Evaluation of Dental Implants Using Computed Tomography

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Abstract—**Edentulism consists in absence of natural teeth and it is a common cause for oral dysfunction, affecting oral and general health as well as overall quality of life. Dental implants are today a successful solution in oral rehabilitation. The ultimate objective of implant placement is a functional, aesthetic and durable restoration. Although others radiographic techniques are used to assessment of implant site, Dental Computed Tomography (Dental CT) is the best method for the morphological, quantitative and qualitative assessment of the available bone on potential recipient site for implant placement. These parameters can define the type of surgical procedure, type of implant or even preclude the endosseous implant placement. This paper presents the role of Dental CT with a clinical case of partial edentulism.**

Keywords—Computed Tomography; dental implants; osseintegration; bone volume; bone density.

I. INTRODUCTION

Computed Tomography (CT) currently has an important role in the aid of diagnostic and the treatment planning in Dentistry. CT examination, complemented by specific dental software (Dental CT), a series of 2D image data sets can be integrated mathematically to generate panoramic and cross-section images of the patients' jaw. These images enable the internal and external viewing and measurement of anatomical structures in slices. Also, provides the ability to perform tridimensional reconstructions of the entire region.

Partial or total edentulism represents partial or complete absence of natural teeth, respectively. Nowadays, approximately 30% of adults aged above 65 years are edentulous [1]. Edentulism is not only a cosmetic impairment, it is a common cause for oral dysfunction, affecting general health as well as overall quality of life. The traditional treatment is to replace the missing teeth with removable dentures. Although, these prostheses provide cosmetic benefits, they are often associated with problems of impaired masticatory function and difficulty with speech [2]. As a result, implant therapy has developed into a successful treatment for partial and complete edentulism. Dental implants are today a widely solution used in oral rehabilitation, improving dental function and aesthetic [3-7].

Dental implants are metal posts that are surgically implanted in the jaw to support a fixed dental prosthesis. There are three types of dental implant (Fig. 1), but the most common type is endosseous, which comprising a discrete, single implant unit (blade or cylinder shaped) placed within a drilled space within alveolar bone (Fig. 2) [2,4]. These dental implants simulate the tooth shape and are based on osseointegration. A successful osseointegration promotes strong bond between the bone and the implant [2].

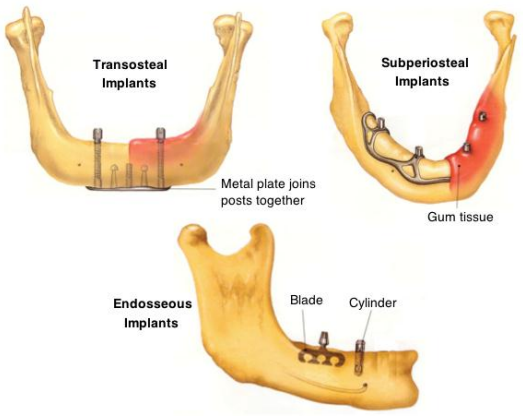

Figure 1. Three types of implants that are used in dental practice: Transosteal implants (posts pass through jawbone), subperiosteal implants (metal framework lies on top of jawbone and gum tissue covers the implant framework except posts' tips, which remains above gum tissue as anchors for replacement teeth) and endosseous implants (implants are placed inside jawbone).

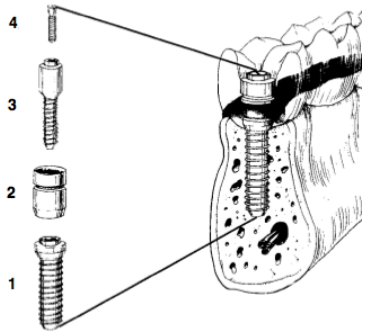

Figure 2. The components of an endosseous dental implant: 1 – Fixture; 2 – Abutment; 3 – Abutment screw; 4 – Prosthesis screw [2].

Endosseous dental implants are very popular worldwide, with recent technologic advances resulting in progressively more viable implants. The success rate is reported as being as high as 90-95% [7,8].

The successful outcome of any implant procedure depend on many factors, which include the behavior and systemic health of patients, the structure of the implant recipient site, the amount and quality of the tissues at the recipient site, the forces exerted onto the implant and surrounding tissues, the implant system and type of implant chosen [3]. All these factors provide the preoperative information necessary in planning the surgical procedure. Particularly, the volume and quality of the available bone play a vital role in the success of dental implant surgery [5,8,9]. Both of these factors can define the type of surgical procedure, type of implant or even preclude the endosseous implant placement. The accurate quantification and qualification of these parameters engendered the need for an appropriate imaging technique, a need that has been met by the Dental CT reformatting program, which provides multiple axial, panoramic and cross-sectional projections that facilitate proper assessment of potential recipient sites for implant placement. Unlike conventional radiographic techniques, Dental CT software can easily measure the height, width and angulation of the alveolar bone and localize the inferior alveolar canal and the maxillary sinuses relative to the bone margin [2,6].

This paper presents the role of Dental CT in planning treatment of a clinical case related with partial edentulism in the upper maxillary.

II. Clinical Case

A. Case Presentation

A 27-year-old female patient presented with a complaint of substantial absence of teeth in the upper maxillary. The patient's medical history indicates good health and no previous systemic disease.

B. Diagnosis and Etiology

The patient's diagnosis reveals partial edentulism in the maxilla and the proposed treatment consist on implantation of an endosseous dental implant. The preoperative evaluation consisted of clinical and radiographic examinations.

In the posterior regions of maxilla, the partial edentulism was due to lack of endodontic treatment. In the anterior maxilla, the teeth underwent endodontic therapy, however root disturbance remained, so the right central and lateral incisor required extraction. The patient used daily a removable dental prosthesis in order to dissimulate the teeth absence as it can be seen in Fig. 3. For the radiographic examination of the implant site, Dental CT images were requested. Only anterior edentulous regions were evaluated in Dental CT images. This region has great impact in facial aesthetic, so it was the first region to undergo treatment. All CT images were performed in Siemens SOMATOM Esprit equipment with slice thickness of 1.5 mm.

Figure 3. Intraoral views revealing the removable dental prosthesis used daily by the patient (left) and teeth absence in the upper maxillary (right).

III. Results

A. Dental CT examination

The feasibility of endosseous dental implant fixation is highly dependent on radiographic examination performed to the patient. Thus, a Dental CT exam was made through axial images acquire at the time of the scanning procedure. During scanning procedure, the patient was instructed to stay motionless in order to avoid motion artifacts. After data acquisition, Dental CT software was used to define the plane and location of the reformatted panoramic and cross-section views. Fig. 4 shows topogram and Dental CT evaluation, which was restricted to the patient´s partial edentulous maxilla (Fig. 4a and 4b). The final cross-sectional and panoramic images are defined using transversal (Fig. 4c) and parallel lines (Fig. 4d) overlapped on the arch of the maxilla, respectively. Fig. 4c and 4d reveal metal artifact introduced in the images due to metallic restorations present on upper left second molar. This artifact will not degrade bone visualization because the artifact is projected at the level of the crowns of the tooth and not over the bone. Fig. 5 and 6 show the finals cross-sectional and panoramic images of the patient´s premaxilla.

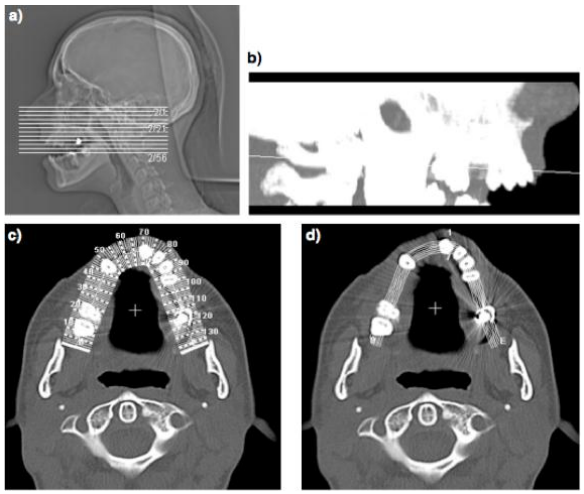

Figure 4. Images obtained in CT exam and Dental CT evaluation. a) Patient´s head topogram showing ROI selected (upper maxillary); b) Lateral MIP (Maximum Intensity Projection) view of maxilla. This image has an orientation line in order to choose an image with the best plane (transaxial or oblique) to define reformatted final images; c) Transversal and d) Parallels lines overlapped on the arch of the maxilla in order to generate de cross-sectional and panoramic images, respectively.

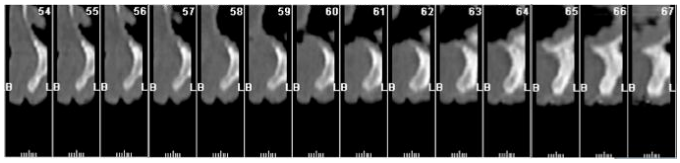

Figure 5. Anterior maxilla cross-sectional images resulting of Dental CT evaluation. These images allow visualization of contour of the alveolar bone.

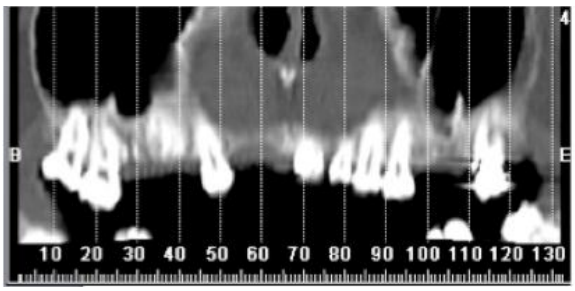

Figure 6. Panoramic image resulting of Dental CT evaluation. The elevated absence of teeth in the patient´s upper maxillary is clearly shown.

B. Measurements in Dental CT images

Due to the proximity of the implant site to the maxillary sinus and adjacent teeth, dimension measurements must be taken. Fig. 7 shows a scheme illustrating how the volume of the available bone was measured.

Bone height and width were measured on the cross-sectional images from Fig. 5. The thickness and density measurements were obtained with axial images acquired at scanning time. The bone density measurements were recorded in Hounsfield units (HU). The HU determined by the software programs in the CT machines ranges from -1000 (air) to 3000 (enamel). The density of structures within the image is quantitative and can be used to differentiate tissues in the region (e.g., muscle, 35–70 HU; fibrous tissue, 60–90 HU, cartilage, 80–130 HU; bone 150–1800 HU) [5]. For an arbitrary tissue T with attenuation coefficient μ_T, the CT value is defined as shows in (1).

$$\text{CT value} = [(\mu_T - \mu_{H2O})/ \mu_{H2O}] \times 1000 \quad (1)$$

Table I presents mean values of the bone volume and density measurements at the recipient site for implant placement: bone height, width and thickness was 14.56 (± 1.93) mm, 4.65 (± 0.99) mm and 4.49 (± 0.52) mm, respectively. Bone density was 696.98 HU.

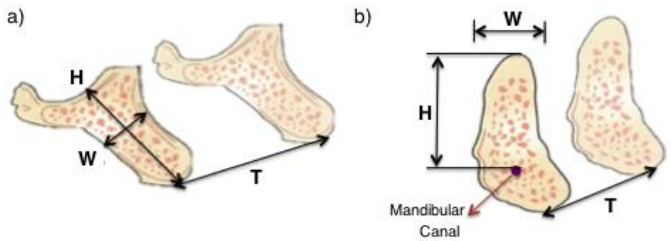

Figure 7. Bone volume measurement scheme to a) maxilla and b) mandible. H – height; W – width; T – thickness of the available bone.

TABLE I. MEAN VALUES OF BONE VOLUME AND DENSITY ON POTENCIAL IMPLANT SITE.

Images 54 to 67	**Bone Volume**			**Bone Density (HU)**
	Height (mm)	***Width (mm)***	***Thickness (mm)***	696.98
Mean value	14.56 (±1.93)	4.65 (±0.99)	4.49 (±0.52)	

IV. DISCUSSION

Endosseous dental implants have revolutionized the fields of dental rehabilitation. Implant placement has become one of the most popular options in the treatment of partial and full edentulism available today [3,8]. They have provided an attractive alternative to standard removable dentures. The available implants are remarkably successful and the long-term life of an implant restoration depends on meticulous care taken in the diagnosis and treatment planning for the patient. The effectiveness and predictability of endosseous implants depend on the patient's medical status, on quantity and quality of bone at the implant site, on minimizing tissue trauma at the time of surgery, on preventing of infection, and good postoperative care, which assists the formation and maintenance of osseointegration [2,3].

Bone quantification and quality are vital factors for achieving successful implant fixation and stability [5,9]. The precise dimensions and density of the alveolar process are important to determine preoperatively because, after the patient becomes edentulous, the normal vertical stress exerted on the bone is no longer present and an atrophy occurs (Fig. 8). This disuse affects height, buccolingual width and density of the alveolar process [2]. Either poor bone volume or low density may preclude the use of implants.

The radiographic evaluation of the qualification and quantification of bone should be accomplished during patient assessment. A regular bone volume dimension consists in bone height superior to 10 mm and width and thickness superior to 5 mm [10]. Using Dental CT, bone height, width and thickness measured in patient´s premaxilla was 14.56 (± 1.93), 4.65 (± 0.99) mm and 4.49 mm (± 0.52), respectively. Compared to standard dimensions, the patient´s potential implant site reveals good bone height and poor width and thickness of available bone, which means that bone atrophy already began. Both latter factors itself preclude the use of endosseous implant in the anterior maxilla region of the patient. For bone inadequate volume or density, bone augmentation procedures may be indicated [8].

Figure 8. Bone loss evolution in the upper jaw [10].

Studies [6] have shown that implant success rate decreases as the bone density decreases. Implants were demonstrated to have less movement, increased stability, and reduced stress concentrations in a high-density bone [5,6]. In order to assessing bone quality, several classification systems were suggested. Misch defined five bone density classes (D1–D5) based on clinical drilling resistance of the bone. Each class can correlate with HU as seen in Table II. In patient´s premaxilla, the bone density was measure by Dental CT and the result was 696.98 HU. Thus, according to Mitch's classification, the bone localized in potential implant site is D3 class, which represents a thin and porous cortical bone and thin trabecular bone. This kind of bone is associated to anterior maxilla regions and is suitable for implant therapy.

TABLE II. MISCH CLASSIFICATION OF BONE DENSITY [5,10].

Bone Classes	Description	Bone Density (HU)	Localization
D1	Dense cortical bone	> 1250	Anterior mandible
D2	Porous cortical bone and dense trabecular bone	850 – 1250	Anterior and posterior mandible; Anterior maxilla
D3	Thin and porous cortical bone and thin trabecular bone	350 – 850	Anterior and posterior maxilla; Mandible
D4	Thin trabecular bone	150 – 350	Posterior maxilla
D5	Non mineralized bone (unsuitable for implant)	< 150	–

Radiographic imaging techniques determine the feasibility of implant placement and they are invaluable guide for surgery. Before the development of CT, conventional radiographic techniques (periapical, occlusal, panoramic and cephalometric radiographies) were used for seeing whether or not patients are candidates for dental implants [3,6,8]. However, these techniques exhibit well-known limitations that restrict accurate imaging: can't distinguish between hard and soft tissue; only distinguish tissue density at the grossest level (bone or not bone); can't make accurate bone measurements (height and width) due to image distortion and magnification; bone thickness measurements can't be determinate because of the absence of cross-section view. The main drawback of conventional radiographic techniques is that the images are two-dimensional. CT solved these problems, providing better diagnostic information than other imaging methods. CT imaging carries both clinical and radiographic information for implant positioning as far as trajectory and depth. Dental CT software program display multiple axial, cross-sectional, and panoramic images of the jaw, which enable accurate and reproducible millimeter measurements of quantity and quality of available bone on recipient site for implant placement [2,5,6,8].

When reviewing imaging modalities for preoperative assessment of the dental implant site, many issues must be considered. The amount of information provided, its accuracy and its applicability need to be weighed against cost, convenience, availability, radiation dose and expertise required to produce and read the output of each modality [6]. Conventional radiography could be used in simple implants and its cost is low [3]. However, for more complex cases, CT is mandatory since accurate information needed is provided. By the same reason, increased cost associated with CT is justified from a patient perspective.

In the clinical case described here, bone augmentation therapy was not performed, so the final restoration consisted in placement of fixed partial prosthesis (dental bridge). This prosthesis was functional and esthetic, it did not compromise adjacent teeth or anatomical structures, and was well accepted by the patient.

V. CONCLUSIONS

Dental implants are a solution for patients with partial and complete edentulism. One of the most significant factors that affect the outcome of the implant treatment is the volume and quality of the surrounding bone. Both parameters are accurately determined by Dental CT, enabling precise three dimension implant placement.

ACKNOWLEGMENTS

This work is supported by FEDER funds through the Programa Operacional Fatores de Competitividade – COMPETE and National Funds through FCT – Fundação para a Ciência e Tecnologia with the reference Project: **FCOMP-01-0124-FEDER-022674**.

REFERENCES

[1] J. A. Saavedra-Abril et al., "Dental Multisection CT for the Placemente of Oral Implants: technique and Applications," RadioGraphics, vol. 30, pp. 1975–1991, 2010.

[2] J. J. Abrahams, and A. Kalyanpur, "Dental implants and Dental CT software programs," Seminars in Ultrasound, CT and MRI, vol. 116, n. 6, pp. 468–486, 1995.

[3] C. H. Hämmerle, and R. Glauser, "Clinical evaluation of dental implant treatment," Periodontology 2000, vol. 34, pp. 230–239, 2004.

[4] Z. M. Isa, and J. A. Hobkirk, "Dental implants: Biomaterial, biomechanical and biological considerations," Annal DentUniv Malaya, vol.7, pp. 27–35, 2000.

[5] I. Turkyilmaz, and E. A. McGlumphy, "Influence of bone density on implant stabilityparameters and implant success: a retrospective clinical study," BMC Oral Health, vol. 8, n. 32, 2008.

[6] H. İplikçioğlu, K. Akça, and M. C. Çehreli, "The use of computed tomography for diagnosis and treatment planing in implant dentistry," Journal of Oral Implantology, vol. XXVIII, n. 1, pp. 29–36, 2002.

[7] A. D. Pye, D. E. A. Lockhart, M. P. Dawson, C. A Murray, and A. J. Smith, "A review of dental implants and infection," Journal of Hospital Infection, vol. 72, pp. 104–110, 2009.

[8] Unknown, "Dental implants in Periodontal therapy", J Periodontol, vol. 71, pp. 1934-1942, 2000.

[9] K. Hyasaet al., "Preoperative Computed Tomography-derived bone densities in Hounfields units at implant sites acquired primary stability," ISRN Dentistry, vol. 2011, pp. 1–5, 2011.

[10] G. M. Scortecci, C. E. Misch, K. U. Benner, "Implants & Restorative Dentistry", Taylor & Francis, 2001.