Review Article

Application of Cone Beam Computerized Tomography in Implantology

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ABSTRACT

Dental implants have gained immense popularity and wide acceptance because of its appearance and function simulating a natural tooth and its ability to replace the crown as well as the root of the missing tooth. It is important for dentists to be able to place the implants in the mandible and maxilla with a high degree of precision. The greater accuracy of Cone Beam Computed Tomography (CBCT) in measurements at lower radiation doses has made it a preferred option in implant dentistry. It has led to improvements in case selection and aids in both qualitative and quantitative measurement of bone, leading to a reduction in implant failure. This article provides an overview of the potential use of CBCT in implantology.

Keywords: Cone Beam Computed Tomography, Dental implants, Radiation dosage, Diagnostic imaging.

For many years, the information required for implant imaging has been obtained from clinical examination and 2D imaging. Conventional linear tomography and computed tomography (CT) have also traditionally been used in presurgical imaging, though the former has overlain ghosting artifacts and the latter has relatively high radiation exposure and cost [1]. Cone Beam Computed Tomography (CBCT) is the newest imaging modality in this regard. Cross-sectional views are recommended for planning dental implants, and these, in combination with the easy accessibility and handling as well as lower radiation dose of CBCT when compared to CT, present the former as a more advantageous implant imaging modality [2]. The goals of use of imaging for presurgical dental implant planning include:

1. **Assessing the morphologic characteristics of the residual alveolar ridge:** This includes considerations of bone volume and quality, vertical bone height, horizontal width and edentulous saddle length that determine the amount of bone volume available for implant placement. This helps in correlating the available bone dimensions with the selection of the number and physical dimensions of the dental implant.
2. **Determining the orientation of residual alveolar ridge:** The assessment of orientation and topography of the alveolar-basal bone complex can aid in determining deviations of residual alveolar ridge that may compromise alignment of the implant fixture with respect to the prosthetic plan.
3. **Identify local anatomic or pathologic boundaries:** The relationship of the target area to anatomic features of jaws including maxillary sinuses, nasopalatine fossa and canal, nasal fossa, mental foramen, inferior alveolar canal and submandibular gland fossa that may compromise and limit implant placement and risk involvement of these structures. Local pathologies such as retained root tips, sinus disease, adjacent inflammatory processes, etc may also restrict or even prevent implant placement [3].

IMPLANT CONSIDERATIONS

Root-form implants are by far the most commonly used implants in dentistry today. Osseointegrated root-form implants are made up of a fixture and an abutment. The fixture is the portion of the implant that is surgically embedded in the osseous tissue of the jaw and is made of titanium, a material that promotes osseointegration. They are manufactured with or without thread and coated with hydroxyapatite and are available in various sizes, ranging from 3.25 to 3.75 mm in diameter and 7 to 10 mm in length. The size of the implant depends on the amount of remaining available bone. Dentists prefer the largest possible suitable implant as it increases the surface area and provides stronger anchorage. It is always preferable to have 1–1.5 mm of bone on either side of the implant fixture and 1–2 mm of bone between the implant and the adjacent vital structures. The abutment, which increases the height of the fixture to a level above the gingival surface, is attached to the fixture with an abutment screw.

The top of the abutment screw contains a small hole that allows the dental prosthesis to be attached by a screw that runs through the prosthesis and into the abutment screw. It is essential that the abutment be in intimate contact with the implant fixture. These fixtures and abutments can be previewed and their placement simulated on interactive tomograms. Today, the entire treatment planning can be completed virtually using interactive software such as SimPlant (Columbia Scientific Inc, Glen Burnie, Md.). Specific considerations for implant planning using CBCT include clinical complexity, regional anatomic considerations, potential risk of complications and esthetic considerations in the location of implants [3].

BONE QUALITY AND QUANTITY ASSESSMENT

An important aspect of radiographic evaluation should be a qualitative description of the bone in the target area. The most favorable osseointegration is thought to occur only in certain types of bone. Bone quality is commonly categorized into four groups: Type I: homogeneous cortical bone; Type II: thick cortical bone with marrow cavity; Type III: thin cortical bone with dense trabecular bone of good strength; Type IV: very thin cortical bone with low density trabecular bone of poor strength. Among these, the type II bone is considered the best bone for osseointegration of dental implants as it provides good cortical anchorage for primary stability yet has better vascularity than Type 1 bone. The implant site has to have sufficient vertical bone height of 12 mm from the alveolar crest to the superior border of inferior alveolar nerve canal and a minimum gap of 2 mm between the tip of implant and mandibular canal to possibly place a 10 mm implant. The experimental site has to have adequate horizontal bone width of at least 3.5 mm [2,4].

The alveolar process undergoes dimensional changes following tooth extraction. The reduction of bone volume at the facial aspect of marginal one third of the socket is more pronounced than in the palatal/lingual aspect, and two thirds of this reduction occurs in the first 3 months of healing. Deficiency of facial bone anatomy has a negative impact on esthetics and is a critical causative factor for esthetic implant complications and failures [2,5].

The need to reduce the treatment times and the number of surgeries in implantology has led operators to new therapeutic protocols. The use of post-extraction implants is one of them. Some factors that must be considered in immediate implant cases to increase the predictability of treatment include the available bone volume, buccal wall thickness, periodontal biotype, the site of the extraction and the correct 3-D positioning of the implant. The correct 3-D positioning system plays a fundamental role in the success of the procedure. Minimally invasive extraction, 3-D positioning of the fixture, the simultaneous bone graft insertion and a tension free wound closure may help achieve healing without complications. The risk factors for soft tissue shrinkage include a buccal positioning of implant shoulder, a thin periodontal biotype and a compromised buccal bone wall at the time of implant placement. Placement of implants in fresh extraction sockets could counteract ridge resorption. The thinner the facial bone wall, the more extensive the loss of facial bone [2].

MANDIBULAR LINGUAL UNDERCUT

A deep lingual undercut is a common finding in the posterior mandibular region and poses difficulty in management due to risk of lingual plate perforation. The major potential risks of encountering a lingual plate perforation are massive hemorrhage of submental and sublingual arteries, airway obstruction and a perforation above the mylohyoid ridge that might injure the lingual nerve. If the extruded implant is left unattended, the infection might spread to the parapharyngeal and retropharyngeal spaces, leading to more severe complications, such as mediastinitis and mycotic aneurysm formation with possible subsequent rupture of the internal carotid artery and internal jugular vein thrombosis with septic pulmonary embolism or upper airway obstruction [2].

Chan et al described 3 types of morphologies using mandibular cross-sectional imaging at the edentulous first molar region [6]. The undercut ridge type (type U) was found to be the most prevalent type (66%). It has a narrow base that expands buccolingually to a wider crest with a prominent point on the lingual plate, giving rise to a lingual undercut. The parallel ridge type (type P, 20.4%) has a more or less parallel ridge form with no lingual undercut. In the convergent ridge type (type C, 13.6%), the base is wider than its crest and no obvious undercut is seen.

EVALUATION OF INFERIOR ALVEOLAR CANAL

Histological studies have shown that the Inferior Alveolar Nerve (IAN) typically courses through the mandible as one major trunk with branches extending to apices of teeth. However there are multiple smaller branches of the inferior alveolar nerve running roughly parallel to the major trunk. Occasionally, these branches are large enough to have a secondary mandibular canal. Even trifid mandibular canals have been reported. Patients with bifid canals are at greater risk of inadequate anesthesia or difficulties with implant placement or other jaw surgeries. IAN may be traumatized by an implant intruding into the canal or penetration by the drill preceding implant placement. Furthermore, a second or even third neurovascular bundle may be damaged causing paresthesia, neuroma development, or bleeding [7,8].

There are numerous reports for prevalence of bifid mandibular canal. Naitoh et al classified variations of mandibular canal to four different patterns using CBCT images [9]. In the retromolar canal (type 1), the foramen of the canal is observed on the bone surface of the retromolar region. The dental canal (type 2) was defined when the end of the canal reached to the root apex of the second or third molar. The bifid canal (type 3) arising from the superior wall of the mandibular canal was referred to as the forward canal. The forward canal type may be present with/without subsequent confluence to the main mandibular canal. The buccolingual canal (type 4) was the bifid canal arising from the buccal or lingual wall of the mandibular canal. Oyuntugs et al added one more group of the trifid canal type to the above classification- Type 5 in which, apart from the mandibular canal, it includes any of the following situations [10]:

1. Two accessory canals of the retromolar canal type
2. Two accessory canals of one retromolar and one dental canal type
3. Two accessory canals of the dental canal type
4. Two accessory canals of one dental and one forward canal type
5. Two accessory canals of the retromolar canal type with two mandibular foramina.

In the study by Oyuntugs et al, it was found that the retromolar canal type was the most common (71.3%), followed by the dental canal type (18.8%), the trifid type (5.8%) and the forward type (4.1%) [10].

ACCESSORY MENTAL FORAMEN AND MANDIBULAR INCISIVE CANAL

The mandibular canal and mental foramen house the inferior alveolar artery and nerve. Images of the accessory mental foramina and its bony canal overlap in various trabecular patterns. Naitoh et al observed the accessory mental foramen in 7% of the subjects using CBCT and stated that its pre-surgical evaluation might reduce the incidences of paralysis and hemorrhage in mental and cheek regions [11]. The accessory mental nerve may communicate with branches of the facial and buccal nerves. Makris et al found that the incisive canal was visible in 83.5% of the scans and the mean endpoint was approximately 15 mm anterior to the mental foramen [12]. The mean distance from the lower border of the mandible was 11.5 mm and its course was closer to the buccal border of the mandible in 87% of the scans. It is indicated that surgical complications might be attributed to existence of mandibular incisive canal with a true neurovascular supply and potential risks might also be related to the presence of the lingual foramen and anatomic variations such as an anterior looping of the mental nerve [2].

NASOPALATINE MORPHOLOGY

The nasopalatine canal is usually located in the midline of the palate, posterior to the maxillary central incisors. The funnel shaped oral opening of the canal in the midline of anterior palate is known as the incisive foramen, and is usually located immediately below the incisive papilla. The canal divides into two canaliculi on its way to the nasal cavity and terminates at the nasal floor with an opening (known as the foramina of stenson) at either side of the septum. The canal contains the nasopalatine (incisive) nerve and the terminal branch of descending nasopalatine artery, as well as fibrous connective tissue, fat, and even small salivary glands. Bornstein MM found that the incisive canal has two to four nasopalatine foramina and one incisive foramen [13]. The anatomic variations of the nasopalatine canal are classified into 3 types: A single canal; Two parallel canals; Variations of the Y type of canal, with one oral opening (incisive foramen) and two or more nasal openings (foramina of stenson). Güncü et al found that the mean incisive canal length and mean canal diameter is more in men than women [14]. Also, men have significantly higher buccal bone dimensions (length and width of the bone anterior to the canal) than women. Absence of teeth in the anterior maxilla corresponded to a decrease in incisive canal length and buccal bone dimensions but the canal diameter was noted to remain unchanged.

Tolstunov L et al reported that cumulative success rate of implants in the mandible seems to be slightly higher than in maxilla [15]. The success rate of implants in the anterior regions seems to be higher than in the posterior regions of the jaws, mostly due to the quality of bone. Therefore, an implant treatment in the anterior mandible appears to be the most successful whereas the posterior maxilla appears to be the least successful region of the jaws for implant rehabilitation.

RADIOGRAPHIC TEMPLATES

A successful implant-supported restoration requires a predictable determination of the final prosthesis in the treatment planning stage. The diagnostic template enables the dentist to incorporate the 3D treatment plan of the final prosthetic result into the imaging examination and indicates precisely the area of restoration on the 3D scan of CBCT [16]. Radiographic templates are manufactured by the dentist after an impression of the ridge and teeth are obtained.3The template is made of acrylic resin as a duplicate from the diagnostic wax-up of the shape of the final planned restoration and fits snugly over the residual teeth and alveolar process [3]. It can also be made by duplicating the patient's existing denture. Many types of radiographic guides are available for single and multiple implants. Radiographic materials such as gutta percha, metal balls, barium sulphate, etc are incorporated in the template to indicate the relationship of the final prosthesis to the bone substrate. When a barium sulphate is processed in the acrylic resin template, the template is then trimmed and tried on patient to verify effortless insertion and proper fit. The patient is then referred for CBCT scan along with the radiographic template. On the CBCT image the outline of the planned restoration is imaged in relation to the bone. CBCT enables measurements to be taken directly from the images using the ruler provided with the appropriate scale or using a measurement program as in case of digital images [16].

Radiographic templates serve a variety of purposes:

1. Selection of the appropriate site and determination of precise measurements.
2. Evaluation of patient's anatomy relative to the proposed implant sites, esthetics and occlusion and serves as a medium to record and transfer these findings to the patient at the time of surgery.
3. Accurate determination of the location and angle of placement of the implant which is especially important for avoiding cortical perforations when implant sites are thin buccolingually.
4. Establishing the vertical angulation of the implant before surgical placement so that the implant can be made parallel to the long axis of adjacent teeth or other implants. This process allows simplification of the restorative phase especially when the path of insertion of the prosthesis is critical [3,16].

GUIDED IMPLANT SURGERY

The 3D planning software by Nobel Biocare (Nobel Guide; Procera software) or by Materialize Dental (SimPlant) contains a library of implants and abutments from which the dentist may select implants relative to the target site. Using this software, the dentist can precisely plan the implant placement relative to the bone and adjacent structures. Safety zone indicators and warning messages in the system ensure 100% safety, avoiding collisions between implants, or implant and nerve or other vital structures. The information is converted into a stereolithographic file and transferred to a 5-axis computer controlled milling machine, which creates the appliance to the SimPlant specifications. The surgical template is now fabricated incorporating a drill guide system to direct the drilling of the osteotomes. During the subsequent implant placement appointment, the surgical template is secured into place using surgical index and anchor pins. The implant site is then prepared using a series of burs and drilling guides that precisely fit into sleeves of the template and the implant is placed as planned in the 3D software.

Fortin et al illustrated a method to transfer data obtained by a cone-beam CT scan machine to a semi-active image-guided implant placement system based on a mechanical device coupled with a template [17]. Thus, overall, the dentist and radiologists can perform a virtual surgery by selecting and placing arbitrary-sized cylinders that simulate root form implants in the images. It enables the development of a 3D treatment plan that is integrated with the patient's anatomy and can be visualized before surgery. Transfer of the plan to the patient at the time of surgery can be accomplished by simple visualization and comprehension by a skilled surgeon converting the diagnostic template into a surgical template. The implant is thus successfully placed and restored predictably as planned [16].

POSTOPERATIVE ASSESSMENT OF IMPLANT SITE

Periapical, panoramic radiographs or CBCT (if clinical symptoms warrant its use) may be used to evaluate the implants postoperatively. Periapical projections are indicated to view the bone–implant interface. It is essential to view the entire implant fixture during postoperative assessment. The bone–implant interface is examined for signs of failure such as a radiolucent rim around the implant body and loss of crestal bone (saucerization) at the implant site. The greatest amount of peri-implant vertical bone loss occurs within the first year after implant placement, followed by a dramatic decrease in the rate of bone loss in subsequent intervals. In some instances, there is complete rejection of the implant fixture due to severe bone loss. Peri-implantitis is a term used to describe the lack of osseointegration along the implant–bone interface due to infection around the fixture [3].

CONCLUSION

The variances of excellent imaging modalities that are available today offer increased success and predictability in dental implantology. The development of surgical templates allows the dentist to place these implants with relative ease and predictability. The higher resolution and lower radiation dose makes CBCT a more desirable imaging modality than CT for implant site assessment. However, selection of projections should be made with consideration to the type and number of implants, the intended location and its surrounding anatomy. As in the case of all imaging, appropriate selection criteria must be applied individually to each patient.

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