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Implant Navigation System: An Innovative Approach - A Review Article

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Abstract

Dental implant technology has widely used for oral reconstruction in recent years. Dental implants provide an alternative treatment for patients who are unsatisfied with traditional partial or full mouth dentures. Well-fabricated dental implant prosthesis depends on the appropriate implant placement, direction, and angle. It also depends on a prosthetic-driven concept that explains the importance of the implant placement. Freehand methods for placement of implant result in significantly more error compared with navigation methods. Dental implant navigation systems are auxiliary systems that are useful for implantations. These systems depend on medical imaging technology in combination with optical positioning. Navigation systems can prevent damage to nerves or critical structures of adjacent teeth by improving safety measures. Dentists can develop a precise plan for dental implants by using this system, according to preoperatively derived data, which helps in increasing the accuracy of dental implants and reducing the risk of dental implant failure. Using dental implant navigation systems can assist dentists in offering high-quality and safe implant services to patients. Also, the navigation system provides accuracy according to the operation site and time. Different guidance techniques have become apparent that transfer the planned digital information to the clinical settings. Some of the methods available are computer-guided (static) implant surgery and computer navigated (dynamic) implant surgery and robotic implant dentistry. Thus, the review article explains the importance of implant navigation systems for precision-driven implant placement and final prosthesis.

Keywords: computerized navigation surgery, Dental implants, Navigation systems, Surgical guide.

Introduction

Dental implants have become an acceptable treatment option to replace lost teeth. It is an alternative treatment for dental bridges and partial denture rehabilitation.[1] Well-fabricated dental implant prosthesis depends on the appropriate implant placement, direction, and angle. It also depends on a prosthetic-driven concept that highlights the importance of implant placement.[2] However, one may face several challenges during implant placement like restricted access to the surgical field, use of local anesthesia for a limited period, and transfer of the radiographic image to the surgical procedure. Dental implants must position accurately to support restorations that aesthetically and functionally align with adjacent and occluding dentition.[3]

A reliable computer-aided intraoperative navigation system allows accurate transfer of the preoperative plan to the patient. It enables the surgeon to minimize surgical exposure, which results in less morbidity and less bone resorption.[4] Pre-surgical planning with the use of a surgical guide during the dental implant placement is, therefore, encouraged.[5] Computerized navigation surgery is a surgical modality in which the instruments are accurately tracking and targeted to a pre-planned location within the surgical field. It depends on the synchronization of the intraoperative position of the devices with the imaging of the patient's anatomy, previously obtained by computed tomography (CT) or magnetic resonance imaging (MRI).[6] Computer-assisted surgical implant placement (CAS) systems are commonly employing for improving accuracy in dental implant placement.[7] These can categorize into static or dynamic. Static methods use guides fabricated with computer-aided design/computer-aided manufacturing (CAD/CAM) based on three-dimensional scans. In contrast, a dynamic system tracks the patient, surgical instruments and presents real-time positional and guidance feedback on a display of computer.[8]

The specific aim of this study was to create and evaluate a surgical navigation system that would be user friendly for the surgeon.[9] The overall accuracy considers the precision of the surgical navigation system, the correctness of the surgical instruments, and the surgeon's skill.

Computer Navigated Implant System

An image-guided surgery system is also known as surgical navigation guidance, which has recently been introduced to implant dentistry.[10] They may be advantageous compared to conventional surgical protocols in patients with a limited amount of bone.[11] The computer navigated implant system is empowered by a motion-tracking technology that tracks the position of patient and dental drills throughout the procedures of implant placement by integrating surgical instruments, optical positioning devices, and three-dimensional images. Computer navigated implant surgery is the placement of an implant using a real-time computer navigated system based on the data generated from the patient's cone-beam computed tomography (CBCT).[3]

Static Guide

"Template-based system," which communicates predetermined sites in the operating field by using surgical templates, manufactured through rapid prototyping technologies such as stereolithography and three-dimensional printing.[12] Fabrication of the imaging guide requires laboratory work before scanning, which will necessitate time delays and additional cost to the team, which is added value to the patient. Digital methods might eliminate the need

for a laboratory-based imaging guide in the future. It is a Computer Navigated static system that uses CT-generated computer-aided design and computer-aided manufacturing (CAD-CAM) to create stents using metal tubes and a surgical method to place implants using the guide stent. The position of the implant is dependent on the stent, and it is not using during the surgicall procedure. No intra-operative position changes can make unless to fabricate a CT-generated surgical guide for static navigation, take a cone-beam CT scan (CBCT) with the prosthetic plan in the mouth as an imaging guide.

The data of CBCT Digital Imaging and Communications in Medicine (DICOM) must enter into the CT planning software. It requires training to use CT planning software. Many clinicians will not learn the software skilfully and use a third party to plan the case. After the team has finalized the plan, upload it to the stent manufacturer. An optical scan of the arch is needed to fabricate a guide to seat accurately on the teeth. It requires impressions, pouring stone, and trimming of the model. All these requirements add time and costs to the static guide method. The manufacturer will evaluate the uploaded scan and check whether it meets the quality control parameters. The clinician might need to repeat all the process if the static guide does not seat accurately on the teeth or tissues. The period between uploading guide stent and delivery can require two weeks.

Once the guide stent has delivered, the surgical procedure can perform. The value of CT-generated static guides will differ between manufacturers. These require preoperative procedures, and their added value, combined with the clinician's unwillingness to gain mastery with the planning software, creates a workflow barrier for static CT-generated guides.[13]

This navigation surgery can classify according to the type of guide support, the type of surgical visibility, and the type of drilling and implant placement facility.[14]

Advantages[13]

1. Accurate implant placement
2. It uses a flapless approach
3. It requires a less-invasive surgical procedure, which results in less patient morbidity.
4. It is useful preoperatively to fabricate fixed provisional restorations.

Drawbacks[15]

1. Incorrect processing of the image
2. Deviations from planned implant positions mainly with the angulation of implant and in the coronal and apical portions of the implants.
3. Inaccurate fixation of the guide results in the implant displacement during perforation.
4. Angulation of the drills causes a mechanical error during perforation.
5. Reduced mouth opening changes the positioning of surgical instruments
6. Fracture of the surgical guide
7. The complexity of the whole system
8. The software program and surgical templates are costly.
9. The potential for thermal injury secondary to reduced access for external irrigation during the osteotomy procedure in flapless implant placement.
10. It does not allow intraoperative modification of implant position.

Dynamic Guide

Computer-assisted dynamic navigation system involves using a surgical navigation system that reproduces a virtual position of the implant directly from CT data

with the optical bur tracking system without an intraoral surgical guide.

The optical systems use active as well as passive tracking arrays. Active dynamic system arrays emit light, which is tracked by the stereo cameras. Passive systems use the tracking systems in which the light emitted from a light source is reflected in the stereo cameras. A passive optical dynamic navigation system requires fiducial markers securely attached to the patient's arch during CBCT scanning. The device connected to fiducial markers, allows for the registration of the arch to the cameras, with the attachment of an array. The array is positioning extra-orally, which contains the fiducial markers. The implant hand-piece also has an array which is a combination of the clip's fiducial markers, and it allows for triangulation leading to accurate navigation.[3]

Dynamic navigation is the real-time coordination of the surgeon's hands and eyes by 3-dimensional (3D) visualization of the preparation with high magnification.[16] The essential components of any dynamic navigation system are the hand-piece attachment, patient jaw attachment, and the system cart, which consists of the cameras, a computer with navigation software. Natural or fiducial markers are using during the radiological scan as reference points for the instrument registration. The navigation system must precisely map the drill tip to the CT image of the jaw to guide the drilling used for planning the implantation. Sensors are attached to the body of the hand-piece and the extra-oral clip attached to the fiducial markers. It achieves this in three steps, performed in the following order[3]-

1. Registration: Mapping the extra-oral clip to the CT image. The physical space coordinates of the patient have to link to the patient's image coordinates.[17]
2. Calibration: Mapping the drill tip to the body of the hand-piece. The drilling axis calibration is done once before the start of the Surgical procedure, and calibrate the drill tip location after each drill change.
3. Tracking: Mapping the body of the hand-piece to the extra-oral clip. It is dynamic and is done throughout the operation by the optical tracking system.[3]

Workflow[3]

1. Securing the fiducial markers to the arch in an area that will not undergo surgical procedure.
2. The CBCT scan should be taken with the clip in place, removed, and stored for use during the surgical procedure.
3. The DICOM (Digital Imaging and Communication in Medicine) data set loaded into the navigation systems computer, which is followed by the placement of the virtual implant. The implants are generating by using the platform diameter and length in 0.1mm increments with required orientation.
4. During the surgical procedure, the fiducial marker is attaching to an array, and the clip with the attached array has to register to the Navigation system. The surgeon can use traditional anesthesia and small incisions with minimal flap reflections.
5. The clip array repositioned securely on to the arch, and the drill lengths registered during the preparation process.
6. The surgeon then positions the patient and arrays for a direct line of sight to the overhead cameras. The drills must orient by the 3D images on the screen.

7. The implant can place partially or fully guided by hand depending on the clinician's preference.

Indications[13]

1. Patients with limited mouth opening.
2. Difficult to access areas such as the second molar.
3. Implant placement in tight interdental spaces when static guides cannot be useful owing to the tube size.
4. Implant placement, when direct visualization is difficult.
5. Implant placement on the same day of the CBCT scan.
6. Implant placement adjacent to natural teeth in situations in which static guide tubes interfere with ideal implant placement.

Advantages

1. The patient can be scanned, planned, and undergo surgical procedures on the same day.
2. The entire field can visualize at all times.
3. Accuracy can verify at all times.
4. The plans can alter during surgical procedures when clinical situations dictate a change.

Disadvantages[3]

1. Increased pre-surgical planning
2. Higher costs
3. Size of the system
4. Technical issues

Conclusion

As the experience of the clinician and their surgical proficiency increases, the use of the dynamic method might predominate. It is because of the time and cost-efficient workflow. In dentate patients, dynamic navigation requires the presence of teeth to stabilize the registration clip and array. The registration and clip array should not place on temporarily cemented provisional restorations or loose teeth. Also, the placement of implants in molar locations with difficult direct visual access in patients with a limited mouth opening or crestal bone loss, resulting in the need for drill extenders. Placement of adjacent implants requires accurate spacing between the implants and adjacent teeth.

Static or dynamic systems can each use; however, the selection will depend on clinician experience and case-specific considerations. In Static surgery, the choice of an implant cannot change easily, once the CT guide stent has fabricated. Thus, the implant position cannot be changed unless the surgeon abandons the use of the CT guide stent. Dynamic navigation is flexible, allowing the clinician to improve the surgical plan as the clinical situation dictates. It also requires no laboratory work, allowing for immediate scanning, planning, and guidance on the same day as patient presentation. The clinician must understand that a learning curve is required to gain proficiency. It could require additional time for training, simulation, and practice on humankind.

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