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DYNAMIC NAVIGATION FOR DENTAL IMPLANT SURGERY

Dental Science

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ABSTRACT

Digital technology allows virtual treatment plans to be created and replicated with great accuracy during dental implant surgery with the use of dynamic navigation.Dynamic navigation system guides the implant placement in real time with the help of motion tracking technology that tracks the position of the dental drill as well as the patient position throughout the implant placement procedure.This literature review evaluates the use of implant navigation system that enhances the safety in implant surgical procedures along with accuracy and precision of the surgical procedure, minimises complications and facilitates surgery in challenging anatomical locations.

KEYWORDS

Dynamic navigation systems, Dental implants, Cone beam computed tomography.

INTRODUCTION-

Dental implants are commonly used to replace lost teeth and have benefits over alternative restoration options such as bridges and dentures.(1)

One may face numerous constraints while placement of dental implants such as restricted visualisation and access to the surgical field, limited period with respect to the use of local anesthesia and transfer of two-dimensional radiographic image to three-dimensional surgical field while taking into consideration the esthetics, anatomic limitations and biomechanics of the prosthetic treatment .(2)

To overcome these limitations, many advancements have taken place, which have computerized the implant-dentistry (3)

The ability to visualise an imaging of the drill in the bone and the adjacent anatomical structures in real time would greatly reduce any iatrogenic injuries and would minimise surgical risks and optimise clinical results.(4)

The use of virtual implant planning and subsequent navigation allows for prosthetic and surgical collaboration with precise planning and accurate orchestration of the plan to achieve a high level of patient-specific results.(5)

COMPUTER NAVIGATED IMPLANT SYSTEM:

Computer Aided Implantology refers to the use of computerized technology to plan and guide the placement of dental implants based on a 3D cone beam computed tomography (CBCT) image of the jaw.(6)

There are two types of computer-assisted surgical implant placement system techniques, namely, static and dynamic navigation. Dynamic navigation systems recognise and track the position of optical reference markers placed over the patient and surgical instruments by means of a tracking system array. (7)

Surgical navigation requires a tracking system enabling the computer to track the position of the patient and surgical instruments three dimensionally in the operating theatre to relate points on the surgical field to preoperative imaging data.(8)

INDICATIONS OF DYNAMIC NAVIGATION SYSTEM:

1. Placement of implants in patients on the same day of the CBCT scan.
2. Patients who have limited mouth opening.
3. Indifficult to access areas such as second molar.
4. Placement of implants in tight interdental spaces when static guides cannot be used owing to the tube size.
5. Implant placement when direct visualisation is difficult.
6. Implant placement adjacent to natural teeth in situations in which static guide tubes interfere with ideal implant placement.(5)

DYNAMIC NAVIGATION TECHNOLOGY

The DN systems are a form of computer-assisted surgery that use optical tracking. There are 2 types of optical motion tracking systems: active and passive. Active tracking system arrays emit infrared light that is tracked to stereo cameras, and passive tracking system arrays use reflective spheres to reflect infrared light emitted from a light source back to a camera. The patient and drill must be over the line of sight of the tracking camera.(9)

The current most commonly utilised DN technology is passive. Light is projected from a light- emitting diode light source above the patient to the patient and the surgical field. The light is reflected off tracking arrays (passive patterned arrays) attached to the patient and the surgical instrument being tracked. The reflected light is captured by a pair of stereo cameras above the patient. The DN system then calculates the position of the patient and the instruments relative to the pre-surgical plan. This is done real-time, or dynamically. A virtual image is then projected onto a monitor for the surgeon to work dynamically on the patient and execute the planned implant surgery. At anytime, the surgeon can change the plan based on the clinical situation.(10)

A passive system requires the use of fiducial markers securely attached to the patient's arch during CBCT scanning.The device attached to the fiducial markers allows for the registration of the arch to the cameras, with the attachment of an array. The array is positioned extra orally which contains the fiducial markers. The implant hand-piece also has an array which in combination of the clip's fiducial markers, allows for triangulation leading to accurate navigation.(5)

DENTATE PATIENT FIDUCIAL-

The fiducial clip allows for an impression of a patient's teeth to be taken. It is important that the CT scan is taken with the fiducial clip seated properly without any mobility.It is placed on 3 teeth with the tracker arm positioned on the buccal side.

EDENTULOUS PATIENT FIDUCIAL- The edentulous fiducials (small screws) are placed in the patients bone to facilitate registration in the CT scan.

IMAGE ACQUISITION AND SOFTWARE PLANNING

Image acquisition includes obtaining 3-D files, usually a CBCT in a Digital Imaging and Communications in Medicine format (.dicom). The field of view of the CBCT/ CT should include the surgical site and all fiducials. The software should be able to import and export generic file formats (.dicom and .stl), superimpose the 3D files, perform dual scan .dicom superimposition and be able to export the images in a common coordinate system as an individual or merged item.The virtual implants should be properly aligned below the virtual crowns for ideal emergence into the prosthetic space. The DN software allows design of a generic implant or previously specified implant, implant platform diameter, implant apex diameter, implant length, and abutment height and angle.Tools allow mirroring to align implants across an arch and paralleling of adjacent implants. (10)

PRINCIPLE OF GUIDANCE :

1. **Calibration:** The instruments to be tracked by the system during surgery must be calibrated such as the contra-angle hand-piece, straight hand-piece and probe tool. Mapping the drill tip to the body of the hand-piece. The drilling axis calibration is done once before the start of the surgery and the drill tip location calibration is done after each drill change.
2. **Registration :**The DN system must be taught the geometry of the patient tracking array relative to the fiducials and thus the planned implants. This process is called registration.Mapping the extra-oral clip to the CT image. The physical space coordinates of the patient are linked to the patient's image coordinates which is done automatically when the image data is imported into navigation system by the software.
3. **Tracking:** Mapping the body of the hand-piece to the extra-oral clip. This is dynamic and is done throughout the operation by the optical tracking system.(10),(11)

WORKFLOW:

- Securing the fiducial markers to the arch in an area which will not undergo surgery.
- The CBCT scan should be taken with the clip in place and then removed and stored for use during the surgery.
- The DICOM data set is loaded into the navigation systems computer followed by placement of virtual implant.The implants are generically generated using the platform diameter and length in 0.1mm increments with required orientation.
- During the surgery the fiducial marker is attached to an array and the clip with the attached array should be registered to the Navigation system.
- The surgeon can use traditional anesthesia and small incisions with minimal flap reflections.
- The clip array should be securely repositioned on to the arch and the drill lengths should be registered during the preparation process.
- The surgeon then positions the patient and arrays for direct line of sight to the overhead cameras. The drills must be oriented in accordance with the 3D images on the screen.(12)
- The tip of the drill, a blue dot, is positioned over the target to indicate ideal planned platform position. The top of the drill a small circle is then centered over the blue dot to indicate ideal planned angle. Depth is indicated by color yellow, green then red. The planned depth is always at the 45 position on the target.(10)

ADVANTAGES-

- CT scanning, planning and surgery in a single appointment
- Reduced harm to the patient
- Unintentional iatrogenic damage to nearby anatomical structures
- Increased safety and predictability.
- Simpler and faster planning
- Ability to view and modify the plan during the surgery
- Lower per-procedure costs.
- Improved irrigation, reducing risk of bone damage due to overheating.
- Works with any implant or drill system.
- Without sleeves, guidance is provided even when interocclusal or interdental space is limited.
- Elimination of guidance failures due to fractured or badly fitting guides. (2),(5)

DISADVANTAGES

They are sensitive to reflections and interference with the line of sight between the sensors and the cameras.
More expensive.
Increased presurgical planning.
Significant learning curve. (3)

CONCLUSION-

Taking into consideration the rapid technological progress that may soon solve some of the problems mentioned, computer-assisted-surgery has the potential to become routine in planning and targeting implants especially in anatomically complex surgical sites.(7)

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