The Advantages of new cone-beam technology in the study of head and neck region

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Introduction

Computed Tomography has a crucial role in maxillofacial imaging for diagnosis and pre-surgical planning. The possibility of selecting slices of the reconstructed volume oriented along any possible direction, free of structure overlapping and geometric distortion allow precise determination of conformation and size of anatomical sites and their relationship with adjacent parts. Nonetheless the dose charge to the patient is in general very high and determining the right balance between risks and benefits is not always easy, especially in young patients. In this context the relatively new Cone-Beam technology (CBCT) responds to the need of more precise representation of anatomical structure, not satisfied by conventional 2D radiology, combined with much lower dose exposure of the patient, being this a major drawback of conventional multislice CT (MSCT).
The key difference between multislice conventional CT and CBCT is implicit in its name: the X ray beam changes its shape from the 'a fan' in the former into a cone in the latter. Figure 1 shows the kinematic in a CBCT acquisition. In comparison with MSCT the linear detector array is substituted by a 2 dimensional detector. This means that while in MSCTs each projection corresponds to a thin slice of the entire volume, in CBCT it becomes a 2D radiograph which covers the entire volume of interest. As a consequence only one tube-detector rotation is sufficient to reconstruct the investigated volume. The projections saved during the tube rotation, being this a short (190^{o}) or a full scan (360^{o}) are elaborated with reconstruction algorithms and then transferred to softwares for further analysis and elaboration. Usually from a reconstructed volume, 2D images such as panoramic, sagittal, parasagital and coronal can easily be extracted.

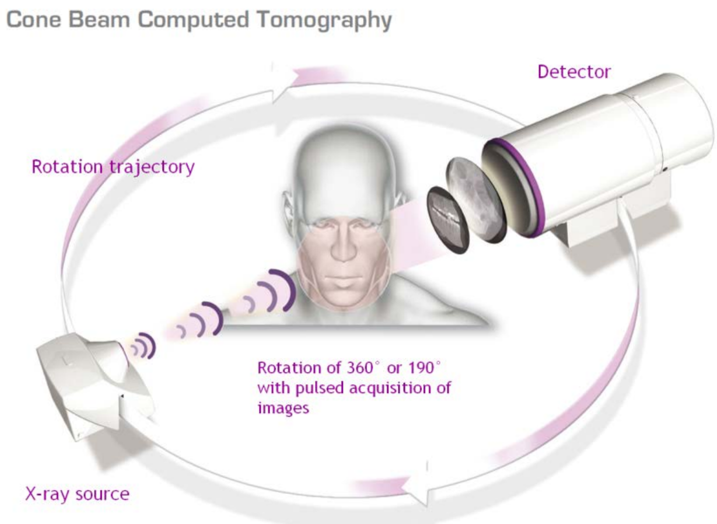

Fig. 1 *Working principle of cone beam CT. The X ray tube rotates around the patient acquiring 2D radiographs which represent the projections used to reconstruct the volume of interest.*

Surely one of the driving factor of the rapid diffusion of this technique is the low dose. According to the ALARA rule (As Low As Reasonably Achievable), risk from X-ray exposure should be always counterbalanced by benefit to patients. However since the first CBCT has been released on the market in 1998, numerous new devices have been presented with different structures and characteristics depending to the need they have tried to respond to. It follows that for example dose values vary significantly from one CBCT to another. Ludlow et al 2008 have demonstrated that while many CBCT effectively provide a dose which is between 1/10 and 1/20 of a conventional CT, others require doses up to half those of conventional CTs. Other factor that differentiates the devices is patient positioning which changes from standing to sitting to laying down. It has been clearly shown that this has immediate effects on image quality as head motion is reduced when patients are laying down even if no head restrains are used. Furthermore during the years the devices have evolved in two main groups: very specialized devices dedicated to one specific field of application or hybrid devices which cover multiple fields. The first type of device may be more suitable for a private practice while the second is addressed to clinics with interdisciplinary activities. The rapid diffusion of CBCTs has also raised an intense debate in particular related to the responsibility of the interpretation of the reconstructed volume. The exposed area is in fact often broader than what exposed in conventional 2D imaging and it is responsibility of the doctor executing the exam to interpret all the findings in the whole exposed area. This may put doctors in difficult situation as they may not feel comfortable in interpreting data outside their area of expertise. The small field of view CBCT, while reducing patient dose exposure also limit the exposed field to what the doctor can comfortably interpret. Small field of view are typical of specialized devices dedicated to the study of localized pathology such as that of few dental elements (4"). 6" field of view have been expressly designed to study both upper and lower jaws for multi-implant surgery. For pathology or treatment involving the entire maxillofacial district wider field of views (9", 12") may be used. Most devices having different field of view allow to select them easily by software or when only one is requested, it can be required at the order. Fig. 2 compares the volume reconstructed using a 4,6 and 9" FOV.

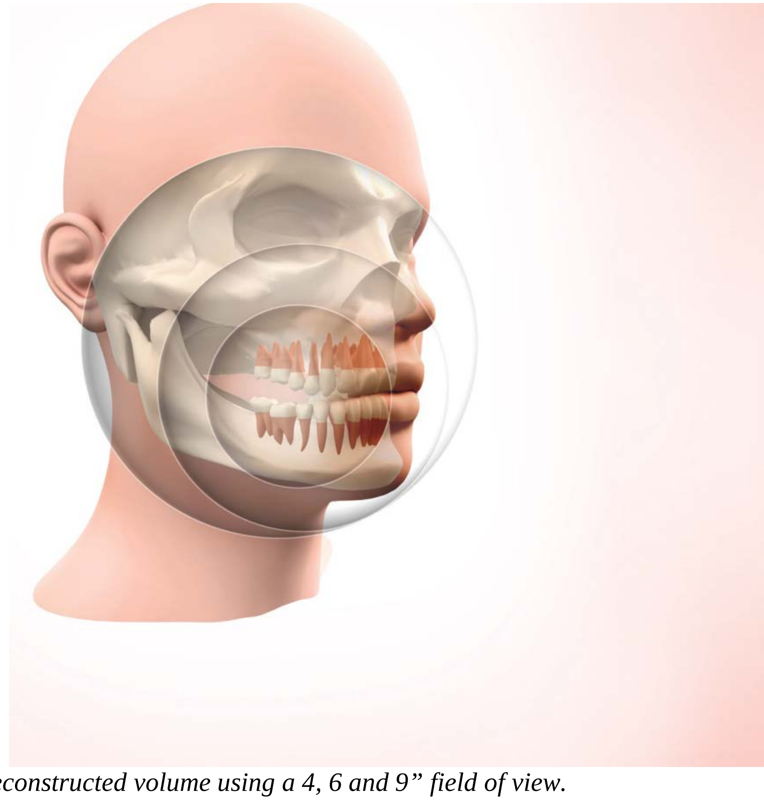

Fig. 2 *Comparison of reconstructed volume using a 4, 6 and 9" field of view.*

For what concerns the range of application, surely dentists have been the first to take advantage of this technology and the development of software dedicated to implant planning is surely becoming an indispensable tool which allows to transfer precisely into the patient mouth what has been planned reducing risks for the patient. Beside the application in dentistry, however many other applications generally related to the maxillofacial area are under intense investigation.

In this paper we present some clinical cases studied using the CBCT SkyVIEW. The clinical study will interest mainly children relative to orthodontic checkups, preoperative surgery planning, postoperative follow-up. Then some cases examined with the 9” field of view will be presented. To conclude several example of new applications, still under investigation will be illustrated.

Materials and Methods

For the present report we have routinely used a digital volume tomograph (SkyVIEW by MyRay, Cefla, Italy, www.my-ray.com). This system (see Figure 3) is a cone beam CT dedicated to oral and maxillofacial application. The system has been previously object of a clinic validation carried out on 51 adult patients and approved by the Ethical Committee of the University Hospital (Protocol Num 102/2007/O/Disp). This validation has demonstrated that the device is adequate for the investigation of pathologies of the oral cavity. The system consists of a pulsed X-ray tube (90 KV) and a beam intensifier detector mounted on a C arm which rotates around the patient head to acquire the projections necessary to the 3D volume reconstruction. Both full (360°) and short scan (190°) may be used. Depending on the area of interest the field of view size may be modified among 4, 6 or 9 inches in order to minimize dose to patient. While KVp and tube current are kept constant, pulse length is varied to achieve different acquisition profile (different mAs).

Parameter	Value
Detector	4", 6",9" Image Intensifier/CCD
X-ray source KVp (KV)	90
X-ray source current (mA)	6.5
Scanning Time (s)	15
Exposure Time (s)	7
Voxel Size (mm)	0.2
Reconstruction time (min)	1.5-3min
Patient Position	lying down

Fig.3 *Photo (left) and table (right) with the characteristic of the CBCT Skyview*

A thorough dosimetric classification has been carried out on the SkyVIEW in comparison with the MSCT LightSpeed 16 (GE). The results indicated that doses to patient are around 1/20 for the typical protocol and 1/10 for the highest dose protocol of those of the MSCT.

Clinical Cases using a 6” FOV

Nowadays medical imaging can provide indispensable information for the care of young patients in oral and maxillofacial pathology. The CBCT is a very attractive technology from this point of view as the biological risk for young people is much higher than in adult. In fact risk should be multiplied by a factor of x1.5 for age range 30-20 ys, x2 for 20-10ys and x3 in children with less than 10ys. It is evident that substituting a CBCT exam to a conventional CT one is highly recommendable for children.

Impacted teeth

Impacted teeth are common in orthodontic practice. The most frequently impacted tooth are the third molars, followed by the maxillary canine. Precise 3-dimensional localization of impacted canines is central to their clinical management and treatment planning.

Case 1: 10-year-old female patient with bilateral impacted canines (Fig 4). CBTC scan can define the exact position relative to neighboring structures and the inclination of the longitudinal axis of the impacted tooth.

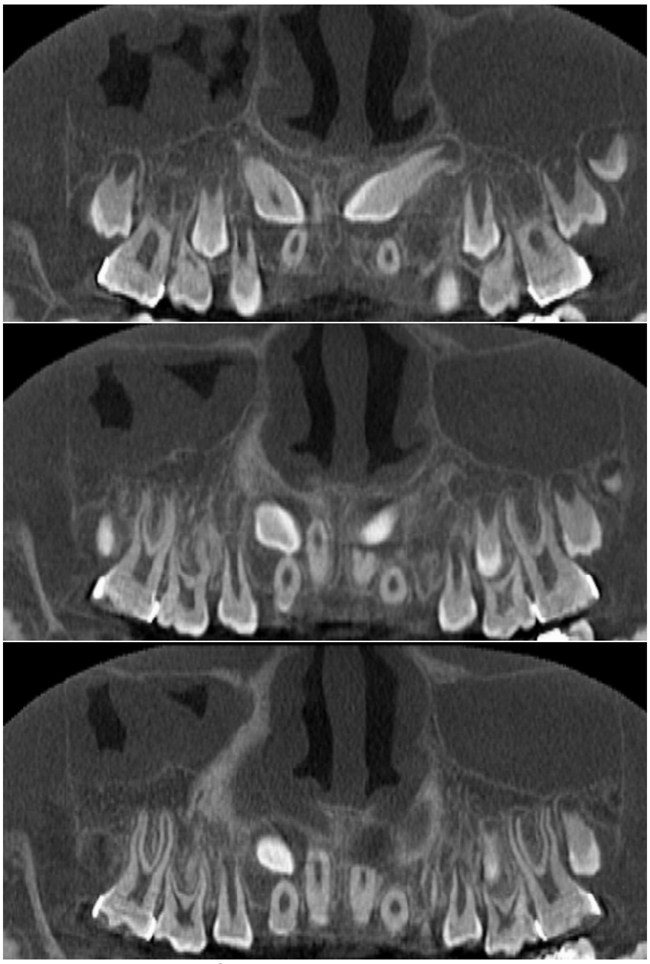

Fig.4 *10-year-old female patient with bilateral impacted canines. Panoramic view shows the relationships among erupted and unerupted dental elements in the 12-22 region.*

Case 2: 20-year-old female patient who referred recurrent sinusitis with undefined opacity at conventional 2D radiology; CBCT scans (Fig 5) showed third molar impacted in the maxillary sinus. The three-dimensional morphology of the tooth, its inclination, proximity to the sinus wall, surgical planning and prediction of prognosis and complications were estimated.

Fig 5 *20-year-old female patient with recurrent sinusitis. Panoramic view of the upper jaw shows 28 included in the left maxillary sinus.*

Sinusitis

CT scans is currently used for diagnosis of sinusitis and assessment of disease severity. CBTC, with much lower dose exposure of the patient, can evaluate location and extent of sinus disease and detect anatomic abnormalities prior to surgery and after functional endoscopic sinus surgery.

Case 3: 11 years old female patient with recurrent sinusitis (Fig 6).

Fig.6: *11 years old female patient with recurrent sinusitis; CBTC scan showing asymmetry of the nasal conhca, sinusitis in the left maxillary sinus and obstructed ostiomeatal complex.*

Supernumerary teeth: mesiodens

Supernumerary teeth are present in 0.8% of primary dentitions and in 2.1% of permanent dentitions. Mesiodentes, the most common supernumerary teeth, can cause delayed or ectopic eruption of the permanent incisors, which can further alter occlusion and appearance. By means of cone beam CT, the position of the mesiodens can be determined precisely and an adequate planning of the operation could be carried out.

Case 4: 10-year-old female patient with mesiodens.

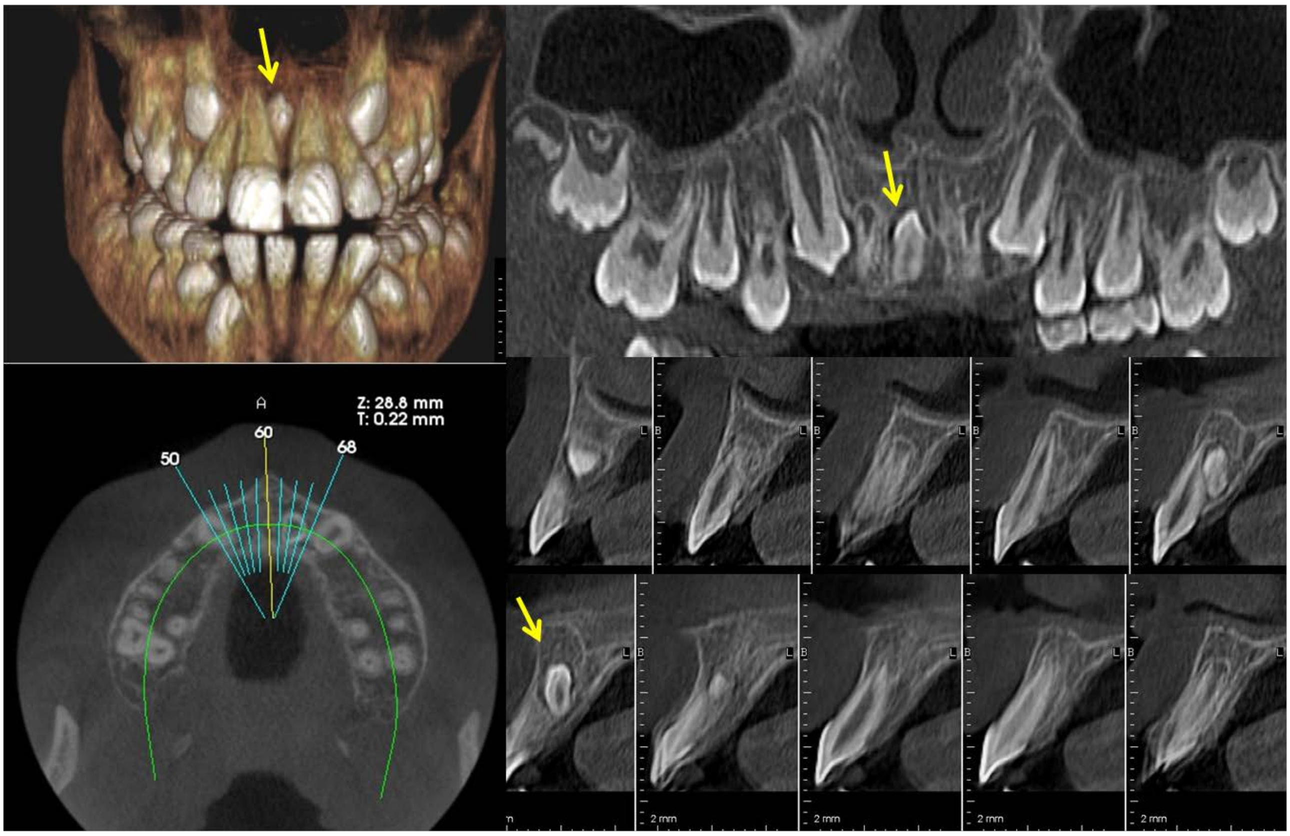

Fig 7 *10-year-old female patient with mesiodens. 3D data set, panoramic view and parasagittal views show the supernumerary tooth with the crown oriented upwards.*

Mandibular Cysts

Many lesions that occur in the mandible have a cyst-like radiographic appearance. Common benign cystic lesions include radicular cysts, follicular cysts, ameloblastoma and odontogenic keratocysts. The use of tomographic data should help establish a differential diagnosis.

Case 5: 10 years old female patient with mandibular cyst (Fig 8). In this case CBCT scan showed a well-defined, noncorticated, cystic lesion with some minimal tooth displacement. The differential diagnosis for this case includes radicular cyst, ameloblastoma, traumatic bone cyst and other odontogenic tumors.

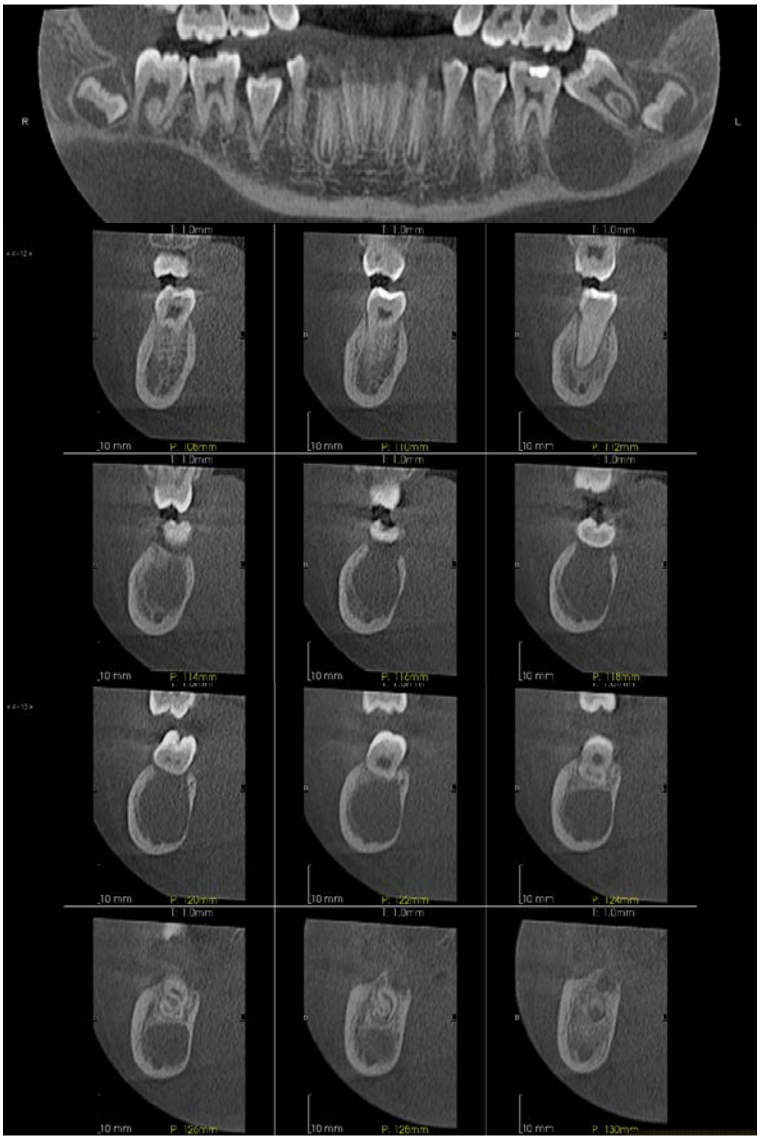

***Fig.8** CBCT scan of a 10 years old female patient shows a well-defined cystic lesion, in close contact with 36 and 37, with some minimal tooth displacement. Parasagittal views indicate a tight adherence with the mandibular canal.*

Clinical Cases using a 9" FOV

A wide field of view may be used when a general overview of the patient status is necessary. This may be used to study simultaneously upper and lower jaw, especially in cases of severe atrophy.
CBCT exams often allow to have information which would not be easily accessible using conventional panoramic images where structure overlapping hides or makes more difficult pathology recognition. In the following we show several cases which demonstrate the advantages of the possibility of exploring a 3D data set.

Case 6 : sinusitis and cyst

A 25 years old male patient with sinutis on the left maxillary sinus, unerupted impacted 38 and 48. The 38 elements is associated with a follicular cysts which extends towards the 37 and 36. Relationships between cyst and tooth roots and mandibular canal can clearly be investigated.

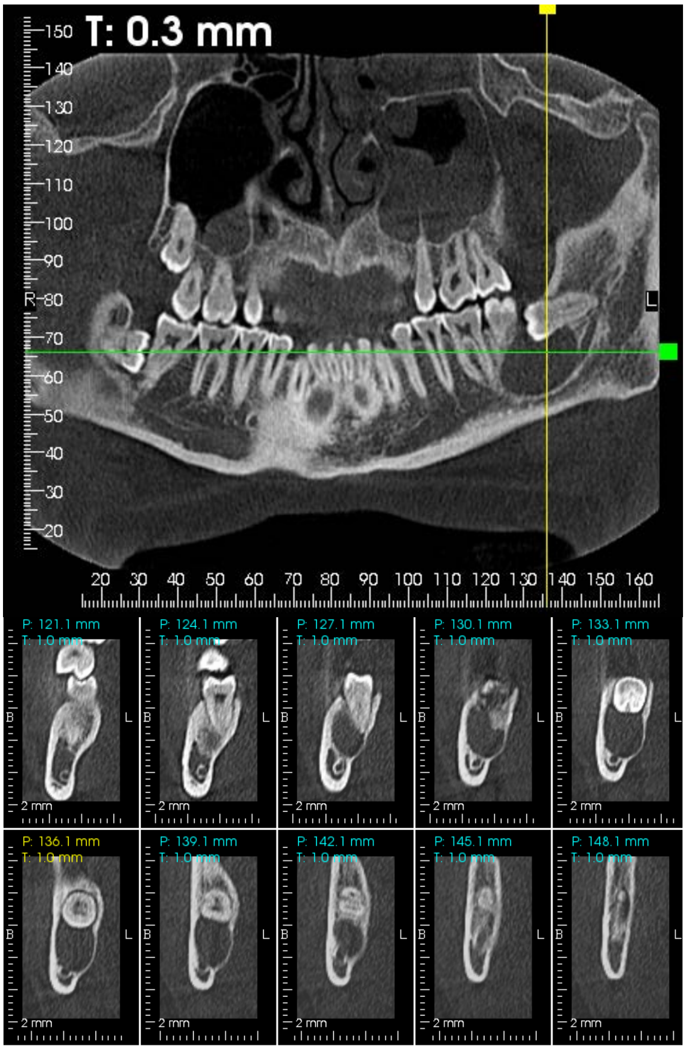

Fig.8 Panoramic view showing the general status of the patient. Sinusitis, impacted molars and follicular cysts are clearly visible. Parasagittal sections across the cyst show the close contact with tooth root and mandibular canal.

Case 7: tooth fracture

A 27 years old male patient showing a fracture on 36. In this case fracture was not visible on the standard panoramic due to structure overlap. Using a ‘cut’ panoramic the fracture on the 36 root became evident.

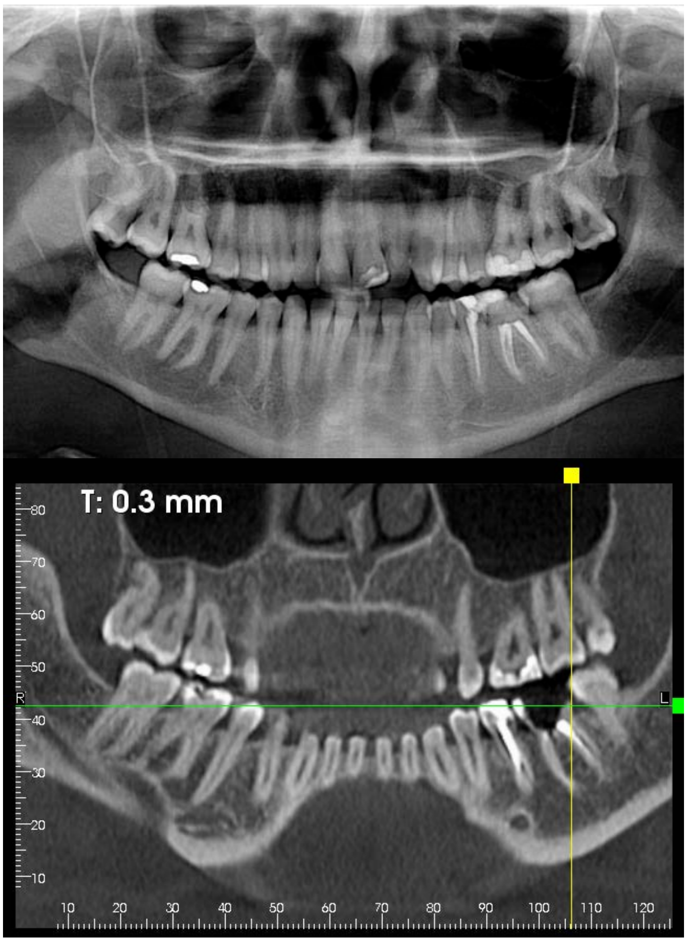

Fig.9 A 27 years old male patient with fracture on 36. The fracture was not visible on control panoramic image.

Case 8: Impacted Canine and granuloma

As in previous cases, the patient presents several pathologies simultaneously. From the conventional panoramic view the impacted canine is visible, but relationship with adjacent element cannot be thoroughly evaluated. On the lower jaw several radiotraslucent region may be suspected from the panoramic but they are not so evident as in the cone beam exam.

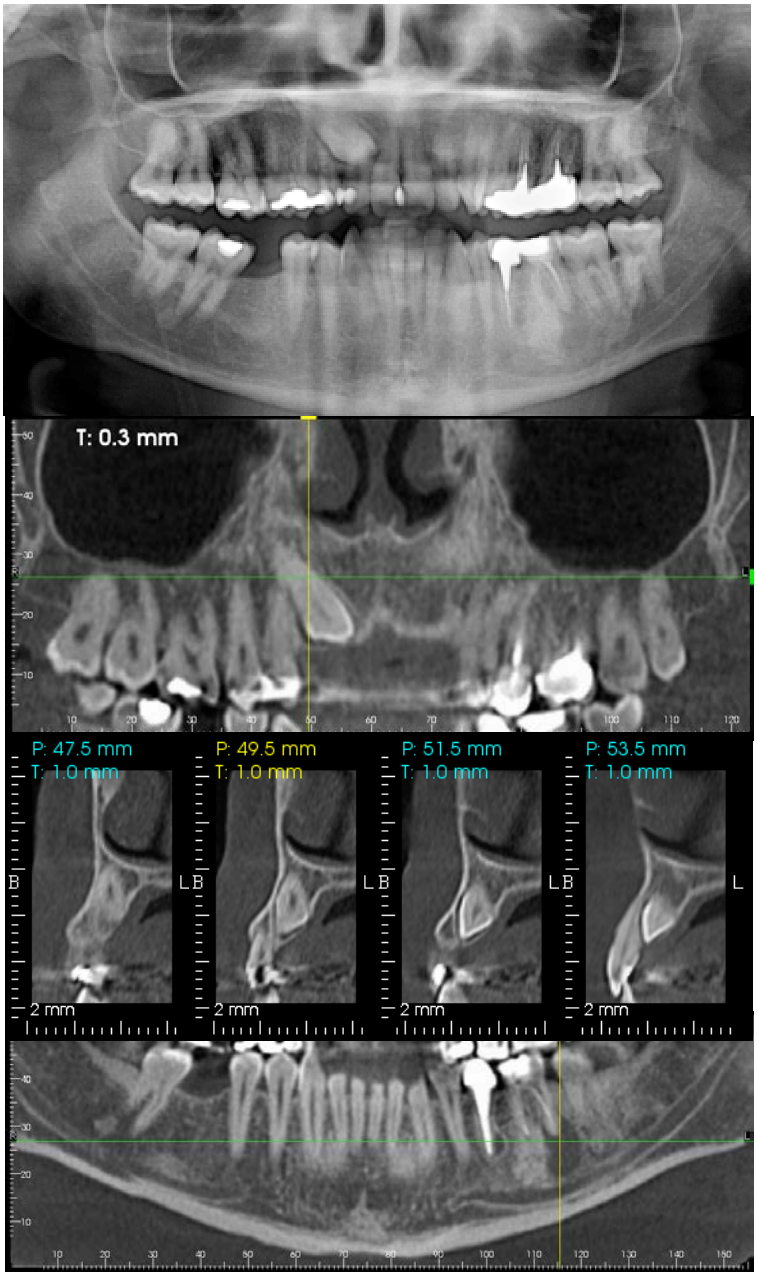

Fig.10 comparison between conventional panoramic and cone beam 3D reformatted images. Relationships among structure can be evaluated more clearly both in the impacted canine region and on the 35 and 36 roots where ipodensity region are clearly detectable.

New Directions for CBCT

Due to the low dose involved the cone beam CT is now being tested for several applications. Some are still related to the study of the head-neck region. For example the 3D cephalometry. Up to now cephalometric traces are all based on recognition of anatomical landmarks on 2D projection. It has been suggested that the use of 3D data set in place of 2D, may allow a more precise determination of the landmarks. In fact so far there are two different approaches: having a 3D data set it is possible to reconstruct a cephalometric-like view that may be used with 2D cephalometric traces. However this approach does not benefit of the advantages of having a 3D data set. New cephalometric traces directly based on the 3D recognition of structure are now being studied. Those imply redefinition of landmark and a different approach in their determination. It is clear that this is still a research application and clinical validation should be carried out before extended use. Fig. 11 shows a cephalometric analysis using a 2D and a 3D cephalometric trace.

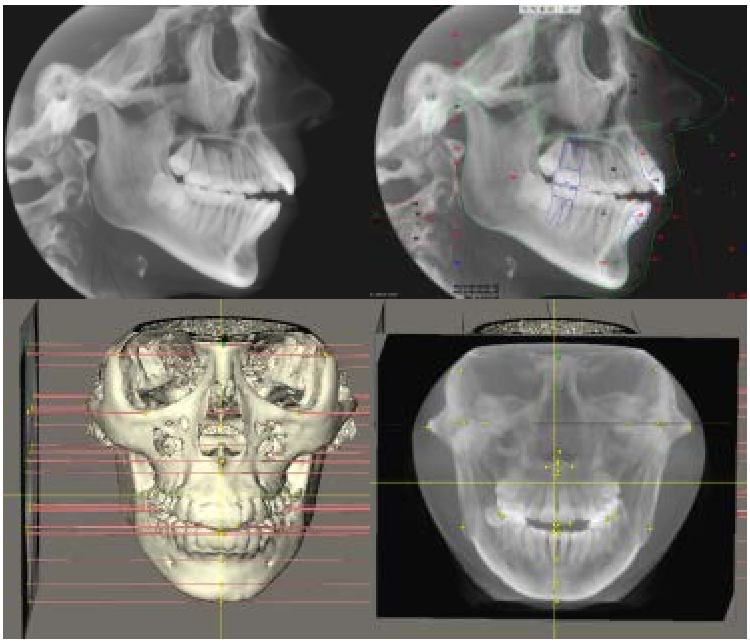

Fig.11 (Top) Use of 2D cephalometric trace on a lateral cephalometric-like view extracted by 3D data set of cone beam SkyVIEW; (Bottom) 3D cephalometric landmarks detected on the 3D volume using dedicated 3D maxilim cephalometric software.

Other field of intense research is the obstructive sleep apnea that can be studied analyzing the 3D data set using dedicated software such as Dolphin, which allows to easily detect the airways and measure changing in their volume.

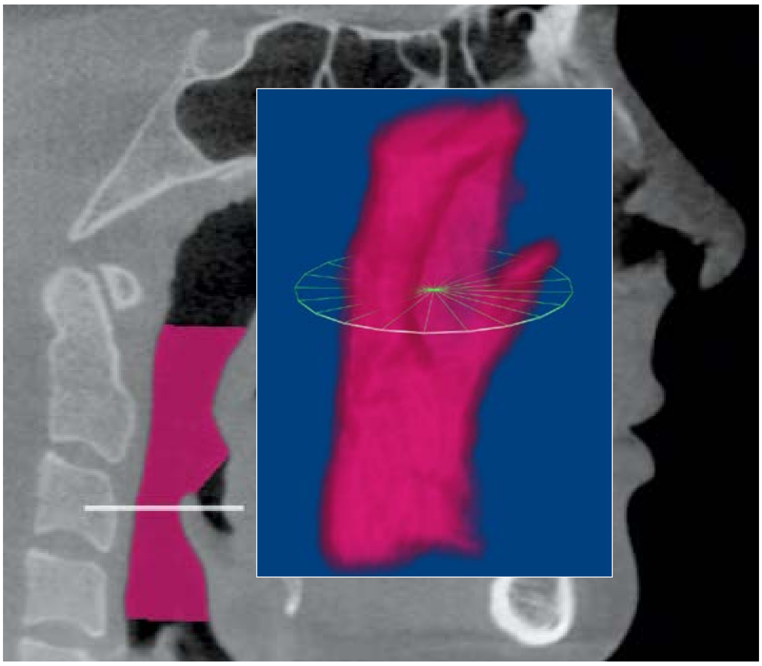

Fig.12 (Courtesy of A.G.Farman-CMI tutorial CARS 2009) Use of dedicated software allow to examin and measure volume of airways for obstrucive sleep apnea studies.

Beside those fields other applications may be related to the study of hands or feet where the possibility of exploring a 3D data set in comparison with 2D radiographs may provide additional interesting information (see Fig.13).

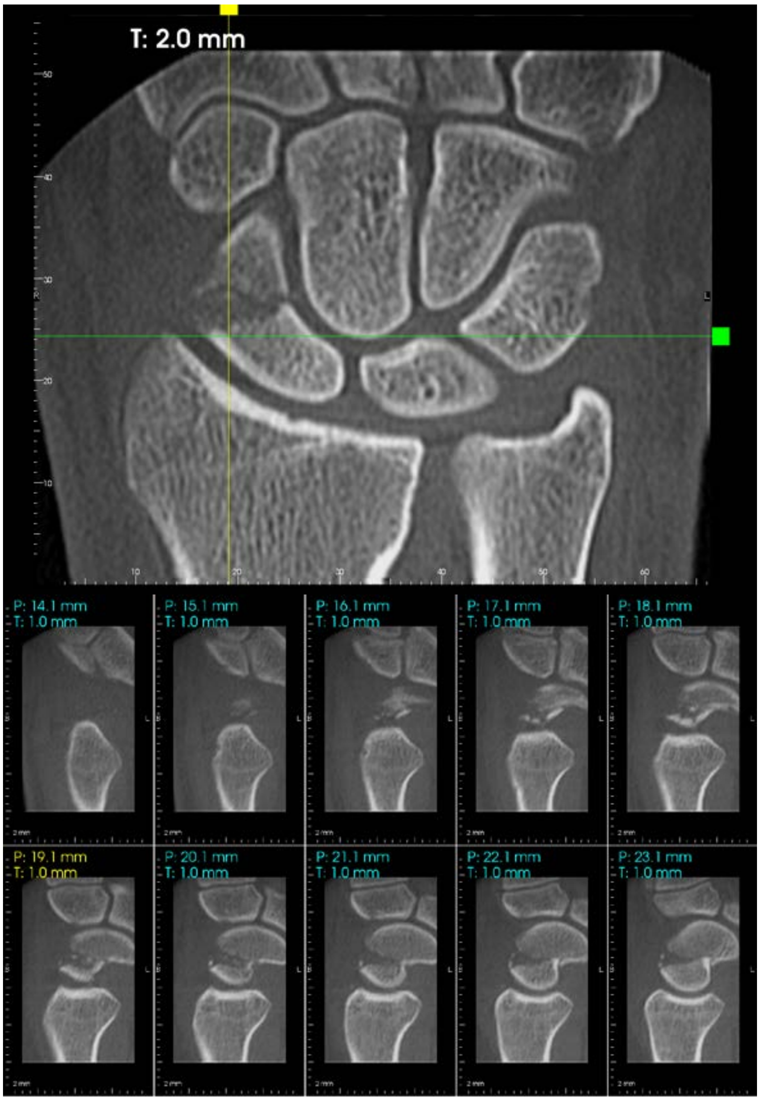

Fig.13. A case of fracture of the scaphoid bone. The 3D data set allows to explore the fracture from multiple point of view gaining a more complete information than a 2D radiograph.

Computed aided surgery of nasal septum based of cone beam data set has been demonstrated. As well as prediction of soft tissue modification following complex maxillofacial surgery or orthognatic treatment. Finally new application may derive from those field were gaining higher spatial resolution is crucial such as the study of the ear. These are only few of the possible development lines. All these should always be accompanied by a thorough clinical validation and by the careful evaluation of the risk-benefit for the patient. Which means, where similar information could be gained using a conventional, lower dose technique, this should always be preferred.

Conclusion

In this paper we have presented the general characteristic of new cone beam devices and discussed their advantages in comparison with conventional multislice CT. The possible applications of this new technology are diverse, ranging from dentistry to general dental maxillofacial surgery to orthodontic treatment. Other possible applications may be the study of the neck, the airways and the hands and feet. While many of these are still under research, it is clear that this technology will soon have considerable diffusion also in fields other than the maxillofacial area.

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