

CLINICAL APPLICATION OF CONE BEAM COMPUTED TOMOGRAPHY FOR EVALUATION OF PERI-IMPLANT BONE THICKNESS AND TEMPORO-MANDIBULAR JOINT IMAGING

Thesis of Ph. D. Dissertation

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List of Publications underlie dissertation

- I. Z. Rasko, L. Nagy, M. Radnai, J. Piffko, Z. Barath: Assessing of Accuracy of Cone Beam Computed Tomography in Measuring Thinning Oral and Buccal Bone
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- II. Z. Barath, Z. Rasko: A Technique for Achieving a Stable Position of the Condylar Process during Temporo-mandibular Joint
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Introduction

Appropriate radiological imaging as well as meticulous physical examination is crucial in the field of dentistry, implantation and oral and maxillofacial surgery for proper diagnostics and treatment of the patient. Traditional orthopantomogram can be applied as basic element of primary and general imaging, but given its two dimensional feature it would not contribute significantly enough amount of acquired data from the anatomical structure of the mandible and maxilla to provide adequate preoperative planning for safe and successful treatment in difficult surgical procedures.

The cone beam – or cone shape beam – has been developed primarily for angiography assessment in the years of 1980 to be possible alternative to traditional fan shape or spiral CT beams as the whole field of interest can be assessed more accurately in shorter time with significant 98% lower exposure of radiation. CBCT is generally used for preoperative planning in the field of implant dentistry to evaluate quantity and quality of available bone, to determine the ideal insertion point of dental implant and its relation to the anatomical structures of the jaw, and to define the size and length of the inserted implant.

Temporo-mandibular joint (TMJ) pain management is one of the most difficult and controversial treatment for physicians. TMJ related pain is common in general population, but only 3-7% of patients attend medical assistance. Imaging of temporo-mandibular joint and its disorders is a fundamental diagnostic step alongside physical examination. Nonetheless physical evaluation of the temporo-mandibular joint can be inconclusive, because the symptoms can overlap each other between internal derangement and dysfunction resulted of myofacial pain.

Some more complicated cases – where significant changes might occur in the bony structure and would be difficult to detect - would require more advanced imaging technologies, such as Magnetic Resonance Imaging (MRI), conventional Computed Tomography (CT) and Cone Beam Computed Tomography (CBCT).

CBCT gathered more and more ground in recent times, since it has a significant advantage to MRI, such as this modality is specifically sensible in identification and assessment of bone anatomy, and has the accuracy in structural analysis.

The use of hyaluronic acid for TMJ osteoarthritis has been proven effective. Injections of the TMJ are inserted into the superior joint space.

Determining the correct injection site and adequate needle angle as well as proper depth of the injection are essential to the effectiveness of the treatment and could reduce the possibility to miss the targeted superior joint space, especially in cases of internal derangement, anatomical deviations, developmental anomalies and post-traumatic conditions. There is a constant request for a 3-dimensional, navigated injection process to eliminate risks and potential side effects such as extravasation of injection fluid around the procedure site, facial nerve or preauricular nerve injury, trauma to the temporo-mandibular joint cartilage, preauricular hematoma, transarticular or intracranial perforation or extradural hematoma. The rate of unsuccessful induction or the fracture of the needle tip is between 2-10%.

Objectives

We wanted to resolve a controversy regarding CBCT:

1. We aimed to determine the finite boundaries of this sophisticated instrument of radiological diagnostics are, in other word what is the minimal expanse of bony structure which can be safely measured without significant loss of accuracy in the presence of dental implants.
2. Our intention was to demonstrate the actual thickness of bone adjacent to dental implant where the CBCT analysis would turn into significantly inaccurate measurement. Besides we wanted to gather appropriate information regarding the distortion of measurement in presence of dental implant. The concept behind our idea was to furnish the clinicians with an appropriate guideline regarding the thickness of the buccal and oral bone that can be measured safely and accurately by CBCT, thus providing a solid ground for preoperative implant planning and determination of insertion place of dental implants.
3. We wanted to to demonstrate the accuracy of CBCT in temporo-mandibular joint imaging and assessment.
4. We intended to develop a reproducible and easy-to-use method for determining the temporo-mandibular joint injection point and applying the single-needle technique by stabilizing the condylar process and this way the superior recess of the joint in the most appropriate position.

Materials and methods

1. We examined the peri-implant alveolar bone quantity in a fresh domestic pig mandible, using a young domestic pig (age: 6 months; weight: 140 kg) with healthy muscles, gingiva, and skin. Anatomical features of the pigs are similar to human anatomy, so we used pig mandible to assess the relationship between cortical and cancellous bone, since there is a close similarity between pig and human mandibles regarding bone density. The domestic pig mandible accurately represents the soft tissue cover of the alveolar bone and attenuates the beam to soft tissue.

All implants were inserted using a full-thickness flap elevation technique with Camlog® Surgical instruments (Camlog Biotechnologies AG, Basel, Switzerland) at the bone level, and in some places with minimal submersion (depth: <0.5mm). The position of the implants was determined by the bone volume, as the protocol used defined a fewer than 2 mm distance from the implant neck on both the buccal and the oral sides. We chose the molar region where adequate amount of bone appeared to be at disposal and there was no tooth in presence. The flap elevation was made gently with a surgical scalpel and periosteal elevator to ensure the correct placement and depth. A constant internal cooling procedure was used during the implant site preparation to avoid overheating the implant-bone interface and causing any measurement distortion. All implant-site preparation steps were made following the CAMLOG® protocols to avoid any distortion in implant quantity and quality. Camlog Screwline implants were used in different size in the study: 1) 4.3mm diameter, 11mm-length on the left side (implant A); 2) 3.8mm diameter, 11mm-length on the right side (implant B); and 3) 3.8mm diameter, 13mm-length on the right side (implant C). In total, 3 implants were used. Three implants were placed in the molar region of the pig mandible. The implant with the largest diameter was placed on the left side (implant A); the 2 implants placed on the right side were slightly thinner (implants B and C). The 2 neighbouring implants located on the right side were placed more than 3 mm from each other, according to surgical protocols.

The buccal and the oral cortical plates of the alveolar bone were flattened using a Lindeman bur-drill for forming and shaping prior to implant insertion to ensure uniformity and to increase the accuracy of measurements. The gradual thinning was executed in 5 phases, before the implants were placed back into the bone, and CBCT measurements obtained after each phase. Reinserting of the implants was easy due to features of the Screwline Implants. Primary stability was not our purpose to achieve.

2. We designed a retrospective study to analyze radiographic data from patients undergoing TMJ treatment in 12 cases. Ethical Approval has been obtained from Human Investigation Review Board University of Szeged (No. 156/2018). We personally performed the injection procedures to make sure that data analysis, targeting measurements and the procedure itself are focused in the same hands.

Anatomical impressions were taken of upper and lower jaws the patients, and a dental technician prepared wax rims about the instructions of the physicians to increase stability and accuracy. The wax was firmly fitted rim into the mouth and applied gutta-percha dissolved in chloroform at the measured and determined Guarda-Nardini injection point with a plugger.

We analysed the anatomical structure of the condyle and the joint surface, measuring their dimensions and their relation to each other on the three-dimensional CBCT scans. The exact position, depth and angle of the injection were determined with high accuracy and a high reliability of safety using axial and multi-planar reformation (MRP) views.

Informed consent was taken after the patient was questioned about detailed medical history. The patients were seated in a dental chair. After sterile standard preparation and draping, the needle was inserted at the allocated insertion point at the precise angle and depth that was previously determined on the 3-dimensional CBCT images with the wax rim in situ.

Discussion

The success of a dental implantation depends on adequate volume and quality of bone, frequently evaluated using 3-dimensional (3D) visualization. Besides it is important to be aware of discrepancies cause by visual artifacts.

Thinning of the bone was found to influence the diagnostic accuracy of CBCT. With thinner bones, the implant site is an air-containing space that leads to over-radiation of the buccal and oral cortical bones. This excess radiation makes the scanned image darker, and the measurements smaller.

Our data show that thinner bone results in greater discrepancy between the measurements with and without implants, and that these differences are driven by beam-hardening artifacts, which cause gray-level reduction both buccally and orally. Only the thinnest level showed differences, and the iCAT software could not handle the small anatomical details. Thus, there were inaccuracies in defining the border of the thin bone wall.

The presence of 2 neighbouring implants also affected the evaluation of peri-implant bone quality negatively because of the appearance of the beam hardening artifacts in between two implants. The size of the implants did not affect the evaluation of bone quantity.

The purpose of thinning the bone was to determine how beam-hardening artifacts caused by the presence of the implants influenced bone thickness evaluation. We determined that thinning of the alveolar bone around the implant site reduces the diagnostic accuracy of CBCT. Further, a thicker alveolar bone (0.72–1.6mm) around the dental implant causes the CBCT to underestimate bone volume by approximately 10%, while rate of the underestimation for a thinner alveolar bone (< 0.72mm) is approximately 70%. This is a significant finding considering about 0.9 mm difference in bone thickness can result in 60% inaccuracy.

We determined that CBCT has limitation of accuracy due to peri-implant bone thinning. These new findings reflect a different light on pre-implantation planning procedure, since we could demonstrate the level of underestimation of CBCT can be significantly high in case of thinner buccal bone, hence clinicians have to consider choosing proper site for implantation after careful assessment of bone thickness. This way we can declare that the safe thickness of buccal and oral bone at the site of desired implantation should be at least 1.5mm, thus the chance of bone underestimation by CBCT can be reduced to less than 10%.

After we could demonstrate the measurement accuracy of CBCT between 0.5 and 1.5mm bone thickness, we wanted emphasize its high reliability in the field of TMJ analysis and its future place in the field of diagnostics and therapy planning of temporo-mandibular joint disorders since the size of the superior recess of the joint is greater than 1.5mm. Application of CBCT imaging and analysis gave us a lead to describe a method of TMJ injection with great safety considering that the treatment of TMJ disorders are always a challenging task for physicians, and the techniques and medications used to address patients' symptoms still remain a matter of dispute.

The use of this method may help to control the injection of hyaluronic acid or other materials into the temporo-mandibular joint with severe degenerative lesion.

The developed method has many advantages:

- i) The procedure causes minimal trauma to the joint as the risk of intra-articular injury is reduced to a very low level
- ii) Postoperative discomfort is tolerable as the extra intra-articular volume dissolves in a short time
- iii) Additional local anaesthetic is not required as a single insertion is needed.

Conclusion

1. We could demonstrate and prove limitations of CBCT in accuracy of bone thickness measurement. This is a relevant finding hence we could determine the level of bone thickness where CBCT images can reach the point of significant underestimation. We could prove that presence of a dental implant has an influence on bone thickness evaluation in particular if there is more than one implant placed in the bone in vicinity to each other. This can provide a definite base to dentists, dento-alveolar and maxillofacial surgeons in their service of implantation in consideration of careful choosing the site of the planned implant. Since adequate volume of healthy bone is crucial for successful implant outcome, we are certain that this new information will be beneficial for providers and patients alike.
2. After we presented limitations of CBCT accuracy and have been aware of bone thickness level where the underestimation was significant, we have been certain that CBCT could be expedient in assessment and treatment of temporo-mandibular joint, as the dimensions of the joint are beyond the underestimation level. We could analyse the anatomical structures of the temporo-mandibular joint utilizing CBCT features.
3. We developed a new safe, reproducible technique for single-needle TMJ injection with application of Cone Beam CT targeting method which is unique as no similar has been published till now in the literature.
4. We could determine the position of the injection point related to the pre-determined Guarda-Nardini-point, and the exact depth and direction of the injecting needle. The described technique could make single-needle injection easier to perform as difficulties resulting from the deviated anatomy can be eliminated and individual values can be defined for the injection.

5. The method is reproducible, as all images and data can be stored, re-evaluated and compared with later stages. The individually fabricated wax-rim can also be stored, thus by repositioning it into the given patient's mouth the condyles can be stabilized in the exact same position for subsequent CBCT assessment and single-needle injection if necessary. This way easier follow-up of the affected TMJ can be reached as CBCT does not require a large radiation load. This method can be helpful in the treatment of TMJ disorders, making the approach simpler, easier and more comfortable for patients and physicians. We intend to further develop and refine our method in the future with addition of a more sophisticated targeting system. Our method can be the foundation for a constantly requested three-dimensional, navigated injection process.

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