Review Article

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Dynamic Navigation System in Endodontics: The Agile way Forward

Abstract:

The purpose of this review is to comprehensively assess and enhance the understanding of the components, workflow and applications of dynamic navigation system in endodontics. Dynamic navigation system is vastly used by oral and maxillofacial surgeons for implant and its use in endodontics has recently been gaining momentum. By offering real time visualization of the surgical site and device this new technology has the potential to revolutionize what were earlier considered as difficult or inoperable cases.

Key-words: Dynamic Navigation System, Guided Endodontics, Optical tracking systems, stereocameras.

Introduction:

The concept of utilizing a certain form of guidance has now become an area of interest for quite some time in endodontics.[1] The commencement of the use of static and dynamic guided novel techniques is now proving to be an effective ally for complex cases to obtain safe and reliable results.[2]

In the past, oral and maxillofacial surgeons in hospitals have been the main users of this technology in the field of dentistry. The medical dynamic navigation systems in use were created largely for craniomaxillofacial-based treatments (identifying foreign entities in the head-neck region and performing orthognathic, trauma, and reconstructive procedures), neurosurgery and orthopedic surgery.[3-4] A dynamic navigation system was created in the US in 2000 to help with dental implant placement in an outpatient office setting. Additional systems have since then received approval for this indication.[3]

In essence, there are two categories of guidance: static and dynamic. Utilizing a fixed surgical stent that was created using CAD-CAM and was based on a preoperative CBCT scan is known as static guidance. Dynamic guidance on the other hand is similar to global positioning systems wherein the map is the patient's scan and the car is the dental tool being used. Using computer software and the imported CBCT data, the site of the virtual implant correlated to reference points is planned during dynamically guided surgery.[1]

Both surgical and nonsurgical endodontics have used the guided endodontics concept, although both have relied on some sort of static guide.[1] Despite being created for implant dentistry, numerous studies have successfully shown how computer-aided dynamic navigation may be used in guided endodontics.[5-8]

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Optical Tracking Systems :

The currently available dynamic navigation systems use optical motion tracking systems. These optical tracking systems are mainly of 2 types [9].

a) Passive
b) Active

The more commonly used amongst the aforementioned is the passive tracking system. The passive tracking system projects light from a LED source down to the patient and surgical field. Tracking arrays that are affixed to the patient and the surgical instrument being tracked reflect the light. Over the patient, a pair of stereo cameras record the reflected light. The position of the patient and the instruments in relation to the presurgical plan is then calculated by the DN system dynamically or in real-time and projected on to the screen.

For the active tracking system, the arrays itself emit infrared light to the stereo cameras. A point of commonality for both active and passive tracking system is that the drill along with the patient should be in the line of sight of the tracking camera.[3]

Fiducials:

Fiducial markers are employed for intraoperative registration because they are stable landmarks that can be recognized on both virtual and actual patients.

These fiducial markers can easily be classified as:

a) Invasive
b) Non invasive
   i. adhesive markers (inherently present)
   ii. dental splints
   iii. anatomic landmarks

The patient must wear dental and adhesive splints before the CT/CBCT dataset is taken.[10]

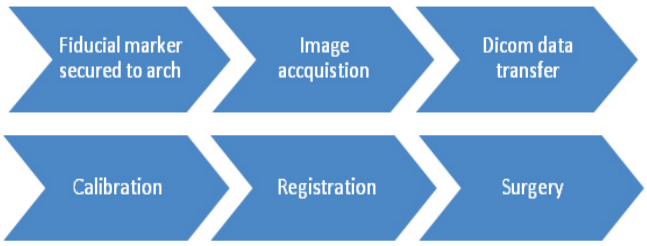
Fiducials For A Dentate Patient :

It's crucial that the fiducial clip for a dentate patient be set correctly in the patient's mouth during the computer tomography (CT) scan, without moving or swaying. It should be placed in a site such that it doesn't interfere while the surgeon/assistant is working during the procedure. The fiducial clip enables the taking of a patient's dental impression in the case of dentate patients which in turn ensures that the clip is seated exactly the same way every time it is placed inside the oral cavity. Fiducials shouldn't be placed on mobile teeth, teeth with ortho wires and pontics of a bridge. The surgeon must make sure the fiducial clips do not contact if numerous fiducial clips are inserted into the mouth for a twin arch situation for more accuracy.

Fiducials For Edentulous Patient:

For edentulous patients small screws (4mm in posterior mandible; 5mm in maxilla) are used as fiducials. These screws can be placed via small stab incisions or directly into the bone. The arch should have a minimum of 4 fiducials distributed evenly across it, with space for an edentulous fiducial plate to be put during surgery.[3]

Workflow:



Advantages[9,11-17]

The dynamic navigation system outperforms static guided and freehand procedures in more ways than other. Some of the advantages are as follows:

1. Image acquisition and treatment planning can all be done in a single appointment
2. It can be used when there is little vertical space available (posterior region) or restricted mouth opening cases as dentist can rely on the navigation screen to maneuver without direct visualization of the operation site.
3. Guides/templates become redundant therefore planning process becomes simple.
4. Poorly fitted guides do not lead to guidance failures as guides are needless.
5. Since there is no obstruction between the water source and the bur, visibility and water cooling are improved.
6. Flexibility offered to operator is greater in DNS as changes can be made in the treatment plan during the procedure
7. Limited risk of damaging critical anatomic structures.
8. Improved precision as compared to freehand method
9. Requiring less intrusive flap reflection/flapless approach than free-hand techniques
10. Better irrigation, lowering the chance of tooth structure loss due to overheating
11. Changes can be made with respect to burs and drills

instead of just specific implant drills like in the case of static guides

12. Visualization via screen lessens the damage to the surgeon by improving posture and reducing back and neck bending.

Disadvantages[1,18,13,9]

1. The cost considerations with DNS are high along with running costs of single use disposable drill tags, handles.
2. A CBCT scan is mandatory whether strictly justifiable or not exposing the patient to ionizing radiation
3. Mild systematic errors may occur due to instability of the jaw tracker mid treatment or the real-time visuals may be lost while readjusting the path of insertion/drilling
4. The entire procedure is monitored by the computer software; any glitches in the computer's ability to process commands could result in iatrogenic problems.
5. A learning curve to develop proficiency to subsist remains because the working position is different from the typical experience of addressing the patient directly.
6. This may require additional time for training and simulation.[1,9]
7. Another requirement for dynamic navigation is a collaborative effort. For effective use of a dynamic navigation system, the surgeon and the first assistant must learn to collaborate.[9]

Application In Endodontics:

1. Endodontic access opening & Pulp Canal Obliteration cases

Krastl G. et al. were the first to propose guided endodontics as a novel therapeutic strategy for teeth diagnosed with pulp canal calcification.[19] Dianat and collegues in their challenging case report made use of dynamic navigation system to successfully locate the calcified distobuccal canal of a first maxillary right molar.They concluded that dynamic navigation system had the potential to successfully locate calcified canals conservatively.[17] Gambarini G et al. presented encouraging results in their in-vitro study where dynamic navigation system used for ultra conservative access cavity design reduced chances of iatrogenic error and errors related to shaping procedures.[20] According to two studies, it takes 11.5 and 195 seconds, respectively, to perform an access opening using DNS which was relatively less than the freehand technique.[20,21] Two more studies by Pirani C et al and Zubizarreta-Macho Á et al reported that DNS helped in more precise, unambiguous, error-free and safe canal location when used for routine and truss access cavity.[21,22] Connert et al in their study demonstrated DNS guided access to be superior to freehand access opening as the former resulted in lesser substance loss.[23] SD Jain and collegues's in vitro study concluded that DNS could be used conveniently to located calcified canals with a mean 3D and 2D deviation of 1.3 mm and 0.9 mm from the canal orifice.[6]

2. Root canal treatment

A systematic review by Zubizar etá-Macho, Á et al concluded that using dynamic computer-aided navigation technique, the root canal systems could be found with great accuracy.[24]

3. Endodontic retreatment

The dynamic navigation technology allowed for highly accurate, less invasive removal of the fibre post, preventing the needless loss of root structure in two case reports by Janabi A et al and Bardales-Alcocer J et al. [8,25]

4. Intraosseous Anesthesia

In comparison to freehand intraosseous drilling, intraosseous anesthetic delivery using dynamic navigation technology proved substantially safer and more precise in a study conducted by Jain SD et al. The dynamic navigation group showed no perforations (0%) as compared to freehand drilling which showed a perforation rate of 22%.[26]

5. Endodontic surgery

Successful osteotomy and root-end resection in an upper lateral incisor was performed by an undergraduate student using dynamic navigation system with minimally invasive approach and minimal iatrogenic error in a case report by Gambarini G et al.[27] Dianat et al. in a cadaver study revealed lesser operative time, linear& angular deflection in the DNS group reinforcing the idea of dynamic navigation system being a reliable and productive technical addition to endodontic armamentarium.[28] Fu W et al. in their series of three case reports successfully demonstrated the use of sophisticated dynamic navigation system for root resection in posterior teeth with no complications.[29]

Associated Errors:

Inherent errors related to dynamic guided systems can broadly be classified under three categories:

- **Machine related**

Non stable fiducials or loose jaw attachments could hamper the accuracy of the dynamic navigation system. Mobile tooth should be avoided and rocking attachments can be fixed using bite registration material or by tightening the attachments

- **Patient related:**

Distorted CBCT could affect image quality and could impede procedure precision

- **Operator related**

The repeated need to look at the screen and operate requires good hand eye coordination. A learning curve is associated with the use of this technology. Improved control over handpiece can be acquired by abundant ex vivo practice.[17]

Future:

Currently Navident[1,6,7,11,20,22,25,27] appears to be the most extensively used dynamic navigation system followed by X-guide[17,28,8], ImplaNav[21] and DENACAM[23]. Despite the high accuracy and precision obtained by using these systems there exists a scope for improvement. The system arrays could be reduced in size to improve handling and comfort of the operator. Possibility of being able to plan markers digitally could also benefit the patient by making a second CBCT dispensible (incase the first CBCT was taken without markers)[30]

Conclusion:

Dynamic navigation system is still in its nascent stage as far as application in endodontics is concerned. With promising results so far more clinical studies are awaited to bring this real-time navigation technology into the mainstay of endodontic treatment planning.

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