

Implant Placement Methods: From Conventional to Unconventional – A Literature Review

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Abstract

Dental prosthesis supported by an osseointegrated implant within the jaw bone is currently recognized as the standard treatment for the replacement of missing teeth. The methods for dental implant placement include free-hand operation and guided implant surgeries with the aid of physical static guides, camera-based navigation, and most recently robotic guidance. As patient awareness about various available treatment options expands, the need to deliver them in as seamless a way as possible is the concern of an updated dentist. Robot-assisted dental implant placement combines the advantages of both the physical constraints of static guides and the flexibility of image-based dynamic navigation. Haptic robotic technology enables dentists to incorporate the digital imaging preoperatively into their operating environment by receiving real-time physical and visual guidance throughout the surgery. This provides accuracy and reliability without the need to manufacture a custom plastic guide or worry about performing an unguided free hand approach. The accuracy of implant placement including its position, angle, and depth within the jaw bone would affect its long-term success rate. Deviations between the plan and the actual implant positions have been associated with prosthetic complications, including misfit of the restoration and the need for occlusal adjustments. This literature review aims to provide an insight into the various advancements in implant positioning methods and their respective advantages and disadvantages.

Keywords: Dynamic navigated implant placement, Guided implant surgery, Implant placement, Robotically assisted implantology.

INTRODUCTION

One of the main challenges encountered by clinicians new to implant dentistry is the determination and controlling of implant location. Poorly placed implants have been demonstrated to be associated with increased marginal bone loss and may lead to the violation of nearby vital anatomic structures. Restoration of poorly placed implants is technically challenging and it may not have an optimal morphology and emergence profile, which can affect esthetics and impede plaque control.^[1]

In rehabilitation of tooth loss with dental implants, a thorough pre-operative planning is an important requirement for a successful restorative result. During the last decade, the technique for implant insertion has developed mostly due to achievements in radiographic three-dimensional (3D) imaging technique and computer technology.^[2]

Dental implants are placed in two general ways, which are implantation with the freehand method and implantation using a surgical guide. Free-hand surgery has many benefits for the dentist because it can visualize and relate diagnostic data to the actual clinical condition by allowing reflection of soft

tissues and examining bone anatomy.^[3] Comparatively, the procedure for guided implant surgery is different. It employs the use of a surgical guide of varying versatility which allows dental implants to be performed in the most accurate location and with the least amount of surgery. The correct position of the implant gives way for optimal designing of the definitive prosthesis and prevents the possibility of cemented repairs by making it possible to design and manufacture recyclable screw prostheses.^[4]

A correct prosthetically driven 3D positioning of the implant is essential for a successful treatment outcome. In addition, correct positioning of the implant enables the definitive prosthesis to be optimally designed and makes it possible to devise and fabricate retrievable screw retained prostheses, thereby avoiding cemented restorations.^[5]

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The art and science of implant dentistry deals with restoring the esthetics as well as the function of the lost tooth or teeth in a patient. While this holistic treatment depends on various factors, implant placement technique that cohesively combines a surgeon's experience and the optimal technology results in a harmoniously restored implant. This review aims to present the conventional and unconventional techniques of implant placement that are at present practiced by dental surgeons all around the world.

FREE-HAND IMPLANT PLACEMENT

It is also known as conventional surgery and mental or brain-guided surgery. In free-hand surgery, panoramic and periapical radiographs are used as aids along with periodontal probes, gauges, or calipers to assess the width and alveolar bone profile available to place the implant and examine the surrounding anatomy.^[6] The surrounding teeth can also be used as a guide for determining the correct position of the implant.^[7] No surgical guides are used while placing the implant. Whereas, a flap is raised before beginning with the drilling sequence for proper visualization of the implant site.

Advantages

- i. Direct visualization of the bone anatomy during the implant placement
- ii. Additional treatments such as bone augmentation can be carried out
- iii. Making a diagnostic replica model gains a better understanding of the available space to determine the exact location of the implant and the prosthesis
- iv. Allows adequate irrigation and cooling of the osteotomy site during the surgical procedure
- v. Elimination of the time required to prepare the guide and reducing the cost of making the guide.

Disadvantages

- i. Clinical judgments will be purely based on visualization of the clinical condition through information provided by cast and radiography
- ii. Free-hand implant placement requires comparatively more extensive thinking and planning
- iii. Less predictable when multiple implants are to be placed
- iv. Increased post-operative recovery time, swelling, pain, and bleeding.

COMPUTER-ASSISTED IMPLANT PLACEMENT

Static computer-assisted implant placement

Static computer-assisted implantology is based on the use of a surgical guide, which can be printed using additive or subtractive manufacturing. The term static indicates that the operator plans the position of the implants in software and then this direction is replicated in a surgical guide thus, preventing the operator from changing the planned position during the surgery. The surgical templates transmit the information from the pre-surgical prosthetic and surgical planning to the patient.^[8]

Dynamic computer-assisted implant placement

This technology uses intraoperative optical tracking of the hand-piece position with installed cameras to guide the surgeon in “real-time,” thus providing visual feedback on a screen. With computer-navigated surgery, the position of the instruments in the surgical area is constantly displayed on a screen with a 3D image of the patient.^[9]

A novel approach is possible by means of using a new workflow of a dynamic navigation system called Trace and Place technology or trace registration that uses an existing cone beam computed tomography (CBCT) rather than preparing a custom stent and scanning the patient 2 times (Figure 1). The registration of the jaw with its computed tomography image is accomplished by tracing the existing teeth as natural fiducial markers and performing the guided surgery without any intraoral appliance. This provides a fully digital implant-prosthetic treatment workflow. This approach is valuable if compared with other such systems because it does not need a radiological stent or radiopaque markers.^[10]

Advantages

- i. Manual errors related to implant placement in this method are greatly reduced
- ii. The CBCT, planning, and surgery can all be done in a single day
- iii. Better accuracy and higher safety, so the results of the implant will be predictable
- iv. Correct placement of implants ensures better periodontal health and hygiene maintenance by the patient
- v. The surgical guide optimizes the location, angle, and depth of implants. Thus, this method greatly increases the survival of implant placement
- vi. Avoiding the retraction of flaps and sutures will reduce postoperative pain, edema and bleeding, and immediate resumption of oral hygiene practices
- vii. Theoretically, the need for augmenting the residual bone may be eliminated or decreased by optimizing implant positioning in the available bone.

Disadvantages

- i. If there is a change in the tissue between the time of ordering and the implant installation, it will change the



Figure 1: Dynamic computer assisted implant placement using trace and place technology

- fit of the prosthesis and ultimately the function of the implant prosthesis
- ii. If the guide is not stabilized and drilling is intended to penetrate hard bone, producing torsional forces on the sleeves, guide dislocation can occur during surgery
- iii. Costs related to purchasing software and special tools and drills are high
- iv. Spending time learning the curves for the treating physician
- v. Surgical guides do not allow for proper cooling of the osteotomy site during surgery.

ROBOTICALLY ASSISTED IMPLANT PLACEMENT

The physical position of a surgeon is often constrained due to the limitation of a patient's mouth opening and the location of missing teeth. Because of this, the surgeon's performance may be affected by stamina and fatigue, and the possibility of human error cannot be eliminated. Therefore, robotic surgery has the advantage of sustained precision, increased stability, greater efficiency, and more flexibility for assisting dental implant preparation and implantation.^[11]

The first study of robot-assisted dental implantation to minimize error was presented by Boesecke and colleagues (Medical Intelligence, Schwabmünchen, Germany) in 2002. This robot system had a working area scope of 700 mm and was used to assist a surgeon during implant osteotomy site preparation by holding a drilling guide.^[12] In 2017, the world's first commercial dental robotic system, YOMI (Neosis, Miami, FL, USA), was developed and received Food and Drug Administration clearance (Figure 2). The guidance system, termed haptic robotic technology, directs surgeons during drilling based on the desired pre-operative trajectory. A software program uses a CBCT scan of the patient and allows the 3D planning of ideal positioning of the implants. However, once the implant plan is optimally positioned, the robotic assistance provides 3D physical guidance of the dental surgical instruments during the execution of the digital plan in terms of the desired location, angulation, and depth. If the tool is in the correct location and orientation, there is no physical resistance provided by the robot. However, if the tool deviates in any way, the robot constrains the tool axis to the planned location and orientation. Similarly, as the instrument reaches the planned depth, the robotic arm stops the tool and does not allow further drilling.^[13]

Another type of robotic dental implant system is a fully automatic system, such as the dental implant robot developed by Yiming Zhao from the Air Force Medical University of China, which could conduct drilling and implant placement automatically according to the pre-operative plan with an optical navigation system.^[14]

HRCDIS or human-robot collaborative dental implant system is another innovative contact positioning method using a hand guiding function of the robot which is yet to be used in humans (Figure 3). The setup described a positioning marker fabricated by stereolithography attached to a resin model in the phantom head by wearing on teeth. The robot mounted with handpiece



Figure 2: YOMI (Neosis) Robotic system



Figure 3: The scheme of the experimental HRCDIS

and drill was dragged close to the marker and the end of the drill was contacted with the holes on the marker, and the apex point coordinates of the drill point were displayed on the screen. Based on these coordinates, the position of the head phantom (or patient) could be calculated through the algorithm of the control system based on certain equations; therefore, the robot, pre-operative plan, and patient's oral cavity could be matched in a universal coordinate system by registering their local coordinate system via the positioning marker. During the drilling process, the patient would have to be instructed to stay dormant, or else the operation would get suspended, and a new preoperative plan will have to be re-matched with the patient's oral cavity before continuing.^[15]

Advantages

- i. Pre-operative planning with 3D imaging minimizes the size of the incision, as tissue reflection is not needed during surgery to visualize the underlying bone

- ii. Robotically guided preparation uses standard drills as the end effector tool. This can be useful in patients with limited mouth opening where stacked static guides along with the added drill length can hinder surgical maneuverability
- iii. Robotic guidance affords adequate irrigation as well, which can be an issue with guided osteotomies
- iv. Complete visualization of the surgical field of view and ease of use of the system
- v. Operator ergonomics are improved.

Disadvantages

- i. Patient motion artifacts may introduce errors in the before and after implantation scan registration
- ii. Learning curve for this implant placement method is critical and long
- iii. Capital investment is bigger.

SELECTION CRITERIA FOR CHOICE OF IMPLANT PLACEMENT METHOD

Number of implants

Narrow spaces <11 mm between teeth could be more suitable for free-hand implant placement in single implant cases due to changes in position and lower angle changes.^[4] However, there is a possibility of approaching the root of the adjacent tooth and requires greater care.

Mouth opening

Static guides are often stacked, providing a drill sleeve that is required for stability. This can, however, create an issue in terms of the length of the stacked guides and the required extended drill lengths. This can be exacerbated in patients with limited mouth opening in the posterior area of the mouth or posteriorly angled implant axes.^[16] Robotically assisted implant placement however, does not employ the use of static guides and hence can be better employed in patients with limited mouth opening.

Surgeon's proficiency

While freehand implant placement is the oldest method being used, dynamic navigation, and robotically assisted implant placement are comparatively newer, lesser used methods for implant placement because of their bigger learning curve. With regards to dynamic computer assisted implant placement, Block *et al.*^[16] concluded that the highest accuracy was achieved after completing 20 patient cases, after studying the outcomes of consecutive surgeries by three implant surgeons.

SUMMARY

High accuracy of implant placement is essential for ideal results and guided surgery significantly increases accuracy, but unfortunately, this method is not yet used exclusively. Some dentists prefer to perform the implant by the free-hand method, which seems to be due to insufficient information to choose the

right method for the implant. Even with technological advances, freehand surgery is still widely used owing to the lower cost of treatment and better depth control when manually inserting the implant. Static guides have been reported to be an accurate method for guiding implant placement. Robotic guidance is proving to be as accurate as the best implementations of static guides. However, with this robotic technology, as with any other technology, proper clinical oversight and judgment must always be exercised. Advanced technology and devices do not replace clinical decision-making but rather augment execution. Ultimately, accuracy of each method differs from clinician to clinician and depends on the clinician's experience and surgical proficiency.

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