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CBCT; In Clinical Orthodontic Practice

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Abstract: *Cone beam Computed tomography has become an increasingly important source of 3D data in clinical orthodontics. It was developed due to increasing demand for 3D information obtained by conventional computerizedtomography scans. A cone beam examination is recommended in detection of facial asymmetry, assessing shape and growth of mandible, localisation of impacted canines, provides information for the placement of temporary anchorage device, evaluation of root resorption repair, assigning changes in oropharynx in growing patients with maxillary constriction treated with rapid palatal expansion etc. This article hopes to give a brief introduction to CBCT technology and explore a number of issues regarding its usage in an orthodontic and clinical setting.*

Keywords: *Computed tomography, Digital imaging, and Cone beam, orthodontics, three-dimensional.*

I. Introduction

Computed tomography has proven to be quite helpful for dental diagnosis, however, conventional helical-CT units were not originally developed for this purpose. The problems in adapting helical-CT scans for dental use include: high cost, large space requirement, long scanning time, high radiation exposure, and low resolution in the longitudinal direction compared with it's relatively high resolution in the axial direction{1,2,3}. The last of these is a result of the method by which longitudinal images are produced, through summation of axial CT images.Each axial slice is produced by one revolution of the fan shaped beam of x-rays. Then, the axial slices are stacked in order to create a complete image of the object under study. In 1997, the Department of Radiology in the Nihon University School of Dentistry set out to resolve some of shortcomings of conventional CT when they developed a radiological unit using a new technology known as limited cone beam computed tomography{1,4,5}. This new machine, theOrtho-CT, was refined and improved; and in 2000 the technology was transferred to the Morita Corporation as the 3DX multi-image micro-CT (3DX). The original prototype was based on existing technology in which film was replaced by an image intensifier;and radiation source was a coneshaped x-ray beam that rotated around the subject being examined . The 3DX machine, marketed by Morita Corporation, has an exposure time of 17 seconds, close to that of a panoramic exposure, and the radiation dose is about 1/100 of the helical-CT.Many other machines have been produced and marketed since the introduction of the 3DX. Generally, most use the same technology which involves a cone-shaped x-ray beam and an image intensifying sensor that rotate around the subject under observation{2}. The i-CAT (Imaging Sciences International, Hatfield, PA) and the Iluma (IMTEC imaging, Ardmore, OK) CBCT systems, however, use amorphous silicon flat panel image detectors capable of producing less image noise than image intensifier tube/charge-coupled device systems.Some of the CBCT acquisition systems now available on the world market7 include: the NewTom 3G by Quantitative Radiology, the i-CAT by Imaging Sciences, the CB MercuRay by Hitachi Medical, the 3D Accuitomo by J Morita Manufacturing Corporation, and the Iluma by IMTEC imaging{6,7}.

Kau, Richmond, Palomo, and Hans review four of these systems in their 2005 article entitled "Three-dimensional cone beam computerized tomography in orthodontics.{8}

Helenius LM, Hallikainen D, Helenius I, Meurman JH, Könönen M, Leirisalo-Repo M, Lindqvist C compared the image quality of fine dental structures using both CBCT and conventional dental CT. The CBCT imaging was carried out using the DVT-9000 (an earlier version of the New Tom 3G), and conventional CT imaging was accomplished using the Light Speed Ultra manufactured by General Electric Company. Over 200 teeth were examined with both systems; and image quality assessment was carried out by three radiologically-experienced clinicians with a minimum of five years experience in analyzing tomographic slices of the craniofacial complex. The image quality of the axial slices through the periodontal ligament space in the root area was examined. The comparison between the two systems was limited to axial slices which allows for the production of high resolution images in conventional CT.The authors concluded that in contrast to dental CT, there were little or no metal artifacts around fillings or implants when CBCT was employed. A single metal filling can render an entire axial slice with conventional CT useless. They also found CBCT to be superior when it came to the examination of major dental and skeletal structures such as relation of teeth and visualization of skeletal structures. However, when it came to examining fine structures like the periodontal ligament space, enameldentin interface, and the boundary of the pulp cavity, the dental CT was superior.{9}

This article hopes to give a brief introduction to CBCT technology and explore a number of issues regarding its usage in an orthodontic and clinical setting.

CBCT Orthodontic Applications

Since the introduction of CBCT in the late 1990s, it has become well established as an effective radiographic tool for oral and maxillofacial diagnosis. CBCT is being utilized for many of the same applications CT has been used for in the past. However, with its improved characteristics, such as lower radiation and improved accessibility and affordability, it is being employed to a much greater degree in orthodontic diagnosis and treatment planning{6,7,8}.

The applications of CBCT in orthodontics include assessment of palatal bone thickness, skeletal growth pattern, severity of tooth impaction, and upper airway evaluation for possible obstructions . CBCT is helpful in treatment planning of orthodontic cases which need buccal tooth movement and arch expansion Cephalometric radiography has been the standard for the assessment of skeletal, dental, and soft tissue relationships since its development in the early 1900s{10}.

Cephalometrics is used to describe craniofacial morphology, evaluate growth, treatment plan, and evaluate treatment results. One of the great shortcomings of the lateral cephalogram is that it is a 2D representation of a 3D structure. Two-dimensional images are not a good representation of the patient's 3D anatomic truth. No individual's face is completely symmetric; and the lack of accurate superimposition of these asymmetric halves creates error in landmark identification and skews cephalometric measurements. Measurement error also results from the magnification produced in conventional cephalometry. CT and CBCT technology makes it possible to create anatomically true (1:1 in size) images devoid of magnification and superimposition{12,13,14}.

Apart from the error that results from operator landmark identification, this significantly reduces the error in linear and geometric measurements.Enlow, in 2000, says this about the future of cephalometric imaging: "The near-future will be based on the actual biology of an individual's own craniofacial growth and development, and it will be determined by a three-dimensional evaluation based on that person's actual morphogenic characteristics, not simply developmentally irrelevant radiographic landmarks. Both the CT and CBCT are able to create accurate 3D representations of the craniofacial complex, however; CT has had little representation in orthodontic diagnosis and treatment planning due to: high cost, elevated radiation, and difficulty in image interpretation{13,14,15}.

2004 study by Lascala, Panella, and Marques evaluated the accuracy of the linear measurements obtained in CBCT images with the NewTom 9000. Thirteen internal and external measurements were made on eight dry skulls with a digital caliper. These same measurements were repeated in CBCT examinations and compared with the real measurements. They found that all CBCT measurements were slightly underestimated relative to the real measurements, but only statistically significant at the base of the skull. A possible explanation for the measurement variability is that most of the measurements were taken outside of the dentomaxillary area, which is the region CBCT scanners are designed to image. Therefore, the authors concluded that CBCT is reliable for linear evaluation measurements of structures closely associated with dental and maxillofacial imaging.

Kobayashi, Shimoda, Nakagawa, and Yamamoto, also investigated the accuracy of linear measurements with CBCT, focusing on dentomaxillary structures alone. Both CBCT and CT measurements were compared with actual digital caliper measurements made on sliced cadaver mandibles. They found that CBCT could be used to measure the distance between two points in the mandible more accurately than with CT. The measurement error was found to range from 0.01 to 0.65 mm on the CBCT and 0 to 1.11 mm for images produced by the CT. The increased measurement error in the CT images may be due to the loss of resolution of the system in the direction of reformatting. Overall, it was concluded that, CBCT proved to be a reliable tool for preoperative evaluation before dental implant surgery due to its high resolution, low cost, and low radiation.{16}

Marmulla, Wörtche, Mühling, and Hassfeld did just that in their 2005 article: Geometric accuracy of the NewTom 9000 Cone Beam CT. They found that the NewTom CBCT scanner could produce volume tomograms whose geometric distortion was below the resolution power of the volume tomograph. A maximum deviation of 0.3 mm was determined from the 216 measurements performed on a polymethylmethacrylate block of known dimensions.{17}

Misch, Yi, and Sarment46 found that CBCT measurement were as equally useful for the evaluation of interproximal defects as traditional methods: periodontal probing and periapical radiographs. However, CBCT has a distinct advantage over conventional periapical radiographs in that it allows the clinician to accurately evaluate the buccal and lingual bony defects as well{18}.

Hilgers, Scarfe, Scheetz, and Farman set out to investigate the accuracy of CBCT TMJ measurements. The purpose of the study was to develop CBCT MPR projections that depict TMJ morphology and select mandibular relationships, and then compare the reliability and accuracy of CBCT measurements with conventional cephalograms in three planes (lateral, posteroanterior, and submentovertex). TMJ articulations of twenty-five dry skulls were inspected using digital calipers for direct measurements, and the imaging modalities mentioned above for radiographic examination. They found that the i-CAT CBCT accurately depicted the TMJ in all dimensions; and was significantly more accurate than the conventional cephalograms in all three orthogonal planes.{19}

It is difficult to categorize the scope of applications of CBCT in orthodontics since it is difficult to narrow down the scope of orthodontic practice to specific clinical interventions. However, all the applications previously discussed in characterization of tooth impaction, assessment of cleft lip and palate and TMJ imaging could equally fall under the category of orthodontic applications. What is more important and more relevant, however, is the potential application of CBCT in mainstream orthodontic practice in routine diagnosis and treatment planning. The orthodontic record is comprised of panoramic radiograph and lateral cephalogram plus light photographs of the patient in profile and frontal positions and the upper and lower dental casts mounted on an articulator in occlusion{18,19,20}. With several practical limits related to time, cost and labour involved in producing, utilizing and maintaining this 'analogue' record, a conscious and steady effort was put forward to find a digital alternative. CBCT provides three-dimensional reconstructions of hard tissue including bone and teeth and softtissue reconstructions of air-bound surfaces including the skin and airway spaces. Also, two-dimensional reconstructions of panoramic and cephalometric radiographs are possible plus it can be combined with 2D or 3D light photographs of the patient face and scalp to create an accurate depiction of the patient's head. All this has nourished the speculation that CBCT can and in fact will replace all conventional orthodontics records as the modality of choice to create a digital orthodontic record. However, before those 3D models can be used in the clinic, their accuracy needs to be assessed.{20}

Many applications are there for cone beam computer tomography, which is given below, from which few applications will be dealt in detail;

1. Impacted canines & other impacted teeth
2. Root resorption.
3. Fractured roots.
4. Cleft lip and palate.
5. Temporary anchorage device placement.
6. Asymmetry.
7. Airway assessment.
8. 3D cephalometrics.
9. Dental measurements: overjet, overbite, arch width, arch length,mesiodistal tooth width.
10. Tooth movement limits.
11. Morphometrics.
12. Dental development.
13. Facial growth.
14. Indirect bonding of brackets.
15. 3D construction of mandibular condyle.
16. Tempormandibular joint degenerative changes.
17. 3D orthognathic surgery simulation using image fusion.
18. 3D virtual models production.
19. Assessment of root length & marginal bone levelm during orthodontic tooth movement.

Impacted Teeth and Oral Abnormalities

Ectopic cuspids are a relatively common occurrence the orthodontist must address. The ectopic or impacted incidences of maxillary cuspids is only second to that of the third molar; and has been reported by various authors in ranges that fall between 0.92% and 3%. Impactions are twice as common in females as in males.Maxillary impactions are most often located palatally (85%) and of the patients with maxillary impactions, approximately 8% are bilateral. The prevalence of mandibular impactions (0.35%) is much lower than that of maxillary impactions Surgical removal of impacted teeth demands precise knowledge of the tooth location in the jaw and its relation to other teeth and surrounding anatomical structures. For instance, in the mandible the relationship of the roots of impacted third molars to the mandibulardental canal must be accurately assessed since the canal is frequently very closely associated with an impacted molar and postoperative complications due to nerve impingement are reported. It is necessary to assess whether a physical contact between the root and the border of the canal is present or not. In the maxilla, localization of impacted canines relative to the lateral and central incisors is central to their management. Information regarding the palatal orientation of an impacted canine and its proximity to the root of the lateral incisor is vital to allow for an effective and timely surgical intervention{5,7,13,18,21} (FIG. 1a-c)

The first challenge in treating impacted or ectopic cuspids is determining their location. The most common way of identifying buccal-lingual position of an object has been through the use of the buccal object rule; also knownas the tube shift technique or Clark's rule. This is accomplished by taking two or more radiographs at different projection angles. The objects position is then identified by the relative positions of two separate objects changing as the projection angle changes. This method has proven to be 92% accurate in identifying the location of impacted or ectopically erupting maxillary cuspids.Another method is to use two radiographs taken at right angles to each other such as a periapical and occlusal film{20,21,22}.

Not only do ectopically erupting cuspids lead to impaction, but they can also lead to resorption of the neighboring permanent teeth{23} (FIG. 3). In 1987 Ericson and Kurol reported a 0.7% prevalence of resorbed permanent incisors due to ectopic eruption of maxillary cuspids. Most reported numbers of resorptions are relatively low, however, it has been suggested that they occur more often than is generally assumed.This may be due to the method of radiographic analysis used in these studies. Often, 2D images are incapable of revealing adequate detail needed to make these diagnoses. Much of this is due to the overlap of the incisors by the ectopic canine.{24}

Ericson and Kurol, in 2000,discovered that 93% of ectopically positioned

canines were in direct contact with the root of the adjacent lateral incisor and 12% with the central incisor. CT scanning substantially increased the detection of incisor root resorptions. In fact, 48% of the subjects in their study had resorption of maxillary incisors due to the ectopic eruption of maxillary canines. In this same study intraoral films and CT scans were compared for their diagnostic abilities in revealing maxillary incisor resorptions. The number of root resorptions on lateral incisors increased by 53% with the use of the CT imaging over intraoral radiographs.With this in mind, it becomes important to consider the diagnostic advantages CT scanning can afford the clinician in management of ectopic canines. Though this technology has been available for some time, it is seldom used due to issues related to cost, risk/benefit, access, and expertise in reading the CT. Walker, Enciso, and Mah10 supports the claims of incisor resorption prevalence made in the previous study. For this study CBCT was used instead of conventional CT; and it proved to be equally effective in: locating maxillary ectopic cuspids, defining their proximity to adjacent teeth, and identifying and quantifying the extent of root resorption caused by ectopic erupting canines.{25}

CBCT can also be quite useful in the detection of other oral abnormalities. Some clinicians across the USA have begun to use CBCT in routine dental examination procedures. Initial reports from these clinicians have revealed a higher incidence of oral abnormalities than previously suspected (i.e. oral cysts, ectopic/buried teeth and supernumeraries).

Kau et al. recommend that: The value of these findings must be taken with

caution, as the number of elective treatments that may be carried out may be limited. This leads to the question of whether to intervene in every abnormality located on these three-dimensional images and the extent to which the patient needs to be informed. In the event that these abnormalities were to lead to pathological episodes, what responsibilities would the clinician hold in the decision making process?This could lead to a host of future medico-legal problems on how clinicians and patients manage information.{26}

Conventional panoramic radiographs are routinely obtained to evaluate tooth impaction preoperatively. However, when compared with CT, the 2D nature of the image and the superimposition of adjacent anatomical structures impede precise assessment of the tooth relative to adjacent anatomical structures. CBCT orthographic tomographic slices and panoramic reconstructions are superior to conventional panoramic radiographs in determining the location, orientation of an impacted tooth and its relationship to adjacent vital structures in the maxilla and the mandible.{27} (FIG. 2a-d)

CBCT diagnostic applications in the maxillofacial region include evaluating the presence of osseous defects in the jaws, cysts, lesions, calcifications, teeth and bone traumas and fractures. CBCT is also playing an increasingly important role in the detection of incidental' pathology in patients referred to dental treatment. Since most CBCT systems currently available acquire volumes that extend beyond the dentition and the surrounding alveolus, unsuspected lesions in the para-nasal sinuses, parotic region, masticatory space, floor of the mouth and the hyoid region are frequently detected and reported. Evidently the threedimensional nature of CBCT allows determination of the exact extension of the lesion in the affected region.{28}

Orthognathic Surgery

Many of the applications of CBCT in conventional orthodontics also apply in combined orthodonticorthognathic surgery treatments. In fact, 3D CT has already been applied to a much greater extent in maxillofacial surgery than in orthodontics (FIG. 4a-d). Conventional CT has been widely used in surgical planning for craniofacial malformations, acquired defects, skull base abnormalities, head and neck cancer; it has also found its place in the measurement of the volume of oral tumors, analysis of primary nasal deformity in cleft lip and palate infants, assessment of naso orbitoethmoidal fractures, and for the evaluation of airway changes as well as for in vitro experimental validation of 3D landmark measurement in craniofacial surgery planning.Conventional CT and CBCT provide the surgeon with the ability to create Biomodels through stereolithography or milling process. Biomodels provide the surgeon with invaluable information to assist in presurgical planning for orthognathic cases, traumatic injury cases, as well as a variety of other applications.{29}

Several applications of CBCT in orthognathic surgery treatment simulation, guidance and outcome assessment have been developed. CBCT 3D surface reconstructions of the jawbones are used for preoperative surgical planning and simulation in patients with traumas and skeletal malformations . Coupled with dedicated software tools, simulations of virtual re-positioning of the jaws, osteotomies, distraction osteogenesis and other interventions can now be successfully implemented. Pre and post-operative 3D CBCT skull models can also be registered (i.e. superimposed on each other) to assess the amount and position of alterations in the mandibular rami and condylar head following orthognathic surgery of the maxilla and the mandible 3D reconstructions of the jawbones from CBCT are of sufficient quality for clinical work. However, 3D models of the dentition still suffer from deformations due to streak artifacts caused by metal fillings, crowns and bridges, orthodontic brackets and other metallic dental appliances. Therefore, virtual 3D models of the dentition are obtained by scanning the dental cast using a high-resolution surface laser scanner. Custom made inter-occlusal wafers can also be scanned separately and then combined with CBCT 3D reconstructions of the jaws to create composite skull models.These so-called 'double scanning' techniques have been successfully applied to patients with jaw asymmetry and severe malocclusion cases.{30}

Temporomandibular Joint

The temporomandibular joint (TMJ) is a complex entity with hard and soft tissue components. TMJ disorders (TMDs) are common but widely variable. MRI has sustained its position as the gold standard imaging modality for diagnosing TMDs since it provides excellent visibility of the disk and the associated joint muscles. Nonetheless, most TMJ examinations start with a panoramic radiograph to visualize any gross changes in the condylar head and temporal components{31}. Panoramic radiography, however, has a low diagnostic accuracy in detecting TMDs that a negative indicator on a panoramic radiograph does not exclude the presence of osseous defect. CBCT para-sagittal and coronal slices show clear images of the condylar head and the glenoid fossa (FIG. 8a-d). Additionally, provides images from different orientations and different reconstruction views thus providing axial, coronal and para-sagittal imaging of the condylar head. CBCT is more accurate than panoramic radiography and conventional tomography for detecting TMDs . CBCT exam was also recommended before image-guided puncture operation of the superior compartment of the joint space.{32}

Condylar resorption occurs in 5–10% of patients who undergo orthognathic surgery. Recent three-dimensional studies have tried to understand how the condyle remodels and preliminary data suggests that much of the condylar rotation resulting in remodelling is a direct result of the surgical procedures alone.TMJ changes following distraction osteogenesis treatment and dentofacial orthopaedics still need further study{32}.

The quality of the images of the TMJ with CBCT machines is comparable to conventional CTs, but the image taking is faster, less expensive, and provide less radiation exposure. This has opened a new avenue for imaging the TMJ.{33,34}

Cleft lip and palate

In cleft lip and palate patients, information regarding the number and orientation of teeth, dental and skeletal age, the amount and quality of available bone and bone graft in the cleft region are considered vital for the clinical management of such cases{11,12}.

Panoramic radiographs are often used to investigate the incidence and number of missing teeth and to determine dental and skeletal age in cleft lip and palate patients. However, the amount and quality of available bone cannot be accurately assessed on panoramic radiograph. Therefore, medical CT is typically used to quantify the amount of bone present. Yet, the young age of cleft patients makes the routine use of medical CT problematic due to the relatively high radiation dose involved. CBCT is rapidly replacing medical CT for this task since it provides excellent 3D visualization of the palate at the pre-maxilla region at a lower patient dose . CBCT is used to determine dental age and when a large scan field of view FoV selection is available, 3D reconstructions of the cervical vertebra can be made and employed to determine skeletal age. Additionally, CBCT has been used to show any deformities in the piriform margin in the nasal platform and the antero-posterior depression of the nasal alar base. 68 Three-dimensional CBCT reconstructions of the skin surface of the face and nose for cleft lip assessment are also possible.{35,36}

Airway analysis

The CBCT technology provides a major improvement in the airway analysis, allowing for its three-dimensional and volumetric analysis. Airway analysis has conventionally been carried out by using lateral cephalograms (FIG. 5a, b). A recent study carried on 11 subjects, using lateral cephalograms and CBCT imaging found that there was moderate variability in the measurements of upper airway area and volume.Three-dimensional airway analysis will no doubt be useful in understanding the reasons why clinical conditions like sleep apnoea and enlarged adenoids affect the way clinicians manage these complex conditions and alveolar height, especially when multiple units are proposed. This has improved the clinical success of these prostheses, and led to more accurate and aesthetic outcomes in oral rehabilitation.{37}

The introduction of CBCT technology means that both the cost and effective radiation dose can be reduced, suggesting that its frequency of use may increase. The CBCT has already been in use in implant therapy and may be exploited in orthodontics for the clinical assessment of bone graft quality following alveolar surgery in patients with cleft lip and palate.{38} The images produced resulted in greater precision in the evaluation of bone sites and, therefore, gave the clinician a better chance of restoring the site with implants and also influenced the decision-making process of whether to move teeth orthodontically into the repaired alveolus{38}.

Model analysis

Kau et al evaluated CBCT digital models and traditional models using the Little's Index. They found CBCT digital models to be as accurate as OrthoCAD digital models in making linear measurements for overjet, overbite, and crowding measurements.El-Zanaty et al, compared dental arch measurements, including mesiodistal widths of teeth, arch widths, arch lengths, arch perimeters, and palatal depths made with the calipers and measurements made digitally with a 3-dimensional-based dental measurements program using scanned images of patients with computed tomography{1}.They concluded that dental measurements obtained from the 3D software are comparable with those from conventional models in the 3 planes of space. Also, this technology has the added benefits of eliminating the need for taking impressions and the time needed for making models. Creed et al compared linear measurements obtained fromCBCT image casts and OrthoCAD models and found a good level of accuracy.{38}

The accuracy of CBCT image casts was considered adequate for initial diagnosis and treatment planning in orthodontics. Anatomage models are generated from CBCT scans, so they record alveolar bone heights while OrthoCAD models which are generated from an impression, record the gingiva. The CBCT models offer diagnostic information, such as bone levels, root positions, and temporomandibular joint status that is not present on OrthoCAD models. The CBCT models are deficient in occlusal anatomy, which makes them a poor choice for an indirect bonding set up.{39}

Root angulations and root resorption

Cone beam images can provide views of unparalleled clarity for determining root angulations as well as resorption on buccal or lingual surfaces not imaged by conventional periapical or panoramic views. Leuzinger et al evaluated 235 interdental sites by orthopantomograph [OPG] and CBCT out of which 47 areas showed contact between adjacent roots in the OPG images. However, the CBCT images showed true contact in only 5 of these areas. Lund et al evaluated the accuracy and precision of cone beam computed tomography [CBCT] with regard to measurements of root length and marginal bone level in vitro and in vivo during the course of orthodontic treatment. The in vitro mean difference between physical and radiographic measurements was 0.05 mm for root length and −0.04 mm for marginal bone level. In vivo the error was <0.35 mm for root length determinations and <0.40 mm for marginal bone level assessments.Kumar et al found no difference in accuracy of identifying defects between periapical radiographs and CBCT images.The CBCT images provide clear view of the maxillary incisor apices in deep bite cases. If the maxillary incisor apex is approximating the dense maxillary cortical bone, then any attempts for intrusion would significantly increase the risk of root resorption.{15}

Asymmetry evaluation

Determination of an asymmetric maxilla or mandible can be accomplished more easily by CBCT. Orthodontist can view these structures in various angulations using the data taken in only one scan instead of using numerous 2D radiographic views{11.12} (FIG. 7a, b).

Soft tissue

The soft tissue data gathered in the CBCT scan, it is possible to rotate and tilt the head in numerous positions to evaluate symmetry of the soft tissue. In addition it is also used for determining the relationship of soft tissue to facial skeleton for planning tooth movement and orthognathic surgeries{11,12,13 (FIG. 6a, b)}.

Insertion of mini-screws

Cone beam imaging can be used to determine the thickness and morphology of bone at sites where mini-implants may be placed or in patients for whom rapid maxillary expansion is being considered. According to Kau et al, 3-D CBCT technology allows better visualization of the effects to the surrounding dentoalveolar structures after TAD placement. They found that of the TADs placed, 65.2% were in contact with the PDL and that there is more space for TAD placement in the mandible than in the maxilla. Also, 71.2% of the length of the screw section of the TAD is embedded in the alveolar bone, but the percentage is often higher in the maxilla than in mandible.{40}

II. Discussion

CBCT scanners represent a significant advancement in dental and maxillofacial imaging. Since their introduction for dental use in the late 1990s129, there has been an increased interest in these devices. The number of CBCT-related articles published per year has increased tremendously over the last few years. We have performed a systematic review of the literature related to CBCT imaging applications in dental practice and summarized the applications of this new imaging technique in different dental specialties.{41} The clinical applications of CBCT imaging in dentistry are constantly increasing. The results of this systematic review showed that of the 540 articles published in the last 12 years, 130 were clinically relevant. The most common clinical applications of CBCT were in OMFS, implant dentistry, and endodontics. CBCT has shown limited use in operative dentistry because of the high radiation dose compared to conventional 2D radiography without any additional benefit.{42}

Grondahl HG8 reported use of CBCT in various areas as follows: Implantology: 40%, Oral surgery: 19%, Or thodont i c s : 19%, Endodont i c s : 17%, Temp o r oma n d i b u l a r j o i n t (TMJ) : 1%, Otorhinolaryngology: (ENT) 2%, Other investigations 2% (Periodontology, forensic dentistry, research).{43}

Adibi S, Zhang W, Servos T, O'Neill PN.9 in the latest review conducted using PubMed, Google, and Cochrane Library searches in the spring of 2011 using the key words "cone beam computed tomography and dentistry." resulted in over 26,900 entries in more than 700 articles including fortyone reviews recently published in national and international journals. This article is based on existing publications and studies and provides readers with an overview of the advantages, disadvantages, and indications/contraindications of this emerging technology as well as some thoughts on the current educational status of CBC.{44}

Alamri HM, Sadrameli M, Alshalhoob MA, Sadrameli M, Alshehri MA7 in their article presented a review of the clinical applications of cone-beam computed tomography (CBCT) in different dental disciplines. A literature search was conducted via PubMed for studies on dental applications of CBCT published between 1998 and 2010. The search revealed a total of 540 results, of which 129 articles were clinically relevant and were analyzed in detail and various %uses were shown as follows :Oral and maxillofacial surgery (OMFS) 26.3%, Endodontics 25.6%, Implant Dentistry 16.3% , Orthodontics 11.6% , General Dentistry 9.3 %, Temporomandibular joint (TMJ) 5.4%, Periodontics 4.65%, Forensic Dentistry 0.80%.{45}

W. De Vos, J. Casselman, G. R. J. Swennenin6 in their study, reviewed Pubmed for CBCT in oral and maxillofacial region. 176 clinically relevant articles out of 375 total articles from 1998 to 2007 were selected. 86 papers (49%) were related to clinical applications, 65 (37%) to technical parameters, 16 (9%) to radiation dose and 26 (15%) were synopsis papers.{46}

Ludlow, Davies-Ludlow, Brooks, and Howerton evaluated the dosimetry of 3 CBCT devices: CB Mercuray, NewTom 3G, and i-CAT.9 These devices were selected for their capacity to perform 12 inch full field of view (FOV) examinations. The 12 inch FOV permits imaging of the full anatomic region used in craniometric calculations for orthodontic diagnosis and treatment planning.{47}

Enlow, in 2000, says this about the future of cephalometric imaging: “The near-future will be based on the actual biology of an individual’s own craniofacial growth and development, and it will be determined by a three-dimensional evaluation based on that person’s actual morphogenic characteristics, not simply developmentally irrelevant radiographic landmarks.” Both the CT and CBCT are able to create accurate 3D representations of the craniofacial complex, however; CT has had little representation in orthodontic diagnosis and treatment planning due to: high cost, elevated radiation, and difficulty in image interpretation.{48}

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Ericson and Kurol, in 2000,discovered that 93% of ectopically positioned canines were in direct contact with the root of the adjacent lateral incisor and 12% with the central incisor. CT scanning substantially increased the detection of incisor root resorptions. In fact, 48% of the subjects in their study had resorption of maxillary incisors due to the ectopic eruption of maxillary canines. In this same study intraoral films and CT scans were compared for their diagnostic abilities in revealing maxillary incisor resorptions. The number of root resorptions on lateral incisors increased by 53% with the use of the CT imaging over intraoral radiographs.50 With this in mind, it becomes important to consider the diagnostic advantages CT scanning can afford the clinician in management of ectopic canines. Though this technology has been available for some time, it is seldom used due to issues related to cost, risk/benefit, access, and expertise in reading the CT.{24}

Walker, Enciso, and Mahsupports the claims of incisor resorption prevalence made in the previous study.For this study CBCT was used instead of conventional CT; and it proved to be equally effective in: locating maxillary ectopic cuspids, defining their proximity to adjacent teeth, and identifying and quantifying the extent of root resorption caused by ectopic erupting canines.{49}

Kim, Graber and Viana performed a meta-analysis of the literature, using the evidence from 31 primary studies to analyze and evaluate the relationship between orthodontic treatment and TMD{50}. The data from their meta-analysis showed no indication that traditional orthodontic treatment increased the prevalence of TMD. In another review of the literature, Luther55 found that orthodontic treatment has little role to play in worsening or precipitating TMD when treated patients are compared with untreated individuals.{51}

Okeson recommends that radiographs should not be used to diagnose TMJ disorder, but instead, serve as additional information to support or negate an already established clinical diagnosis.{52}

Dixon suggests that in consideration of other imaging techniques for detecting osseous abnormalities, the panoramic radiograph is an excellent choice for a screening view of the TMJ due to its cost effectiveness, high availability, and relatively low radiation dose. However, the diagnostic capability of panoramic radiographs is limited to gross osseous changes.Only obvious erosions, sclerosis, and osteophytes of the condyle can be identified. It has limited use for the identification of early lesions, and no capability to provide information on joint soft tissue status.{53}

Tsiklakis, Syriopoulos and Stamatakis63 describes a reconstruction technique for radiographic examination of the TMJ using CBCT. The technique results in obtaining lateral and coronal CBCT images as well as 3D reconstructions of the TMJ. To assess range and type of condylar movement a second scan was made with the patient's mouth open. This procedure was employed for four case studies presented in the report. Tsiklakis et al. concluded that the technique provided a complete radiographic investigation of the bony components of the TMJ, reconstructed images were of high diagnostic quality, the scanning time and radiation dose were smaller than that of conventional CT, and therefore, should be considered the imaging modality of choice for the examination of bonychanges in the TMJ.{32}

The specific aim of this paper was to explore some of the potential applications of CBCT in the clinical fields of orthodontics and endodontics. On a larger scale this work is part of an ongoing international effort to assess the efficacy of CBCT for various dental applications. CBCT was first introduced in clinical dentistry back in 1997 and was quickly dubbed a 'revolutionary technique' in maxillofacial imaging since it brought CT imaging technology to the dental clinic, which was largely inaccessible to most dentists due to radiation dose, cost and labor constraints. However, as more research evidence became available, some concerns were raised about theaccuracy and applicability of this imaging modality for the many 'proclaimed' applications. The concerns stemmed from the observation that there were many different CBCT systems on the market with very different technical designs. Currently, there are more than 20 different commercial clinical

CBCT available from different manufacturers. The characteristics of those scanners in terms of specifications of technical design, image quality, radiation dose and scan protocols are so distinct from each other that the efficacy results from one scanner cannot be automatically extrapolated to another system. The research results published in literature and the conclusions about the value of CBCT for a certain clinical application are largely confined to the system used and the specific model from that particular manufacturer.{54} Additionally, image quality within any one CBCT system is itself inconsistent. Scanning and reconstruction parameters play major role in determining image contrast and spatial resolution. Image quality is not only variable among the different systems but is also dependant on the scan protocol used and the chosen FoV for each system.{54,55}

The literature over the role of CBCT in clinical orthodontics is inconsistent. Several review articles and short communications in orthodontic journals describe the potential applications of 3D CBCT imaging in orthodontics 6,7 while currently scarce research evidence actually exists on the accuracy and efficacy of CBCT for those cited applications. Localization of tooth in impacted canines has been regarded as an important clinical application.

The added value of CBCT 3D information on the decision making of management of orthodontic patients with tooth impaction was demonstrated. Assessment of the amount of bone available in the pre-maxilla and hard palate regions for the placement of mini-screws has also been marked as a potential application . Nevertheless, the current debate in orthodontics is on the use of CBCT scans as replacements for the conventional orthodontic records. Specifically, the proposal is to replace the traditional dental impression and cast system with digital 3D surface models of the dental arches from CBCT and to substitute the conventional 2D lateral cephalogram with 3D surface models reconstructions of the maxillofacial region . Those models can potentially be used to aid in diagnosis and treatment planning, simulation and outcome assessment. Threedimensional surface models are superior to conventional records because they depict the actual patient in full 3D revealing the state of dentition including teeth crowns and roots structures, impactions and stage of development. With digital study models, inter-arch linear measurements can be made, teeth can be digitally relocated to their desired location using special software tools and treatment outcomes can be assessed by superimposing pre and post operative models on each other {11,12}. The cephalometric planes can be defined in 3D based on three or four bilateral points instead of the traditional two points approach adhered to with conventional cephalometry {12,13,14}. This allows distinguishing the right and left sides and virtually eliminates any superimposition artifacts.{56,57,58}

III. Conclusion

CBCT technology is beneficial to both patients and practitioners, it provides clinicians with good resolution images of high diagnostic quality with relatively short scanning times (10 -70 seconds) and low radiation dose. It is especially important to orthodontic field because of its ability to capture the mentire anatomy needed for orthodontic treatment planning. When used correctly, the data derived from CBCT imaging provides information for treatment planning that is more accurate when compared with other imaging methods, and allows clinicians to provide better results.

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Legendes

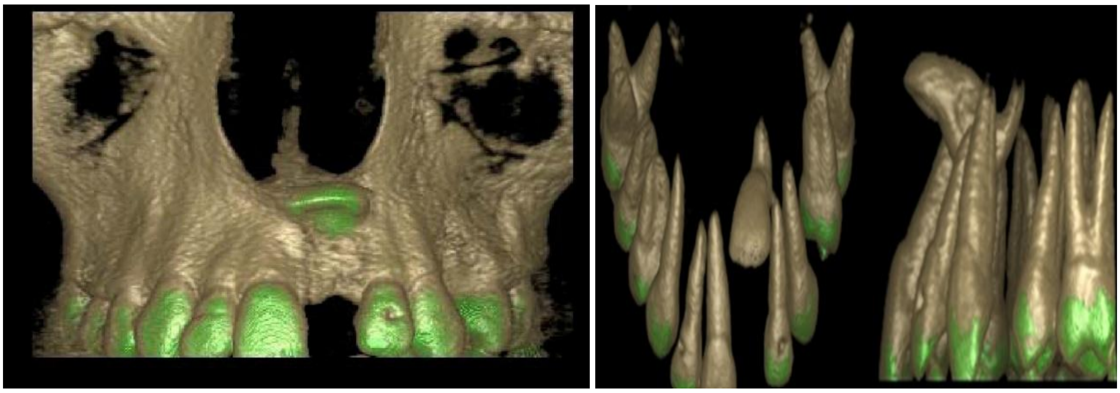

Fig. 01a, b: DVT showing the impacted tooth 21 In Detail (b) is to see the unfavorable root form, so that exposure and orthodontic adjustment contraindicated.

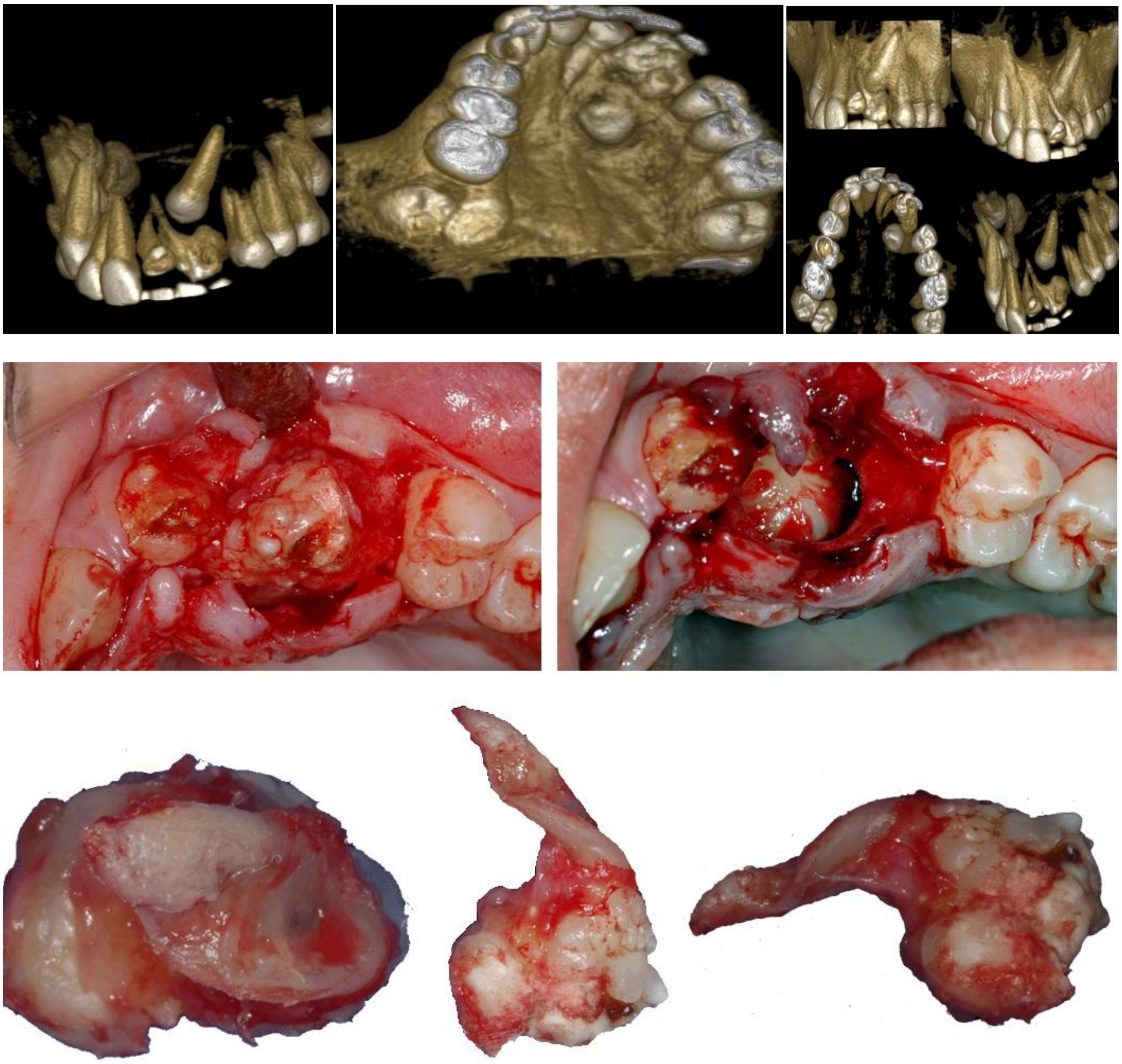

Fig. 02a-d: DVT for the representation of the traumatized tooth 22, and the impacted tooth 23. The picture c shows the topography of the affected teeth. Clinical picture (d) shows the teeth after extraction of the traumatized teeth.

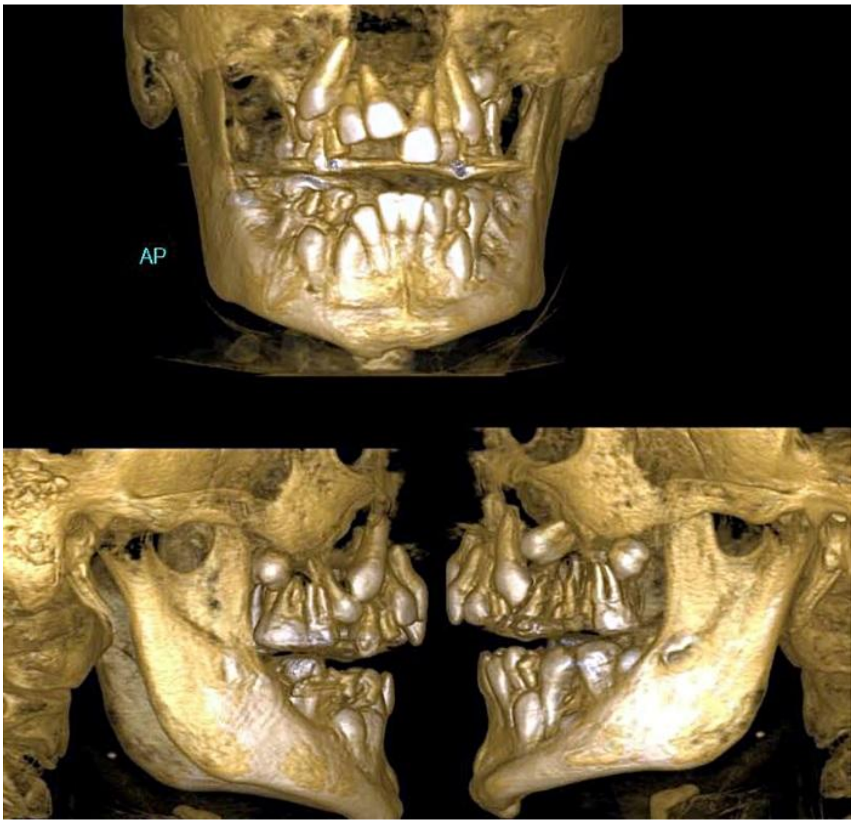

Fig. 03: Representation of displaced teeth in both jaws.

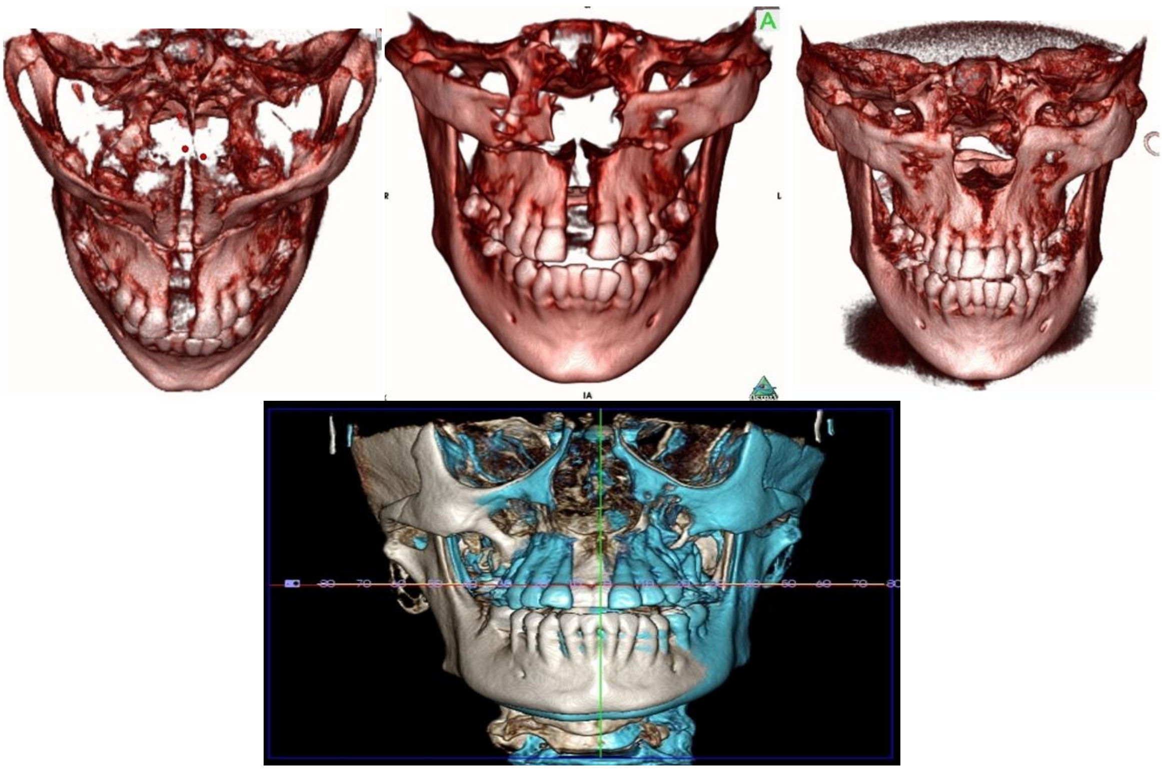

Fig. 4a-d: DVT representation of a case before surgical RPE (a) and after (B, C). The rapid palatal expansion will be accurately represented. Superimposing (d) shows the bone changes following the surgical RPE (SARBE).

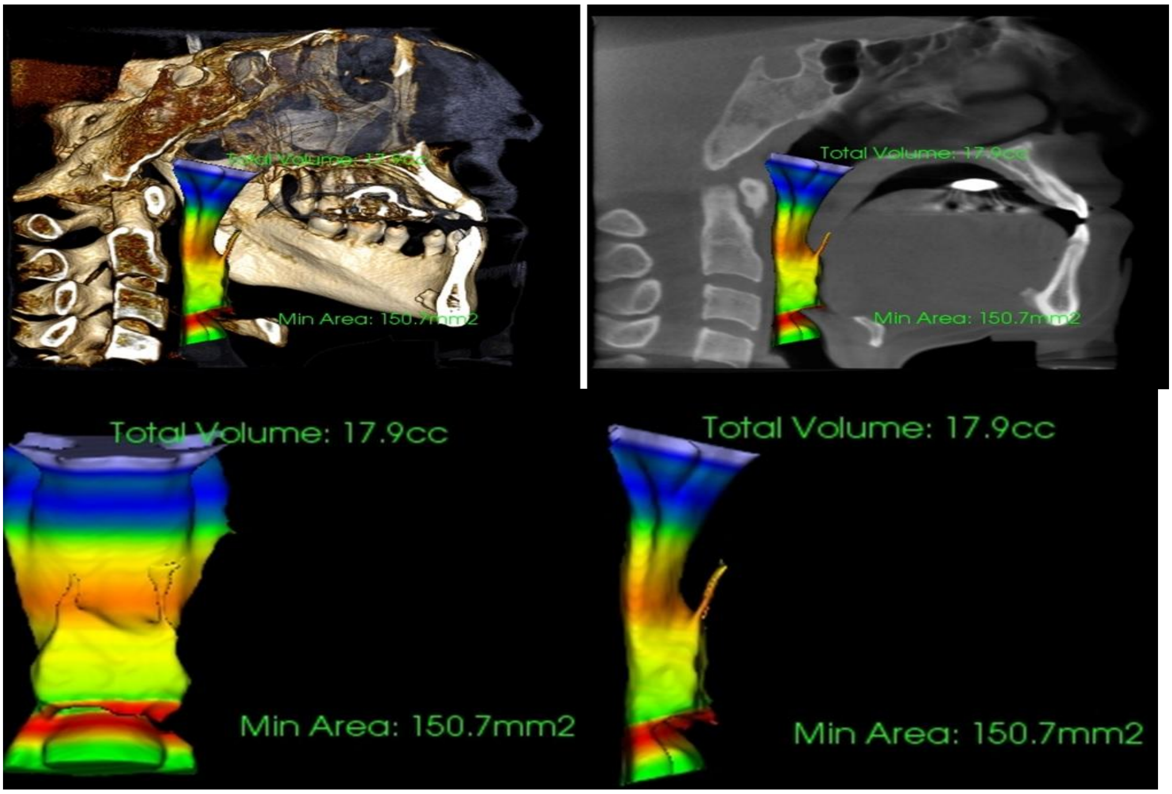

Fig. 5a, b: Usage of the same DVT for the representation of the airways

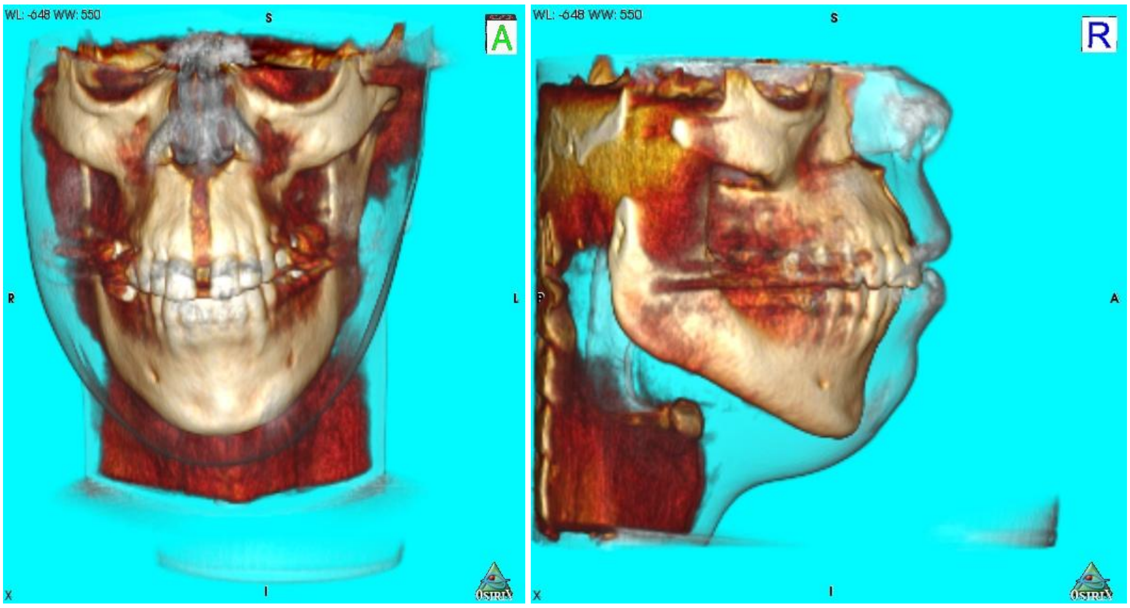

Fig.6a, b: Pictures shows the changes in the soft tissue structures by surgical RPE.

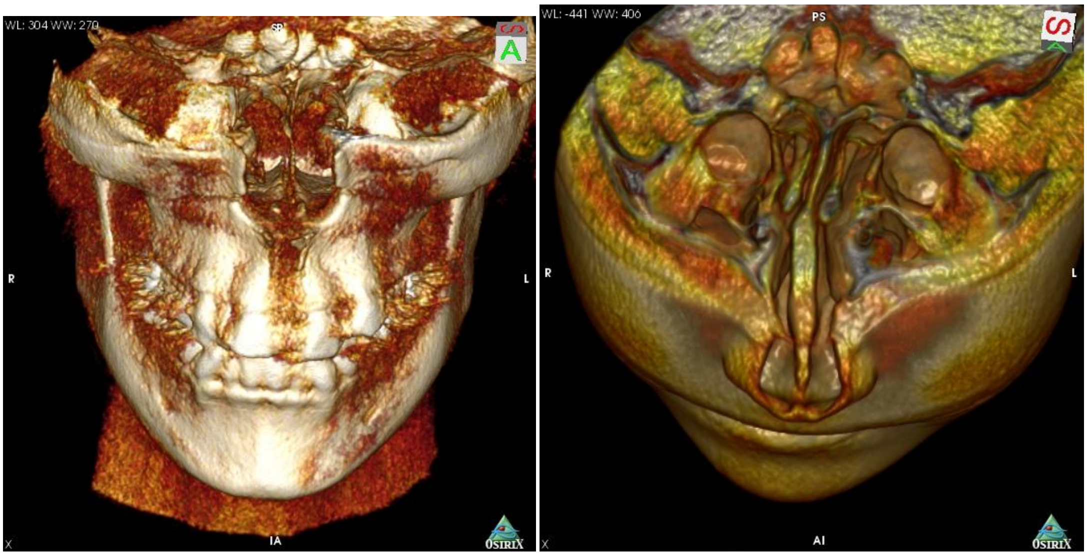

Fig. 7 a, b: Representation of the nasal septum after surgical RPE.

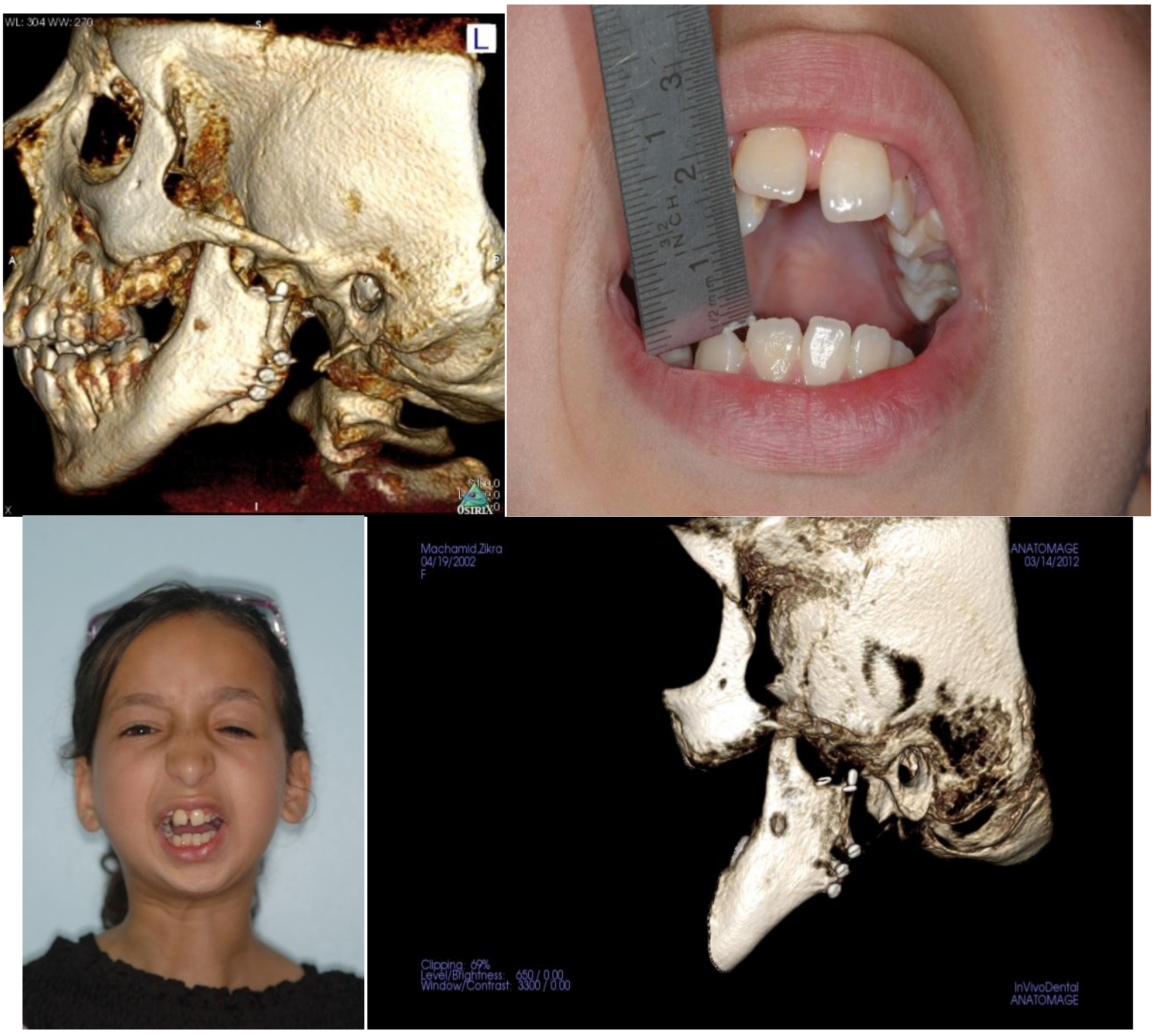

Fig. 8a-d: Clinical and radiological presentation of a patient after she had an accident and surgery who has a limited mouth opening. The coronoid process blocks the mouth opening because of overlength of the coronoid process and their contact with the Zygomatic arch.