional radiographs with 3D-capable devices therefore appears to be an unstoppable trend.[6] This is depicted by the fact that despite an initial period of limited interest in CBCT technology and the relatively long time that elapsed between the introduction of the first dental CBCT scanner in 1998 and its successor in 2002, there has been a recent surge of interest. This

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Table 1 Overview of the available CBCT scanners on the market

Name	Manufacturer	Patient position	Detector type	Scan dimension Øxh (mm)	Voxel dimension (mm)	Scan time (s)	Exp. time (s)	Degree	Voltage (kV)	Current (mA)	Focal spot size (mm)	Year	Base size (cm)
NewTom 3G	Quantitative Radiology-srl, Verona, Italy	Supine	Image intensifier (6, 9, 12 inch) and CCD camera	200×200 150×150 100×100	0.1–0.4	36	5.4	360	110	< 10	0.5–1.5	1998 and 2004	200×250
3D Accuitomo	J. Morita Mfg, Kyoto, Japan	Seated	Image intensifier and CCD camera	40×30	0.125	18	–	360	60–80	1–10	0.5×0.5	2002	162×120
CB MercuRay	Hitachi Medical System, Singapore	Seated	Image intensifier (6, 9, 12 inch) and CCD camera	190×190	0.2–0.376	10	–	288	60–120	10–15	–	2002	196×190
i-CAT	Imaging Sciences International, Hatfield, Pennsylvania, USA	Seated	Cesium-iodide scintillator and amorphous silicone flat panel	170×130 170×170*	0.4–0.2	20–40	–	360 360×2	120	3–8	0.5	2004	149×112
ILUMA	IMTEC Imaging, Ardmore, Oklahoma, USA	Seated	Cesium-iodide scintillator and amorphous silicone flat panel	170×100 190×190	0.1–0.4	< 40	–	360	120	4	0.3	2006	107×142
PROMAX 3D	Planmeca OY, Helsinki, Finland	Vertical	Cesium-iodide scintillator and amorphous silicone flat panel	50×40 50×80 80×80	0.16	18	6	194	50–84	—	0.5	2006	–
3D Accuitomo FPD	J. Morita Mfg, Kyoto, Japan	Seated	Cesium-iodide scintillator and amorphous silicone flat panel	40×40 60×60	0.125	18	–	360	60–80	1–10	0.5×0.5	2007	162×120
GALILEOS	Sirona, Bensheim, Germany	Vertical	Image intensifier and CCD camera	150×150	> 0.15	< 15	–	>200	85	5–7	–	2006	–
NewTom VG	Quantitative Radiology-srl, Verona, Italy	Vertical/ seated	Cesium-iodide scintillator and amorphous silicone flat panel	155×105	0.3	~24	3.6	360	110 (90)	< 15	0.3	2007	144×110
3D eXam	Kavo Dental, Biberach, Germany	Seated	Cesium-iodide scintillator and amorphous silicone flat panel	160×130 230×170	0.12–0.4	8.5–24	–	360	90–120	3–8	0.5	2007	120×110
Picasso Pro & Master	E-WOO Technology, Republic of Korea	Vertical/ seated	Cesium-iodide scintillator and amorphous silicone flat panel	120×70 200×190 200×150	0.1	15–24	–	360	40–90	2–10	0.5	2005	180×170
Scanora 3D	Soredex, Helsinki, Finland	Seated	Cesium-iodide scintillator and amorphous silicone flat panel	60×60 100×75 145×75	0.13–0.35	10–20	2–5	–	65–85	0.5–8	0.4	2007	154×110
9000 3D	Kodak, Carestream Health, Rochester, New York USA	Vertical	Cesium-iodide scintillator and amorphous silicone flat panel	50×37	0.076	~14	–	360	60–90	2–15	0.5	2007	190×170
PreXion 3D	Tera Recon, San Mateo, California, USA	Seated	Cesium-iodide scintillator and amorphous silicone flat panel	81×76	—	19–37	–	360	90	4	0.2	2007	117×157

resulted in the introduction of at least 6 new CBCT devices in the last 3 years (Table 1). Yet, there might be a number of unanswered questions for orthodontists. At the Department of Orthodontics of Aarhus University, a NewTom 3G scanner (Quantitative Radiology, Verona, Italy) has been used for more than 3 years. The present study is based on our experience with cone-beam technology.

HOW DOES A CBCT SCANNER WORK?

A fixed anode (and in few cases, a rotating anode) is positioned on 1 end of a rotating stage. On the other end, a detector is mounted. This can be either an image intensifier detector (IID), typically a phosphor-photocathode screen coupled with a charged-coupled device (CCD) camera, or a flat-panel detector (FPD), typically a cesium-iodide array scintillator coupled with a photo-sensor array. Typically, the anode-detector complex rotates 360 degrees around the head of the patient (Table 1), and for each degree, a radiograph (projection) is taken. Each projection is preliminarily corrected for geometrical and dynamic distortions; subsequently, all the projections are reformatted using a 3D-filtered, back-projection algorithm to generate the 3D data sets.[1] For a more exhaustive explanation, refer to the technical description by Feldkamp et al[7] and possible applications within orthodontics.[6,8]

WHAT ARE THE MAIN DIFFERENCES BETWEEN CONVENTIONAL RADIOGRAPHIC DEVICES AND CBCT SCANNERS?

Due to the differences in the acquisition procedure, CBCT scanners differ substantially from conventional radiographic devices. Accordingly, conventional radiographs and CBCT-generated images are different. CBCT data sets are truly 3D and therefore allow for dynamic generation of images, while conventional radiographs can only generate a single planar static image per examination. The static versus dynamic implies that from a single CBCT scan, it is possible to reformat the original data set to reproduce images (for example, OTPS and lateral and frontal cephalograms) typically obtained by conventional radiographs, whereas the other can generate only a static image that cannot be changed.[9]

WHY CHOOSE CBCT INSTEAD OF A MEDICAL CT SCANNER?

Dental CBCT machines are specifically built to study only the craniofacial skeleton; therefore, they are less complex than medical CT scanners. CBCT scanners present a limited gantry opening or a swing arm only large enough to accommodate the head of a patient. This construction allows for better collimation and efficiency in using the radiation beam. Among the advantages of CBCT to CT scanners are facility of use, less radiation, smaller footprint, and limited cost.[8,10–14] On the other hand, unlike medical CT scanners, CBCT scanners are not calibrated against density and therefore do not provide true Hounsfield units (HU).[5] This implies that the values assigned to each voxel in a CBCT scan are relative to HU and cannot be used directly to estimate bone density.

WHICH CBCT DEVICES ARE ON THE MARKET?

Table 1 shows that at the time of this writing, there are at least 14 CBCT scanners available. Also, CBCT scanners are not all built the same, and for that reason, they vary with respect to the information they provide. Comparing their field of view, the way the patient is positioned in the scanner, and, as stated by Farman and Scarfe, "CBCT-derived 2D cephalometric projections are limited to equipment that can image from nasion to gnathion vertically and from zygoma to

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Table 2 Advantages (+) and disadvantages (−) of image intensifier detectors (IIDs) and flat-panel detectors (FPDs)

	Complexity	Robustness	Distortion	Read out	Dynamic range	Radiation damage	Resolution	Physical dimension	Image dimension	Price
IIDs	=	=	−	+	=	=	=	−	+	=
FPDs	+	+	+	−	=	=	=	+	−	−

+, clear advantage; −, clear disadvantage; =, no advantages or disadvantages.

zygoma coronally,"[15] it is obvious that not all available CBCT scanners are suitable for use within orthodontics.

Another important aspect is the type of detector used in various CBCT scanners. While the first devices were equipped with IIDs, FPDs are used in more recent models. This shift reflects technological development, as well as differences in production costs of the detectors. Indeed, despite the fact that the interest in flat-panel imaging has been rising since the end of the last century,[16–18] the first CBCT scanner equipped with a FPD was the i-CAT scanner (Imaging Sciences International, Hatfield, Pennsylvania, USA), presented in late 2002 and commercially available in 2003. Some machines require the patient to be in a supine position, but the majority allow for patients to sit upright or stand during the examination. This shift influenced not only the marketing but also the way the CBCT machines are built. Indeed, CBCT scanners equipped with FPDs require less robust construction than the ones with IIDs and are less complex. This allows smaller vertical-type machines, which orthodontic practices seem to favor. The advantages and disadvantages of IIDs and FPDs are summarized in Table 2. More detailed information on this subject, as well as a description of the various detectors, can be found in the available literature.[19–21]

HOW DOES THE INFORMATION OBTAINED WITH A CBCT SCANNER COMPARE WITH THAT OBTAINED VIA OTHER METHODS?

A CBCT scanner can provide accurate 3D images of the bony structures of the skull, and by using the inverse image, it is possible to visualize the void inside the skull (ie, airways and sinuses). Moreover, by reformatting data sets, it is possible to generate an infinite number of images.

CBCT versus conventional panoramic radiographs

The conventional orthopantomogram (OTP) is affected by distortion and magnification errors, which are caused by the distance of the object to be examined (ie, teeth and skeletal structures) to the film and X-ray source. Therefore, the errors will vary according to the size and form of the mandible and will also be influenced by asymmetries in the dental arches and mandible (Fig 1). CBCT-generated OTPs are produced by tracing outlines on axial images. The generated images do not present any distortion or magnification errors. An additional advantage is that they do not present superimposition of the contralateral side or spinal column[22] (Figs 2a to 2c). Moreover, it is possible to generate multiple OTPs from CBCT data sets,

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Fig 1 Patient with symmetrical teeth. On the OTP, the teeth were distorted and exhibited a different magnification (ratio left/right molar = 0.78; ratio left/right deciduous molar = 0.74).

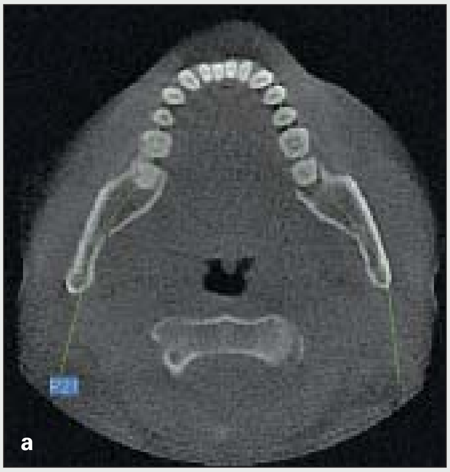

Fig 2 **(a)** Outline of the an axial image. **(b)** The corresponding CBCT-generated panoramic. **(c)** Conventional panoramic radiograph of the same patient. (Note the absence of superimposition of the contralateral side and spinal column on the CBCT-synthesized image.)

which, for example, can be relevant in cases of large overjet or asymmetries between the maxillary and mandibular arches: It is possible to generate 2 OTPs, 1 for each arch.

From conventional OTPs, it can be difficult or even impossible to establish pathologies related to the condyles. Therefore, if there is suspicion of pathology in the condylar area, extra radiological examinations (tomograms) may be ordered. In that case, the dose of radiation would be increased, even exceeding that of a CBCT scan, the latter allowing for more detailed analysis. As an example, the patient depicted in Fig 3 was referred after an

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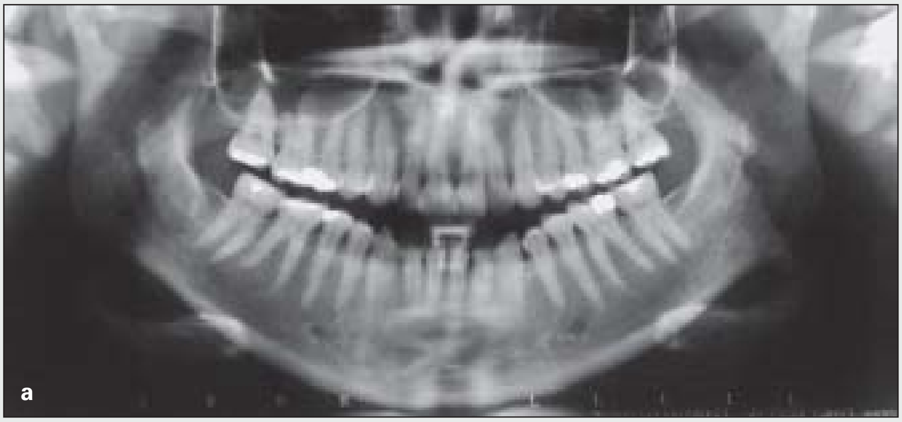

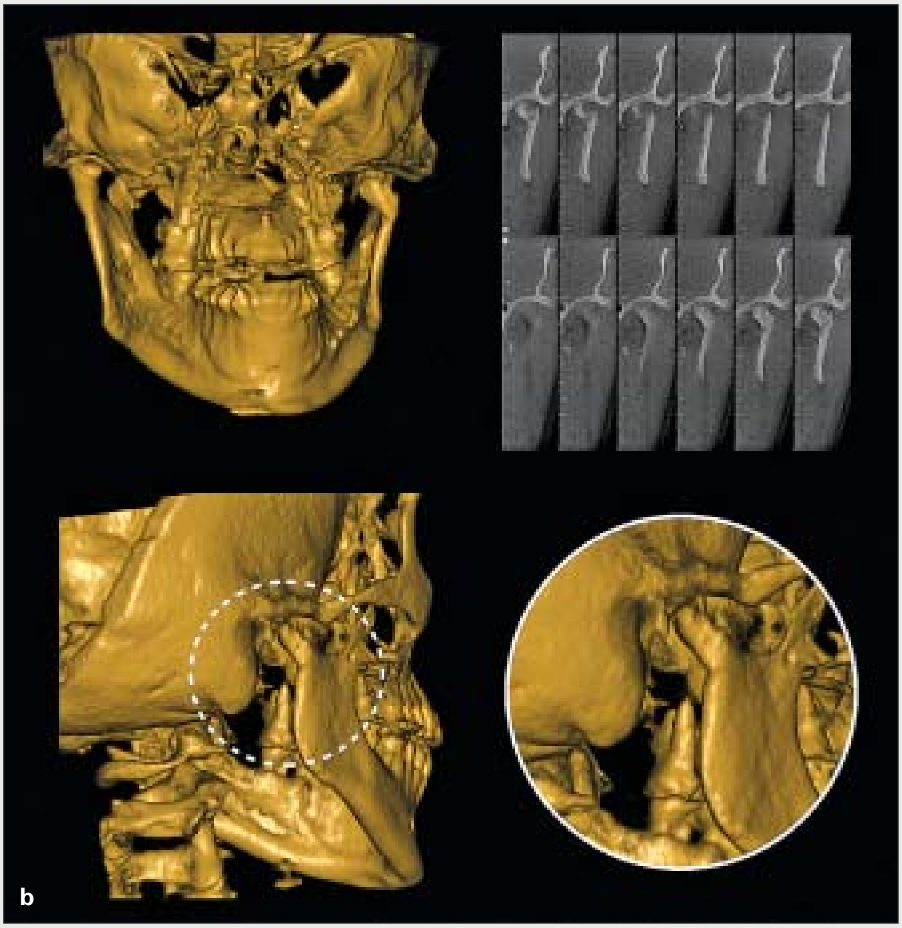

Fig 3 **(a)** Conventional panoramic image and **(b)** CBCT-generated images of a patient displaying a fracture of the right condyle.

accident that had resulted in asymmetry of the face. The patient was suffering from severe pain in the condylar area. From the conventional OTP (Fig 3a), only a slight shortening of the affected condyle was visible, but it was not possible to detect that the right condyle was fractured. On the other hand, from CBCT-generated cross-sectional images and 3D renderings (Fig 3b), the fracture of the condyle could easily be demonstrated and it could be seen that the fractured condyle had been displaced medially. This could explain why the OPT failed to depict the fracture, as the fractured condyle was positioned out of the plane of focus. This also explains

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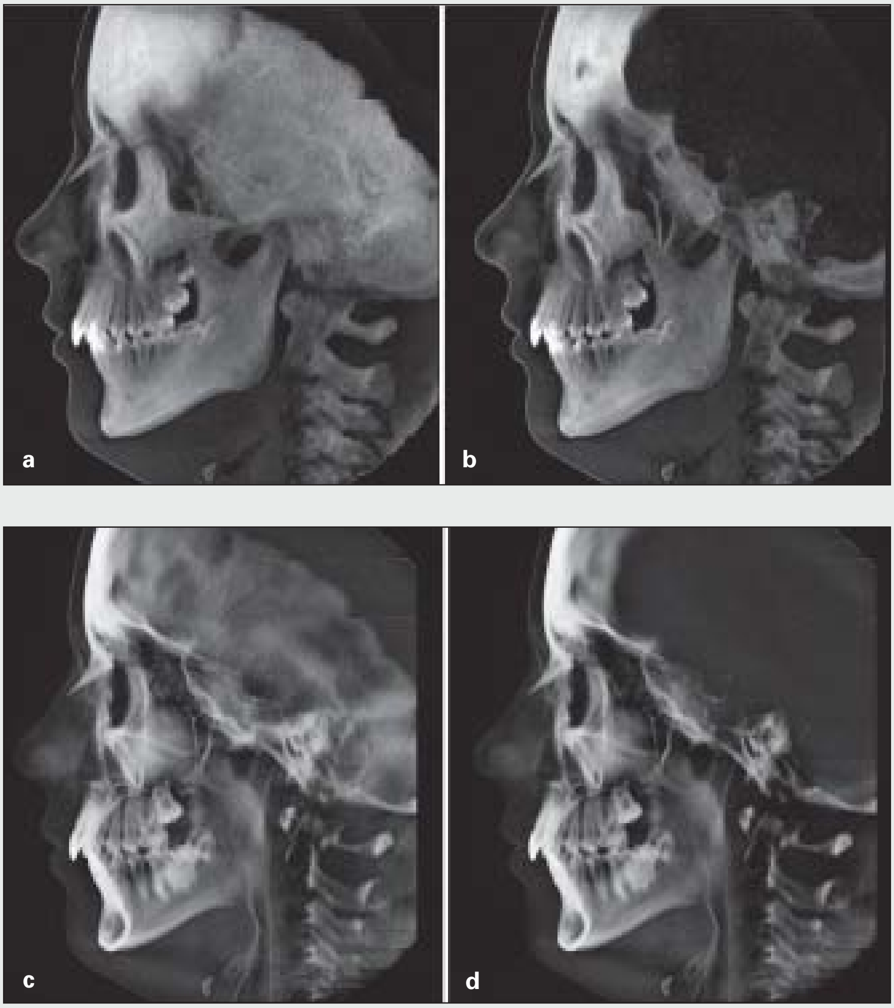

Fig 4 CBCT-generated lateral cephalometric images. **(a and b)** The MIP technique is applied. **(c and d)** RayCast technique is used. Note that in b and d, the left part of the skull and the right parietal bone are virtually removed and only the right part of the skull is represented.

why a conventional OTP will fail to illustrate the true morphology of a distorted mandible. The CBCT does allow a customized OTP, which can follow the actual shape and therefore reproduce the true morphology when constructing the image.

Conventional lateral cephalometric radiographs

The quality of conventional lateral cephalometric radiographs depends on the equipment used to capture the radiographic images. Indeed, the distance between the anode and film plays an important role in determining the degree of magnification between the right and left side of the head on the film. Moreover, the tendency is to reduce the dimension of radiographic machines and therefore the errors inherent in the cephalometric images recently became greater as the distances from anode to film were reduced from the 190 cm traditionally used in early cephalometric studies to the 150 cm in newer appliances. As the distance between the film and patient's head cannot be changed, the distortion errors, as well as the differential magnification of bilateral structures, have been further increased. In the past, to improve the quality of cephalometric imaging, a lead raster grid was used to diminish scattering.[3] This technique had the drawback of requiring an increased radiation dose and is no longer used.

From CBCT data sets, it is possible to generate lateral and frontal cephalometric images using visualization techniques such as the maximum intensity projection (MIP) algorithm and RayCast (Fig 4).

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Fig 5 The exact position in space of an ectopic canine is clearly visible when solid rendering of CBCT scans is adopted.

CBCT data sets offer the possibility to simulate parallel X-rays and represent the right and left parts of the skull separately. As such, superimposing of the bilateral structures can be avoided, the position of the teeth in the 2 sides can be determined, and it is possible to virtually excise all nonpertinent structures (Figs 4b and 4d).[22] Moreover, while not possible in conventional cephalometric images, the errors due to malposition of the patient during image acquisition can be corrected in CBCT-generated cephalograms by iterative adjustment of the data set.

Lateral and frontal cephlometric radiographs have been used in orthodontics for more than half a century to plan and analyze treatment modalities.[23] Kumar et al have demonstrated in an in vitro study involving dry skulls that CBCT-generated lateral cephalometric radiographs could be successfully used to make cephalometric measurements that are no different from measurements taken from conventional radiographs.[24] In our department, an equivalent study compared cephalometric measurements made on lateral CBCT-generated and conventional lateral cephalograms. The results corroborated those described by Kumar et al[24] and demonstrated that the RayCast technique is superior to MIP in visualizing structures needed for cephalometric analyses. This type of study suggests that the transition from an existing standard database based on 2D lateral cephalograms to 3D analysis of the skeleton can be gradually accomplished by using CBCT-generated cephalograms and therefore be more easily accepted by clinicians.

2D plain radiographic images, cross-sectional tomosynthetic slices, and CT scans

For particular patients, it is necessary to localize structures of the maxillofacial area with great precision in the 3 planes of space. In the past, to solve this problem, the combination of 2 paired coplanar images was suggested by Baumrind et al,[25] while Grayson recommended combining 2 perpendicular images.[4]

In relation to impacted canines, different methods using a combination of standard radiographs has been proposed.[26] More recently, a few researchers have gone so far as to use medical CT scanners to diagnose and make treatment plans in cases of impacted canine(s).[27–29] From these studies, it is evident that a CT investigation provides 3D information that is equal or superior to what could be obtained by using standard radiography. This information has proved to be essential for treatment planning of retained or ectopically erupting canines. CBCT technology has been adopted to achieve the same 3D visualization as using a medical CT scanner, so that a precise localization of the ectopic canines could be determined (Fig 5) without the inherent risks associated with CT examination.[30–32] In a study recently performed in our department,[33] the benefits of using CBCT scans instead of conventional 2D radiographic exami-

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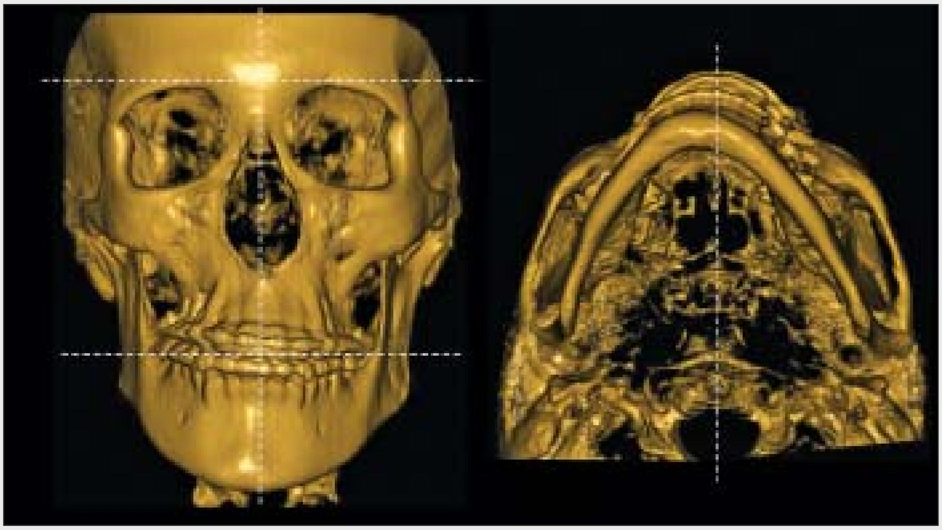

Fig 6 Skeletal asymmetries depicted using volume rendering.

nations have been demonstrated. 3D images make a difference in the treatment approach, especially in cases of canines in the center of the alveolar process.

In relation to patients with facial asymmetries, it is necessary to combine the information obtained from lateral, frontal, and axial radiographic examinations. Grayson attempted to solve the problem related to the localization of the asymmetry by combining several coronal and transversal planes.[34] This technique would be characterized by inherent difficulties due to different magnification of the various structures in the images. As with the medical CT, CBCT solves these problems but with lower cost and radiation dosage (Fig 6).

In patients with TMJ problems, cross-sectional tomosynthetic slices are sometimes required.[35] However, this technique requires multiple radiographic exposures, thus increasing the level of radiation dose. Even so, the orientation of the tomograms cannot be optimized unless based on previous axial images.[36] Tsiklakis et al described the advantages of using CBCT technology in the examination of the TMJ in respect to medical CT.[37] An example of how the TMJ can be visualized using CBCT technology can be seen in Fig 3b.

Like standard cephalometric images, CBCT-generated images taken at certain intervals can be superimposed. Whereas the lateral cephalometric images can illustrate the sagittal and vertical changes of the midsagittal structures of the facial skeleton in relation to the cranial base, CBCT images can be superimposed on various stable structures and changes quantified in all planes of space.[22] Indeed, in recent years, the capability of inducing substantial transversal expansion using "high-tech" wires and "intelligent" brackets has been almost universally advocated.[38] However, all the studies published have focused on the expansion taking place at the dental level but have failed to detect what had been happening at the periodontal tissue level. CBCT scans can be used to measure and quantify bone (re)modeling during orthodontic expansion of the jaws on large series of consecutive patients. The same type of study would be considered ethically unacceptable if medical CT examinations were used. A prospective study analyzing the treatment outcomes, as well as bone (re)modeling in patients undergoing orthodontic treatment, has recently been reported.[39]

Temporary skeletal anchorage devices (TSAD) represent another area where the advantages of CBCT technology could be fully exploited. TSAD are becoming more available in orthodontics, and CBCT scans represent a valuable way to analyze both bone thickness and quality at

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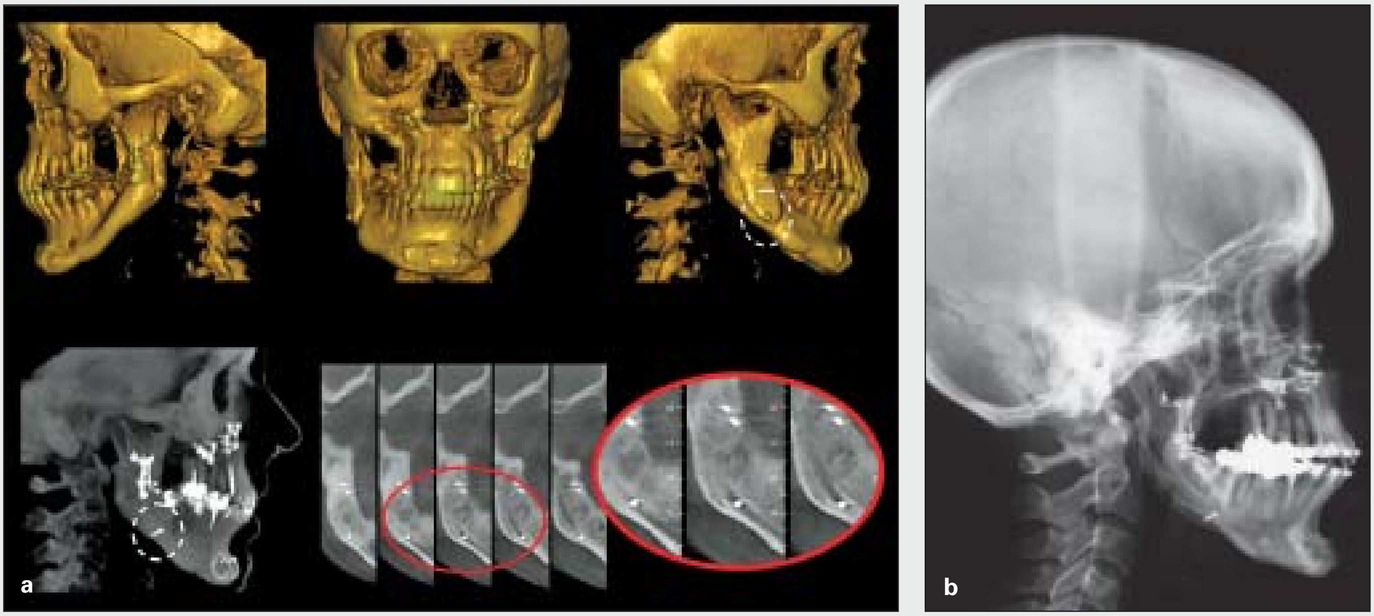

Fig 7 **(a)** Misplacement of an osteosyntesis screw highlighted with the CBCT technique. **(b)** Note that it is not possible to precisely locate the position of the screw on a conventional lateral cephalometric image.

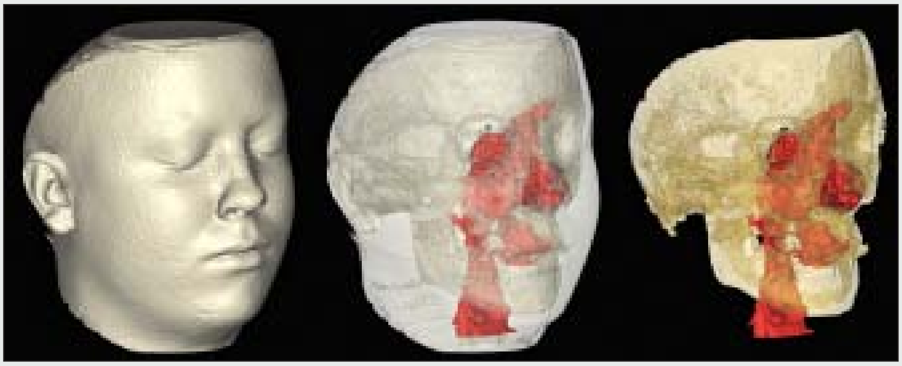

Fig 8 Segmentation and volume rendering of the airways.

the insertion site and improve the placement precision. The failure rate could thus be reduced and misplacement of TSAD could be avoided, as the actual insertion position can be evaluated in 3D. As an example, the misplacement of an osteosynthesis screw, easily highlighted using CBCT (Fig 7a), could not be verified on the conventional lateral cephalometric radiograph (Fig 7b).

CBCT represents a valid alternative to medical CT examination for planning orthognathic surgery. The assessment of the craniofacial structures for treatment planning and outcome evaluation has been proved to be satisfactory.[14,40–44]

A final advantage of CBCT technology is the possibility to clearly determine the boundary between soft tissues and air[15] (Fig 8). The 3D outline of airways, paranasal sinuses, and nasal cavities can be easily depicted and the volume of the nasopharyngeal area measured.[45] Unlike medical CT images, CBCT-generated data do not allow for discrimination among various types of soft tissues that display the same density.

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IS THE RADIATION DOSE AN ISSUE IN ORTHODONTICS?

Radiation dose is an important issue whenever radiographic examinations are needed. This holds true for CBCT examinations, as well as conventional radiographic investigations. It has been reported that a patient-effective dose from a CBCT machine varies from 45 µSv to 650 µSv.[46] This range is large, but it should be noted that this spread is strongly related to the machine, as well as to the type of examination performed.[47] On the other hand, it is worth reporting that 1 exposure for a full analog mouth series accounts for about 150 µSv[48] and that an analog OTP accounts for 54 µSv.[49] The patient-effective dose from a CBCT scanning session is similar to the 139 µSv a passenger receives during a round-trip flight from Paris to Tokyo.[50,51]

Ludlow et al[47] concluded that despite the fact that patients receive more radiation from CBCT scanners than conventional radiological examinations, the dose is not high compared to that of a medical CT scan. Moreover, these authors report that by using the BERT index (Background Equivalent Radiation Time), a NewTom 3G scan corresponds to 4 to 6 days of the equivalent per capita background dose (environmental radiation).

One cannot simply compare the radiation dose of a CBCT scan with that of standard radiography. Indeed, though the radiation dose of the latter is smaller, the images are static and cannot be changed; the information they provide is limited. On the other hand, the innate 3D characteristics of the CBCT data sets allow for the generation of virtually infinite numbers of reformatted images. For this reason, as clearly stated by Farman, CBCT scanners can demonstrate their innate superiority when a truly 3D data set is needed and therefore they should be used when the inherent 3D information could improve the outcome of the treatment provided,[52] always taking into account the "As Low as Reasonably Achievable" (ALARA) principle.

WHAT IS MORE IMPORTANT IN A CBCT DATA SET: THE VOXEL DIMENSION OR QUALITY?

This question could be reformulated as, "What do we need to see in a CBCT data set?" To evaluate how good a CBCT data set is, 2 factors have to be considered: the resolution and quality of the voxels of the data sets generated. While the resolution is strictly related to the way the machine is built, voxel quality is less easy to understand, though it is as important as the resolution. The voxel quality depends primarily on both the detector and number of projections. However, the amount of radiation plays an important role, as well. Indeed, the voxel quality is dependent on the noise in the image and the image contrast. By increasing the radiation dose, the noise can be reduced easily and quickly, thus improving the voxel quality. This procedure contrasts with the ALARA principle, however, and is therefore a compromise between the diagnostic value and dosage to be found. In this respect, it is important to prioritize what it is necessary diagnostically. It is essential to know if, from a diagnostic point of view, a CBCT scan is necessary at all and if so how the scan will be analyzed. Within the dental community, some clinicians are concerned about dose minimization, while others are primarily concerned in obtaining maximum-quality data sets regardless of radiation. An editorial by Farman[52] is quite enlightening: " . . . no matter how low is the dose, it is excessive if it is unlikely to improve the outcomes of the treatment provided." This concept, applied here to CBCT scanning technology, should also be considered when determining what radiographic examinations are really needed.

WHO IS RESPONSIBLE FOR THE INTERPRETATION OF THE CBCT SCAN?

Optimally, a maxillofacial radiologist would report the diagnostic assessment

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to the orthodontist. As this is rarely possible, interpretation could be up to the orthodontist, who should have acquired sufficient skill through his/her education to interpret most of the anatomy of the skull and neck and therefore identify pathologies. The basic courses in radiology are focused on the interpretation of 3D structures on a 2D image. The 3D CBCT image seems to be closer to the anatomical reality and therefore the interpretation should come more naturally. However, courses in 3D radiography could be part of the orthodontics curriculum and offered as continuing education programs so orthodontists could master the CBCT data sets. In cases of suspect anomalies/ abnormalities, orthodontists should confer with a radiologist. Therefore, given the fact that the orthodontist should be competent enough at least to recognize if something does not look right, close collaboration with a radiologist is necessary, especially if the orthodontist is not yet fully acquainted with CBCT scans. This approach has been followed at our department and is also used by Jerrold,[53] who, in his paper, focused on the liability of reading and interpreting the CBCT scans in light of nonexistent regulation at present. As progress cannot be stopped because of a lack of legislation, the orthodontist will face an initial period where some errors would undoubtedly happen. Medicolegal problems related to incidental findings are also dealt with by Kau et al,[46] who noted that by using CBCT, a "higher incidence of oral abnormalities than previously suspected" was found. The statement was supported by a study of 500 consecutive maxillofacial CBCT scans.[54] Incidental findings were found in 123 patients. Therefore, the matter of responsibility when these findings lead to pathological consequences is relevant.

WHAT RESOURCES ARE NEEDED TO TAKE AND INTERPRET A CBCT SCAN?

One of the aspects that hass not been fully discussed in the available CBCT-related literature is cost-benefit ratio. This can be calculated by weighing the total expected benefit from the use of a CBCT scanner against the total expected resources that have to be employed to take advantage of the device. The latter comprises both the pecuniary aspect, as well as the effort necessary to install the machine and run it efficiently. In this respect, the time required to retrieve and interpret relevant data from CBCT scans is quite important. Indeed, in contrast to traditional radiographic examination, CBCTs are by nature dynamic. As such, it has to be determined what images should be generated to fully exploit the information available from CBCT scans. The processing time can have a major impact on the workflow in an orthodontics practice. User-friendly software that can help speed the process of constructing and visualizing CBCT-generated images is needed. The software typically bundled with CBCT scanners can be augmented with third-party dedicated software to fulfill specific tasks (for example, orthodontic analysis and orthognathic surgery planning).

CONCLUSIONS

The combination of conventional radiographs, OTP, and cross-sectional tomosynthetic slices may be sufficient in a number of clinical situations; nevertheless, multiplanar imaging techniques (CT-generated images) do present advantages.[13]

Despite the fact that the shift from 2D to 3D appears to be irreversible, the replacement of the old system, based on "a conglomeration of geometrically unrelated, inaccurate two-dimensional images" with a more accurate method based on 3D information, is not going to happen immediately.[6] Yet, an increasing amount of 3D pre- and posttreatment data will soon be available to the orthodontic community. All this information could be stored in a database composed of records from universities and private practices. This will give an unprecedented possibility to analyze treatment

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outcomes in a truly 3D perspective. The resulting database would include records of frequently encountered situations, as well as rarely seen conditions. Data extracted from such databases could help evaluate different approaches to treatment and make treatment choices more evidence-based. Furthermore, this will help fully implement the concept of paperless portability and accessibility of patients' records.[55]

Every time new technology is introduced, many potential users initially reject it because its real value is not yet fully understood. After this initial phase, a small group starts to accept it, but the mainstream contends that it is still not useful (even if it might be applicable later). After time, a majority adopts the new technique. Finally, it becomes an industry standard. This evolution applies perfectly to CBCT technology.

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