Dynamic Implant Navigation Systems: A Review

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Abstract

Innovations in the field of implantology can enhance the accuracy during implant placement to reduce the inaccuracies resulting from operating in a confined space and in proximity to anatomical structures. 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 systems for precision driven implant placement.

Keywords: Computer navigated implant surgery, Dynamic navigation systems, Dental implants, Cone beam computed tomography (CBCT).

Introduction

Implant placement has become a widely accepted and a routine modality of dental treatment with high success rates1-2. However, one may face numerous constraints while placement of dental implants such as restricted visualization 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 treatment3. Accurate position of the dental implants is required for achieving the ideal functional and esthetic results and further leading to the success of the final prosthesis4-5.

Thus, thorough preoperative planning should be carried out to overcome these limitations via the newly developed techniques that aid in digital implant planning and placement6. Various guidance techniques have emerged that transfer the planned digital information to
the clinical settings. Some of the techniques available are the computer guided (static) implant surgery, computer navigated (dynamic) implant surgery and robotic implant dentistry.

What is computer navigated implant system?

Computer navigated implant system is empowered by a motion tracking technology, which tracks the dental drill and patient position throughout the implant placement procedures by integrating surgical instruments, three-dimensional images and optical positioning devices. Computer navigated implant surgery is placement of implant using real time computer navigated system based on the data generated from the patients cone beam computed tomography (CBCT).

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 visualization is difficult.
6. Implant placement adjacent to natural teeth in situations in which static guide tubes interfere with ideal implant placement.

How does dynamic navigation system work?

The current dynamic navigation systems display the images on the monitor using optical technologies to track the patient and the handpiece. The optical systems use either active or passive tracking arrays. Active system arrays emit light which is tracked by the stereo cameras. Passive systems use tracking systems in which the light emitted from a light source is reflected back to the stereo cameras.

A passive optical dynamic navigation 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 handpiece also has an array which in combination of the clip’s fiducial markers, allows for triangulation leading of accurate navigation.

Components

The basic components of any dynamic navigation systems are the handpiece attachment, patient jaw attachment and the system cart which consists of the cameras, a computer with a navigation software.

Natural or fiducial markers that are used during the radiological scan as reference points for the instrument registration.

Principle of guidance

To guide the drilling, navigation system must precisely map the drill tip to the CT image of the jaw used for planning the implantation. Sensors are attached on the body of the handpiece and the extraoral clip attached to the fiducial markers. It achieves this in three steps, performed in the following order:
1. Registration: Mapping the extraoral 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.

2. Calibration: Mapping the drill tip to the body of the handpiece. The drilling axis calibration is done once before the start of the surgery and the drill tip location is calibration is done after each drill change.

3. Tracking: Mapping the body of the handpiece to the extraoral clip. This is dynamic and is done throughout the operation by the optical tracking system\textsuperscript{12}.

Clip with fiducials that are placed in the patients mouth before cone-beam computed tomography scanning. The fiducial markers allow for the registration of the patient’s maxilla for triangulation during implant placement procedure\textsuperscript{9}.

Navigation system for dynamic surgical guidance\textsuperscript{3}.

(A) Workstation, graphical user interface and stereoscopic camera (courtesy of IVS Solutions AG, Chemnitz, Germany).

(B) Surgical drill with tracking elements (courtesy of RoboDent GmbH, Garching b, M\text{"u}nchen, Germany).

(C) Dynamic reference frame mounted to a denture-supported template (Courtesy of RoboDent GmbH, Ismaning, Germany)

Workflow

1. Securing the fiducial markers to the arch in an area which will not undergo surgery.
2. The CBCT scan should be taken with the clip in place and then removed and stored for use during the surgery.
3. The DICOM (Digital Imaging and Communication in Medicine) 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.
4. 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.
5. The surgeon can use traditional anesthesia and small incisions with minimal flap reflections.
6. The clip array should be securely repositioned on to the arch and the drill lengths should be registered during the preparation process.
7. 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
8. The implant can be placed fully or partially guided by hand depending on the clinician’s preference.

What are the pros and cons of dynamic navigation system?

The success of any surgery is dependent on the preoperative planning and preparation which allow us to predict any difficulties that may arise during the surgery and may boost the surgeon’s confidence.

Dynamic navigation system forces the surgeon to plan the surgery and placement of a virtual implant in terms of angulation, depth, location, size and depth thus allowing for a well-planned surgery. Placement of implant using dynamic navigation is more accurate compared with implant placement with Free Hand approach.

Advantages of dynamic navigation system:

- CT scanning, planning and surgery in a single appointment (when a CBCT is available on site).
- Reduced harm to the patient: minimally invasive surgery, leading to reduced patient discomfort, reduced risk of infection, and faster recovery.
- Unintentional iatrogenic damage to nearby anatomical structures
- Increased safety and predictability due to ability to verify guidance accuracy at any time.
- Simpler and faster planning (no plaster models, wax-ups and guide fabrication).
- Ability to view and modify the plan during the surgery, for example to accommodate tactile feedback or unexpected complications.
- 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.
- Improved ergonomics

One of the main difficulties with the dynamic navigation system are the high cost of the navigation system, its updates and maintenance of the system which might not be financially feasible for the surgeon. Every system has its own planning software thus one might not be able to use any other advanced software. Adequate learning is expected from the clinician as a learning curve is associated with it.
Disadvantages of dynamic navigation system:

- Increased presurgical planning
- Higher costs
- Size of the system
- Technical issues

Conclusion

Computerized navigated implant surgery is a promising technology, although certain challenges, such as cost, accuracy and learning curve, remain to be addressed. The use of this technology in dentistry may substantially contribute to superior quality of treatment rendered.

References

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