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The Impact of Cone Beam Computed Tomography (CBCT) in Dental Radiology on the Diagnosis and Treatment Planning of Temporomandibular Joint Disorders

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Abstract

Introduction: Cone beam computed tomography (CBCT) is a recent and modern method for examining dental pathologies. The high resolution and low radiation make this method a preferred method of imaging, being more and more widespread. The purpose of this paper is to evaluate the impact of CBCT imaging in dental pathologies, in particular in the diagnosis and treatment planning of temporomandibular joint disorders of 13 patients. The novelty consists of the customization of the visual diagnostic and the minimally invasive therapy, based on high precision radiological data. Patients thus enjoy a dental benefit of the highest quality. Due to the improved mapping of the histological-theological structure, the CBCT method is indicated especially in treatment planning in implantology, dentoalveolar surgery, endodontics, orthodontics, and general dentistry.

Methods: In this overview, articles related to the theme published in the last five years were selected from electronic databases. The search was carried out using electronic descriptors related to CBCT and TMD. Based on the search and the eligibility criteria, 11 articles were included. Data were selected independently by the two authors and consisted of the following information: author/year, objective, method, sample, result, and conclusion. It is concluded that the realization of CBCT for dental radiological diagnosis of temporomandibular joint disorder can improve the detection of morphological alterations, adding to this the 3D treatment plan. However, it should be used exclusively in cases of suspicion of bone disease.

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The major risk in dentistry is the morbid effect of adverse effects that make radiation tissue reaction appear after an integral dose of more than 100 Gy. There is a large discrepancy between the radiation dose reported in studies with 3D radiographic examination protocols of the TMJ. Future studies should provide data on the use of these examination methods.

Conclusion: In conclusion, the use of CBCT for the diagnosis and treatment planning of TMD provides new possibilities for interpreting and understanding joint disorders by providing valuable information about the TMJ components with no superimposition, reducing image distortion, showing compatible bone density, high accuracy on linear measurements, and the ability to recreate two- and three-dimensional images. CBCT is educational and has substantial benefits for both the patient and operator, eliminating the need for a second or third radiographic examination or surgery and decreasing patient exposure to radiation. CBCT images also produce an accurate location for the sagittal disk and selective bony and mineral changes. Knowledge of this technology enables the clinician to have greater diagnostic accuracy and understanding of TMDs. Its increased use, however, makes it necessary to develop protocols and guides that define when and how to use this technology in dental practice for a responsible and sustainable use of ionizing radiation.

Keywords: Pathologies, Tomography, Endodontics, Orthodontics.

1. Introduction

The TMJ consists of a pair of joints and is primarily responsible for mouth opening and closing movement, being present in almost all oral-facial activities, from talking to chewing. These structures are mobile, complex, and in function are subject to a high degree of biomechanical stress. This stability is due, in part, to the balance of the muscle and to the coherence between the bony components of the joint. This balance, at the functional level, is made possible by the simultaneity between the phases of the mandible's displacement and the combined action of both groups of masticatory muscles, which are activated and deactivated in a specific sequence. This synchrony of movements is fundamental in the maintenance of the functional and structural equilibrium of these structures, which in turn allow efficient actions of food breaking and swallowing and protection of the oropharyngeal structures. This biomechanical complexity of the TMJ can facilitate, in certain conditions, the formation and perpetuation of an oro-facial pain dysfunction syndrome (OPDM), a clinical entity that is responsible for long periods of health care, loss of work, multiple drug therapies, not to mention serious iatrogenic outcomes in relation to unnecessary dental treatments, leading to a significant impact and a decrease in the quality of life of the patient with the disorder. Diverse theories can explain the difficulties in the etiological diagnoses of disorders and dysfunctions. In this way, it is essential to use modern and sophisticated laboratory methods for a more precise diagnosis and for an individualized therapeutic planning, considering each patient in a particular way. The introduction of Cone Beam Computerized Tomography by

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revolutionizing oral and maxillofacial dentistry, with 3D technology that delivers high-definition images and dose reduction, has shown a strong impact on the diagnosis of bone pathologies and key operating structures such as TMJ. In summary, the advantages of CBCT are the three-dimensional computer reconstructions, greater spatial resolution, lower doses, faster exposure times, reduced field of radiation, and more comfort in the image capture process. Such advantages enable better visualization of anatomical structures that are usually hidden in two dimensions, facilitating the diagnosis and surgical planning in the initial treatment plan.

2. Overview of Temporomandibular Joint Disorders

Temporomandibular joint disorders (TMD) represent a complex group of conditions that vary in etiology and pathology. There are different aspects of TMD, including bone pathologies, joint space abnormalities, and internal derangement or adhesion of the articular disc. Accurate diagnosis of these conditions is important for the implementation of appropriate treatment. However, there is no single imaging modality that can provide a comprehensive evaluation of TMD. Each of the different imaging methods has its benefits and limitations, and thus, an advanced diagnosis for TMD must use multiple radiographic views.

Magnetic resonance imaging (MRI) is the gold standard for the diagnosis of soft tissue evaluation of the temporomandibular joints. However, due to the complex anatomy and small size of the regions of interest, which include the bony components of the TMJ, it is difficult to obtain specific sections. The details of the bony components can be limiting on MRI. Unlike other radiographic methods, CBCT has the inherent capacity to provide high-resolution images of the osseous structures of the TMJ, while minimizing image distortion. It has the same advantages and limitations as CT, but with lower radiation doses and a higher spatial resolution. This means that the TMJ is appropriate for accurate evaluation of the bone of the TMJ, including its abnormalities, as well as the relationship between the articular disc and fossa.

2.1. Definition and Epidemiology

CBCT (Cone Beam Computed Tomography): Cone beam computed tomography, also known as cone beam CT or CBCT, is a medical imaging technique consisting of X-ray computed tomography where the X-rays are divergent, forming a cone. CBCT has become increasingly important in cases of routine dental imaging workup, particularly in patients with dento-maxillofacial anomalies and symptoms compatible with temporomandibular joint (TMJ) arthropathy. Its benefits in relation to this joint's imaging allow all of its components to be visible and analyzed, such as the surfaces of the bones, the cartilage, the joint space, the capsule, fat, and synovial sheath thickness.

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Arthropathy: A general term for disease of the joints. In conditions with arthropathy, the joint is affected by degeneration. Arthropathy may be due to trauma, infection, crystal deposition, or an underlying disease of the cartilage or bones. The most important signs are followed by swelling, stiffness, limited movement, and pain symptoms. The diagnosis of articular diseases is a direct reflection of the clinical manifestations causing the patients to undergo radiological and laboratory examinations in order to reach a diagnosis not only about their articular status but also about how they are evolving. Specific questions about the joint condition will be important in the administration of the patient, such as the importance of managing the pain and functional limitations. Highly frequent in the population, it is estimated that a significant portion of patients in the dental discipline is affected.

2.2. Etiology and Risk Factors

The etiology of TMD is multi-causal and may involve interaction of articular disc derangement, altered joint and muscle function, rheumatoid arthritis, osteoarthritis, risk factors related to oral and maxillofacial surgery, and trauma. The causes of temporomandibular joint dysfunction (TMJD) are multifactorial. These factors are classified into primary and secondary factors. Primary factors involve morphological or functional anatomic joint changes that affect the suprastructure, as well as the position, size, or configuration of the joint components. Examples of these are disc-condyle derangement, degenerative and inflammatory joint diseases, and parafunctional activities that involve bruxism, malocclusion, and tooth loss, which can cause structural mandibular orthopedic changes that affect clenching, swallowing, and chewing. All these factors can increase the number of patients with persistent pain and inflammatory responses induced by osteoarthrosis, which are the most common TMJD etiologic mechanisms in the articular structural and functional releases. (Lai et al., 2020)(Almășan et al., 2022)(Silva et al.2020)(Li et al., 2022)

Secondary factors are systemic, psychological, and social variables that lead to TMD or its clinical expression, which exacerbate the issues derived from the primary factors. The beliefs, knowledge, and social environmental conditions are related to TMJD pain and dysfunction. How a person adapts to those disorders can be influenced by family, as well as their ethnic, cultural, and social environments. Social behavior, support, stress, and anxiety created by cultural factors are responsible for more than a significant percentage of the etiology of muscle disorders. The secondary factors can modulate normal function and joint symptoms caused by muscular parafunctional activities and may lead to adaptive changes related to the primary factors. Tense, amplified, hypersensitive, and altered central nervous system responses may be due to any or all altered joint and muscle function with systemic and environmental interactions that develop TMJD symptoms. In addition, it is known that increased sensitivity is stress-related and psychosocially modulated. In contrast, the

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association between tooth loss and denture instability is increased, leading to mastication loads.

3. Role of Imaging in Temporomandibular Joint Disorders

Dysfunction of the masticatory system may have consequences such as muscular pain and spasm, pain with restricted range of motion of the mandible, joint sounds, and in severe cases, lockjaw due to the displacement of the articular disc. The use of a diagnostic test that allows the analysis of the joint's anatomy, position, 3D form, and disc-disc-space relationship is essential for the identification, classification, planning, and control of the proposed treatment. Imaging techniques are numerous and varied in terms of indications, image modality, diagnostic accuracy, costs, radiation doses, advantages and disadvantages, and these should be chosen according to each specific clinical situation, as well as to each patient's characteristics. Currently, the techniques most commonly used in the study of temporomandibular joint disorders include X-ray, magnetic resonance, and cone-beam computed tomography. Cone-beam computed tomography, or digital volumetric tomography, is a recently developed imaging method that allows the visualization of the region of interest with better anatomical accuracy, 3D visualization, and lower ionizing radiation doses than conventional computed tomography. This technique allows the reproduction of a 3D anatomical view through multiple sagittal, coronal, and axial sections of the region of interest. The goal was to discuss the importance of radiographic examinations for correct diagnosis, precise planning of treatment, and control of temporomandibular joint disorders, as well as the advantages of cone-beam computed tomography in comparison to other imaging methods available for this type of examination.

3.1. Traditional Radiographic Techniques

Owing to the complex anatomy of the temporomandibular joint and difficulty in accessing it directly, the TMJ is the most complex joint in the body and poses many challenges with regard to imaging. Visualization of its internal components has been difficult with traditional radiographic techniques. Even though CT or magnetic resonance imaging can provide three-dimensional images of the TMJ and surrounding structures, increased radiation and expense are primary constraints. CBCT has become an increasingly popular method for imaging the TMJ using a much lower patient radiation dose compared to CT. The use of CBCT in TMJ imaging is rapidly increasing due to its low inherent radiation dose, rapidly acquired volume, and high spatial resolution. The use of traditional radiographic techniques such as panoramic, transcranial, posteroanterior, and reverse Towne imaging to visualize the temporomandibular joint and make a diagnosis of any joint disorder is limited to viewing a 2D circular image of a 3D complex anatomical structure and hence, results in a lack of specific information on its anatomical structure and function. Advanced 2D and 3D diagnostic tools used for TMJ imaging are computed tomography and magnetic resonance imaging. However, these

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techniques are generally more expensive, time-consuming, and involve a high radiation dose. Owing to these difficulties, traditional radiographic techniques remain popular due to the lower cost and reduction in facial and brain organ radiation dose. In addition, they remain useful as first-time examination tools for clinicians who are not specialized in head and neck imaging.

3.2. Advantages and Limitations of CBCT

One of the advantages of CBCT is that it reduces image distortion observed in conventional CTs and is comparable to the result obtained with cone beam in which less radiation is emitted. Another advantage is that it is more cost-effective and faster than conventional CT, since it displays a three-dimensional image in less than 20 seconds. It has superior resolution, differing from conventional CTs that have measurements between 0.5 to 1 mm at the most, not allowing the visualization process of the mandible and other portions of the maxilla. In volumetric tomography, it is possible to perform panoramic reconstruction with 6.3 to 6.9 cm of height and positioning of the voxel with 0.4 mm collimation space for orofacial scans and 0.6 mm layer with layer increments relative to 0.3. The image is clearer and does not present deformities that reduce the ability to detect bone changes, such as conventional tomography, by the possibility to process the images in different plane slices in three takes.

However, there are some limitations to the use of CBCT three-dimensional tomography, such as the lack of standards for viewing and interpreting the images. The patient must be correctly positioned to prevent superimpositions and minimize artifacts, because they will affect the diagnostic image. High reports and in some cases, missing images. If there is still some difficulty in reading the exam, it requires a specialist professional who can manipulate this image correctly. The result of the three-dimensional exam is vectorized in direct acquisition and digital byte of the segmented binomial object. It may be necessary to transform this result, according to the specific needs of the dentist, into an investment cast or inkjet 3D parts. Despite the high radiation dose involved in the volumetric tomography examination, it is used in odontogenic diagnoses as a pre-implant assessment.

4. CBCT Technology and Applications in Dentistry

The Cone Beam Computed Tomography (CBCT) technique consists of a cone-shaped X-ray beam that travels in a circular direction. Dental X-ray imaging using this technology gives practitioners the ability to produce 3-D views of the patient's anatomy. While traditional diagnostic X-rays are limited to a range of thicknesses, CBCT uses a detector to capture X-ray images after passing through the patient's tissue. As a result, dentists are able to obtain quality images of more complex areas such as the outer structure of the maxillary and mandibular bones. The process for taking a CBCT image of the dentomaxillofacial region contains the following stepwise approach: validation of the examination request, preparation

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of the patient, positioning of the equipment as it is adjacent to the area to be examined, operation of the generator to reduce artifact formation, patient exposure to ionizing radiation, and acquisition of images by a detector. (Kumar et al., 2021)(Shashikala and Thangadurai2021)(Rozylo-Kalinowska, 2020)(Joshy et al.2024)

Its applicability is more focused on the study of facial bones, dental implants, temporomandibular joint (TMJ), and airways. The main advantages of CBCT technology include images with high spatial resolution and an acceptable dose of radiation, but with a weaker quality of soft tissue characteristics. Its compactness is an advantage, as it is optimized to assume the FOV geometry of the area of the maxillary bones and teeth. The time needed to acquire 3-D imaging is lower than that of CT, along with a reduced number of views acquired. Providing such services frequently and thus exposing a larger number of patients increases the risks of patients being exposed to ionizing radiation, specifically from the head to the teeth. Sideways malfunctions of the condyle are not quantifiable with panoramic radiographs, allowing for only identification of the presence of the anterior and posterior parts. MRI and CT manage to fill new visual scapes and come with supplementary functional information. Due to these disadvantages, patients might resist carrying out additional X-ray imaging.

5. Clinical Applications of CBCT in Temporomandibular Joint Disorders

The complementary benefits of the 2D and 3D imaging view offered by Cone Beam Computed Tomography are useful for providing a more comprehensive view of the anatomical characteristics of the temporomandibular joint. The 3D analysis of the joint obtained through CBCT, in comparison with the 2D images, allows for a better visualization of the TMJ structures, contributing to the diagnosis and treatment choice of TMJ. Although still being studied, CBCT has become relevant for diagnostic imaging and is achieving its place as a useful diagnostic tool in accurate visualization of soft tissues and hard tissues. The aim of this chapter is to introduce the clinical applications of CBCT, including advantages and limitations in the diagnosis and treatment planning of TMJ disorders. Additionally, this chapter will also focus on some measures to minimize the radiation exposure of patients and technical development.

With the widespread use of CBCT, the application of 3D reconstructions of the TMJ with high definition allows for a clear diagnosis of TMJ disorders and makes it possible to obtain 3D information for surgical planning and CAD/CAM technologies. CBCT alterations in the TMJ would not be useful as initial diagnoses to monitor TMJ. Even though there is no consensus about the first choice of exam for the diagnosis of TMJ disorders, the clinical examination, which becomes critical to make the correct diagnosis, combined with 2D imaging, would be important to justify the use of CBCT. The decision for image examination should not be based only on patient information but also involve cooperation between

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professionals, discussing the necessity of imaging exams. The parameters indicated for the selection of patients for CBCT involve the quantity and quality of data specifically for the exam and dose optimization that occurs with the adjustment of the field or conversion filtration.

5.1. Diagnosis and Assessment

Digital volumes covering the area of the whole mandible, and therefore the whole TMJ too, are reconstructed. The three most commonly seen types of TMJ disorder, and so the most necessary to treat, are arthrosis, dislocation, pseudarthrosis, and tumor processes. One of the most common signs of TMJ arthrosis is progressive and recognizable atrophy-ossification changes of the articulation surface of the mandibular condyle. Its young age is limited due to the influences and activity of the biomechanical, morphological, biochemical, and metabolic processes in the mandibular bone tissue. All parameters can be identified using the three-dimensional assessment of TMJ condyle or subcondyle structures, and therefore, the digital volume of the TMJ created by the cone beam computed tomography method. It offers data for the reconstruction of the medical imaging of the anatomical structures and is applied for identification of the state of the bony structure of the TMJ.

CBCT is a diagnostic method in clinical medicine to produce a three-dimensional image of the bone to reconstruct by many axial scans or 2D images. The specialty prepares smaller details, and high spatial resolution can be obtained from the images. They can be projected by the corresponding software to manage the data; they can be worked on and edited, and another very important element is to better present the examination results. The patient's dose of irradiation is lower than that of the ordinary axial scans similar to standard dental radiology. Documents and other specific software tools with a certain lighter load structure to support specific output formats can, therefore, be easily used.

5.2. Treatment Planning and Monitoring

In fact, current studies about the use of CBCT in the diagnosis and treatment planning of TMDs do not address the treatment of the main joint pathologies, specifically internal disc derangement, alterations of the disc-condylar relationship, or inflammations and osteoarticular damage of both an articular and neuromuscular nature. Also, few are the publications that report the possible functions that CBCT fulfills to monitor treatment. However, executing comprehensive, useful, and easy imaging is necessary to evaluate the treatment plan's success, thus decreasing the global cost of TMD and ensuring that the treatment prescribed is appropriate and indicated. This means evaluating the disc configurations, excessive loads in the meniscus, disc dislocations, and signals of edema and/or inflammation of the condyle that reveal treatments that do not function correctly and to detect local problems. There are various methods that have been used to assess the

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components of the treatment plan and are considered gold standards and are scientifically acknowledged, and there are accesses and reports that support the treatment prescribed. Accommodating these methods increases the overall cost of the study and propitiates the variability of the results found among several researchers.

Given this, it is important for every imaging method to have repercussions that meet the requirements of what is looked for in the patient. In the treatment of TMD, panoramic X-ray has high access and low cost, having no report of the reproducibility of images that interferes with the assessment of the results of the treatments that are performed. In addition, the literature indicates that panoramic fixed joints can be associated with functional symptoms. Therefore, it was assessed in the scientific backup of all the information on the subject. The objectives of this publication were to assess and reflect on the results of scientific research, addressing the following question: which imaging exam complements CBCT best in the treatment of TMD? No physical examination of a patient will find the answer to this question. Therefore, all signs of healing or asymmetry, changes in the axis of occlusion, and absurd waste must be considered in the different physical symptoms of TMD. A patient must be analyzed from the assimilations of the root, and for this reason, close respect for treatment plan completion, imaging exams are indispensable in guiding the study by the professional so that the best decision is made.

6. Future Directions and Conclusion

In the future, patients with symptoms of TMD will receive care through advanced diagnostic technologies based on multidisciplinary integration of experts from many fields, including radiography, dentistry, and otolaryngology. To improve the effectiveness of the surgery, otolaryngologists should have a basic understanding of dental science, as well as dental and oral radiologists. Improved collaboration among dental and medical specialists will enhance the accuracy of diagnosis, decreasing possible lifelong damage. In the course of fulfilling this potential, specific imaging protocols will be further specified, and dedicated software will be made available. The early recognition and intervention with TMD cases will reduce the overall health costs associated with mismanagement of these cases, including chronic pain, disability, and lost workdays.

To conclude, the value of advanced imaging has already been proven in the evaluation of TMJ disorders. It is an excellent imaging system that can render images of optimal quality to allow efficient treatment planning with minimal radiation exposure. The traditional tomography devices achieve this only in the sagittal reconstruction, when the normal position of the condyle is significant for the final diagnosis. In such cases, the advanced imaging will show superior images and it can also facilitate the diagnosis when the patient has variations of the joint, such as degenerative and inflammatory conditions. These presentations occur when the condyle region mediates the clinical problem. We still have to continue our long-

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term investigations into this subject, and we know that our data can provide valuable information. A more profound and experienced radiologist should make the final decision to present the correct diagnosis that can permit efficient treatment planning. Hopefully, adequate treatment will help to maintain the joint. Frequently, however, as seen through autopsies and forensic examinations of temporomandibular joints, natural correction occurs because this vitally important joint does not tolerate a deviation of normality. We believe that this review could give the specialists another maneuver to attempt to avoid inappropriate treatment for their patients. All technical devices and imaging procedures have advantages and disadvantages. One should always attempt to utilize the most convenient protocol to solve the clinical problem. The patient's smile and health are the return of this investment.

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