VOLUME - 10, ISSUE - 04, APRIL- 2021 • PRINT ISSN No. 2277 - 8160 • DOI : 10.36106/gjra

Original Research Paper

Dental Science

DENTAL IMPLANT IMAGING : HOW CT SCAN BECAME A HELP TO SURGERY

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ABSTRACT

Imaging has always been an important part of dental implant procedures from its beginning. Radiologists and dentists always worked together in the dental implant field, where imaging takes a major place. At the beginning, dentists performed imaging. Originally dental panoramic X-ray was prescribed for first screening checkup (Abrahams, 1990, 1993 [1,2]). Of course the emergence of CT scan at the end of the seventies revolutionizes data collection (Bränemark, 1983 [4], Albrektsson & Johansson, 2001 [3]), dentists had quickly understood dentascan's interest. They didn't have access to heavy medical imaging tools without radiologists. They lost the monopoly of imaging management.

These radiologists took place at the heart of radiation risk assessment, and played a major role in image generation and distribution. So collaboration between radiologists and dentists came out. Each actor's role was well-defined. Radiologist controls radiological source and imaging data management, dentist handles implant plan. But development of dedicated software modifies habits. In fact it enables dentists recovery and utilization of imaging data. Radiologist sometimes becomes service provider, dentist managing by himself images and data. More recently, in the last five years, a revolution is occurring with the availability of "cone beam" CT machines (Rouas et al., 2006, 2007 [20,21]) in dental offices and directly in dental surgery enables dentists to manage all the stages, from diagnosis, choice of imaging technique, generation and distribution of imaging data, implant planning, to surgical step. Nowadays radiologist takes place as a specialist in dental imaging, that pays attention to up-to-date and evolution of dental implant techniques.

The three principal softwares created for dental implant planification are called Simplant, Nobel Guide, and Robodent. They are mainly designed for surgical act. These technologies represent a real and very interesting progress. As a conclusion, we can see that dental imaging has a major role in implant techniques, with noticeable precision and reliability in pre-implantal planification and surgical help. If practitioner purely respects implant plan process, these technologies supply very accurate and repeatable data in user-friendly and intuitive environment. It gives security in surgical act by using positioning guides, also in drilling with drill-stop. It enables instant prosthesis' loading. Surgeon should focus on surgery accuracy and improve aesthetic and functional results. He should be able to increase aesthetic and functional results, broadening medical indications.

At present, these technologies are reserved to very experienced practitioners and surgeons and require a significant work to analyze each case and to prepare laboratory models. At last, these systems bring competitive communication's tools for patient and prosthodontist. These tools are essential in diagnostic stage as well as surgical act. We see that dentists can manage all steps of the proceeding. What role can we assign to radiologist? What role can we assign to dentist? This problem is proper to every specialized medical field with imaging development. For radiologists, we stress upon the necessity of being attuned to these dental innovations.

KEYWORDS :

INTRODUCTION

Imaging has always been an important part of dental implant procedures from its beginning. Radiologists and dentists always worked together in the dental implant field, where imaging takes a major place. At the beginning, dentists performed imaging. Originally dental panoramic X-ray was prescribed for first screening checkup (Abrahams, 1990, 1993). Of course the emergence of CT scan at the end of the seventies revolutionizes data collection (Bränemark, 1983 [4], Albrektsson & Johansson, 2001[3]), dentists had quickly understood dentascan's interest. They didn't have access to heavy medical imaging tools without radiologists. They lost the monopoly of imaging management.

These radiologists took place at the heart of radiation risk assessment, and played a major role in image generation and distribution. So collaboration between radiologists and dentists came out. Each actor's role was well-defined. Radiologist controls radiological source and imaging data management, dentist handles implant plan. But development of dedicated software modifies habits. In fact it enables dentists recovery and utilization of imaging data. Radiologist sometimes becomes service provider, dentist managing by himself images and data. More recently, in the last five years, a revolution is occurring with the availability of "cone beam" CT machines (Rouas et al., 2006, 2007 [20,21]) in dental offices and directly in dental surgery enables dentists to manage all the stages, from diagnosis, choice of imaging technique, generation and distribution of imaging data, implant planning, to surgical step. Nowadays radiologist takes place as a specialist in dental imaging, that pays attention to up-to-date and evolution of dental implant techniques.

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Help To Diagnosis (Cavézian Et Al., 2006 [7])

1 Dental panoramic X-ray

This radiography shows at one sight lower and upper jawbone overall. It's bringing to light missing teeth of course, but also radicular lesion, radicular granuloma, dental fillings extrusion, calcifications, demineralization, bone lesions, included tooth (Liu, 2006 [14]). It often shows maxillary canal. But this imaging does not allow dentist to take measurements, indeed it is a flat projection of curved surface. It is just a first screening checkup. However this technique is sufficient to reject implant plan because of substantial demineralization.

2 Denta-scanner

It is a very accurate method of jawbone's exploration. It enables dentists to obtain morphological analysis of implant site and bone structure. The initial acquisition gives millimetric slices in axial plan with high resolution. They give different measurements as bone cortical thickness, and dental space (Cazevian et al., 1995[6], Chiarelli et al., 2010[8]).

There are some artifacts, caused by amalgam or metallic prosthesis.

3 Cone Beam CT

It consists in a new device family using cone-shaped X-ray emission. It enables multiplanar reconstructions of dento-maxillary sphere (Hauret et al., 2009[12]). The device includes X-ray source which emits cone-shaped beam with constant width. X-ray run through body to explore and finish the course on a flat detector (Hintze, 2007 [13]). This system generates a single 360 or 180 degrees rotational movement around the head of the patient. A short X-ray pulse is released each degree, giving 360 (or 180) images (Patel et al., 2007 [18]). Because of cones haped beam, the rotation of this complex is sufficient to give raw data, without patient's translation (Cazévian et al., 2006 [6]).

Purposes

The purpose of pre-implant check up to the present was to locate the implant site, to determine quantitatively and qualitatively the bone volume of implant place and to detect an anatomical obstacle. We only remind principles.

Quantitative evaluation of bone volume requires three measures and sizes:
1. height to mandibular canal in mandibular level and to lower bone cortical of maxillary sinus or nasal cavity in maxillary level
2. width in vestibulo-lingual level,
3. length in mesio-distal level.

Qualitative analysis of bone volume using:
1 subjective specification : cortical thickness, alveolar bone density,
2 objective specification: densitometry and different methods using Hounsfield unit measures, but at the present time no method is recognized .

The implant place has to be marked by axe and guide (fig. 1).
At **last Imaging has to look for anatomical obstacle** restricting bone volume:
1 maxillary level: maxillary sinus or nasal cavity bottom, nasopalatine canal, dorsal palatal artery,
2 in mandibulary level: above all mandibular canal,
3 included tooth, tumor, inflammatory or infectious lesion palatal artery.

Fig. 1. Example Of Radiological Guide With Gutta Percha Radio-opaque Spots

Help to surgery

Recent years much software for implant planification and navigation are developed. Meticulous protocol is needed to computerised implant planning whichever software is choosen (Verstreken et al., 1996, 1998 [25], [26]).

The two principal softwares created for dental implant planification are called Simplant and Nobelguide, they are mainly designed for surgical act, and a work tool to show dental surgeon the way in implant installation called Robodent (Treil et al., 2009 [23]).

1 Simplant

Study begins by making articulated models (Corcos, 2007 [10]). Then a wax setting simulates the final dental prosthesis and allows surgeon to visualize technical constraints. He visualizes imperatives implementation of implant prosthesis.

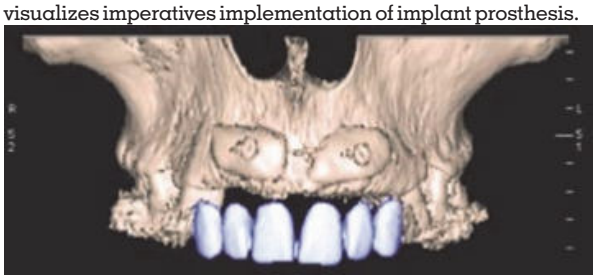

Fig. 2. Example of radiological guide with false teeth, on tridimensional reconstruction.

Then the radiological guide derived from prosthetic model can be achieved (fig. 1). Either radio-opaque commercial false teeth are inserted or baryum sulfate balls are included in wax (fig. 2 and 3). While different barium sulfate concentrations are adjusted, we can precisely differentiate and individualize masks of different density. A cylindral cavity focused on occlusal tooth's side and emerging from cervical side makes the main tooth axis visible (fig. 2).

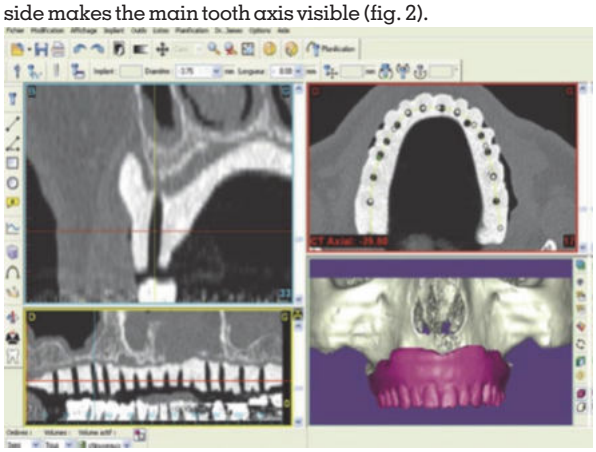

Fig. 3. Example Of Simplant Planification Of Upper Jawbone

a) CT scan

Patients wear the radiological guide during the CT scan acquisition. Dental arches must notbe in contact together, in order to make the CT scan data processing easily. Radiologist has to take care of:
1 stability and well-positioning radiological guide, with control of accommodation or adjustment with mucous membrane,
2 determination of axial plane that is parallel to the teeth occlusal area,
3 visibility of teeth occlusal area, that has to be full visible.

B) Implant Planification

Several points have to be controlled by dentist:
1 check CT scan accuracy,
2 location of axial emergence on incisal side or occlusal face,
3 put the implant on a lateral view,
4 set up guide anchor cotters,
5 check on implants parallelism, confirmed on 3D view (fig. 3 and 4),
6 check bone fenestrations,
7 check on bone density,
8 place an order of surgical guide.

C) Surgical Time

Then after planification and dentist's control, time comes for surgical act. The surgical guide is achieved by a stereo-

lithographic system: a pure and initially clear wax hardens by laser action. This guide is aimed to laboratory technical expert, used to make a plaster model with implants duplication in order to fabricate temporary prosthesis.

Simplant software allows surgeon to make a dental guide with bone or mucous support.That simplifies surgery, and enables surgery without incision reducing surgical length and post-operative complications. Detailed precision with accuracy to within one millimeter is essential:
. maximal horizontal deviation to 0.6 mm,
. maximal vertical deviation to 0.9 mm,
. maximal angulation deviation to 6.1.

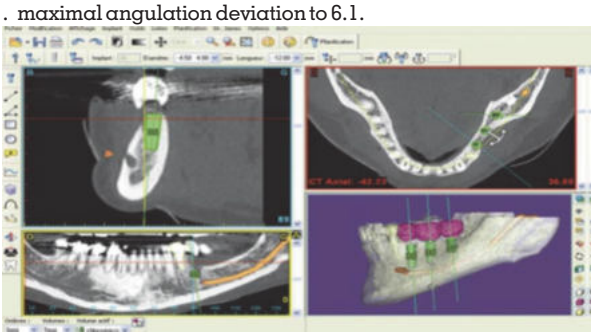

Fig. 4. Simplant Planification. Implants Simulation With Implants Parallelism

This technique allows immediate loading. Simplant software enables dentist to mark anatomical pieces (fig. 4) and bone volume evaluation to "sinus lift" choice among all existing implants, and choice of adjusted pillar.

2 Nobelguide

Nobelguide is the same concept as Simplant one, including five steps (Van Steenberghe et al., 2002 [24], Vaida et al., 2007 [25]) .

1 Temporary prosthesis

It is a very important step in planification, aesthetic assembly and occlusal plan are the same for the definitive prosthesis. Prosthesis efficient stability is very important and seeked throughout the procedure. This temporary prosthesis is mostly used as radiological guide. It is most often made in radio-transparent acrylic resin with eight to twelve balls of radiopaque small-diameter gutta percha (1.5 mm) . These balls are placed on vestibular and lingual side of prosthesis on different occlusal plans.

Figure 5 **Figure 6**

Fig. 5 Temporary prosthesis made in acrylic resin with radio-opaque gutta percha balls

Fig.6. Three dimensional CT scan reconstruction of temporary prosthesis with gutta percha balls.

3 Occlusal Positioning Index

Prosthesis should be well-positioned in mouth and above all stable. Its position compared to antagonist teeth is registered with a specific material for occlusal registration. This material must be rigid, radio-opaque or not .

CT Scan

A double CT scan acquisition is needed to obtain a reliable account of bone on the one side and radiographic guide on the other side. Gutta percha balls included on radiological guide are essential marks to merge accurately the two CT scans.

The first CT scan is acquired on patient bearing radiological guide stabilized and by occlusal index well-positioned. It brings to us important information about bone detail and gutta percha balls positioning through detailed data. The acquisition always follows parallelism of occlusal plan, covering lower or upper jawbone and part of antagonists teeth.

Second CT scan is acquired with only radiologic guide, without occlusion. That gives very detailed informations about radiologic guide and gutta percha marks. This acquisition must be precisely realized in the same conditions as the previous one.

Planification

Software enables practitioner to position radiologic guide on alveolar bone and as the same time to keep carefully a gap for mucous layer, and to position virtually dental implants.

Surgical Guide

Planification enables to manufacture surgical guide by scanner technique . It is radiological guide replica converted to allow drilling and setting up of implants. Surgical guide replaces toothprint for prosthesis laboratory, to cast the framework model. Nobelguide concept helps to computerization of implants planification according to initial prosthetic project, to manufacturing of surgical guide and prosthesis before to put down implants. Surgical guide manufacturing should be provided at the same time as prosthesis conception. Guide conception and its stability guarantee a setting up corresponding to planification. Its initial stability when practitioner installs prosthesis in mouth depends on occlusion bite and cotter introduction in preoperative period . These cotters must go through surgical guide in vestibular region in wax extensions thick enough to avoid guide's wrist over drilling. Then these extensions must be apical enough so that cotters' shaft be horizontal, and to realize bone's insertion outside the anatomical hurdles.

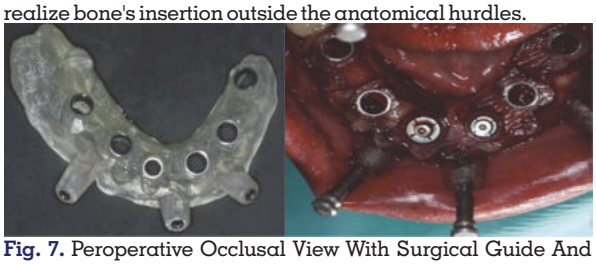

Fig. 7. Peroperative Occlusal View With Surgical Guide And Cotter, And Firsts Implants

3 Robodent

Softwares such as Nobelguide or Simplant give way to undeniable surgical help, particularly for surgical step (Penel et al., 2007 [19], Miller&Bier, 2006 [16], Ewers, 2005 [11] , Casap, 2006 [5]). But it requires a rigourous procedure and laboratory time to transfer all the data of preimplant check-up. New tools recently appear that leads surgeon's hand while implants installation. Softwares enable a real-time interface between pre-implant plan and rotating instrumentation for implant site. In addition the surgical tool named Robodent is a navigational instrument. Surgeon can also follow the drills progress on line in comparison to contiguous anatomical structures.

It pilots the surgeon's hand while he drills the bone. Optical tracer is fixated on wax prosthesis, as well as on the drill. Then their motion is captured by a camera and worked out with three-way correlation. The more advanced systems use to

optical tracers. Optical tracers, passive (ceramic balls) or active (LED) according to system secured with dental arch. Then their motion is captured by a camera and worked out with three-way correlation. It is a real-time tool to follow the drill in anatomical pieces . Prosthetic analysis happens as usual. A diagnostic wax model is made for functional and aesthetic necessities. Radiological guide as a gutter, secured with facial arch contenting radiological marks is adapted to dental arch . This guide should serve as a support for location system in surgical navigation. The CT scan is acquired with this system on dental arch. A temporary removable prosthesis should be used for toothless jaw; it has to be secure and motionless meanwhile.

Fig. 8. Occlusal View At The End Of Surgical Act And The Prosthesis Insertion

A CD is burned with CT images in DICOM format, given to dentist. He validates the choice of anatomic sites for implants with analyze and planification software . These accurate tools enable dentist to simulate whole implant plan. Two- or three dimensional representations of implant make surgical plan easier. Furthermore this global approach enables patient to understand surgical act and to give enlightened consent. It represents a very good tool for communication with patient. Surgical operation happens in a standard way, but surgical area and rotary instrumentation are adapted. Patient's dental arch and drill carry marks, a camera check their spatial position in order to enable respective motion following. Computer calculates this position and transcribes drill coordinates in bone structures on the screen real time. Control device gives surgeons visual tracking with a sight and audible alarm .

Fig. 9 , 10 : Robodent: radiological guide and the extremity of drill present optical marks to give the spatial position

Sonorous alert gives constantly position control of shaft and drill depth. Accuracy and measures reliability are remarkable: 0.1 mm for linear deviation, 0.3° for angular deviation. However surgeon should acquire experience with guides' obstruction. He must also position himself to avoid crossing with optical follow-up.

CONCLUSIONS

These technologies represent a real and very interesting progress. As a conclusion, we can see that dental imaging has a major role in implant techniques, with noticeable precision and reliability in pre-implantal planification and surgical help. If practitioner purely respects implant plan process, these technologies supply very accurate and repeatable data in user-friendly and intuitive environment. It gives security in surgical act by using positioning guides, also in drilling with drill-stop. It enables instant prosthesis' loading. Surgeon should focus on surgery accuracy and improve aesthetic and functional results. He should be able to increase aesthetic and functional results, broadening medical indications.

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