ASDJ
AINSHAMS DENTAL JOURNAL

Print ISSN 1110-7642
Online ISSN 2735-5039

AIN SHAMS DENTAL JOURNAL
Official Publication of Ain Shams Dental School
September 2024 • Vol. 35

Validity of CBCT for Soft Tissue Examination in the Maxillofacial Area: A Review of the Current Literature

Shaimaa Mohamed Abu el Sadat Ali[1,2], *Sara M. Elkhateeb*[1,3]

Soft tissue examination is a crucial aspect of dental diagnosis and treatment planning Unlike hard dental tissues which are examined well with conventional imaging modalities, soft tissues are not easily assessed visually. Advanced imaging modalities are beneficial in providing valuable information about oral and maxillofacial soft tissues.
Conventional radiographs provide limited soft tissue details like some swelling or soft tissue calcification. Cone-beam CT (CBCT) provides detailed 3D information mainly on hard tissue with poor soft tissues contrast.

This review aim was to evaluate the use of CBCT as an imaging modality for assessment of soft tissue in the dento-maxillofacial region by reviewing the existing literature and formulate recommendations to be considered in future research. The following data were extracted from articles: methodology, applications and clinical significance which clarify the use of CBCT for evaluating soft tissue in the dento-maxillofacial region. Literature searches were performed in web of Science and PubMed. A total of 55 studies were included, most of the studies were review or original articles.

CBCT could be only used in linear measurements of soft tissue thickness. it is a valuable tool in obstructive salivary gland diseases, sinusitis, and help surgeons to avoid damaging vital structures. Finally, CBCT is not the imaging modality of choice when a detailed soft tissue imaging of the head and neck is required.

It is recommended that attempts should be made to use all the possible means to decrease the amount of scatter and hence, enhancing the contrast resolution and image quality of CBCT.

1.Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.
2. Visiting Scholar, University of Minnesota, MDRCBB, USA.
3. Basic Dental Sciences Department, College of Dentistry, Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia.
Corresponding author: Sara M. Elkhateeb, email: saraelkhateeb77@gmail.com

Introduction

In recent years, there has been a push to develop a three-dimensional imaging tool that can replace conventional CT scanners with reduced radiation exposure and lower costs. This led to the introduction of Cone Beam CT (CBCT), which has transformed the field of tomographic imaging and enabled volumetric image reconstruction.[1, 2]

CBCT is a radiographic technique which had acquired significant importance since its initial use in dental practice in the United States in 2001. [3] The impact of CBCT in dentistry has been significant, as it has improved diagnostic accuracy and investigation in various ways. This includes both routine assessment and more complex evaluations of unusual pathologies and congenital deformities. Additionally, CBCT has been instrumental in surgical guidance through the use of third-party software applications.[4]

As a matter of fact, CBCT scanners provide enhanced diagnostic precision owing to the high spatial resolution produced by the small voxel size of the CBCT machines. It is regarded as an ideal tool for hard tissue imaging of the maxillofacial region. However, CBCT demonstrates some limitations. Among those, is the radiation dose in comparison to the 2D imaging tools and the inability to properly disclose the soft tissue of the maxillofacial region.[5, 6]

In addition to the poor soft tissue contrast because of the higher noise and the low-contrast detectability compared to multidetector CT (MDCT) and magnetic resonance imaging (MRI). The use of MDCT could improve contrast resolution, but at the cost of increasing radiation exposure. MRI, on the other hand, is a more time-consuming and expensive alternative.[3, 7]

Also, MRI generates high soft tissue contrast and provides very detailed images of soft tissues including the dental pulp, nerves, and gingiva. MRI provides relevant additional diagnostic information of inflammatory processes in soft and hard tissues. However, until now, few reports have been published on the application of MRI in dentistry.[8] Although MRI is evolving in the diagnosis of odontogenic diseases such as periodontal and periapical disease, there is no consensus that MRI alone can meet the dental clinical need.[9]

CBCT images can evaluate dental and maxillofacial areas in oblique and multiplanner views, due to cross-sectional nature and their absolute coordinates-based 3D reconstruction.[10] CBCT modality provides valuable insight into bone morphology/dimension, and to some extent into bone quality during the implant planning phase. However, there are disadvantages such as higher direct and indirect radiation exposure, image artifacts from metallic objects, limited dynamic range, and its inherent non-quantitative nature. Therefore, CBCT is valuable during the pre-implant planning phase, but CBCT has limited value to identify complications after implant placement compared to ultrasound.[10]

Ultrasound is a non-ionizing, non-invasive, real-time, and chairside modality that provides cross-sectional images for the evaluation of soft and hard tissue. Although it has positive features, ultrasound has low spatial resolution and commercially available transducers had been large.[11]

Recent efforts in clinical and preclinical dental studies [12-14], have shown that ultrasound is a feasible, valid, and accurate device for diagnosis of pathologies, as well as to obtain soft and hard tissue dimensions. Also, ultrasound is used as an adjunct tool for assessment of tissue perfusion. [15-17]

Ultrasound has been widely used in dentistry as a diagnostic tool for oral cancer, muscle dynamics, salivary gland diagnosis, bone structure dimension, lesion diagnostics, and vital structure localization.[12]

Contrast resolution is the capability of an imaging technique to distinguish variances in tissue attenuation, as measured in Hounsfield unit (HU).[18] Low-contrast detectability in CBCT equipment relays on both the dynamic range and temporal resolution of the detector as well as the X-radiation scatter and quantum noise.[19]

Two major factors diminish the contrast resolution of CBCT. Firstly, scattered radiation, while it can contribute to increasing the noise in the image, is also a significant factor in reducing the contrast of CBCT systems. Scattered X-ray photons can reduce material contrast by adding background signals that do not represent the anatomy, thereby diminishing the quality of the image.[6, 20]

The second point to consider pertains to intrinsic flat panel detectors (FPD), which can be prone to several artefacts that affect their linearity and response to X-rays. These artefacts include saturation, which occurs when pixel effects become nonlinear beyond a certain level of exposure, dark current, which refers to the accumulation of charge over time (with or without exposure), and bad pixels, which are unresponsive to exposure. Furthermore, there may be pixel-to-pixel gain variation across different areas of the panel, resulting in uneven sensitivity to radiation across the entire region.[6]

Although, CBCT shows low contrast resolution and failure to discriminate soft tissue in some instances. Nevertheless, it has been examined in different dento-maxillofacial applications for the appraisal of soft tissues and proved efficient in a considerable number. Our objective was to evaluate the use of CBCT as an imaging modality for assessing soft tissue in the dento-maxillofacial region by reviewing the existing literature.

1. Applications of CBCT in Soft Tissue Imaging in Different Dental and Maxillofacial Fields

1.1 In Implantology and Periodontology

The expanding requirement for dental implants to replace missing teeth requires a method capable of attaining profoundly accurate alveolar and implant site measurements to affirm cautious preoperative assessment and treatment planning. Not only the osseous component should be assessed prudently but on top the soft tissue component or in other terms the periodontal phenotype including the gingival thickness, the available keratinized mucosa, and the bone morphotype.[21, 22]

Soft tissue thickness measurements before or after implant placement have been achieved through several methods. e.g., as transgingival probing, ultrasonography (US), CBCT imaging, and CBCT imaging in adjunct to optical 3D images obtained either by direct intraoral scans or impressions scanned and digitized using desktop scanners.[23] Several studies have assessed the validity of CBCT in assessment of soft tissue thickness prior to implant surgeries [24, 25, 26] and demonstrated its effectiveness compared to other methods.[24]

A soft tissue CBCT (ST-CBCT) approach was described by Januario et al [27] to predict and assess the gingival thickness. They used lip and cheek retractors during scanning to avoid the downfall of the soft tissues on the gingiva, since, both soft tissues have the same contrast resolution and consequently, cannot be separated [24, 27] A cotton roll could be also used, elating the lip from the alveolus enhancing the vision of the gingival soft tissue. One way to measure gingival thickness is by directly examining cross-sectional CBCT images, while another method involves creating soft tissue masks and overlaying CBCT scans if follow-up measurements are needed (Figure 1). [28, 29]

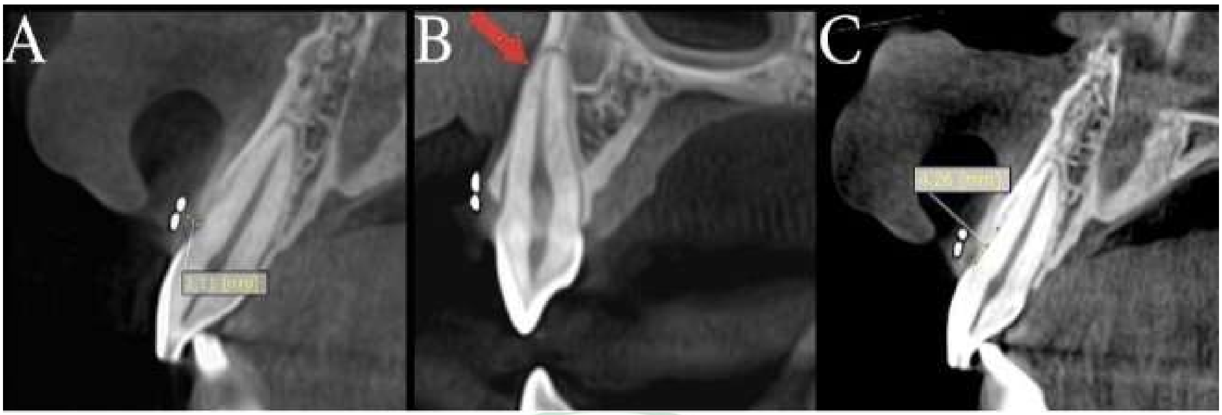

Fig 1. Cross-sectional cuts of a CBCT image used to obtain the measurements using cotton rolls to separate the lips from the gingiva. A: Measuring the gingival thickness (GT) from the central hole on the composite button to the bone or tooth surface (thickness = 1.11 mm; yellow line, perpendicular to the long axis of the tooth). B: Red arrow shows the labial bone fenestration. C: A dehiscence of 4.26 mm is observed. [18]

In immediate implant placement with augmentation using guided bone regeneration and connective tissue grafting both, the horizontal soft tissue width or the gingival width was also appraised using CBCT.[30]

Although the employment of CBCT was proved effective and correlated to other methods in detection of gingival thickness, [31] its use is still controversial because of the increased cost, more radiation exposure, and decreased imaging quality induced by metal artefacts. Alternatively, US with the use of non-ionizing radiation, real-time imaging and low-cost have been examined.[32]

CBCT scans conceivably could be used in combination with intraoral scanning to acquire 3D models. In Kuralt M et al.[23] approach, the DICOM files obtained from a CBCT scan and exported as an stereolithiography (STL) were registered with the STL of the soft tissue and teeth model acquired using an intraoral scanner (Figure 2).

The soft tissue thickness was envisioned and assessed using color mapping. By visualizing and estimating the palatal areas, the optimal grafting site can be identified, making the previously proposed approach an effective means of facilitating pre-surgical planning for periodontal surgeries and implantology. Since this approach does not require any additional invasive procedures, it helps minimize the risk of complications and improve patient outcomes.[23]

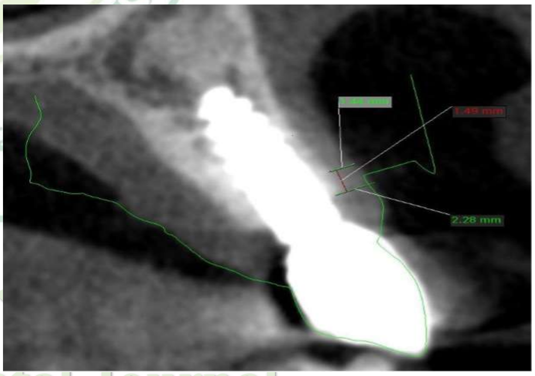

Fig 2. Cross-sectional cut showing registration of STL file on CBCT using OnDemand software.

1.2In Maxillofacial and Guided Surgery

1.2.1 In guided surgeries and surgical guide fabrication In the advancement of digital technology, the precision of computer guided implant surgery together has been established. Accuracy of designing and fabrication of surgical guide enhances the treatment outcomes especially in serious hard and soft tissues situations that requires special consideration.[33]

CBCT plays a crucial role in the production of surgical guides, either used alone in dual scan protocols for completely edentulous patients or combined with digital 3D optical scans for other cases. The dual scan protocol involves taking two scans of the patient while wearing a radiographic guide with a fiducial guide and then with the radiographic guide alone. The two scans are then matched and registered using the fiducial markers, providing sufficient information about mucosal thickness. However, in the case of partially edentulous patients, a combination of CBCT and 3D digital models is required to obtain dental and soft tissue information.[34]

1.2.2 In Orthognathic Surgeries

Maxillofacial surgeons now use CBCT software programs in virtual 3D orthognathic treatment planning to predict post-surgery soft tissue profiles and educate patients. This involves registering CBCT scans and 3D photographs of patients preoperatively using specialized software like "Dolphin 3D" Imaging Software (Dolphin Imaging & Management Solutions, Chatsworth, CA, USA), which can estimate soft tissue changes after surgery. However, according to Resnik et al.'s study, the ability to accurately predict 3D soft tissue changes is limited and prone to errors.[35] Also, Shobair N et al reported the limited accuracy of Dolphin 3D in the soft tissue prediction of bimaxillary orthognathic surgery.[36]

According to the systematic review carried out by Paredes de Sousa Gil et al [37], superimposition of CBCT scans empowers 3D assessment of nasal and labial morphological changes in particular the nasolabial fold in orthognathic surgeries, and consequently could be used as an efficient tool for assessing both skeletal and soft tissue changes.

The complex nature of soft tissue changes following orthognathic surgery requires a three-dimensional analysis. CBCT has been demonstrated to accurately confirm soft tissue changes and the impact of a minimally invasive surgical approach in the nasolabial area following segmented and non-segmented Le Fort I osteotomy. This is achieved through the evaluation of 3D volume surfaces by registering scans taken prior to the surgery, as well as one month and one year after the surgery, and measuring the difference in soft tissue measurements at the nasolabial fold. [38] Special software programs used for virtual orthognathic surgeries are used for the process of segmentation and registration.[39]

Although, CBCT delivers appropriate knowledge about skeletal structures and is sometimes used to measure soft tissue changes. Yet, and as a result of its low contrast resolution and deficiency of data of skin consistency and color, the precision of the assessment of facial soft tissues is not warranted. Hence, other modalities as Laser surface scanning and light emitting diode (LED) white light scanning, were presented themselves as alternative tools. Besides, the LED white light scanning does not use any type of hazardous radiation causes no harm to the human eyes. Three-dimensional facial scanning could be a useful measure to evaluate the soft tissue after orthognathic surgeries and specially the alar soft tissue. [40]

2.In Sinonasal and Miscellaneous Oral and Maxillofacial Lesions MDCT is still considered the modality of choice for examining sinonasal complex and in particular advanced sinus lesions. [(41)] However, CBCT scans can easily show maxillary sinus cavities that are radiographically partially or fully obliterated demonstrating lesions involving the sinus cavity. CBCT could be a valuable tool in displaying the ostiomeatal complex, inflammatory lesions (mucosal thickness, sinusitis, pseudocysts, and polypoid masses), antrolith and osteomas involving the sinuses (figure 3).[42]

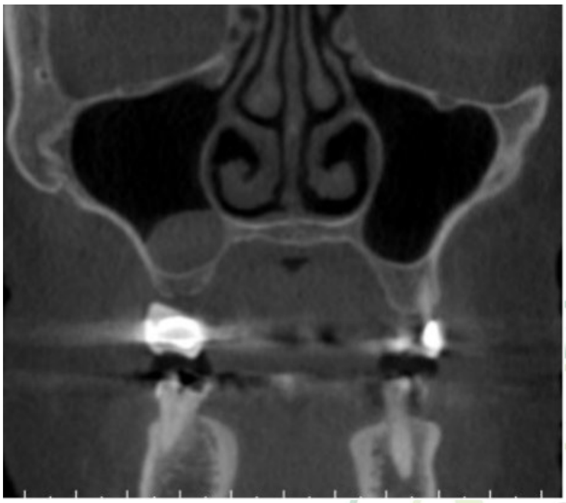

Fig 3. Coronal CBCT cut showing polyp in the right maxillary sinus.

In essence, CBCT is mainly recommended for oral and maxillofacial lesions that are confined to the bones because of the excellent bony details provided by the modality (figure 4).

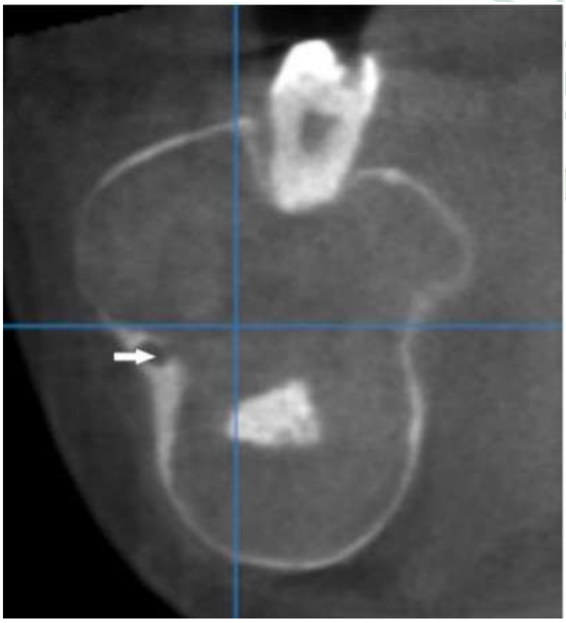

Fig 4. Coronal cut shows a buccolingual bony expansion of ossifying fibroma with the displacement of the mandibular canal (white arrow).[43]

Even though, the soft tissue contrast of CBCT scans is poor, sufficient information could be established to reach a preliminary differential diagnosis and deciding the requirement for more advanced imaging modalities (figure 5). [44, 45]

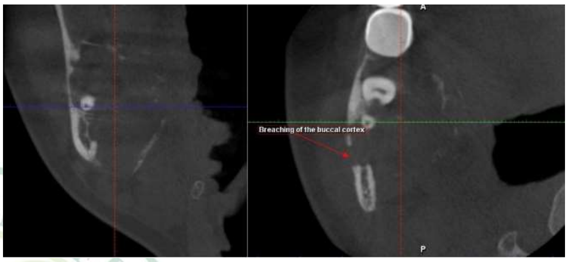

Fig 5. Coronal and axial cuts showing expansile bony central giant cell granuloma causing breaching of the buccal cortex and undulating border.

The role of CBCT in soft tissue assessment in the sinonasal area is constrained to particular conditions, like the detection of opacification in the paranasal sinuses and airway obstruction.

However, when it comes to examining maxillofacial lesions, it is recommended to use MDCT with or without contrast or MRI for a more accurate and detailed imaging of lesions that are either aggressive or classified as vascular anomalies. The enhanced contrast resolution of both MDCT and MRI superiorly display infiltration in malignant lesions or invasion of adjacent structures in vascular anomalies. CBCT has its limitations in detecting aggressive benign lesions, especially those that invade cortical boundaries or affect neighboring soft tissues like osteomyelitis. CBCT is most favorable for benign pathology that is confined to bone due to the enhanced spatial resolution, availability, and lower cost and radiation dose.[6]

3.In CBCT Sialography The major salivary glands can be investigated using ultra-sonography, CT, MRI and sialography. Drage and Brown [46] were the first authors to describe 3D-CBCT sialography in two patients with obstruction in salivary gland formerly examined with conventional sialography. CBCT sialography is the best modality in revealing the ductal system of the gland in cases that have obstructive salivary gland diseases, as a substitute to conventional sialography. It revealed the existence of calcifications, mucous plugs, strictures, dilatations and to investigate normal glands. As with CT scan or CBCT, 3D-CBCT sialography can define the quantity and the accurate location of salivary stones, involving those less than 2 mm in diameter. The major benefit of this modality is that it provides precise illustration of salivary ducts and injuries through three-dimensional reconstruction and multiplanar reformatting (MPR). It is appropriate as a guide to therapeutic endoscopic procedure.[47]

Many authors stated that CBCT sialography is a highly sensitive and cost-effective technique for illustrating changes in the fine ductal anatomy because of its comparatively high spatial resolution and relatively low radiation dose.[6] Despite the advantages of CBCT yet, it exhibits limitations as it cannot examine the function of the gland or explore the prenchemya. Additionally, it is only possible to perform CBCT approximately 3-6 weeks after an acute infective or inflammatory episode, and there is a risk of duct perforation, stone mobilization, infection, and allergic reactions to the iodine contrast medium.[48]

4.In Orthodontics

4.1 Virtual patient simulation The combination of three-dimensional data from diverse anatomical structures (skeleton, dentition, and facial soft tissues) allows for the development of a 3D virtual patient. Furthermore, it permits the simulation of treatment outcomes on the patient's face, leading to better communication with both colleagues and patients. Virtual patient planning in orthodontics could be accomplished by integrating CBCT with facial scans, or CBCT with intraoral or extraoral digital scans, or combining intraoral scans with facial scans. Several studies have investigated the superimposition methods of 3D diagnostic records to obtain virtual patients. The ability to create a virtual patient is a crucial advancement in the diagnostic and treatment approach in orthodontics. [49]

5.1 Assessment of midfacial soft tissue after maxillary expansion The use of CBCT has been employed to examine changes in midfacial soft tissue resulting from maxillary expansion and to investigate the correlations between variations in hard and soft tissues following maxillary expansion treatment. Numerous studies have utilized 3D CBCT images to assess alterations in both skeletal and soft tissues of the face. [50, 51] Fusion of CBCT images pre and post orthodontic treatment was used also to evaluate both the skeletal and soft tissue changes and to investigate potential correlations between hard tissue expansion amounts and soft tissue projection.[52, 53]Camps-Perepérez et al. [54] conducted a systematic review to examine the dependability of CBCT imaging in the evaluation of Dento-maxillofacial structures, nasal airway, periodontal and soft tissue changes after surgically assisted rapid palatal expansion. It came out with the conclusion that CBCT imaging can be used as a consistent tool to estimate soft tissue outcomes which reflects the underlying dento-alveolar changes.

4.2Assessment of the thickness of the masseter muscle CBCT has been employed to detect post-orthodontic treatment thickness of the masseter muscle. Prior to this, imaging modalities such as MRI and CT were utilized for visualization of the masseter muscle. Nevertheless, CBCT is considered a 3D reconstruction tool with a lesser radiation dose and high spatial resolution. It is quite obvious that the soft tissue is less clearly projected in CBCT compared to the CT or MRI images, which may pose a challenge in the segmentation process, particularly when using manual segmentation techniques.[7]

5.In Cleft lip and palate patients Cleft lip and palate (CLP) are the highest communal craniofacial anomaly and needs an incorporated multi-disciplinary and staged procedures to management. Nine-years of age is the typical age for orthodontic involvement when frequently a quick palatal expansion is essential to treat maxillary transverse deficiencies. The use of CBCT in evaluating CLP patients is highly beneficial as it aids in determining the need for secondary alveolar bone grafting, confining the location of unerupted teeth, monitoring the movement of teeth adjacent to the cleft, and assessing bone condition for potential future prosthesis placement.[6]

6.In removable prosthodontics The fabrication of an obturator prosthesis can be a challenging process due to the need for a perfect impression of both the affected and healthy areas in patients with maxillary defects. Traditional impressions are being replaced by imaging methods such as MDCT and CBCT. CBCT, in particular, provides precise radiographic and volumetric information with the added benefits of being cost-effective and involving lower radiation doses. It can even be used to create virtual impressions. However, the CBCT's visualization of oral soft tissue and teeth may be somewhat limited due to contrast resolution and potential artifact production.[55]

Compared to CBCT, intraoral scanners (IOSs) have the advantage of providing high-resolution data without producing artifacts in the oral soft tissues, dentition, and restorations. Even though obtaining digital impressions of edentulous arches can be challenging, it is still achievable. By combining CBCT and intraoral scans, virtual casts that include the soft and hard tissues, dentition, and the defective area can be created to facilitate the design of obturators.[55] Kuralt et al. [56] proposed a novel approach for evaluating bone and mucosal changes in the foundation area of removable partial dentures (RPDs) by superimposing CBCT scans with optical scans. This method allowed for the assessment of both hard and soft tissues underlying the RPDs over a period of 9 months. The study concluded that CBCT, in combination with 3D optical images, was a viable approach for assessing changes in the bone and soft tissues in RPD foundation areas.

7.In soft tissue calcifications Soft tissue calcification (STCs) is a rare occurrence in the maxillofacial region and is typically found as an incidental finding during routine radiographic examinations or while obtaining Dento-maxillofacial images for other dental purposes. Detecting the type of soft tissue calcification requires a comprehensive understanding and proficiency in recognizing the anatomical location, morphology, and distribution. CBCT allows for a 3D and precise assessment of these calcified structures. Although CBCT scans exhibit lower contrast in soft tissues, they offer greater sensitivity than conventional radiography in detecting various calcifications such as carotid artery calcifications, calcified triticeous cartilage, calcified lymph nodes, and dystrophic calcification of the tonsils (figure 6). [57] According to the recommendations of the Academy of Oral and Maxillofacial Radiology, CBCT images represent a valued tool for defining the location of STCs. [58]

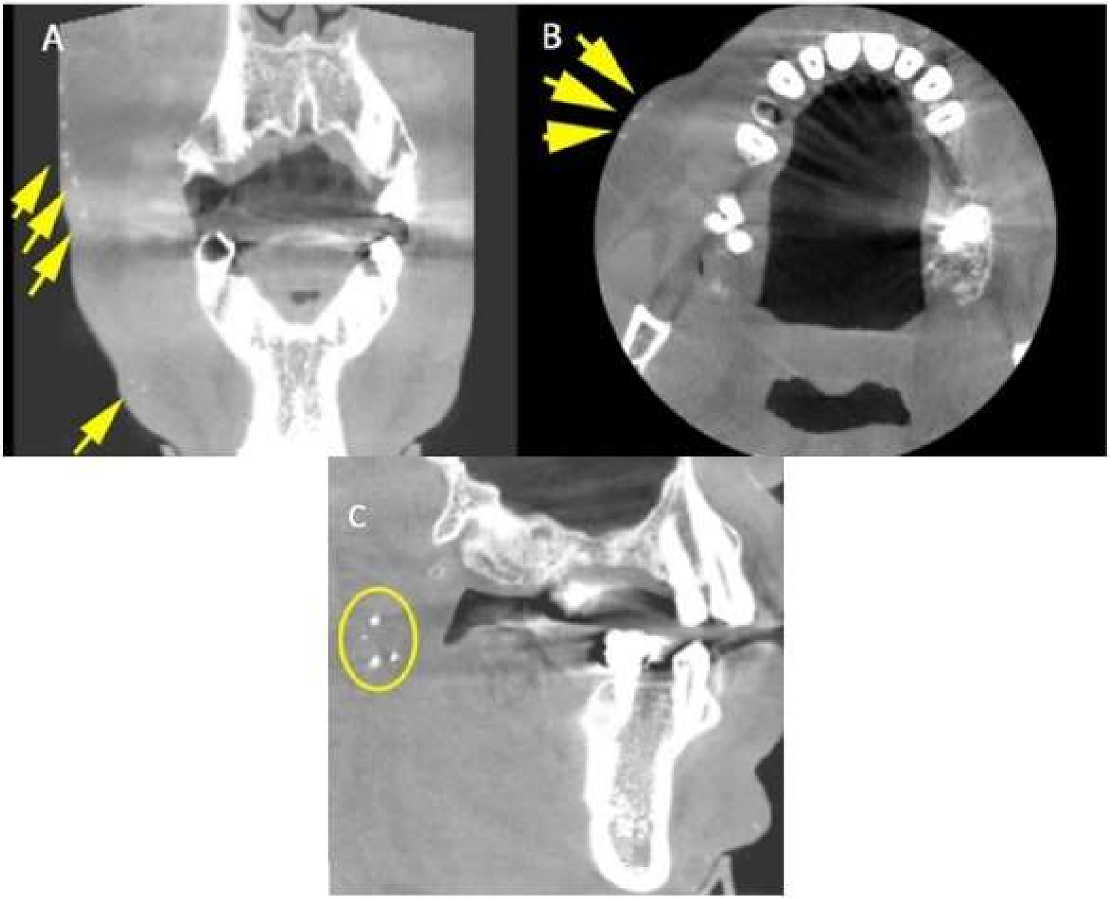

Fig 6. Axial and coronal sections. A) Coronal cut showing multiple radiopaque masses along the dermal layer lateral to the buccinator muscle indicated by yellow arrows. B) Axial cut with yellow arrows showing 3 small concentric nodules in the buccal cheek. [33] C) Sagittal section displaying multiple small radiopaque masses in the left palatine tonsils consistent with tonsilloliths (yellow circle). [33]

But because CBCT has poor soft tissue contrast, the location of a calcification is frequently explained in relation neighboring bony structures such as the cervical vertebrae, the hyoid bone and pharyngeal airway. Missias et al. [57] in 2018 study, showed that 62.6% of the studied subjects disclosed at least one type of calcification. It is essential to identify these entities on CBCT scans as their occurrence may intensify patient mortality and morbidity.

7.In Incidental findings Incidental findings in CBCT scans may be initially detected during CBCT studies performed for implant placement or other diagnostic purposes. It might be assumed that CBCT imaging is less likely to result in the identification of incidental findings when compared to other medical imaging modalities due to the discernability of soft tissue. Though, several studies reported the prevalence of incidental findings on CBCT. However, these studies differ depending on the population studied, the age groups, the field of view, and category of findings.[3,6] In order to comprehensively review CBCT images, incidental findings can be categorized according to their anatomic relations and clinical significances. CBCT images may only reveal dental structures in the maxillary and mandibular arches or may a larger field of view to display paranasal sinuses, nasal fossa, pharyngeal airway, TMJ. Images of the entire skull may disclose the base of the skull and temporal bone, the cervical spine, and the soft tissues of the neck.[3, 59]

Incidentally detected findings can include various abnormalities in the paranasal sinuses, such as thickening of the mucosa, air-fluid levels, mucous retention cysts, mucoceles, and opacification. Additionally, variations in the maxillary sinuses may be identified, including deviations in the nasal septum, concha bullosa, Haller cell, Onodi cell, and agger nasi. [59] Vertebral degenerative changes and soft tissue calcifications (e.g., calcified stylohyoid ligaments, calcified pineal glands, tonsilloliths etc.).[3]

Incidental findings are classified based on their clinical significance, which can be low, intermediate, or high. Low significance findings usually do not require any further action, while those of intermediate significance may require follow-up. Findings with high significance typically warrant intervention.[6]

Calcification of atherosclerotic plaques is considered of a high risk finding in particular the carotid arteries which may result in the sluggish of blood to the brain, and hence considered a serious finding. Although the condition is controversial, it might lead to stroke. Thus, can assist in the identification of cases that are not diagnosed with cardiovascular disease and consequently could be lifesaving.[6] Sunil Mutalik and Aditya Tadinada [60] concluded that the occurrence of intracranial carotid calcifications rises when extracranial calcifications are discovered. In dental practice, the volumes acquired often show the extracranial carotid vessel area. Therefore, the presence of extracranial calcification may indicate the presence of intracranial carotid calcification and require further investigations and referrals. It is important that findings in CBCT are not overlooked and are the responsibility of the person who requested the scan. Practitioners should be trained to identify any significant findings or seek the assistance of an oral and maxillofacial radiologist to ensure a thorough assessment of the volume.

8.In Forensic Studies Facial approximation, also known as facial reconstruction, involves creating a representation of a person's face based on skeletal remains, which can help in identifying the individual. This method is used as a last resort in forensic examinations when other identification methods fail to recognize skeletal, or human remains. In other words, facial approximation is an alternative method used when no other options are available. Facial approximation is typically carried out by utilizing average facial soft tissue thickness (FSTT). FSTT is influenced by various factors including sex, age, Body Mass Index (BMI), malocclusion types, population origin, and more. Therefore, the development of a comprehensive and standardized database of facial soft tissue thickness is crucial to improve the accuracy of facial reconstruction.[61]

Manual or computer-based methods can be used for facial reconstruction, both of which rely on two critical components: skull morphology and facial soft tissue databases. CBCT can be utilized to establish databases of FSTT and analyze its correlation with influential factors to predict facial soft tissue characteristics in specific ethnicities or populations.[6] The CBCT measuring protocol provides standardization and reproducibility of measurements of the facial soft tissue. The skeletal tissues obtained using CBCT could help in the prediction of the soft morphology in combination with the age, sex, and skeletal maturation.[50]

While other modalities like needle puncture and ultrasound require direct contact with the skin, CBCT is a non-contact method that can be used on living individuals. Furthermore, unlike CT scans which require a supine position, CBCT can scan subjects in an upright position. It is well-known that facial morphology can differ with changes in body position, and as a result, various approaches can yield different results in FSTT assessment. Out of all the methods available, CBCT is considered to be superior.[62]

Dao-Ngoc et al. [63] anticipated a technique that was considered to be reliable for facial skin structure segmentation and thickness measurements, with no soft tissue deformation. The technique showed a quicker and simpler method other than ultrasonic scanning techniques. The method demonstrated the capability of being an adjunctive tool for CBCT-driven studies as such; forensics, anthropometrics, and few medico-dental applications.

Recent trends for the enhancement of soft tissue contrast in CBCT scans Several methods have been proposed to enhance the soft tissue perception in CBCT scans amongst are:

1.Increasing the contrast-to-noise ratio (CNR) ratio:Studies have shown that the use of an anti-scatter grid can increase the contrast-to-noise ratio (CNR) ratio in CBCT. However, the practice of using a high grid-ratio for CNR enhancement has been discontinued because the noise produced outweighs the contrast enhancement. To address this issue, Sanghoon Cho et al.,[64] proposed a method to increase CNR and improve the visibility and detection of soft tissue in the head and neck region without increasing radiation dose to patients. This was achieved by reducing the number of projections and increasing the exposure to compensate for the decrease in the number of projections. As a result, image quality was enhanced without an increase in patient radiation dose, and noise levels were reduced compared to a conventional scan with an anti-scatter grid.

2.**Dual energy imaging technology (DECT)**A new DECT (dual-energy computed tomography) scanner that utilizes a single X-ray source, and split spectral filters has been developed. This scanner separates the polychromatic x-ray photons into two adjacent beams with different energy spectra. The use of filter-based DE-CBCT (dual-energy cone beam computed tomography) imaging with an x-ray source featuring two focal spots operating at the same tube voltage helps to reduce metal artifacts and improve the overall image quality produced by CBCT scanners.[65]

Conclusions

1. CBCT could be only used in linear measurements of soft tissue thickness only in the subsequent fields; periodontology and implantology, orthodontics, orthognathic surgeries, forensic studies.
2. Volumetric assessment of soft tissue using CBCT is quite challenging and fails in certain instances.
3. CBCT is a valuable tool in obstructive salivary gland diseases.
4. CBCT could be used in the combination with modalities as US, 3D optical tools and laser scanners for enhanced diagnostic ability of the soft tissue.
5. CBCT is not the imaging modality of choice when a detailed or definite soft tissue imaging of the head and neck is required.

Recommendations

1. Future research in unexplored dental and non-dental applications should be carried out to examine the validity of soft tissue imaging.

2. Attempts should be made to use all the possible means to decrease the amount of scatter and hence, enhancing the contrast resolution and image quality as follows:

- Hardware-based techniques like anti-scatter grids or air gap collimation placed between the patient and the detector.
- Software-based techniques (Reconstruction Algorithms): scatter correction algorithms, advanced iterative reconstruction algorithms or scan protocol optimization by either field-of-view (FOV) limitation or tube current modulation:
- Artificial intelligence (AI) based methods which still under investigation and need huge CBCT datasets images.

3. Dual energy-CT (DE-CT) should be implemented in the dental field as it's widely used in the medical field and proved to be efficient in improving the soft tissue contrast.

Declarations

Competing interests
No conflict of interest

Funding:
This research was self-funded by the authors.

Authorship
Author 1: Contributed to conception, design, data acquisition and interpretation, writing and revised the manuscript.
Author 2: Contributed to editing, revising, and submitting the manuscript.

References

1. Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofacial Radiology. 2004 Sep;33(5):291-4.
2. Zöller JE, Neugebauer J. Cone-beam volumetric imaging in dental, oral, and maxillofacial medicine. Fundamentals, diagnostics, and treatment planning (2008). European Journal of Orthodontics. 2008;30: 668-70.
3. Dief S, Veitz-Keenan A, Amintavakoli N, McGowan R. A systematic review on incidental findings in cone beam computed tomography (CBCT) scans. Dentomaxillofacial Radiology. 2019 Oct 1;48(7):20180396.
Iqubal MA, Panat SR, Khan M, Khan KP. Application of cone beam computed tomography (CBCT) in dental practice : A review.2015, 2(1):37–40
4. Attaia D, Ting S, Johnson B, Masoud MI, Friedland B, El Fotouh MA, El Sadat SA. Dose reduction in head and neck organs through shielding and application of different scanning parameters in cone beam computed tomography: an effective dose study using an adult male anthropomorphic phantom. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology. 2020 Jul 1;130(1):101-9.
5. Scarfe WC, Angelopoulos C, editors. Maxillofacial cone beam computed tomography: principles, techniques and clinical applications. Springer; 2018 Jan 4.
6. Pan Y, Chen S, Shen L, Pei Y, Zhang Y, Xu T. Thickness change of masseter muscles and the surrounding soft tissues in female patients during orthodontic treatment: a retrospective study. BMC Oral Health. 2020 Dec;20:1-10.
7. Tymofiyeva O, Boldt J, Rottner K, Schmid F, Richter E-J, Jakob PM. High-reslution 3D magnetic resonance imaging and quantification of carious lesions and dental pulp in vivo. MAGMA 2009; 22: 365–74. https://doi.org/10.1007/s10334-009-0188-9.
8. Johannsen KM, Fuglsig JM, Matzen LH, Christensen J, Spin-Neto R. Magnetic resonance imaging in the diagnosis of periodontal and periapical disease. Dentomaxillofacial Radiology. 2023 Oct 1;52(7):20230184.
9. Abdinian M, Aminian M, Seyyedkhamesi S. Comparison of accuracy between panoramic radiography, cone-beam computed tomography, and ultrasonography in detection of foreign bodies in the maxillofacial region: an in vitro study. J Korean Assoc Oral Maxillofac Surg 2018;44(1):18–24.
10. Betancourt AR, Samal A, Chan HL, Kripfgans OD. Overview of ultrasound in dentistry for advancing research methodology and patient care quality with emphasis on Periodontal/peri-implant applications. Zeitschrift Für Medizinische Physik. 2023 Mar 13.
11. Sayed AM, Lamarck R, Cruz E, Chaves E, Mukdadi OM. Quantitative Assessment of

Gingival Inflammation Using High- Resolution Ultrasound Ex-Vivo. Journal of Mechanics in Medicine and Biology 2018;18(03):1850012.
12. Sönmez G, Kamburoğlu K, Gül"sahı A. Accuracy of high-resolution ultrasound (US) for gingival soft tissue thickness mesurement in edentulous patients prior to implant placement. Dentomaxillofac Radiol 2021;50(5):20200309.
13. Hériveaux Y, Audoin B, Biateau C, Nguyen V-H, Haïat G. Ultrasonic Propagation in a Dental Implant. Ultrasound Med Biol 2020;46(6):1464–1473.
14. Mozaffarzadeh M, Moore C, Golmoghani EB, Mantri Y, Hariri A, Jorns A, Fu L, Verweij MD, Orooji M, de Jong N, Jokerst JV. Motion-compensated noninvasive periodontal health monitoring using handheld and motor-based photoacoustic-ultrasound imaging systems. Biomed Opt Express 2021;12(3):1543–1558.
15. Chan H-L-A, Kripfgans OD. Ultrasonic Imaging for Evaluating Peri-Implant Diseases, Dental Ultrasound in Periodontology and Implantology. Springer; 2021. p. 161–175.
16. Fiori F, Rullo R, Contaldo M, Inchingolo F, Romano A. Noninvasive in-vivo imaging of oral mucosa: state-of-the-art. Minerva Dent Oral Sci 2021;70(6):286–293.
17. Izzetti R, Nisi M, Aringhieri G, Vitali S, Oranges T, Romanelli M, Caramella D, Graziani F, Gabriele M. Ultra-high frequency ultrasound in the differential diagnosis of oral pemphigus and pemphigoid: An explorative study. Skin Res Technol 2021;27 (5):682–691.
18. Miracle AC, Mukherji SK. Conebeam CT of the head and neck, part 1: physical principles. American Journal of Neuroradiology. 2009 Jun 1;30(6):1088-95
19. Wiegert J, Bertram M, Schaefer D, Conrads N, Noordhoek N, de Jong K, Aach T, ose G. Soft-tissue contrast resolution within the head of human cadaver by means of flat-detector-based cone-beam CT. InMedical Imaging 2004: Physics of Medical Imaging 2004 May 6 (Vol. 5368, pp. 330-337). SPIE.
20. Scarfe WC, Farman AG. What is cone-beam CT and how does it work?. Dental Clinicsof North America. 2008 Oct 1;52(4):707-30.
21. Alamri HM, Sadrameli M, Alshalhoob MA, Alshehri MA. Applications of CBCT in ental practice: a review of the literature. General dentistry. 2012 Sep 1;60(5):390-400.
22. Jepsen S, Caton JG, Albandar JM, Bissada NF, Bouchard P, Cortellini P, Demirel K, de Sanctis M, Ercoli C, Fan J, Geurs NC. Periodontal manifestations of systemic diseases and developmental and acquired conditions: Consensus report of workgroup 3 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. Journal of clinical periodontology. 2018 Jun;45:S219-29.
23. Kuralt M, Gašperšič R, Fidler A. 3D computer-aided treatment planning in periodontology: A novel approach for evaluation and visualization of soft tissue thickness. Journal of Esthetic and Restorative Dentistry. 2020 Jul;32(5):457-62.
24. Gürlek Ö, Sönmez Ş, Güneri P, Nizam N. A novel soft tissue thickness measuring method using cone beam computed tomography. Journal of Esthetic and Restorative Dentistry. 2018 Nov;30(6):516-22.
25. Alves PH, Alves TC, Pegoraro TA, Costa YM, Bonfante EA, de Almeida AL. Measurement properties of gingival biotype evaluation methods. Clinical Implant Dentistry and Related Research. 2018 Jun;20(3):280-4.
26. Lau SL, Chow LK, Leung YY. A non-invasive and accurate measurement of gingival thickness using cone-beam computerized imaging for the assessment of planning immediate implant in the esthetic zone—a pig jaw model. Implant Dentistry. 2016 Oct 1;25(5):619-23.
27. Januario AL, Barriviera M, Duarte WR. Soft tissue cone-beam computed tomography: A novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. Journal of esthetic and restorative dentistry. 2008 Dec;20(6):366-73
28. El Khalifa M, Abu el Sadat SM, Gaweesh YS, Gaweesh YY. Assessment of Gingival Thickness Using CBCT Compared to Transgingival Probing and Its Correlation with Labial Bone Defects: A Cross-Sectional Study. International Journal of Oral & Maxillofacial Implants. 2022 May 1;37(3).
29. De Bruyckere T, Eeckhout C, Eghbali A, Younes F, Vandekerckhove P, Cleymaet R, Cosyn J. A randomized controlled study comparing guided bone regeneration with connective tissue graft to re-establish convexity at the buccal aspect of single implants: A one-year CBCT analysis. Journal of Clinical Periodontology. 2018 Nov;45(11):1375-87.
30. Fujita Y, Nakano T, Ono S, Shimomoto T, Mizuno K, Yatani H, Ishigaki S. CBCT analysis of the tissue thickness at immediate implant placement with contour augmentation in the maxillary anterior zone: a 1-year prospective clinical study. International Journal of Implant Dentistry. 2021 Dec;7:1-9

31. Chan HL, Sinjab K, Li J, Chen Z, Wang HL, Kripfgans OD. Ultrasonography for noninvasive and real-time evaluation of peri-implant tissue dimensions. Journal of clinical periodontology. 2018 Aug;45(8):986-95.
32. Thöne-Mühling M, Kripfgans OD, Mengel R. Ultrasonography for noninvasive and real-time evaluation of peri-implant soft and hard tissue: a case series. International Journal of Implant Dentistry. 2021 Dec;7:1-3.
33. Shi M, Wang X, Zeng P, Liu H, Gong Z, Lin Y, Li Z, Chen Z, Chen Z. Analysis of the sagittal root angle and its correlation with hard and soft tissue indices in anterior teeth for immediate implant evaluation: a retrospective study. BMC Oral Health. 2021 Dec;21:1-5.
34. Weber HP, Cano J, Bonino F. Digital implant surgery. Clinical applications of digital dental technology. 2015 Jun 8:139-66.
35. Resnick CM, Dang RR, Glick SJ, Padwa BL. Accuracy of three-dimensional soft tissue prediction for Le Fort I osteotomy using Dolphin 3D software: a pilot study. International journal of oral and maxillofacial surgery. 2017 Mar 1;46(3):289-95.
36. Shobair N, Diaa M, Barakat A, Ghanem A. The Prediction Accuracy of Dolphin 3D Software for Facial Soft Tissue Changes After Bimaxillary Orthognathic Surgery. Ain Shams Dental Journal. 2021 Sep 1;23(3):55-61.
37. de Sousa Gil AP, Guijarro-Martínez R, Haas Jr OL, Hernández-Alfaro F. Three-dimensional analysis of nasolabial soft tissue changes after Le Fort I osteotomy: a systematic review of the literature. International Journal of Oral and Maxillofacial Surgery. 2019 Sep 1;48(9):1185-200
38. de Sousa Gil AP, Guijarro-Martínez R, Haas Jr OL, Masià-Gridilla J, Valls-Ontañón A, de Oliveira RB, Hernández-Alfaro F. Nasolabial soft tissue effects of segmented and non-segmented Le Fort I osteotomy using a modified alar cinch technique—a cone beam computed tomography evaluation. International Journal of Oral and Maxillofacial Surgery. 2020 Jul 1;49(7):889-94.
39. Swennen G, editor. 3D virtual treatment planning of orthognathic surgery: a step-by-step approach for orthodontists and surgeons. Springer; 2016 Nov 1
40. Jung J, Lee CH, Lee JW, Choi BJ. Three dimensional evaluation of soft tissue after orthognathic surgery. Head & face medicine. 2018 Dec;14:1-8
41. Al Abduwani J, ZilinSkiene L, Colley S, Ahmed S. Cone beam CT paranasal sinuses versus standard multidetector and low dose multidetector CT studies. American journal of otolaryngology. 2016 Jan 1;37(1):59-64
42. Mallya S, Lam E. White and Pharoah's oral radiology: principles and interpretation. Elsevier Health Sciences; 2018 Sep 12.
43. El Sadat SM, Al Ashiry MK, Mostafa RA, Abdelkarim AZ, Syed AZ. An immature ten-year long-standing case of ossifying fibroma. Cureus. 2018 Jun 11;10(6).
44. Abdelkarim AZ, El Sadat SM, Chmieliauskaite M, Syed AZ. Radiographic diagnosis of a central giant cell granuloma using advanced imaging: cone beam computed tomography. Cureus. 2018 Jun 5;10(6)
45. Ehlers SA, Bozanich JM, Arashlow MT, Liang H, Nair MK. Large airway-obstructing retropharyngeal lipoma in an asymptomatic patient: a case report. International Journal of Implant Dentistry. 2020 Dec;6:1-5.
46. Drage NA, Brown JE. Cone beam computed sialography of sialoliths. Dentomaxillofacial Radiology. 2009 Jul;38(5):301-5.
47. Amer ME, Abo-Taleb NS. Assessment of the role of cone beam computed sialography in diagnosing salivary gland lesions. Imaging science in dentistry. 2013 Mar;43(1):17.
48. Bertin H, Bonnet R, Delemazure AS, Mourrain-Langlois E, Mercier J, Corre P. Three-dimensional cone-beam CT sialography in non tumour salivary pathologies: procedure and results. Dentomaxillofacial Radiology. 2017 Jan 1;46(1):20150431.
49. Marradi F, Staderini E, Zimbalatti MA, Rossi A, Grippaudo C, Gallenzi P. How to obtain an orthodontic virtual patient through superimposition of three-dimensional data: A systematic review. Applied Sciences. 2020 Aug 3;10(15):5354.
50. Allam E, Mpofu P, Ghoneima A, Tuceryan M, Kula K. The relationship between hard tissue and soft tissue dimensions of the nose in children: a 3D cone beam computed tomography study. Journal of forensic sciences. 2018 Nov;63(6):1652-60.
51. Brons S, van Beusichem ME, Bronkhorst EM, Draaisma J, Bergé SJ, Maal TJ, Kuijpers-Jagtman AM. Methods to quantify soft-tissue based facial growth and treatment outcomes in children: a systematic review. PLoS One. 2012 7(8):1–10.
52. Nguyen H, Shin JW, Giap HV, Kim KB, Chae HS, Kim YH, Choi HW. Midfacial soft tissue changes after maxillary expansion using micro-implant-supported maxillary skeletal expanders in young adults: A retrospective study. Korean journal of orthodontics. 2021 May 5;51(3):145

53. KILINÇ D, Dilaver E. Evaluation of soft tissue projection on axial cone beam computed tomography images after surgically assisted rapid maxillary expansion. Meandros Medical And Dental Journal. 2021;22(1)
54. Camps-Perepérez I, Guijarro-Martínez R, Peiró-Guijarro MA, Hernández-Alfaro F. The value of cone beam computed tomography imaging in surgically assisted rapid palatal expansion: a systematic review of the literature. International journal of oral and maxillofacial surgery. 2017 Jul 1;46(7):827-38.
55. Murat S, Batak B. Fabrication of a 3-dimensionally printed definitive cast for an obturator prosthesis by merging intraoral scan image with cone beam computed tomography data: A clinical report. The Journal of Prosthetic Dentistry. 2021 Aug 1;126(2):256-e1.
56. Kuralt M, Bukleta MS, Kuhar M, Fidler A. Bone and soft tissue changes associated with a removable partial denture. A novel method with a fusion of CBCT and optical 3D images. Computers in Biology and Medicine. 2019 May 1;108:78-84.
57. .Missias EM, Nascimento EH, Pontual ML, Pontual AA, Freitas DQ, Perez DE, Ramos-Perez FM. Prevalence of soft tissue calcifications in the maxillofacial region detected by cone beam CT. Oral diseases. 2018 May;24(4):628-37.
58. Cakmak ES, Bayrak S, Atakan C. Prevalence and characteristics of soft tissue calcifications in cbct images of mandibular region. Clinical and Experimental Health Sciences. 2020 Mar 1;10(1):68-71.
59. Avsever H, Gunduz K, Karakoç O, Akyol M, Orhan K. Incidental findings on cone-beam computed tomographic images: paranasal sinus findings and nasal septum variations. Oral radiology. 2018 Jan;34:40-8.
60. Mutalik S, Tadinada A. Assessment of relationship between extracranial and intracranial carotid calcifications—a retrospective cone beam computed tomography study. Dentomaxillofacial Radiology. 2019 Dec 1;48(8):20190013
61. Deng C, Wang D, Chen J, Li K, Yang M, Chen Z, Zhu Z, Yin C, Chen P, Cao D, Yan B. Facial soft tissue thickness in Yangtze River delta Han population: Accurate assessment and comparative analysis utilizing Cone-Beam CT. Legal Medicine. 2020 May 1;44:101693.
62. Gomes AF, Moreira DD, Zanon MF, Groppo FC, Haiter-Neto F, Freitas DQ. Soft tissue thickness in Brazilian adults of different skeletal classes and facial types: A cone beam CT–Study. Legal Medicine. 2020 Nov 1;47:101743.
63. Dao-Ngoc L, Liu CF, Du YC. A Segmentation Enhancement Method for the Low-Contrast and Narrow-Banded Substances in CBCT Images. Electronics. 2020 Jun 11;9(6):974.
64. Cho S, Lim S, Kim C, Wi S, Kwon T, Youn WS, Lee SH, Kang BS, Cho S. Enhancement of soft-tissue contrast in cone-beam CT using an anti-scatter grid with a sparse sampling approach. Physica Medica. 2020 Feb 1;70:1-9.
65. Tse JJ, Dunmore-Buyze J, Drangova M, Holdsworth DW. Dual-energy computed tomography using a gantry-based preclinical cone-beam microcomputed tomography scanner. Journal of Medical Imaging. 2018 Jul 1;5(3):033503-.