Chapter 7

# CAD/CAM Technology in Implant Dentistry

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Additional information is available at the end of the chapter

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## 1. Introduction

When a patient presents with a need and a desire for implants to replace missing teeth, correct execution will only occur with thorough planning [1-4]. Recently introduced technology may benefit both the dentist and the patient when restoring with dental implants, in that the implants will be placed in an ideal, predictable, and planned location [4-7]. Implant dentistry is constantly challenging the practitioner to be aware of recent advances. Though it may feel overwhelming for a practitioner to stay informed with the continuous introduction of new technologies, implant dentistry is undergoing an exciting time, and in order to take full advantage of it, the practitioner has a duty to practice at the highest level. This chapter aims to inform the practitioner about the latest technologies, their history and importance, and the current options on the market.

## 2. Computerized tomography

Computerized tomography is a tool that is based on the original concept of conventional tomography [8,9]. Tomography is a type of image in which a 2-D slice is captured and the surrounded slices are blurred. This works by the sensor and the x-ray tube moving in opposite directions around the source. During this movement, the plane of interest remains fixed, and the surrounding planes become blurred due to constantly changing positions on the sensor. A panoramic image is a single tomographic image [9]. Panoramic radiographs cover large anatomical areas, have low radiation doses, and are easily and quickly done, though their distortion and 2-D quality limits their diagnostic value.

Computed tomography (CT) was introduced in 1973 by Godfrey Hounsfield. It works by an x-ray tube and a series of detectors which rotate in synchronous directions, as the x-ray tube emits fan-shaped beams through the region of interest and onto the detectors. The data captured is processed in a computer which displays the resulting image in voxels, or volume elements [10]. Benefits of CT include high resolution and absence of superimposed images, but they emit large radiation doses and are expensive.

More recently, a new technology called cone-beam computed tomography (CBCT) has become popular [1,10-13]. This works by the x-ray tube emitting beams onto a 2-D sensor. The x-ray tube and sensor rotate around the region of interest and expose an image at each degree of rotation. These slices can subsequently be arranged into a 3-D image which can provide detailed and accurate information which has been reported to be within 2% of geometric accuracy. Benefits of CBCT include cost effectiveness, ease of use, low radiation dose, and accurate gathering of information [14,15].

## 3. Cone-Beam Computed Tomography (CBCT)

When utilizing CBCT technology, the practitioner should be aware of several features [14,15]. The resolution of a CBCT image acquired is measured by voxel size. The majority of CBCT's used for dental implant planning has a voxel size of 0.4 mm, and the accuracy of measurements made on the CBCT are directly related to this size. When reading a CBCT, one way to analyze bone density is through the Hounsfield index. This index was named after the inventor of computed tomography, as previously mentioned. The scale ranges from-1,000 to+1,000, in which air reads at-1,000, water reads at 0, and extremely dense bone reads at+1,000 [16]. Different anatomical structures have varying Hounsfield units. It is important to know how to apply the Hounsfield scale because the differences in bone densities will alter the chosen surgical protocol. For instance, if the CBCT scan shows very dense bone, more implant preparation drills will be required. Each implant system has a unique protocol for soft and dense bone. The average Hounsfield units for human tissues are shown in Table 1 [16].

| Tissue | Hounsfield Unit |
|---|---|
| Trabecular bone | 150-900 |
| Cortical bone | 900-1800 |
| Dentin | 1600-2400 |
| Enamel | 2500-3000 |
| Muscle | 35-70 |
| Fibrous tissue | 60-90 |
| Cartilage | 80-130 |

**Table 1.** Average Hounsfield units for human tissues.

Most implant planning software is structured from the images produced by medical computed tomography. The conversion of a cone beam computed tomography image into a medical

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computed tomography image has not been studied, though it is hypothesized that there is no difference in linear measurement between the two.

When planning for implant surgery, few complications should occur when utilizing cone beam computed tomography. The most common complication, called beam hardening, occurs when the patient already has implants or a large amount of metal restorations [17,18]. This is a phenomenon that occurs when the metal causes the x-ray to increase in energy and become "hard" as it passes through an object. Beam hardening makes it difficult to visualize surrounding structures, thus altering the accuracy of measurements of crucial anatomical sites, such as the inferior alveolar nerve and the buccal plate thickness [17,18].

When ordering a scan, clear written instructions should be communicated from the practitioner to the radiologist. The practitioner should specify the reason for the scan (i.e., implant placement, sites), the size of the scan (small or large), and any additional anatomical regions that should be included (such as a TMJ or sinus evaluation). A small volume scan should be ordered for single tooth implants, and a large volume scan should be ordered for full-arch implants, inclusion of sinuses, or evaluation of TMJ or OSA.

## 4. Surgical guides

Not only does cone-beam technology provide valuable information for evaluation before placing dental implants, but it also translates into completely digital planning of surgical cases. Utilizing a CBCT scan as a template, a surgical guide may be fabricated based on the precise location of a planned implant [1,4,19,20]. All of the major implant companies offer software which can be used for planning the specific location of implants in the CBCT image, and eventually a guide can be ordered and fabricated. The software allows the virtual placement of implants into the CBCT scan at the precise location you choose, while taking into account considerations such as anatomic landmarks, adjacent dentition, type of restoration to be fabricated, and occlusal scheme.

It is beneficial, and many times essential, to utilize a radiographic guide in order to aid in choosing the correct position of the implants. If a patient is missing several teeth, a radiographic guide should be worn by the patient during the CBCT scan. The guide allows the practitioner to locate where the future teeth will be restored in space. Radiographic guides can be fabricated in many ways, and one must consider the protocol of the implant planning software one chooses to use. For example, the Nobel Clinician prescribes a dual-scan protocol in which the patient wears the guide during the patient's scan, and then the guide is scanned separately [21,22]. Fiduciary markers, or small gutta percha points placed into the radiographic guide, allow the software to overlap the two scans and merge the two files together. In this way, the guide may be virtually removed and replaced on the patient's scan in the computer. Another way to fabricate a radiographic guide is by placing radiopaque denture teeth into the guide. These teeth will ultimately be visible in the scan so that the implants may be planned accordingly.

Regardless of which system is chosen, the practitioner must be able to understand when it is important to utilize a radiographic guide. When planning for single implant replacements, with adjacent teeth on both sides, it is often not necessary to use a radiographic guide because enough adjacent landmarks exist in order to surmise the future location of the single crown. In an edentulous patient, the decision to use a radiographic guide depends largely upon the type of restoration that will be fabricated. For a mandibular locator overdenture with two implants, it is often unnecessary to use a radiographic guide because the clinician has some freedom in the positioning of these implants. This is unlike an edentulous patient that is planned to receive metal ceramic restorations in which the abutment-screw access hole must open through the occlusal surface of the posterior teeth and the cingula of the anterior teeth. In this case, it is paramount to plan for the precise implant positioning, and the radiographic guide must have the identical anticipated tooth positions of the final prosthesis. If the patient is unhappy with the tooth position or shape on the radiographic guide, this must be fixed before utilizing it as the guide.

## 5. Virtual implant planning

The purpose of utilizing virtual implant software is to plan the placement of the implants in prosthodontically driven positions [22,23]. Of course an implant may be placed anywhere the bony anatomy allows, but in order to build a successful prosthesis for that implant, the correct planning must be done. In the past, a panoramic tomography scan was performed while the patient wore a radiographic template with integrated metal spheres at the implant site. In this manner, the magnification of the radiograph was able to be calculated, and the approximate placement of the implant was planned. This conventional model was flawed in that it did not convey any 3-D information [24].

The most contemporary technique utilizes cone-beam CT technology which provides the essential 3-D information. The technique begins with fabrication of a radiographic guide with ideal tooth positions. This guide may be a duplicate of the patient's exiting denture, only if that denture offers tooth positions that are acceptable by the patient and practitioner. If the denture is not ideal, a new one should be fabricated until the esthetics and functional demands are met. It is not until this point that a CBCT scan should be taken. The next step involves interpretation of the scan and possibly a re-working of the original treatment plan. This may include an additional surgery for bone grafting, or a different prosthesis choice. For example, if metal ceramic restorations were originally planned for, but the scan clearly shows that an implant cannot be placed in the proposed position, either a new design or a new prosthesis must be chosen. Lastly, the practitioner can virtually place the implants into the bone at the exact position that optimizes prosthodontic benefit as well as osseointegration potential. These positions are then translated into the surgical guide which will be used on the day of surgery for the placement of the implants.

The benefits of virtual planning and fabricating surgical guides from the planning are numerous. The patient's chair time is decreased, the surgery is more predictable and less

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stressful, the implants are placed in a restoratively driven manner, and the case difficulty is learned ahead of time [6,25]. These factors allow the dentist to plan accordingly in regards to time and fees. Increased lab costs due to customized abutments may be realized during planning, and extra surgical procedures may be foreseen. The patient will know what to expect and will appreciate the dentist for the knowledge rendered.

### 5.1. Indications

As mentioned before, not all cases are advocated for radiographic guides. Similarly, not all patients are candidates for surgical guides. There are several limiting factors involving surgical guides. Firstly, the patient must have adequate opening. Depending on the guide, length of implant, and drill system used, the normal minimal opening is 35 mm at the first molar. This must be evaluated before ordering the guide, as the guides are custom made and non-returnable. Secondly, the patient must be aware that this is an added cost to the treatment. Surgical guides range anywhere from $200 to $1,000 depending on the complexity of the case and the company chosen to fabricate the guide.

Surgical guides allow prosthodontically driven implant placement, which ultimately will give the patient the best prosthesis to satisfy esthetic and functional needs. Surgical guides also allow more accuracy during implant placement. Not only are the implants placed in the exact pre-determined positions, but the surgery may take less time and ultimately will be more comfortable for the patient.

### 5.2. Steps for the practitioner

Some of the steps involved in virtual implant planning are different depending on which company you choose to utilize, but they are all based on the same principles. As mentioned before, the first step is to fabricate trial dentures for the completely edentulous patient or a trial tooth arrangement for the partially edentulous patient. Once this is approved by the patient and practitioner, the denture may be converted into a radiographic guide.

### 5.3. Fabrication methods

There are three basic methods of fabricating a radiographic guide. The generic method involves any type of scan template that has radiopaque material to indicate the desired implant positions. There are many radiopaque materials that may be used. These include radiopaque denture teeth (SR vivo TAC, Ivoclar, Vivadent, Amherst, NY), radiopaque acrylic (Biocryl X, Great Lakes, Tonawanda, NY), and triphenylbismuth added to denture acrylic.

Another type of guide, termed a dual density radiographic guide, is fabricated as a duplicate denture utilizing denture teeth of a high radiopacity and denture base of a lesser radiopacity. This type of guide prescribes a single scan protocol.

Lastly, the dual-scan protocol requires a radiographic guide with fiduciary markers placed into it. These are small divets 1.5 mm in diameter that are filled with gutta percha. Eight markers must be placed in each guide at different horizontal, vertical, and transverse levels.

The term "dual-scan" comes from the way in which the patient is first scanned while wearing the radiographic guide, and then the guide is secondarily scanned alone on a plexi-glass table.

### 5.4. CBCT scan

Once the type of guide is chosen, the CBCT scan may be performed. During this procedure, that patient's occlusion must be opened at least 5 mm. This may be done by injecting PVS material on the patient's occlusal surface and having the patient bite down at an open vertical dimension. A radiopaque material should never be used for this, as it will obscure the region of interest on the scan. This opened bite allows us to distinguish the maxillary teeth from the mandibular teeth in the radiograph.

### 5.5. Digital planning

Next, the case may be planned using the software of your choice. Most major implant companies sell their own software, but there are also universal software companies available which allow you to place any implant of your choosing. These will be reviewed later in the chapter.

## 6. Surgical guide support

The type of surgical guide must be chosen at this point. Three types exist based on the type of supporting tissue: bone, mucosal, and tooth [1,19,26,27].

### 6.1. Bone-based guides

Bone-based guides are indicated for the fully or partially edentulous arch, when immediate implants are being placed, when alveoloplasty is required, and when anatomic limitations exist which require visualization of the bone. Bone-based guides may provide a more accurate seating of the guide because of the rigidness of the bony base. Sufficient bone support is essential for a stable guide positioning. During surgery, an incision is made along the alveolar ridge and mucoperiosteal flaps are elevated. The guide sits directly on the bone and complete visibility is acquired. Limitations of bone-based guides include a lengthier surgical appointment, longer healing times for the patient, and difficulties gaining adequate palatal reflection in certain patients. Some argue that they may be a poor choice in a patient with a thin buccal plate which can be prone to resorption after tissue reflection.

### 6.2. Mucosal-based guides

Flapless implant surgery is an alternative method for implant placement. Advantages of a flapless surgery include less trauma to the hard and soft tissues during surgery, shortened procedure, rapid healing, fewer postoperative complications, decreased infection risk, and increased patient comfort [28-31]. A significant advantage of the flapless implant surgery is the decreased amount of bone loss as well as the preservation of the gingival margin of the adjacent teeth and interdental papillae [31]. More bone loss occurs during flapped procedures

http://dx.doi.org/10.5772/59322

since the gingiva is unable to provide nutrients to the bone during the surgery. The preservation of tissues will help prevent the appearance of black triangles after healing.

Though flapless surgery offers many advantages, many surgeries still require a flap to be elevated. Reasons for this include the need for more visualization, bone grafting, and alveoloplasty. If the patient's alveolar bone is thin, it is wise to elevate a flap and visualize the bone before placing an implant.

A mucosal-based guide is a good choice for a fully edentulous arch with a minimum of 2 mm of bone buccal and lingual to the proposed implant site. This amount of bone is necessary because of the increased risk of cortical bone perforation related to implant placement without direct visualization of the bone. The conventional flapless surgery relies on the experience of the surgeon to correctly predict the shape of the underlying bone when placing an implant. Recently it has been suggested that using a surgical guide fabricated virtually utilizing a CBCT may be beneficial in these cases.

Mucosal-based guides are good choices in the maxilla due to difficulty in reflection of the soft tissue of the palate which is necessary for a bone-based guide [32]. A mucosal-based guide can also be used in conjunction with osteotome sinus lifts [33]. Limitations include error when seating the guide due to the mobility of mucosa which ultimately can affect the implant positions. Furthermore, a mucosal-based guide will mimic the fit of the radiographic guide, which is most often fabricated as a duplicate of the denture. So it is important that the denture be very stable before utilizing it as a radiographic guide.

Three retention pins are required to be placed in these guides to stabilize them on the edentulous arch. The retention pins must be spread out, must not protrude into the vestibule, and must be an adequate distant from the implant sites so as not to hinder their placement.

The literature shows conflicting results when comparing mucosa-based versus bone-based guides. Some say that mucosa-based guides may have a decreased accuracy as compared to bone-and tooth-borne guides [27,34] and some say that mucosa-based guides have increased accuracy as compared to bone-and tooth-borne guides [20]. In the end, the literature shows that mucosal-based guides offer adequate accuracy of implant placement. Several studies have displayed a mean of about 1.0mm deviation at the apical aspect of the implant from the planned placement on the CBCT [20,35]. Some authors recommend a certain safety zone (2.0mm) due to the inevitable deviation of the planned versus actual osteotomy site [35].

### 6.3. Tooth-based guides

A tooth-borne guide is indicated for the partially edentulous arch with adequate remaining sound dentition. A plaster cast or an optical scan of the cast is necessary for the laboratory fabrication of this type of guide. The remaining teeth will determine how stable a tooth-borne guide will be, so this must be evaluated carefully. It is recommended to use this type of guide when placing a single implant or several implants when minimally invasive surgery is required. Often times, a flapless surgery may be performed with a tooth-borne guide. In a partially edentulous patient, the treatment planning may be more difficult due to anatomical limitations, so utilizing computer-aided techniques can optimize the efficiency and accuracy of implant placement [36].

### 6.4. Surgical preparation

When preparing for surgery, several steps must be taken when utilizing a surgical guide. First, the guide should be disinfected according to the instructions provided from the company who fabricated the guide. Many guides may be placed in a chemical disinfectant for 10 to 12 minutes, and most guides will not tolerate heat disinfection. Also, if utilizing a mucosal-based guide, it is a good idea to place holes into the guide before the surgery begins, so that anesthesia may be administered throughout the surgical procedure. If this step is missed, the practitioner must remove the mucosal based guide, after removing the retention pins, administer anesthesia, and replace the guide in the exact same position. Or the practitioner must drill through the guide to gain access to the anesthesia locations. Lastly, when seating a mucosal-based guide on the day of surgery, the same interocclusal record which was used during the CBCT scan should be placed in the patients mouth along with the guide. At that point the retention pins can be placed into the bone to lock the guide into place while using the patients occlusion to stabilize the guide in the correct location.

### 6.5. Stereolithographic versus conventional guides

Surgical guides can be made through many techniques and several different materials. Recently, stereolithography has become a popular method of fabricating surgical guides [5,19]. Stereolithography is an additive manufacturing process. This process utilizes a bath of light-sensitive liquid resin which is cured one layer at a time by a laser which traces the 3-D model which the computer demands of it. Guides made from stereolithography are light sensitive as well as heat sensitive. These guides should always be kept in their original packaging in a cool dry environment.

Stereolithographic guides are very rigid in comparison to a conventional resin cured guide. When restoring a large edentulous area in which the guide has the potential to flex under pressure of the implant drill, it may be a wise decision to choose a stereolithographic guide so that the implant positions are not compromised. Stereolithographic guides also allow more precision when placing implants as compared with conventional guides. One study compared the difference between the planned implant position and the actual osteotomy at the apex. The conventional guides had an average of 2.1mm difference whereas the stereolithographic guides had an average of 1.0mm difference [37].

Surgical guides may be fabricated from the radiographic guide. The radiographic guide can be sent to a manufacturer which will convert it, through a mechanized process, into a surgical guide with included guide sleeves. If this technique is chosen, the radiographic guide must incorporate the correct orientation and placement of the implant into the guide. This can be accomplished either by using a radiographically opaque denture tooth, gutta percha markers through the long access of the tooth, or any other radio-opaque material which can orient the planned implant into the radiographic guide.

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Alternatively, a mapping technique may be used to fabricate a computer generated surgical guide. This is a technique which eliminates the need for a radiographic guide. The patient is scanned while wearing a radiolucent interocclusal record to disclude the patient's posterior teeth by about 5 mm. Then a cast of the patient is scanned and a diagnostic wax-up is scanned. The computer is then able to orient these images to each other and the practitioner can digitally plan the implant placement in reference to the patients alveolar bone and planned tooth positions. A surgical guide can then be fabricated from the digital design.

All of these choices are viable options for fabricating a surgical guide. Each situation is unique and depending on the practitioners resources and relationship with their radiologist, the practitioner may choose any option he or she prefers.

## 7. Companies

The aim of this section is not to advertise any specific company, and we just want to share our experiences with these surgical guides. Surgical guides are fabricated by many manufactures, most notable the major implant companies. Each company has a unique planning software program as well as various choices for scanning protocol, guide materials, and design of the guide. Depending on the case, different manufacturers must be considered in certain situations. For example, if dual-scan protocol was desired, only NobelBiocare and Anatomage offer this option.

**Things to Consider When Choosing a System**

- How well can you maneuver the software program? Or will your radiologist be manipulating most of the digital implant planning for you?
- If you plan on doing the virtual placement yourself, make sure you are comfortable with the program. Each company offers a different program and these are not all as user-friendly as the next.
- What kind of radiographic scanning protocol to you plan on using? Do you prefer the dual-scan protocol in which a denture can be quickly converted into a radiographic guide? Or do you prefer to have your lab fabricate a separate radiographic guide for the scan?
- Do you plan on using bone, mucosa, or tooth supported guides? Or do you want to have the option of using all three, depending on the case?

These are all considerations that must be taken into account before investing in any imaging software because once you do, you will be limited by that companies available options.

Another consideration is that different implant-planning softwares allow different levels of resolution of the CBCT data. So even if the CBCT machine is capable of taking high resolution images, the planning software you choose may not be able to open the full resolution which was recorded. When placing implants, any fraction of a millimeter in the wrong direction may have a significant compromise on the outcome.

| Company | Implant Systems | Support Type | | | Material | | Cost |
|---|---|---|---|---|---|---|---|
| | | Bone | Mucosa | Tooth | Resin | Stereolith | |
| Keystone | Universal | | | ✔ | ✔ | | $$ |
| Biohorizon | Universal | | ✔ | ✔ | ✔ | | $$ |
| NobelBiocare | NobelBiocare | | ✔ | ✔ | | ✔ | $$ |
| Anatomage | Universal | ✔ | ✔ | ✔ | ✔ | | $ |
| Materialise | Universal | ✔ | ✔ | ✔ | | ✔ | $$$ |

### 7.1. Keystone

Keystone offers one of the most basic surgical guide systems, hence the coined term "Easy-Guide" for their planning software. EasyGuide can be utilized for planning implant placement in single tooth edentulous spaces, partially edentulous spaces, and completely edentulous arches. The Keystone surgical guide can only be used in single tooth edentulous spaces and partially edentulous spaces.

During the CBCT, the patient wears a laboratory fabricated radiographic guide with barium sulfate incorporated in the areas where the teeth will be replaced. This guide also has a built in radiographic "X Marker", which is subsequently used by Keystone to fabricate the surgical guide. The clinician then plans the implant placement in the EasyGuide computer program and virtually sends this information to Keystone to fabricate the surgical guide, if desired.

The surgical guide is fabricated from the digital planning. The clinician must send the radiographic guide with the incorporated "X Marker" to Keystone, which uses this to orient the guide to the patient's jaw. Keystone then will fabricate the surgical guide either as "directional" or "depth and directional", depending on the clinician's wishes. This means that the guide can be used to direct the implant at the correct angle and it can also be used to direct it to the correct depth in the bone.

### 7.2. Biohorizons

Biohorizons is another very simple and basic implant planning program that offers a user-friendly technique but limited options to the clinician. The surgical guide, called a Compu-Guide, can be fabricated for single implant placement, partially edentulous multiple implant placement, and fully edentulous multiple implant placement.

The patient wears a laboratory fabricated radiographic guide during the CBCT which is fabricated to the planning software, VIP, specifications. Then the clinician may digitally plan the implant placement using the VIP computer software. This software allows the placement of any type of implant system.

This information along with the radiographic guide is sent to Biohorizons which fabricates the Pilot Compu-Guide, a surgical guide that allows only the pilot drills to be sequenced through the guide. The clinician inserts the Compu-Guide and stabilizes it. The pilot osteomoties are drilled to length, then the guide is removed, and the twist drills are then used free-hand

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without the guide, according to the implant manufacturer's protocol. This method increases the possibility of error because the angulation may be altered when using the twist drills.

### 7.3. NobelBiocare

NobelBiocare offers a very sturdy stereolithographic surgical guide with multiple indications for use, but can only be used with NobelBiocare implants. This system can be used for single tooth edentulous sites, partially edentulous sites, and completely edentulous arches.

The CBCT prescription requests a dual-scan protocol. The dual-scan protocol requires two scans: one scan of the patient while wearing the radiographic guide and one scan of the radiographic guide by itself. The radiographic guide has built-in fiduciary markers, which allow the software to overlay the two separate scanned images. Fiduciary markers are gutta percha dots added into the radiographic guide. If the patient is already wearing a well-fitting denture, these markers can be added to the denture very easily. If the patient does not have a well-fitting denture, a new tooth-set up should be tried in and then duplicated or processed into a radiographic guide. The fiduciary markers can be added to the radiographic guide by drilling eight to ten round divots throughout and filling them with gutta percha. They should be 1mm x 1 mm in size, and spread throughout the guide in different horizontal and vertical levels.

The planning software, NobelClinician, will fuse the two files, using the fiduciary markers, so that the patient's anatomy can be visualized with and without the radiographic guide in place. In other words, the anatomical data and prosthetic data can be visualized separately. NobelClinician allows various views and reslices of the scan. It also shows a yellow safety zone around implants, which is especially important when performing flapless surgery. This safety zone helps prevents implants from being placed too close to anatomical structures or to other implants. The program also shows technical restrictions in red. For example, the software prevents the clinician from placing implants close to each other due to the width requirement of the metal sleeve in the guide. This is a complication of the fabrication of the guide to be the strongest possible in the areas where the implant drill will be entering. If the acrylic between two sleeves is thin, the guide may break in that area. If a clinician desires to place implants fairly close together, another system may be better suited.

NobelBiocare offers tooth-borne and mucosal-borne guides, but not bone-based guides. So for the completely edentulous patient, a mucosal-borne guide must be chosen. The clinician will run into a problem if the edentulous patient has very thick gingival tissue. The mucosal-based surgical guide is fabricated so that the head of the implants are placed 3 mm from the intaglio surface of the surgical guide, assuming the average patient has 3 mm of gingival tissue thickness. So if the patients gingiva is more than 3 mm thick, and the implants were digitally planned to be at the crest of bone, then the intaglio surface of the surgical guide will impinge upon the patients tissue. The easiest way around this is to relieve the intaglio surface of the guide around the drill hole, before placing it in the patient's mouth.

The virtual planning will be completed on NobelClinician, which is one of the only programs that runs on Windows and Mac OS X. The NobelClinician software also allows planning of the abutments with digital visualization. This is particularly useful when placing angled implants which will need angled multi-unit abutments. The planned information from NobelClinician is sent electronically to NobelBiocare Production Center where the Nobel-Guide is produced centrally.

The following photos show how to make a Nobelguide and to restore a patient with an immediate implant-retained overdenture (Figures 1-20).



**Figure 1.** Complete denture with fiduciary markers is used as radiographic guide.

**Figure 2.** Patient wears complete denture with fiduciary markers during CBCT scan.

http://dx.doi.org/10.5772/59322

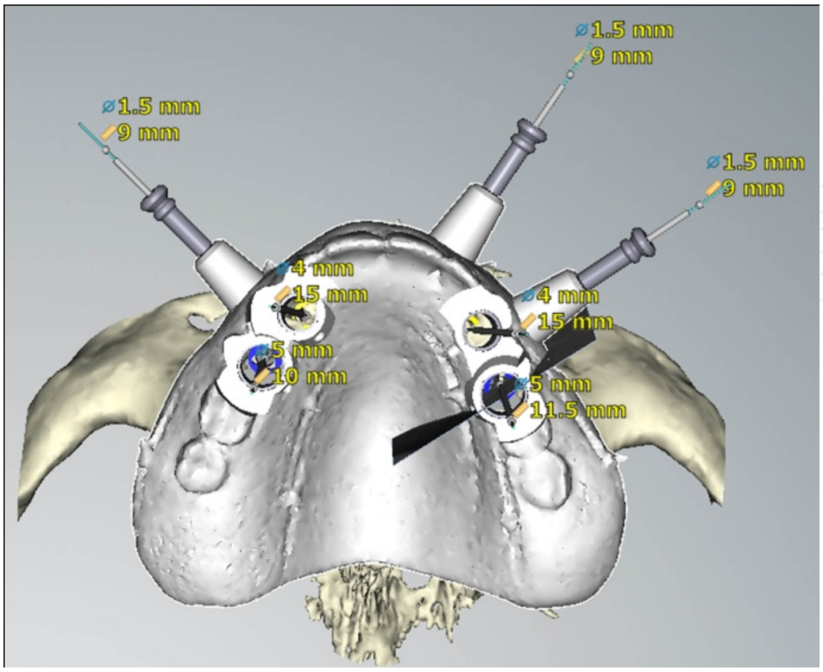


**Figure 3.** Occlusal view of maxillary surgical guide and maxilla on software.

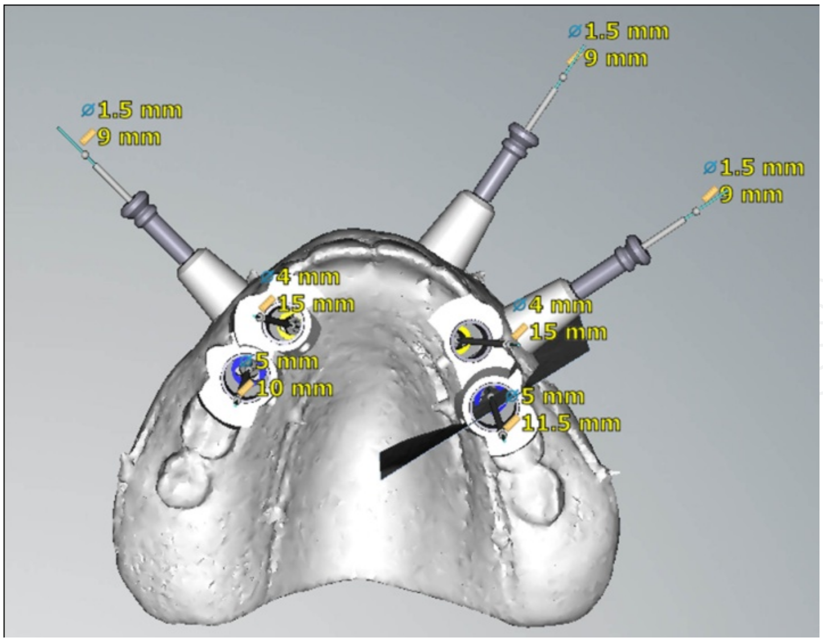


**Figure 4.** Occlusal view of maxillary surgical guide on sofware after removing maxillary bone.

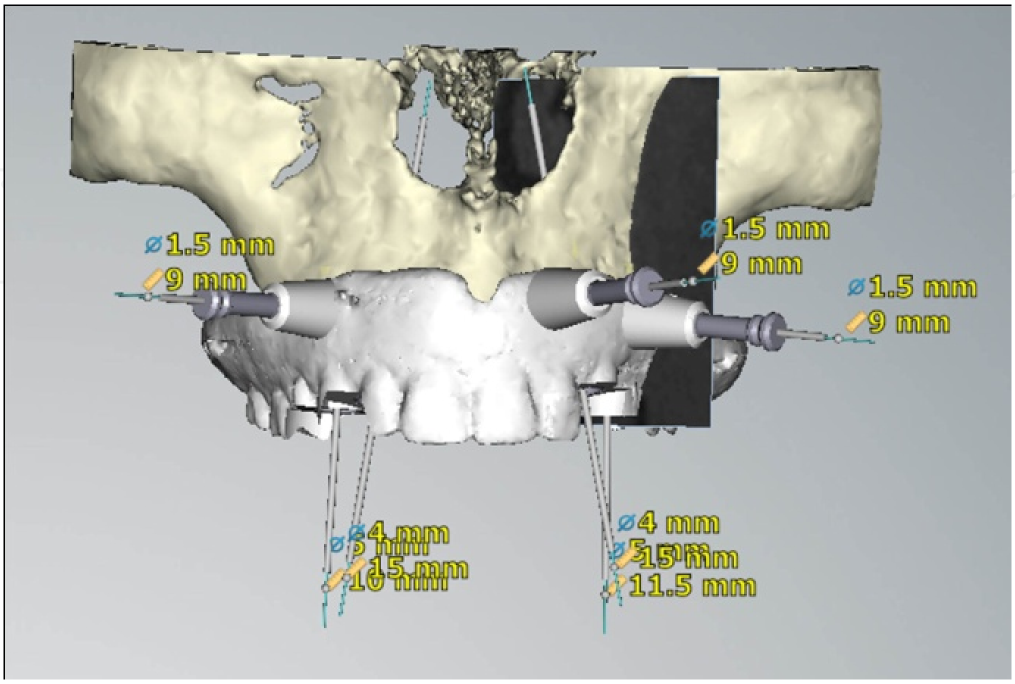


**Figure 5.** Frontal view of maxillary surgical guide and maxilla.

**Figure 6.** Occlusal view of actual surgical guide fabricated at NobelBiocare production center.

http://dx.doi.org/10.5772/59322

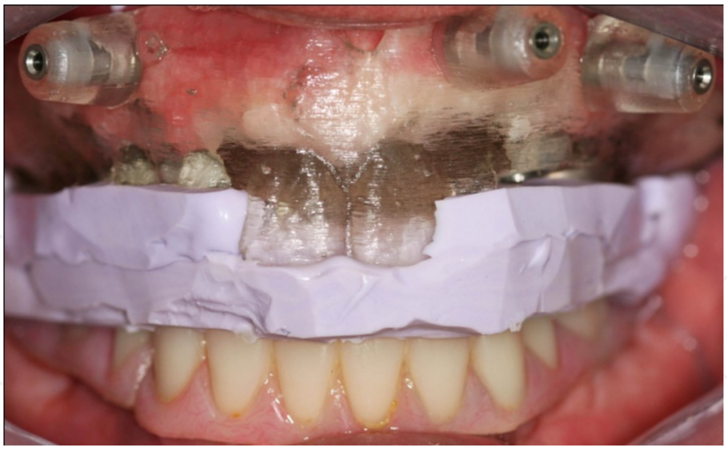

**Figure 7.** Surgical guide is inserted with bite-registration.

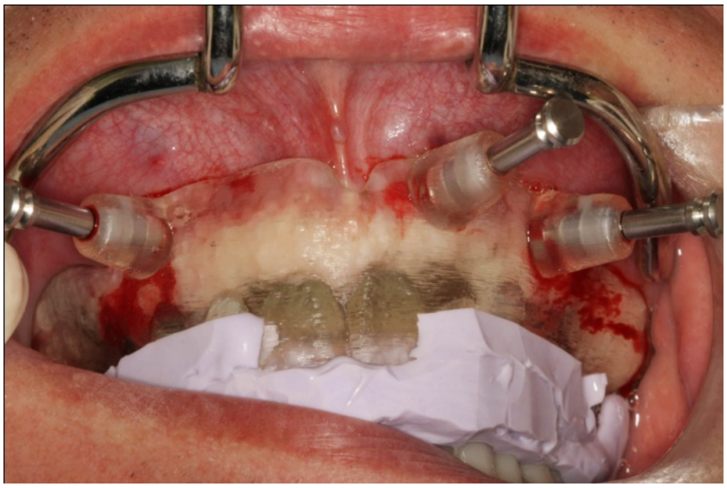

**Figure 8.** Anchor pins are placed to secure surgical guide.

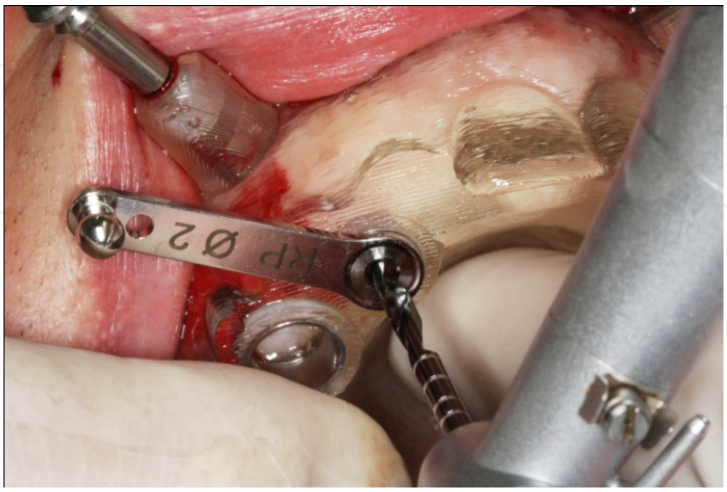


**Figure 9.** Drills are used to prepare implant sockets.

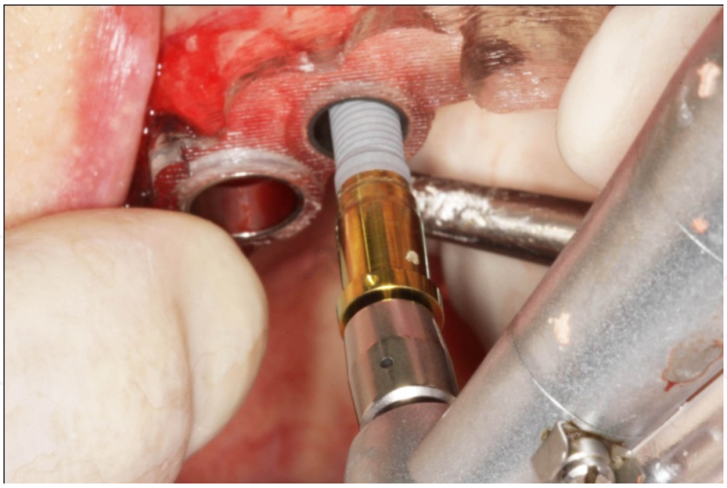

**Figure 10.** Implants are placed through metal sleeves.

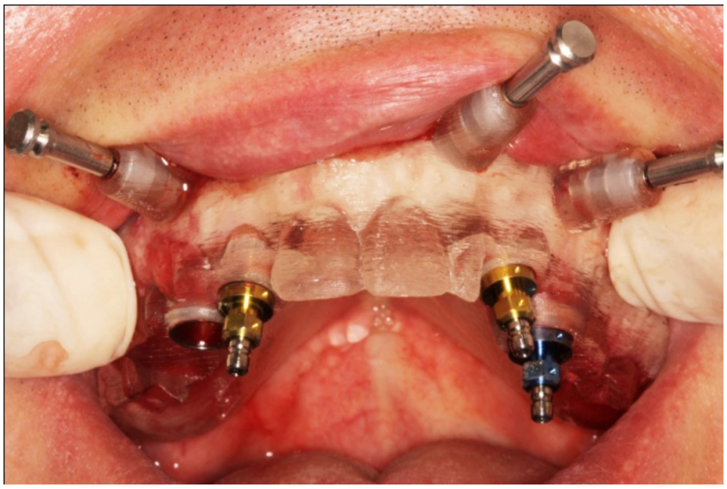

**Figure 11.** All implants are placed.

**Figure 12.** Surgical guide is removed after all implants are placed.

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**Figure 13.** Locater abutments are screwed on implants.

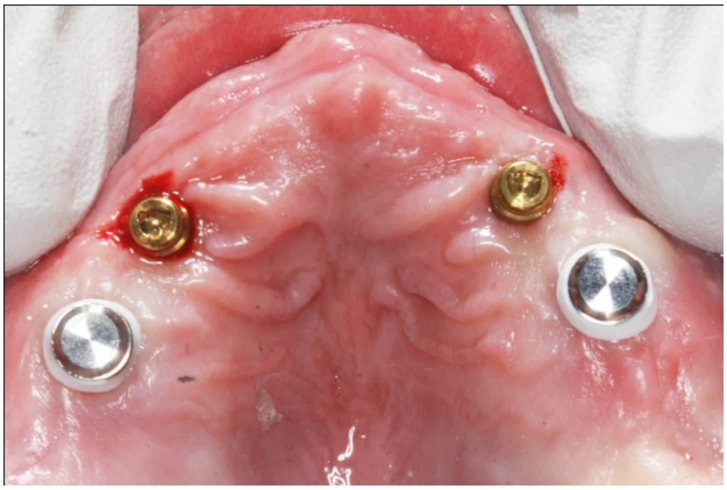

**Figure 14.** Metal housings are seated on locaters.

**Figure 15.** Enough room is needed for locaters and metal housings.

**Figure 16.** Enough room is created for locaters and metal housings.

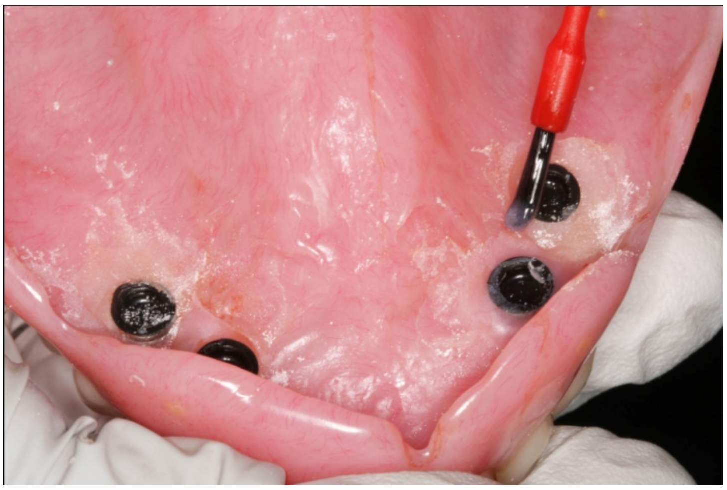

**Figure 17.** Metal housing are attached to complete denture.

**Figure 18.** Complete denture is converted to immediate implant-retained overdenture.

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**Figure 19.** Intra-oral view of patient.

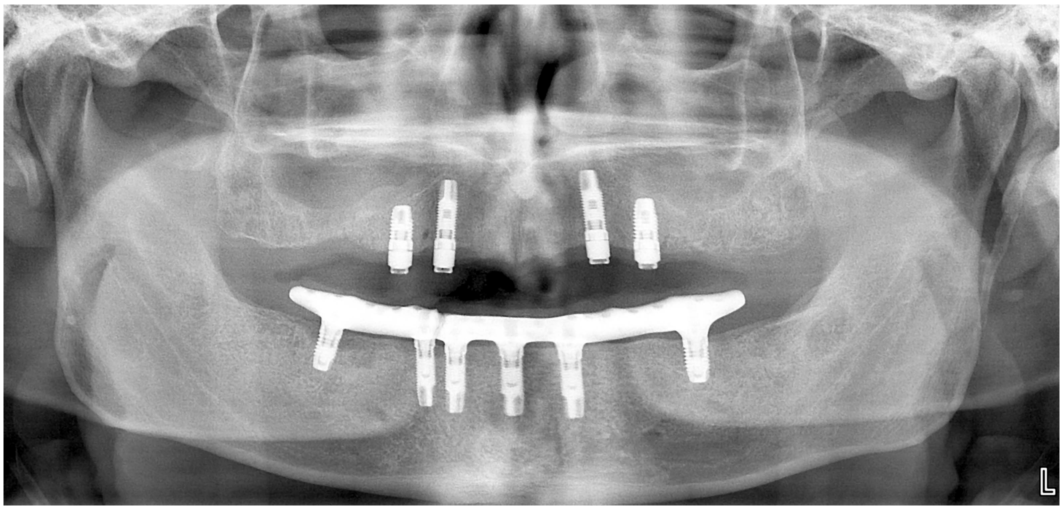


**Figure 20.** Panoramic radiograph of patient.

### 7.4. Anatomage

Anatomage is a system which offers some of the most options when planning implant placement with a surgical guide. The biggest downside of this system is that the guides are fabricated out of a conventional acrylic resin, which easily flexes under high loads of stress during implant placement. One must be very careful when choosing to use this system in a patient with a large edentulous area because it can easily be torqued out of position. Due to the material used, one benefit of this system is that the guides are cheaper than any other system. The price is a fixed price no matter how many implants are being placed.

This system, similar to the NobelClinician, prescribes for a dual-scan protocol. The company boasts that their planning software does not require a scanning appliance (or radiographic guide). Instead, a stone model and/or wax-up is scanned in order to visualize the planned positions of the teeth on the image. The planning software, InVivo5, allows the planning of any type of implant as well as bone-based, mucosal-based, and tooth-based guides. InVivo5 offers high quality volume rendering with some of the best visualization options. The volume easily switches between transparent hard tissues, as well as detailed bone, airway, or skin profiles.

The surgical guide is fabricated centrally by Anatomage in order to preserve the fixed price. Along with the surgical guide, the clinician may choose to order specialized depth control drills to gain the most guidance.

### 7.5. Materialise

Materialise offers the most versatile implant planning program. They will provide bone-based, mucosal-based, and tooth-based guides. And all three types are fabricated by stereolithography so that they are the most rigid. A tooth-supported SurgiGuide is suitable for minimally invasive surgery. Since the guide was fabricated from virtual planning, it is not necessary to raise a flap for implant placement. A plaster cast of the pre-surgical teeth must be sent to Materialise with the SimPlant virtual plan. A mucosa-supported SurgiGuide is indicated when minimally invasive surgery is necessary for a fully edentulous case. A bone-supported SurgiGuide is appropriate for a partially or fully edentulous case when increased visibility or more surgical procedures are necessary.

The patient is scanned using the clinicians method of choice, either single-scan or dual-scan protocol. If choosing the dual-scan protocol, the clinician may purchase the dual scan markers from Materialise or add the fiduciary markers on their own. The digital planning is then performed using the software Simplant Planner. SimPlant Planner provides a library with more than 8000 different implants and abutments to provide easy surgical guide fabrication. Any implant system may be prescribed when using Materialise. The planned information is virtually sent to Materialise, and the surgical guide, Surgiguide, is fabricated.

If the clinician would like to convert the CBCT images into the 3D representation, the software SimPlant Pro is available for this. When using SimPlant Planner this conversion is performed by Materialise. SimPlant also offers a free software program, called SimPlant View, which allows anyone to view the files. So when planning a case between different team members, such as a surgeon, restorative dentist and lab technician, all team members may view the case on their personal computer.

There are three different options when choosing the surgical guide, SurgiGuide: Pilot, Universal, and SAFE. The Pilot SurgiGuide offers the guidance during the initial pilot drilling, and then the guide is removed and the drilling sequence is completed free-hand. This is best used in straightforward and simple cases. It is similar to Biohorizons Pilot Compu-Guide. The Universal SurgiGuide offers a fixed implant position and angulation, without depth control. The drill depth is provided in the prescription sent with the SurgiGuide so the clinician knows how deep to drill. The drills are guided through the SurgiGuide, and when the drilling sequence is completed, the guide is removed and the implants are placed in the osteotomies. Lastly, the SAFE SurgiGuide offers a fixed implant position, angulation, and depth. This guide provides the most controlled system.

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Materialise also offers bone reduction guides. If the clinician is planning for a prosthesis which requires more restorative space than is available, a bone reduction guide can first be used to perform a precise amount of alveoloplasty. Afterwards, a bone-based implant surgical guide is placed, according to the amount of bone reduction, and the implants are predictable placed at that new bone level. When positioning the implants in the SimPlant Planner, place them at the desired subcrestal positions. The white dots around the implants in SimPlant show the bone height desired after placement. These can be moved up and down as desired. The SimPlant designers then have enough information to produce the drill guide as well as the bone reduction guide.

### 7.6. Laboratory procedures

A virtually planned surgical guide for the placement of implants offers not only a predictable method for the surgical placement of the implants, but also a more convenient and time saving method for the fabricating provisional restorations. A clinician may use a surgical guide to its full advantage by preparing the provisionals before the day of surgery. Either the clinician or a lab technician can prefabricate the implant provisionals using the surgical template. First, a master cast is fabricated using the surgical guide. Implant analogs are attached to the guide, large undercuts are blocked out, a soft tissue matrix is fabricated, and stone is poured into the guide. This master cast can then be mounted against the opposing cast using the premade bite index which was utilized during the CBCT scan. Provisional restorations can be fabricated on this master cast, which will then be ready for chairside pick-up of the implants after surgery. This method provides an easy way to do immediate loading of implants on the day of surgery.

This is a popular method being advertised worldwide and is an advantageous strategy for attracting patients to your office. Patients are given an immediate result with predictable esthetics, phonetics, and function if the laboratory steps and chairside pick-up are followed correctly.

## 8. Alternative benefits of virtual planning

Another advantage of using virtual planning for dental implants is the ability to fabricate implant frameworks through scanning of the master cast. After implants have osseointegrated, a final implant-level impression is made, and a master cast is made and verified. Then a 3-D scanner will scan the implant positions and the framework can be designed virtually for the final prosthesis. From the virtual design, the framework is then milled from a block of metal [3]. Each scanning company has different milling materials to choose from. The framework can support a hybrid, bar-overdenture, or implant-supported fixed dental prostheses (such as screw-retained PFM crowns or FDPs). This framework can either be designed virtually or it can be designed in acrylic on the master cast and scanned (i.e., copy-milled). The latter of the two options is a better choice for complicated clinical situations with no room for error, such as implant-supported fixed dental prostheses. This prosthetic design requires very specific dimensions for the final porcelain layer, and thus should always be copy-milled. Hybrid cases which were planned well with enough restorative space can usually be designed virtually with retention elements added for the acrylic which will be surrounding the milled metal framework.

Milling provides a much more accurate framework than conventional casting because there is no shrinkage involved. When a multiple-implant framework is waxed and cast, it takes extra time because it must be sectioned and soldered after shrinkage. The milled frameworks, on the other hand, are milled to fit the implant positions exactly and involve no shrinkage or distortion of the metal. The major disadvantage of choosing a milled framework is that the companies offer only a limited number of material choices. Most companies do not offer a metal which porcelain can be added to predictably.

The following photos show how to make a milled titanium framework using NobelProcera software and scanner and to restore a patient with an implant-supported fixed dental prosthesis (Figures 21-34).

**Figure 21.** Final impression for each arch is made.

**Figure 22.** Denture teeth are arranged in the laboratory.

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**Figure 23.** Both trial dentures are verified clinically.

**Figure 24.** Mandibular definitive cast is sprayed with zinc-oxide powder before placing scanning abutments.

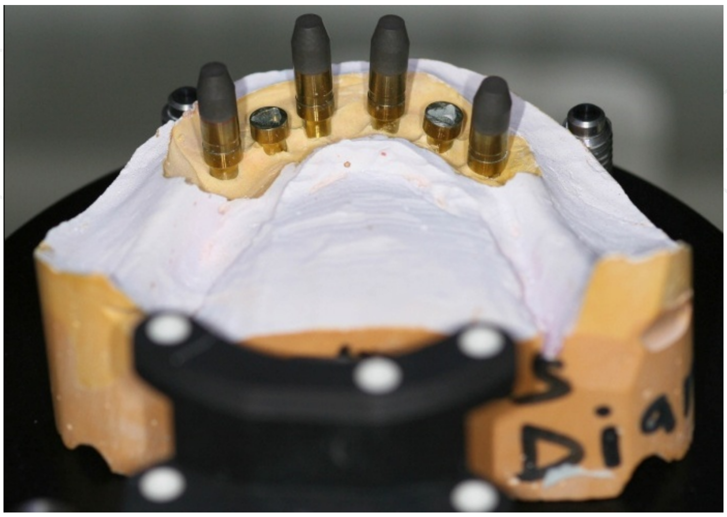

**Figure 25.** Scanning abutments are screwed on the implant replicas, and definitive cast mounted for scanning.

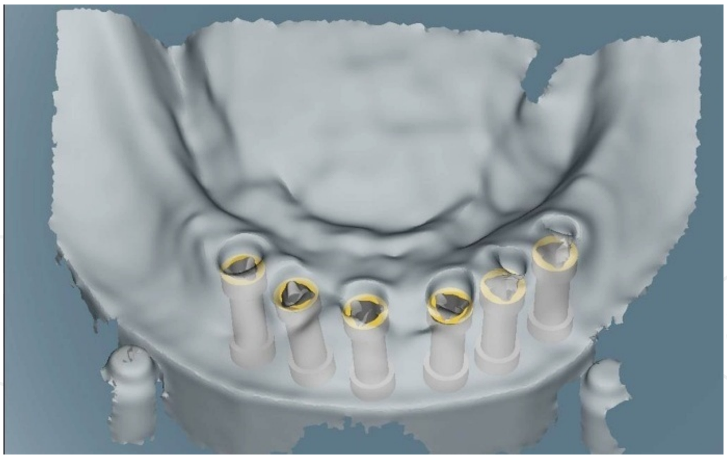

**Figure 26.** Occlusal view of mandibular cast with implant positions after scanning process.

**Figure 27.** Trial denture is sprayed with zinc-oxide powder after placing it on definitive cast.

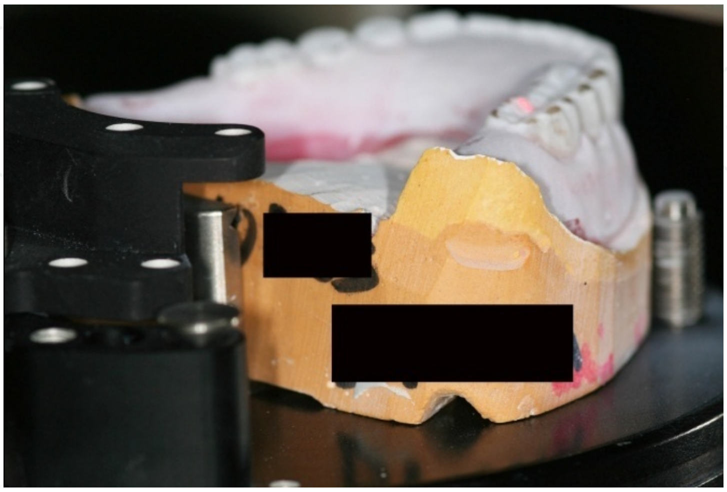

**Figure 28.** Note red line generated by laser probe during trial denture scanning process.

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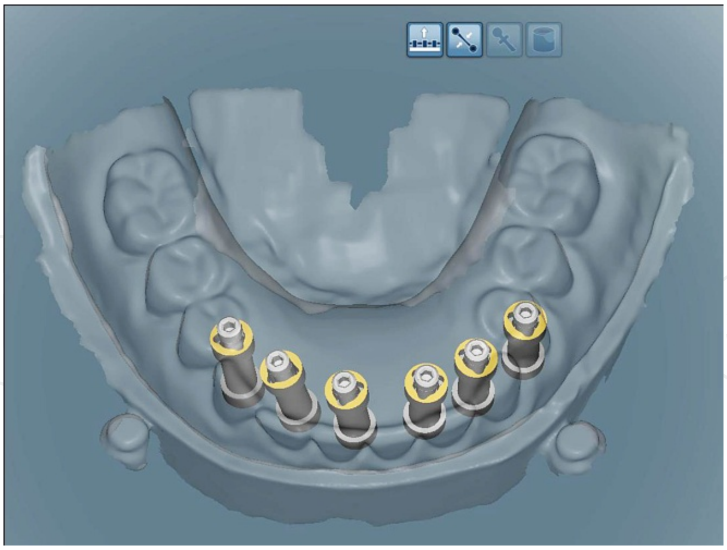

**Figure 29.** Occlusal view of trial denture overlapping mandibular cast including implants after scanning process.

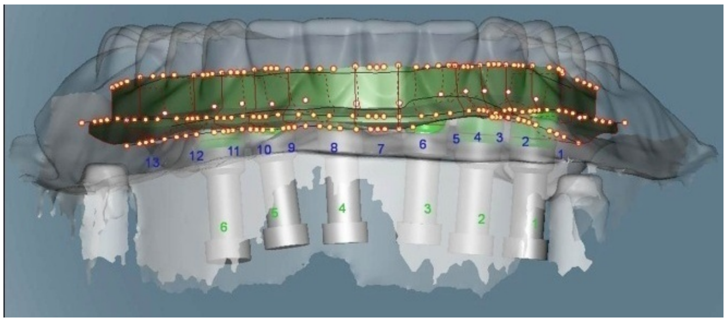

**Figure 30.** Frontal view of final design of mandibular framework.

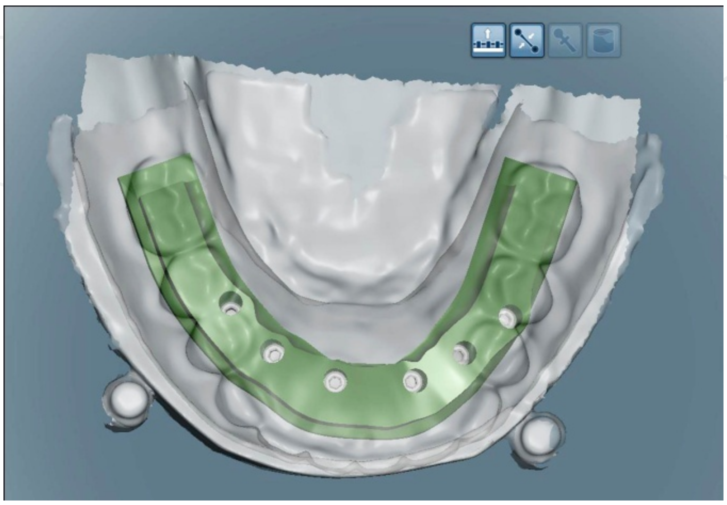

**Figure 31.** Occlusal view of final design of mandibular framework.

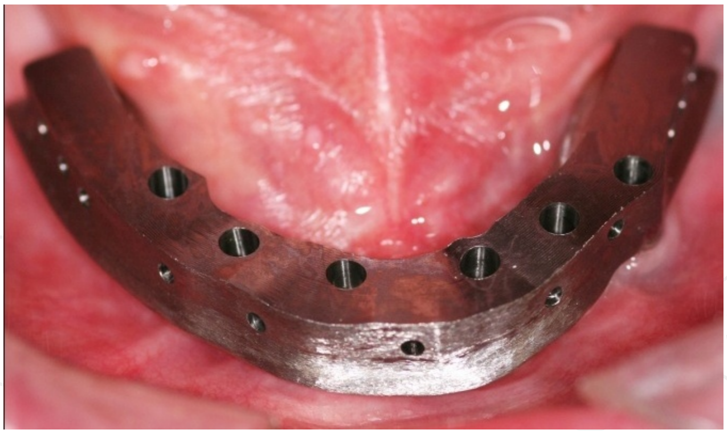

**Figure 32.** Clinical fit of mandibular framework verified.

**Figure 33.** Intraoral view after both restorations are inserted.

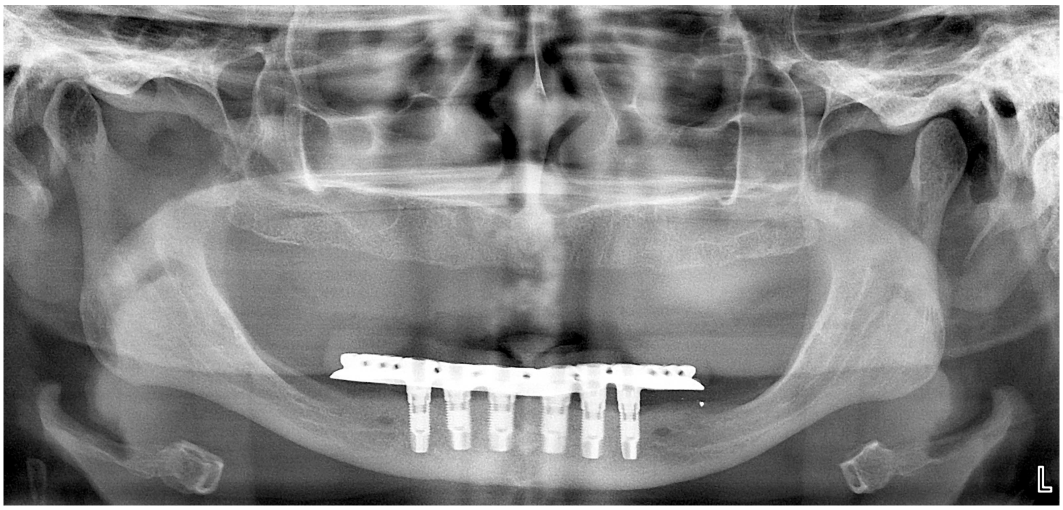


**Figure 34.** Panoramic radiograph after maxillary complete denture and mandibular FDP are inserted.

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## 9. Conclusion

This chapter aimed to explain virtual treatment planning by using softwares, scanners and CAD/CAM technology. Each person involved in this process should possess the knowledge to use these softwares and hardwares, which require advanced training and experience. Otherwise, failures would be inevitable and costly. Although each step was explained and illustrated in great detail, the readers need to make to sure that they have proper knowledge, armemantarium, and experience before attempting to these types of treatment.

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## References

[1] Ersoy AE, Turkyilmaz I, Ozan O, McGlumphy EA. Reliability of implant placement with stereolithographic surgical guides generated from computed tomography: clinical data from 94 implants. Journal of Periodontology. 2008;79(8):1339-45.

[2] Ganz SD. Dental implantology: an evolving treatment modality. Compendium of Continuing Education in Dentistry. 2013;34(8):628-9.

[3] Turkyilmaz I, Asar NV. A technique for fabricating a milled titanium complete-arch framework using a new CAD/CAM software and scanner with laser probe. Texas Dental Journal. 2013;130(7):586-92.

[4] Abboud M, Wahl G, Guirado JL, Orentlicher G. Application and success of two stereolithographic surgical guide systems for implant placement with immediate loading. International Journal of Oral and Maxillofacial Implants. 2012;27(3):634-43.

[5] Cushen SE, Turkyilmaz I. Impact of operator experience on the accuracy of implant placement with stereolithographic surgical templates: an in vitro study. The Journal of Prosthetic Dentistry. 2013;109(4):248-54.

[6] Vasak C, Kohal RJ, Lettner S, Rohner D, Zechner W. Clinical and radiological evaluation of a template-guided (NobelGuide™) treatment concept. Clinical Oral Implants Research. 2014;25(1):116-23.

[7] Tardieu PB, Vrielinck L, Escolano E, Henne M, Tardieu AL. Computer-assisted implant placement: scan template, simplant, surgiguide, and SAFE system. The International Journal of Periodontics and Restorative Dentistry. 2007;27(2):141-9.

[8] White SC, Pharoah MJ. The evolution and application of dental maxillofacial imaging modalities. Dental Clinics of North America. 2008; 52(4):689-705.

[9] Pharoah MJ. Imaging techniques and their clinical significance. The International Journal of Prosthodontics. 1993; 6(2):176-9.

[10] Hounsfield GN. Computerized transverse axial scanning (tomography). 1. Description of system. British Journal of Radiology. 1973;46(552):1016-22.

[11] Choi JH, Baek SY, Kim Y, Son TG, Park S, Lee K. Automatic detection of inferior alveolar nerve canal from cone-beam computed tomography images for dental surgery planning. Studies in Health Technology and Informatics. 2014;196:61-5.

[12] Bornstein MM, Scarfe WC, Vaughn VM, Jacobs R. Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. International Journal of Oral and Maxillofacial Implants. 2014;29 Suppl:55-77.

[13] Pedroso LA, Garcia RR, Leles JL, Leles CR, Silva MA. Impact of cone-beam computed tomography on implant planning and on prediction of implant size. Brazilian Oral Research. 2013;25(1):46-53.

[14] Gray CF. Practice-based cone-beam computed tomography: a review. Primary Dental Care. 2010;17(4):161-7.

[15] Chau AC, Fung K. Comparison of radiation dose for implant imaging using conventional spiral tomography, computed tomography, and cone-beam computed tomography. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2009;107(4):559-65.

[16] Resnik RR, Kircos LT, Misch, CE. Diagnostic Imaging and Techniques In: Contemporary Implant Dentistry, (Misch CE) 3rd ed. Mosby Elsevier, St. Louis, Missouri; 2008, pp. 38-67.

[17] Schulze RK, Berndt D, d'Hoedt B. On cone-beam computed tomography artifacts induced by titanium implants. Clinical Oral Implants Research. 2010;21(1):100-7.

[18] Hunter AK, McDavid WD. Characterization and correction of cupping effect artefacts in cone beam CT. Dentomaxillofacial Radiology. 2012;41(3):217-23.

[19] Turbush SK, Turkyilmaz I. Accuracy of three different types of stereolithographic surgical guide in implant placement: an in vitro study. The Journal of Prosthetic Dentistry. 2012;108(3):181-8.

[20] Arisan V, Karabuda ZC, Ozdemir T. Accuracy of two stereolithographic guide systems for computer-aided implant placement: a computed tomography-based clinical comparative study. Journal of Periodontology. 2010;81(1):43-51.

[21] Spinelli D, Ottria L, De Vico G, Bollero R, Barlattani A, Bollero P. Full rehabilitation with nobel clinician and procera implant bridge: case report. Oral Implantology (Rome). 2013;15(6):25-36.

[22] Pozzi A, Sannino G, Barlattani A. Minimally invasive treatment of the atrophic posterior maxilla: a proof-of-concept prospective study with a follow-up of between 36 and 54 months. The Journal of Prosthetic Dentistry. 2012;108(5):286-97.

[23] Katsoulis J, Pazera P, Mericske-Stern R. Prosthetically driven, computer-guided implant planning for the edentulous maxilla: a model study. Clinical Implant Dentistry and Related Research. 2009;11(3):238-45.

[24] Widmann G, Bale RJ. Accuracy in computer-aided implant surgery--a review. International Journal of Oral and Maxillofacial Implants. 2006;21(2):305-13.

[25] Marra R, Acocella A, Rispoli A, Sacco R, Ganz SD, Blasi A. Full-mouth rehabilitation with immediate loading of implants inserted with computer-guided flap-less surgery: a 3-year multicenter clinical evaluation with oral health impact profile. Implant Dentistry. 2013;22(5):444-52.

[26] Ochi M, Kanazawa M, Sato D, Kasugai S, Hirano S, Minakuchi S. Factors affecting accuracy of implant placement with mucosa-supported stereolithographic surgical guides in edentulous mandibles. Computers in Biology and Medicine. 2013;43(11): 1653-60.

[27] Ozan O, Turkyilmaz I, Ersoy AE, McGlumphy EA, Rosenstiel SF. Clinical accuracy of 3 different types of computed tomography-derived stereolithographic surgical guides in implant placement. Journal of Oral and Maxillofacial Surgery. 2009;67(2): 394-401.

[28] Turkyilmaz I. Immediate provisional restoration of implant placed using flapless surgery and ridge mapping: Case report. New York State Dental Journal. 2011;77(3): 21-3.

[29] Ozan O, Turkyilmaz I, Yilmaz B. A preliminary report of patients treated with early loaded implants using computerized tomography-guided surgical stents: flapless versus conventional flapped surgery. Journal of Oral Rehabilitation. 2007;34(11): 835-40.

[30] Bidra AS. Flapless implant surgery to overcome anatomic challenges in the anterior mandible for overdenture therapy: a clinical report. The Journal of Prosthetic Dentistry. 2014;111(3):175-80.

[31] Oh TJ, Shotwell J, Billy E, Byun HY, Wang HL. Flapless implant surgery in the esthetic region: advantages and precautions. The International Journal of Periodontics and Restorative Dentistry. 2007;27(1):27-33.

[32] D'haese J, Van De Velde T, Elaut L, De Bruyn H. A prospective study on the accuracy of mucosally supported stereolithographic surgical guides in fully edentulous maxillae. Clinical Implant Dentistry and Related Research. 2012;14(2):293-303.

[33] Nikzad S, Azari A, Ghassemzadeh A. Modified flapless dental implant surgery for planning treatment in a maxilla including sinus lift augmentation through use of virtual surgical planning and a 3-dimensional model. Journal of Oral and Maxillofacial Surgery. 2010;68(9):2291-8.

[34] Cassetta M, Stefanelli LV, Giansanti M, Di Mambro A, Calasso S. Depth deviation and occurrence of early surgical complications or unexpected events using a single stereolithographic surgi-guide. International Journal of Oral and Maxillofacial Surgery. 2011;40(12):1377-87.

[35] D'haese J, Van De Velde T, Komiyama A, Hultin M, De Bruyn H. Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature. Clinical Implant Dentistry and Related Research. 2012;14(3):321-35.

[36] Marchack CB. CAD/CAM-guided implant surgery and fabrication of an immediately loaded prosthesis for a partially edentulous patient. The Journal of Prosthetic Dentistry. 2007;97(6):389-94.

[37] Sarment DP, Sukovic P, Clinthorne N. Accuracy of implant placement with a stereolithographic surgical guide. International Journal of Oral and Maxillofacial Implants. 2003;18(4):571-7.