Section A-Research paper
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Utility, scope and applications of dynamic navigation systems in dental implant surgeries : A review

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Abstract

The standard technique of implant placement uses the free-hand approach. In this, after the necessary evaluations, the surgeon places the implant into the bone using structures adjacent to the surgical site as references. An additional device whose sole purpose is to direct the position and angulation at which the implant should be inserted and placed is not used, as is done in guided surgeries. It is for this reason this technique is also known as brain-guided surgery. Navigation in surgery acts as a measuring tool and information centre for the surgeon by providing him/her with the correct information during the surgical procedure : The location of the surgeon's anatomical target, the route to reach it safely, the current location of the surgeon in relation to the surrounding anatomical structures and the precise location and angulation at which the implant has to be positioned. Dynamic navigational surgery is a surgical modality in which surgical instruments are accurately tracked and targeted to a pre-planned location within the surgical field. This is dependent of the co-ordination of intra-operative position of instruments with the pre- operative radiographic images of the patient's anatomic site. It allows for precise localization and aids the surgeon's orientation intraoperatively within the surgical field.

Keywords: Dynamic navigation systems, implants, dental surgeries

Introduction :

The fundament of an esthetic and functional implant-supported prosthesis is reliant on proper positioning and angulation of the implant. Precise positioning helps decrease the biomechanical load on the implant, ensures optimal occlusion and implant loading and allows optimization of design of the final prosthesis thereby aiding in maintenance of optimum dental hygiene. The long-term success of the dental implant is ultimately dependent on its proper positioning. Therefore, meticulous pre-surgical planning ensures precise placement of the implant according to the treatment plan designed.[1] In the past 3 decades, technology has slowly emerged to now become an integral part of our routine lives. One of the prime examples of technological advancement being applied to medicine is the concept of navigation in surgical procedures.[2]

Dynamic navigation in surgeries :

Navigation is the process or activity of accurately tracking one's position by subsequently planning the route to follow and reach it. Some of the routine examples of navigation in our daily lives range from the GPS-systems used to navigate our vehicles to our smartphones.[3]

Navigation in surgery acts as a measuring tool and information centre for the surgeon by providing him/her with the correct information during the surgical procedure :The location of the surgeon's anatomical target, the route to reach it safely, the current location of the surgeon in relation to the surrounding anatomical structures and the precise location and angulation at which the implant has to be positioned.[2]Coller set forth the goal of navigation in 2010 – to achieve optimum surgical accuracy with minimal impact on time. The aid of technology to navigation brings the surgeon closer to achieving this goal.[3]

Dynamic navigation is also known as navigation-guided surgery. It mainly differs from the conventional surgeries in that it includes three-dimensional exploration, prosthetic analysis and

planning of the implant site before commencement of the surgical procedure. The entire surgical procedure from bone-drilling to implant placement is tracked with the aid of special instruments and specific softwares designed for this purpose.[4]

Dynamic navigational surgery is a surgical modality in which surgical instruments are accurately tracked and targeted to a pre-planned location within the surgical field. This is dependent of the co-ordination of intra-operative position of instruments with the pre-operative radiographic images of the patient's anatomic site. It allows for precise localization and aids the surgeon's orientation intraoperatively within the surgical field.[2]Dynamic navigational surgery is a surgical modality in which surgical instruments are accurately tracked and targeted to a pre-planned location within the surgical field. This is dependent of the co-ordination of intra-operative position of instruments with the pre- operative radiographic images of the patient's anatomic site. It allows for precise localization and aids the surgeon's orientation intraoperatively within the surgical field.[2]

This technology originated in neurosurgery following which it found its application in other surgical disciplines.[7] Except in neurosurgery the target registration error ranges between 2.5 – 4.2 mm due to brain's movement in CSF between CT scan time and surgery. This value also varies depending on the ability of the surgeon to follow on-screen guiding indicators.

But in cases of dental implants, this value is well below 1 mm owing to mainly 2 factors :

i. Rigid fitting of radiographic interfacing templates.

ii. Precision of motion tracking system.[5]

As opposed to rigid intra-oral guides used in static systems, dynamic navigation systems make

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use of visual imaging tools on a computer monitor to aid in communication of selected implant position to an operative field. A pre-operative CT or CBCT scan provides anatomical information using which the surgeon alters the surgical procedure and implant position in real time with the aid of computer-aided navigation technologies.[6] With the help of a virtual planning software, 2D thin-cut, axial CT data is imported into the computer and a precise 3D virual representation of the anatomical site is generated. The planned surgery is performed virtually and then imported into an intraoperative navigation system which guides the real-time surgery. A computer digitizer is utilized to track the location of the patient and instruments in space.[5] There is a scope for last-minute modifications as an avatar of the drill in a 3D relationship to the patient's previously scanned anatomy is visible to the surgeon during the on-going procedure. A virtual guidance is provided by the navigational approach and if the conditions during the surgical procedure are found to differ from as interpreted on the previous scans, the surgeon may alter the procedure accordingly.[6]

Principle and mechanism :

The global positioning system make use of triangulation with various geostationary satellites to locate and track an object. As opposed to this, the modern surgical navigation makes use of a different localisation technology. It mainly involves the use of stereomicroscopic camera, infrared light and marker spheres in different ways, which are explained in detail further. Before commencing the surgery, a set of marker spheres are attached to the patient, and the other set to the surgical instruments using reference arrays. For the computer to be able to calculate the position and orientation of each instrument, each reference array must comprise of at least three marker spheres. The real-time tracking of these marker spheres ultimately helps in location of three-dimensional position of prominent anatomical structures. The co-relation between position of tracked instrument and tracked patient reference is what makes intraoperative movements of camera possible.

A basic dynamic navigation surgery set-up requires mainly a stereromicroscopic camera, computer platform with screen and navigational software. The navigational systems can either be mobile platforms can be rolled in as and when required.[2]

Currently, most dynamic navigation systems for dental implant placement use optical tracking technology using active or passive arrays. In active systems, the infrared light emitted from active array system is tracked actively by stererocameras. Passive systems, with the aid of reflective spheres, reflect light emitted from a light source back to stereocameras. Some passive optical dynamic navigation systems require fiducial markers which are secured to patient's arch during CBCT scanning. This device containing fiducial markers help in registering the arch to the computer by attaching an array. One set of array is attached extraorally to a clip containing fiducial markers. Another set of arrays is attached to the implant handpiece. Each reference array must comprise of at least three marker spheres for precise calculation of orientation. The co-ordination of these two sets of reference arrays allow for triangulation, thereby achieving navigation. Both the drill as well as patient-

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mounted arrays need to be within the line of sight of overhead stereocameras for accurate tracking on the monitor.[7]

Another tracking technology is electromagnetic tracking (EMT). EMT consists of three components – field generators, sensor units and central control units. The field generator uses several coils to generate a position varying magnetic field that is used to establish the co-ordinate space. The sensor unit attached to the object contains small coils in which current is induced via magnetic field. By measuring behaviour of each coil, position and orientation of object can be determined.

EMT has some definitive advantages over optical tracking technology. Although optical tracking is more precise, it needs continuous visibility of markers during the procedure. EMT eliminates this need, ultimately eliminating hindrance of line of sight during the procedure. Also, EMT reduces radiation consumption due to ability of magnetic fields to penetrate human tissue. EMT sensors are small, light-weight, so the seight as well as length added to the tool is negligible. The motions with limited movements or forces during dental implant surgery completely change in presence of current optical tracking markers, a shortcoming which is overcome by the use of EMT.

Some of the commercially available EMT systems are Fusion™ ENT (for otorhinolaryngology) by Medtronic and NAVI electromagnetic (for endoscopy) by Karl Sturz (Germany). They have limited application and scope in craniomaxillofacial surgeries. So far only a few scientific researches and studies have demonstrated feasibility of EMT systems in stomatology applications.[8]

Dynamic reference frames :

The dynamic reference frame is a referring device used in surgical navigation systems. Surgical navigation systems allow real-time visualisation of position of surgical instruments during the surgical procedure with the aid of 3D patient image data obtained pre-operatively. Therefore, to optimise precision and minimise errors. It becomes necessary to record and monitor the position as well as orientation of a specific body part on which a surgical procedure is to be carried out. For this purpose, reference frames are used.

Conventional referring devices consist of reference frames containing light-reflecting spherical markers, the light reflected off which is captured by stereocamera systems. This allows precise location of the referring device. But, the conventional reference frames face certain shortcomings. They have a limited range of motion. Also, achieving and maintaining a sterile operative environment is difficult with these. The newer advances in dynamic reference frames attempt to overcome these deficiencies.

Fiducial markers :

Passive optical dynamic navigation systems require fiducial markers which are secured to the patient's arch during image scanning. This device containing fiducial markers helps in registering the arch to the computer.[9]

In a dentate patient fiducial clip is firmly supported by teeth which ensures it is seated in the same location in the patient's mouth each time. CT scan of the patient's mouth should be made with the fiducial clip seated properly without any rocking or movements of the fiducial

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clip. The fiducial clip is placed on the arch where implant is being placed with the tracker arm attachment section of the fiducial clip on the buccal side of the patient. Care should be taken that the fiducial clip does not interfere with the drilling of implants. Also it should minimise optical interference by the surgeon's or assistant's hands and instruments. Mobile teeth, those bearing orthodontic appliances or those serving as ponticsfor fixed partial dentures should not be involved if possible. After placing the fiducial clip in hot water bath (140°-160°F / 60°-71°C) for approximately 3-5 minutes, the thermoplastic turns clear which is
an indication it is ready for use. It is then cooled to reach room temperature (<104°F / 40°C). This fiducial clip is now placed on three teeth, maintaining equal distance on buccal and lingual sides with tracker arm on buccal side. Vertical pressure is now applied on it and an impression is made. The fiducial clip is removed without rocking motion, placed in a cold water bath and tried again in the patient's mouth to ensure accurate seating without any impingement of soft tissues. In cases of teeth with short clinical heights or those without undercuts to retain the fiducial clip, composite may be added to teeth to make the fiducial clip immobile. In case of multiple fiducial clips, the surgeon must ensure they do not touch each other.[10]

In edentulous patients small screws (called edentulous fiducials) are placed in the patient's bone to facilitate registration in CT scan. These can be placed either through soft tissue apical to mucogingival junction or directly into the exposed bone. The surgeon must choose the sites for placing theses edentulous fiducials carefully so as to avoid damage to anat,oical landmarks. These screws should be 1.5mm in diameter, 4-5mm in length, self-drilling, self-tapping, low-profile and stable. The edentulous fiducials are placed in the arch where implants are to be placed. They should be placed apical to area of proposed bone reduction if vertical bone reduction is anticipated. An edentulous fiducial plate is to be inserted during the surgery for which room should be left while planning and placing the edentulous fiducials.[10]

Image acquisition and software planning :

A CBCT or CT scan of the surgical site including all fiducials with the plane of occlusion of implant site parallel to the floor is obtained in a DICOM format. For dental implant planning purposes care must be taken to place a radiolucent material like a cotton roll between the dentition and the labial or buccal mucosa to create an air contrast zone. This allows visualisation of soft tissue of free gingival margin on CBCT.

In case of dual scan technique, at least five 2mm fiducials should be applied to the denture. A high-resolution CT scan of the denture itself is obtained, after which another CT scan of the denture in the patient's mouth is obtained. Care should be taken to not disturb the fiducials on the patient and on the denture.

Other alternative is the use of intraoral scanners (IOS) but the drawback is theyr provide three-dimensional surface images and not volumetric images like CBCT. Therefore, they are highly accurate when it comes to single and quadrant impressions by the accuracy decreases when full arches are scanned. For IOS, scans are performed before extraction of teeth. These images can be used later for planning ideal implant position and fabrication of provisional prosthesis. Upon acquiring and storing these images, next they are loaded into treatment planning software. Selection of software must be based on the presence of some key features related to image processing and analysis like importation and exportation of generic file formats (.dcm and .stl), superimposition of 3D files, superimposition of dual scans in dicom format and ability to export images in a common co-ordinate system as an individual or merged item. Superimposition of these clean .stl images on CBCT data makes the osseous as well as soft tissues clearly visible and thereby helps in implant planning. When beginning to plan on the dynamic navigation software, a panoramic curve for the arch requiring implants is developed on the axial plane of the patient's scan. Important anatomical landmarks may also be identified and marked. Ensuring multiple areas of co-ordination between images for accuracy of merging, the patient's scan and IOS image of denture or denture scan are merged.

The planning of implants should be restoratively driven. For this the occlusion is evaluated and the restorative envelope of virtual teeth is placed in the proper occlusal position by either using virtual implant crwons available in the dynamic navigation software or by using a separate prosthetic software.For the latter, the plan is exported from the prosthetic software and imported as a .stl file into the dynamic navigation software. After finalising the implant crown, the virtual implants are aligned below the virtual crowns for ideal emergence into the prosthetic space. The design parameters of the implant like implant platfrom diameter, implant apex diameter and implant length as well as abutment height and angle is planned with the dynamic navigation software. It also allows mirroring to align implants across an arch and parallel to adjacent implants.

Technical procedure :

To guide the drilling of the implant site, the tip of the drill must be mapped precisely to the pre-acquired CT image of the jaw. For this, sensors are attached to the body of the handpiece and the extraoral clip is attached to fiducial markers. It is achieved in broadly three steps.

i. Calibration – This includes mapping tip of the drill to the body of handpiece.[11] The instruments to be used during surgery need to be tracked by the navigation system. For this the geometry of the tracking arrays relative to the instrument being used must be determined by the tracking system. These instruments include mainly both the contra-angle as well as straight handpieces and probe tool. The assembled parts are placed in front of stereocameras as the software learns their geometry.[12]

ii. Registration – This covers mapping the extraoral clip to the pre-acquired CT image of the patient's jaw by linking physical space co-ordinates of the patient to the patient's image co-ordinates. The registration workflow is specific for dentate and edentulous patients. The surgeon must select a handpiece. The handpiece and its chuck are calibrated approximately 60-80 cm from the camera. A probe tool is also calibrated to the chuck plate. An implant drill bit is placed on the handpiece, aligned perpendicular to centre target and after verification of drill length the operator proceeds to drill. In an edentulous patient, a calibration probe and edentulous tracker plates are used. A subperiosteal flap is reflected in an area of the bone where there are no edentulous fiducial screws and the edentulous tracker is placed which is then attached to a patient tracker arm. By touching the fiducials with the probe, the patient tracker and edentulous fiducial screws are registered to the dynamic navigation sytem. The drill bit is placed on fiducial clip for edentulous patients are on three fiducial spheres in case of dentate patients. If all three fiducials have green indicators the system calibration is within 20 micrometers. Before beginning surgery and after every drill bit is changed a system check is performed by the surgeon to ensure the instruments are calibrated and the system is registered to the patient.

iii. Tracking – This is the last step. This relates drills to the patient's jaws and allows the surgeon to see them on the monitor in real-time.

Source of guidance errors :

Accuracy of the navigation system is mapping the drill tip to the CBCT image of the jaw determines the accuracy of the osteotomy site preparation. Errors in this mapping can be attributed to a number of reasons like slight deviations between geometrical assumptions made by the mapping software and reality. Sometimes if time lapses after the motion tracking system was calibrated, mechanical, thermal or optical changes cause it to drift away from perfect calibration. This is known as optical tracking noise. Also, a compromise in the rigidity of involved components degrades accuracy. Other probable reasons are movement of patient during CBCT scanning process, improper seating of jaw attachment, bending of arms or connectors during the surgical procedure and movement of the tip of the drill relative to the handpiece handle being tracked. Additionally, inherent human hand-eye co-ordination and individual variability with fine motor control renders the surgeon's control of the handpiece imperfect. Thus, dynamic navigation is partly a manually controlled operation which introduces an element of operator-dependant error irrespective of advanced accuracy offered by technology.[13]

Discussion :

The general indications to choose dynamic navigation over a free-hand approach would be when a flapless approach is desired by the clinician in ridges sites which are previously augmented and disturbance of the superficial part of the graft with flap elevation is to be avoided. It is also advocated in situations where multiple adjacent implants are to be placed in an edentulous space and appropriate spacing needs to be ensured both between implants as well as between the implant and adjacent tooth. In anterior sites where aesthetics is a major concern or in screw-retained prostheses over implants, an accurate implant angulation is mandatory. This can be achieved by navigation surgical procedures. In situations where the depth of placement of the implant is crucial and needs to be controlled to avoid injury to underlying anatomical structures or when such structures like the floor of the sinus or nasal floor needs to be engaged intentionally for bicortical implant stability, dynamic navigational surgical procedures are preferred. Dynamic navigation is specififcally indicated in patients with a restricted mouth opening where implant placement can be slightly tedious or when implants are to be placed in difficult -to-assess locations and where direct visualisation is

difficult. It is also indicated in cases where implants have to be placed on the same day of CBCT scan. In cases of tight interdental spaces where the use of static guides is difficult due to site of tube as it may interfere with ideal implant placement, dynamic navigation may be of value.
Dynamic navigation is not as such contraindicated in cases but its use may be limited in cases where CT-generated guides can be used to pre-operatively fabricate a provisional prosthesis on models generated from the static guide itself. Also, in edentulous cases, static-guided approach is preferred over dynamic navigation as currently intrabony fiducial markers cannot be used to register jaw to the navigation system.[14]
Pre-operative planning and preparation plays a crucial role in the success of any surgery. Dynamic navigation allows the planning of a virtual implant in terms of angulation, depth, location, size as well as depth thus paving way for a well-planned surgery. This allows prediction of any difficulties which may be encountered during the surgery. It also boosts the confidence of the surgeon.[15] According to comparative studies performed, dynamic navigation has improved precision of implant placement over both free-handed and static-guided approaches. Certain studies have proven enhanced accuracy in terms of implant angulation as the most striking advantage of this technique. Also, along with correct placement maintaining parallelism it provides active feedback during the procedure which allows the surgeon to modify the surgical plan if need arises.[16]

The CT scanning, planning as well as surgery may be performed in a single appointment. Since it is a minimally invasive surgery it reduces patient discomfort by aiding faster recovery and also reduces risk of infection. It also reduces risk of iatrogenic damage to neighbouring anatomical structures. This technique eliminates the use of plaster models, wax-ups and guides thereby making the planning simple and fast. It is compatible with any implant or drill system. It can be executed properly even in situations where the interocclusal or interdental space is limited. It also eliminates the possibility of failure of guidance due to fractured or ill-fitting guides. Also, it aids in improving ergonomics by allowing the surgeon to look at the screen intraorally.[15]

Some of its shortcomings are it is an expensive system and its maintenance may not be financially feasible as every system needs its planning software which might not be compatible with other systems. Also, per-case cost of fiducial clips, markers and plates adds to the financial investment. A learning curve is associated with this navigation system. According to studies proficiency increases after placement of 10-20 implants . Currently, additional surgery is needed in edentulous patients to place fiducial screws and tracking plates. Advances are underway in which patient’s anatomical structures will be used instead of fiducial markers rendering the procedure fiducial-free.[17]

Presently, the surgical procedural options available for implant placement can be broadly divided into three approaches – free-hand surgical placement, placement using static guides and with the use of dynamically navigated systems. Therefore, to make an informed choice, it becomes mandatory to know the degree of accuracy which can be attained by using each of these. Several comparative studies have been conducted in the recent past evaluating different parameters which could potentially affect the accuracy of placement as well deviations in parameters between planned and placed implants using these three surgical approaches. Some of these studies and their outcomes are discussed further in this chapter.

In an in-vitro study conducted, a comparison in accuracy of implant placement using freehand, static-guided and dynamic navigation systems was made. The primary outcome variables were angular deviation, coronal. Apical and global deviation. The results obtained were global deviation was significantly lower with dynamic navigation system than freehand approach but accuracy of dynamic navigation was not significantly different compared to static-guided. Therefore, this study observed that dynamic navigation allows implant positioning accuracy comparable to that offered by static guides but superior to freehand approach.[18]

In the study conducted by Alfonso Mediavilla Guzman to compare accuracy of computer-aided dynamic and static navigationfor dental implant placement, the accuracy of computer-aided dynamic navigation was compared to computer-aided static guides for implants placement. Here a CBCT was made post-placement and degree of accuracy was analysed by therapeutic planning software and student's t-test. The results showed no significant difference between apical deviation but statistically significant differences were observed between angular deviations.[19]

In a study conducted by Ting Mao Sun, accuracy of implant placement using conventional freehand methods use of a laboratory guide, dynamic navigation system and dynamic navigation system with a surgical guide was compared. 32 implants were in each group in patients belonging to an identical age group. The measurement of accuracy was performed by superimposition of post-operative CBCT on the virtual pre-surgical implant placement. Dynamic navigation system with a surgical guide was the most accurate method. The total, longitudinal and angular error deviations were significantly different but the level of accuracy did not differ for different jaws and tooth positions.[20]
A split-mouth randomized control clinical trial was conducted by Mrs. Ceyda Aydemir and Prof. Volkan Arisan to evaluate deviations of planned and placed implants assisted by a micron tracker-based dynamic navigation device or freehand methods. With a thermoplastic fiducial marker adapted on anterior teeth, a CBCT was performed. A minimum of one implant was surgically inserted in each side of posterior maxilla using dynamic navigation devise or freehand method randomly. A final CBCT image was made. The planning data was matched with this CBCT image to measure linear deviations (in mm) between the planned and placed implants. Differences in linear deviations were observed in both the shoulder and tip of the implants.[21]

In an in-vivo study to compare accuracy of implant placement via freehand and dynamic navigation system approaches, 86 implants were placed and linear deviation values in the shoulder of the implants were calculated using the commercial software (GPower, Dursedolf, Germany). The difference in linear deviation between shoulder of dynamic navigation system and conventional freehand methods was observed to be 30 %. The secondary outcome variables were angular deviation, effect of mouth opening, site of application and learning curve. No significant co-relation was found between mouth opening and method of implant placement but statistically significant co-relation between angular deviation and mouth opening was observed in freehand technique.

The graphical representation of the rate of learning how to place implants with better accuracy over time or repeated experiences is defined as the learning curve (Karsite et al, 2019). It is assumed to play a role as per previous studies but this study found no statistically significant evidence to support the same. Golop Deep et al. described young professionals improved significantly in speed and angulation deviation by using a dynamic navigation system. Sun et al. described a steep learning curve for longitudinal and angular deviations for an experienced dentist. Marques-Guasch et al. saw a decreased learning curve for a young inexperienced surgeon and concluded that the navigation technique requires a lot of practice to learn the right hand–eye coordination. However, dynamic navigation could be a good alternative to the standard procedures and could enable young dentists to perform targeted and reliable therapy that is gentle on the patient settings.

In a study conducted by Johannes Spille to evaluate the effect of learning curve on accuracy of implant placement by young dentists using dynamic navigational systems, 10 students placed 160 implants on acrylic mandibular models. Although in this study the dynamic navigation system was handled outside the mouth, experienced surgeons also demonstrated a learning curve for dynamic dental placement to achieve satisfactory results in vivo. Students seemed to be able to achieve steeper learning successes with dynamic navigation. It was observed that deviations would be greater in vivo due to disruptive factors such as limited mobility, restricted mouth opening, or patient movement

In the current study, the young professionals felt much more confident with the implant placement as well as the handling of the navigation system after the first weekend and another practice time on the second weekend. The field of view during operation appeared to be a challenge. The positioning of anterior implants seemed to be easier to learn. As a right-handed person, the view of the left side is restricted (especially right posterior mandible), which makes exact drilling more difficult.

Furthermore, the young professionals described the coordination of the handpiece with the monitor as a problem. This could be due to the weight of the handpiece, which is occupied by the camera and complicates the operation. In addition, the detection of the marker with the camera was not easy to perform. The marker as an additional intraoral medium can also negatively influence the view. Observing the patient and the monitor correctly during the entire operation can lead to complications and inaccuracies.

The current study had also some major limitations. First, because the study was based on a small group of ten young professionals, a larger cohort study is needed to improve statistical power. Besides that, not all anatomical structures such as the inferior alveolar nerve or prosthetic sense were considered in the implant position. Furthermore, the lab conditions cannot be accurately compared to real life. The learning curve in real life happens on different patients with different anatomy and bone quality. Ultimately, a higher level of surgical experience with dynamic navigation improves the accucacy of implant placement and may also provide a good alternative in daily surgical treatment; the dynamic computer-assisted surgical system enables dentists to plan and operate on the patient quickly.[22] Based on existing literature and studies reviewed, it can be concluded that navigational technique helps in a more accurate transfer of virtual pre-planning of implant placement to patient's jaw intraorally. The deviations in most parameters between planned and placed implants is minimal with dynamic navigation system, somewhat similar with use of static guides and maximum with freehand approach. Secondary factors like site of placement in jaws, mouth opening and learning curve associated with techniques also plays a role while choosing a surgical approach.

References :

1. Rungcharassaeng K, Caruso JM, Kan JY, Schutyser F, Boumans T. Accuracy of computer-guided surgery: A comparison of operator experience. *J Prosthet Dent*. 2015;114(3):407-413. doi:10.1016/j.prosdent.2015.04.004

2. Mezger U, Jendrewski C, Bartels M. Navigation in surgery. *Langenbecks Arch Surg* 2013;398(4):501-514. doi:10.1007/s00423-013-1059-4.Panchal N, Mahmood L, Retana A, Emery R 3rd. Dynamic Navigation for Dental Implant Surgery. Oral Maxillofac Surg Clin North Am. 2019 Nov;31(4):539-547. doi: 10.1016/j.coms

3. Bobek SL. Applications of navigation for orthognathic surgery. Oral Maxillofac Surg Clin North Am. 2014 Nov;26(4):587-98. doi: 10.1016/j.coms.2014.08.003. Epub 2014 Sep 16. PMID: 25239214.

4. Gargallo-Albiol J, Barootchi S, Salomó-Coll O, Wang HL. Advantages and disadvantages of implant navigation surgery. A systematic review. Ann Anat. 2019 Sep;225:1-10. doi: 10.1016/j.aanat.2019.04.005. Epub 2019 May 4. PMID: 31063802.

5. Casap N, Wexler A, Eliashar R. Computerized navigation for surgery of the lower jaw: comparison of 2 navigation systems. J Oral Maxillofac Surg. 2008 Jul;66(7):1467-75. doi: 10.1016/j.joms.2006.06.272. PMID: 18571032.

6. Tahmaseb A, Wismeijer D, Coucke W, Derksen W. Computer technology applications in surgical implant dentistry: a systematic review. Int J Oral Maxillofac Implants. 2014;29 Suppl:25-42. doi: 10.11607/jomi.2014suppl.g1.2. PMID: 24660188.

7. Block, Michael & Emery, Robert. (2015). Static or Dynamic Navigation for Implant Placement—Choosing the Method of Guidance. Journal of Oral and Maxillofacial Surgery. 74. 10.1016/j.joms.2015.09.022.

8.A Real-Time Dental Implant Tracking System: A Review Umesh Babu M.E. Electrical Engineering International Journal of Technical Research & Science ISSN No.: 2454- 2024 (online)

9. Block MS, Emery RW. Static or Dynamic Navigation for Implant Placement-Choosing the Method of Guidance. J Oral Maxillofac Surg. 2016 Feb;74(2):269-77. doi: 10.1016/j.joms.2015.09.022. Epub 2015 Sep 30. PMID: 26452429.

10. Panchal N, Mahmood L, Retana A, Emery R 3rd. Dynamic Navigation for Dental Implant Surgery. Oral Maxillofac Surg Clin North Am. 2019 Nov;31(4):539-547. doi: 10.1016/j.coms.2019.08.001. PMID: 31563194.

11. Dynamic navigation for dental implant surgery – Dr. Amit Benjamin, International Journal of Scientific Research, Volume - 9 | Issue - 6 | June - 2020 | PRINT ISSN No. 2277 – 8179

12. Panchal N, Mahmood L, Retana A, Emery R 3rd. Dynamic Navigation for Dental Implant Surgery. Oral Maxillofac Surg Clin North Am. 2019 Nov;31(4):539-547. doi: 10.1016/j.coms.2019.08.001. PMID: 31563194.
13. Chen JT. A Novel Application of Dynamic Navigation System in Socket Shield Technique. J Oral Implantol. 2019 Oct;45(5):409-415. doi: 10.1563/aaid-joi-D-19-00072. Epub 2019 Aug 7. PMID: 31389753.
14. Block, Michael & Emery, Robert. (2015). Static or Dynamic Navigation for Implant Placement—Choosing the Method of Guidance. Journal of Oral and Maxillofacial Surgery. 74. 10.1016/j.joms.2015.09.022.
15. Dr. Amit Benjamin, Dr Nawamee Phadnis. (2020). Dynamic Implant Navigation Systems: A Review . World Journal of Advanced Scientific Research, 1(2), 117 - 122. Retrieved from https://ubipayroll.com/wjasr/index.php/wjasr/article/view/148
16. Gargallo-Albiol J, Barootchi S, Salomó-Coll O, Wang HL. Advantages and disadvantages of implant navigation surgery. A systematic review. Ann Anat. 2019 Sep;225:1-10. doi: 10.1016/j.aanat.2019.04.005. Epub 2019 May 4. PMID: 31063802.
17. Panchal N, Mahmood L, Retana A, Emery R 3rd. Dynamic Navigation for Dental Implant Surgery. Oral Maxillofac Surg Clin North Am. 2019 Nov;31(4):539-547. doi: 10.1016/j.coms.2019.08.001. PMID: 31563194.
18.Implant Placement is more accurate using dynamic navigation Michael S. Block, DMD* Private Practice, Metairie, La Robert W. Emery DDS* Private Practice, Washington, DC Daniel R. Cullum, DDS* Private Practice Coeur D'Alene, Idaho Ali Sheikh Software Engineer X-Nav Technologies, LLC *Dr. Emery, Dr. Block, and Dr. Cullum have a financial relationship with X-Nav Technologies, Inc. This study was performed under BioMed IRB, San Diego, California, protocol number 2014-10-\15.

19.Mediavilla Guzmán A, Riad Deglow E, Zubizarreta-Macho Á, Agustín-Panadero R, Hernández Montero S. Accuracy of Computer-Aided Dynamic Navigation Compared to Computer-Aided Static Navigation for Dental Implant Placement: An In Vitro Study. J Clin Med. 2019 Dec 2;8(12):2123. doi: 10.3390/jcm8122123. PMID: 31810351; PMCID: PMC6947513.

20. Sun TM, Lee HE, Lan TH. Comparing Accuracy of Implant Installation with a Navigation System (NS), a Laboratory Guide (LG), NS with LG, and Freehand Drilling. Int J Environ Res Public Health. 2020 Mar 22;17(6):2107. doi: 10.3390/ijerph17062107. PMID: 32235745; PMCID: PMC7142827.
21. Aydemir CA, Arısan V. Accuracy of dental implant placement via dynamic navigation or the freehand method: A split-mouth randomized controlled clinical trial. Clin Oral Implants Res. 2020 Mar;31(3):255-263. doi: 10.1111/clr.13563. Epub 2019 Dec 29. PMID: 31829457.
22. Spille, J.; Helmstetter, E.; Kübel, P.; Weitkamp, J.-T.; Wagner, J.; Wieker, H.; Naujokat, H.; Flörke, C.; Wiltfang, J.; Gülses, A. Learning Curve and Comparison of Dynamic Implant Placement Accuracy Using a Navigation System in Young Professionals. *Dent. J.* **2022**, *10*, 187. https://doi.org/10.3390/dj10100187