http://dx.doi.org/10.35630/2199-885X/2021/11/6.23

METHODS OF POSITIONING CYLINDRICAL DENTAL IMPLANTS: A LITERATURE REVIEW

Received 13 October 2021;
Received in revised form 10 November 2021;
Accepted 11 November 2021

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ABSTRACT — Advanced digital technologies and respective software offer dentistry much wider opportunities. Computed tomography, for one, is becoming more and more affordable and almost every dental tomograph has the necessary software installed for dental manipulation 3D planning. Dental implantation in Russia has seen significant development allowing dental implants to be installed even with scarce bone tissue. The purpose of this paper is to offer a review of various methods that can be employed to plan the installation of a dental implant as well as the preparation of surgical templates. Dentistry has always had a close connection with other fields of science and industry, attracting a large number of innovations. Here, we have collected data showing how the treatment procedure is changing through integration of computed diagnostics technologies (CT) and manufacturing (CAD/CAM) technologies. Consequently, we gain access to more efficient and less traumatic dental implantation planning systems, all this being based on accurate data and computer calculations that minimize any potentially negative technological or human factor.

KEYWORDS — dental implantation, CAD/CAM technologies, navigation templates.

INTRODUCTION

Advanced digital technologies and respective software open new and much wider opportunities before dentistry [1–3,10,40–42]. Computed tomography, for instance, is becoming more and more affordable. Literally every dental tomograph has the required software for 3D planning of dental manipulations. Dental implantation in our country has got significant development, allowing dental implants to be installed even with scarce bone tissue [16, 18, 63]. Dental implantation in our country has got a significant progress impetus. Dental implants now can be installed even with insufficient bone tissue. Such interventions benefit greatly from using guiding templates. Their application technology implies preliminary planning of the parameters and the location of dental implants, setting their number and axial position [4–6, 14, 17, 51, 62]. After that, a surgical template is made in the laboratory, which must be fixed securely on the prosthetic bed and have guides for surgical cutters, which are used to prepare the implantation bed [19, 20, 49, 52]. This article offers an overview of various methods of dental implant installation planning, as well as the manufacture of surgical templates. Preliminary planning of the dental implant is carried out on plaster models or relies on X-ray examination data [7–9, 11, 21–23].

METHOD OF BIOMETRIC PLANNING ON PLASTER MODELS

Once the impression is taken, the prosthetic bed topography is transferred to the plaster model. The thickness of the mucous membrane at the dental implant is detected through the sound method, which involves a sterile probe with a marker to be used. As a rule, 5 points are used for probing at each site: the vestibular and oral parts of the alveolar process base at the level of 2/3 of the alveolar process height and along its apex. A so-called fabric map is created, which helps to transfer the data to the plaster model. The model is cut out, with respective points marked on each surface that was involved in mapping. Afterwards, they are connected, which results in the topography of the bone tissue at the implantation area.

COMPUTER SYSTEMS FOR X-RAY DATA ANALYSIS

Computer analysis facilitates the identification process: the number of implants; the shape and size (length and diameter) of the implants; possible issues in the bone tissue around the implants; possible need for bone grafting. Nowadays, there are many computer systems available on the market, while all of them could be divided into: A) systems relying on radiographic data; B) systems using computed tomography data; C) systems employing computed tomography data, with possible online computer navigation; D) systems using computed tomography data with possible manufacture of a surgical template [24, 25, 43–45].

SYSTEMS EMPLOYING X-RAY DATA

There are several software products available on the market, which are some type of specialized 2D image graphic editors based on orthopantomograms [26–28, 54, 59, 61]. These allow certain accuracy in terms of identifying the implant topography, the implant shape, implant (diameter and length), the need for sinus lifting and methods for that, as well as the type and shape of future restoration [30].

However, due to the 2D nature of the data offered for analysis, as well as given possible distortions of up to 10% vertically and up to 20% horizontally, when analyzing orthopantomograms, the systems in question appear to have serious limitations if used in complex anatomical circumstance [12, 15, 29].

SYSTEMS EMPLOYING COMPUTED TOMOGRAPHY DATA

Computed tomography is 40–50 times more sensitive, if compared to the conventional X-ray examination, since it features a better visualization for the difference in the object density, thus allowing designing its 3D shape with accurate dimension details [46–48]. These features will help plan the installation of a dental implant in 3D space, which virtually guarantees the exact topographic integration of the implant into the bone. Therefore, the recent years have witnessed a number of software products coming to the market that, since based on CT data, allow virtual installation of 3D implant samples in model of jaw bones, at the same taking into account the height and width of the respective bone tissue, as well as the mandibular nerve position [31–33, 55, 56].

SYSTEMS EMPLOYING COMPUTED TOMOGRAPHY DATA WITH POSSIBLE ONLINE COMPUTER NAVIGATION

I. Equipped with infrared sensors

Video surgery (surgery under visual monitoring) is something to be seen in many areas of medicine. This system incorporates the GPS (Global Positioning System) principle. Such systems allow not only CT planning of dental implant installation, yet also monitoring it in the real time mode on the screen, which displays the projection of the tip and the working surgical cutter involved in preparing the implant bed, in relation to the jaw tissue bone, which, in turns is a way to help control the entire process of preparing the bone bed through the surgery [7, 8, 34, 35, 52]. The principle of such system operation relies on the technical features of the equipment used:

Example of the dental navigation system. Fig. 1, 2.

1. The system – the emitter tip. Next to the patient's chair, there is a unit including a monitor and a LapDoc platform, with an infrared stereo camera on it, equipped with optical diode sensors. The handle of the nozzle is equipped with three infrared emitters. The position of the tip is calculated in relation to the jaw.

2. The system — the alveolar process radiator. During the operation, the system identifies the jaw position with an acrylic template attached to the teeth or the alveolar bone. The bezel has a U-shaped register with 10–12 ceramic (titanium) balls (diameter — 3 mm). The optical system offers an accuracy of ab. 1 mm. The downside of this system is that there must be free passage of the infrared beam with no refraction from the emitter to the sensors. In case of the beam refraction the system will issue a notification (signal) [36].

II. Equipped with ultrasound sensors

One of the latest developments in the area of online navigation. The pilot plant was developed by the European Institute of Implant Robotics (Institut Europeen de Robotique Implantaire / France), its difference from the two above-mentioned systems being the type of sensors it relies on — not infrared yet ultrasonic. The tip is positioned with an accuracy of 0.3 mm, unlike the conventional infrared systems, which ensure a good static calibration of 0.1 mm, yet feature poorer dynamics — 0.6–1 mm. The system described herein provides a static accuracy of 0.05 mm, the dynamic accuracy reaching 0.3 mm.

The methods employed to manufacture surgical templates can be broken into two main groups: templates manufactured following the classical laboratory technique, and those manufactured with computer systems.

Manufactured based on the classical laboratory technique.

In dental implantology, there are various options used to manufacture surgical templates by hand.

1. The simplest way is to make an analogue of a removable prosthesis in a dental laboratory, with a partial overlap on the teeth remaining on the jaw on its base, thus ensuring its effective fixation through the surgery. Artificial teeth in such sort of a prosthesis give an understanding of the localization for further dental implant installation.

2. A modified version of the method described above, which allows simultaneously planning the dental implant location using CT data, which relies on the fact that either a radiopaque substance is to be applied to the template artificial teeth prior to computed tomography, or the artificial teeth themselves are to be made with such substances added. In this case, a CT

Fig. 1. *The alveolar process bed preparation to install the implant; a — the reference pin; b — the bone cutter is matched against the reference pin; c — the physio dispenser tip; d — the laser emitter; e — the occlusive stabilizer; f — the craneostat; g — the extra notification system displaying the zero (reference) angular position of the bone cutter*

Fig. 2. *The positioning and installation of the dental implant in the alveolar ridge. a — the physio dispenser tip; b — the laser emitter; c — the craniostat; d — the extra video broadcasting system*

scan with an X-ray model of this type is done in the patient's oral cavity, through which the doctor will obtain not a 3D image of the jaw anatomical structures alone, but the spatial position of the planned artificial teeth, which will help planning the installation of dental implants.

3. Ez Stent Technology (Applied Dental Inc.). When dealing with defects embedded in the dentition, the technology in question allows an easier creating of a surgical template using a thermoplastic billet with a titanium casing in the center. The template, if placed for 1 minute in a rubber cup with 60° C–hot water, becomes transparent as well as gains elasticity. In this condition, it is placed on the model at the implant, and the two adjacent teeth in the defect area get compressed. As template loses its transparency, it means it is gaining its rigidity back, along with and readiness for use.

4. Making a template by thermo-forming takes first marking the plaster model with spots pointing at the areas for the subsequent implantation, and these are the points where the teeth are to be modeled with wax or glued together as taken from a set.

Then, a vacuum forming machine (e.g., Plastvac, Erkoform, etc.) is to be used to press a sheet of thermoplastic material (thickness — 3 mm) against the surface of the cast model, while maintaining a specified temperature mode, under vacuum conditions. After cooling, the mold is to undergo processing. Wax teeth are removed with a jet of water, and the model is to get perforated at the sites for implants to be installed. Following that, the entire vestibular part of the template is cut out at the next implant, nearly coming to the center of the alveolar ridge.

DENTAL IMPLANTATION PLANNING SYSTEMS EMPLOYING COMPUTER TOMOGRAPHY DATA WITH POSSIBLE MANUFACTURING OF A SURGICAL TEMPLATE (CAD/CAM TECHNOLOGY)

The advance of computer control systems has created grounds allowing the introduction of CAD/CAM into dental practice, which in most cases makes it possible to do without human involvement through the orthopedic devices production stage.

In dentistry, this technology has penetrated into the production of non-removable orthopedic devices, and now is going on to be used further — in the production of surgical templates as well as in dental implantology [37, 38, 60].

There are two types of CAM systems used in dental implantology nowadays:

I. Prototyping.

II. Sequential deformation of a thermoplastic CAM.

I. Prototyping.

Compared to other methods (making models of foam, wood, wax by hand or on CNC machines), which had been common until the mid-1980s, the advance of rapid prototyping systems proved to be a technological revolution.

Prototyping is a new technology that is progressing actively in R&D (design and production). It allows obtaining physical parts and models with no actual tool production, and implies converting data from the CAD system, while having previously obtained 3D drawings and projects.

There are three types of surgical templates used for dental implants:

1. A template relying on a bone. The e-type of the surgical template is modeled using a 3D CT model, created on a stereolithographic device.
2. A template based on adjacent teeth in the defect area (a mandatory condition is the availability of two adjacent teeth on each side of the defect).
3. A template relying on the mucosa.

VIP (Implant Logic SYSTEMS), USA

Impressions should be obtained both with a prosthesis (temporary restoration) and without one. The position of the central occlusion (the upper jaw ratio) is to be identified, too. After that, the doctor contacts the Implant Logic Systems or gets a request form from the company's website. Upon completing the form, it is to be sent, along with the template, to the company to get the radiographic templates produced, and after surgical models are made, CT diagnostics is performed, with the respective data recorded in DICOM 3 format. Using the software, the doctor carries out the dent planning. The planning information is then sent to the company's laboratory, where a surgical template is made [13, 19, 50, 53, 57].

The company supplies the types of surgical templates for the doctor to choose from:

1. The basic Compu-Guide™ Template. This template allows the cutter to move directional through drilling. It contains 2 mm sleeves with precise position, angle and vertical level to ensure due surgical protocol.
2. The Compu-GUIDE™ ADVANCED clamp relies on a set of replaceable bushings that can be replaced stage by stage, depending on the perforation level, which allows full control of osteotomy with the surgical template.

Besides, a removable prosthesis (Compu-Temp ™) can also be prepared, where the surgical cases are located to ensure the fixation of the temporary structure following implantation.

CAD Implant (CAD Implant, Inc.), USA.

The company has been using this technology since 1994. The destination of the model is mucous membrane. First, computed tomography with radiographic templates is done, which takes a registration cube (CAD Implant Registration Cube). Using special software, the doctor models a surgical template, the e-version of which is sent to the CAD Implant, Inc., where it is manufactured through stereolithography and computer milling [24, 58].

Implant Master (iDent), USA, Israel

The company's promotion claims that iDent Imaging is a dynamic visualization technology that simplifies, as well as improves qualitatively, the accuracy of planning and installing dental implants. However, nothing is mentioned regarding how this effect is ensured. There is a computed tomogram with an X-ray template done; the doctor analyzes the anatomical area and plans installation of the next dental implant. The planning data from the Implant Master is delivered to the iDent service center, where the surgical template is produced digitally.

Planning involves the Procera Software Planning — software based on a 3D analysis of a dental implant. The software helps identify the optimal topography of implants, in view of the anatomical status, as well as the orthopedic and aesthetic requirements. In case of full adentia, three horizontal locking pins (d = 1.5 mm) ensure the surgical template is fixed reliably during the surgery. In case adentia is of partial nature, fewer pins are to be used, whereas cases of only tooth missing require fixture relying on the neighboring teeth.

The requirements for the surgical template are as follows: thickness — at least 2.5–3.0 mm. Enhanced strength can be achieved through reinforcement.

II. Sequential thermoplastic CAM-deformation

Used currently only by the TactileTech company in the ILS (Implant Location System). This system features a number of functions that make it different from others. Apart from computed tomography data, it can be used to detect the degree of the bone tissue mechanical elasticity in the alveolar process in at the implantation area. For this purpose, a special frame is used, which is fixed on the alveolar process. Further, a matrix with microneedles is installed on it, while the needles penetrate into the gum tissue up until they come into contact with the bone. The elasticity coefficient is determined by the vestibular and oral surfaces. Further on, the information is transmitted to the analytical unit, where a dental implant installation is planned relying on the data from the elasticity coefficient and computed tomography. The information is then referred to the CAM device. There is a hollow plastic tube installed in a special cylinder bed, while the other part of it is fixed on a rod, which is involved in the following deformation under the effect of respective temperature conditions [22, 35, 36].

Thermal sequential deformation of the pipes is followed with them installed in a block that is mounted in a frame system.

CONCLUSION

Dentistry has always enjoyed close connection with other fields of research and production, attracting a large number of advanced innovations and developments. This article offers an analytical view on the treatment changes, which are due to the integration of computed diagnostics (CT) and manufacturing (CAD/CAM) technologies. Given that, there are more efficient and less traumatic dental implantation planning systems available, which are based on accurate data and computer calculations, which, in turn, minimizes potential effect of technological or human factors.

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