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Review Article

Dynamic Navigation in Implant Dentistry: A Panoramic Review

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Abstract

Navigation surgery has been called the concept that concerns the installation of implants according to pre-surgical planning with a prosthetic focus through 3D planning software. There are two types of Navigation surgery, static and dynamic. Both approaches seek to transfer pre-surgical design planning with high accuracy to the patient's mouth. This in order to achieve predictable treatments with excellent functional and aesthetic prognosis. The further development of computer technology and the associated computer-aided methods have increased the use of dynamic navigation in clinical practice in recent years. However there is still little scientific evidence and knowledge on Dynamic Navigation systems compared to Static Navigation. The objective of this panoramic review is to give a brushstroke to the general theory that supports the use and development of this technology.

***Keywords:** Dynamic Navigation, Computer-assisted surgery, computer-aided surgery, dental implants, accuracy, dynamic Navigation System, Navigation workflow, Trace Registration.*

Introduction

Dental implants are the gold-standard treatment in partially and total edentulous patients. Actually Prosthetic-driven implant placement for optimal esthetic and functional restoration has been increasing in demand and requires a higher accuracy.[1] Correct implant placement in the 3 dimensional space (3D); angulation, platform position, apical implant position and depth in the ideal position is an essential goal from both esthetic and functional standpoint. This also ensures the preservation of the surrounding anatomical structures, allows correct prosthetic rehabilitation, permits the achievement of good esthetics results, and contributes to long-term implant and rehabilitation success. The accuracy of implant placement is a key index for judging successful implantation.[2, 3,4]

Achieving ideal three-dimensional (3D) implant position prevents surgical complications, such as bleeding, sinusitis and nerve injuries. Also prevents esthetic outcomes; the need for hard and soft tissue grafting, good prosthesis contours, symmetry, allowing correct access for hygiene, determinate the types of restoration (cement vs screw retained) and long term soft and hard tissues stability and the long term success of all the implant treatment.[6,8]

Navigation surgery and other terms such as computer-aided surgery, computer-assisted surgery or image-guided surgery, have all been used to describe this concept. Design the implant position according to the preoperative cone-beam computed tomography (CBCT) and whit specific 3D implant planning software, and to guide the accurate implantation of implants.[4,5] This information can be transferred to the patient, facilitating more accurate implant positioning. So, navigation implant surgery has recently been introduced to reduce deviations from the virtually planned implant position to the patients during surgery. Whit the establishment of navigation surgery in dentistry implant field, two approaches Dynamic and Static Navigation was introduced.[3,8]

Dynamic Navigation (DN) involves the use of 3D exploration software simultaneously whit bone drilling and implant placement, providing to surgeons a real time navigation tool in a screen a GPS, to improve the accuracy of implant placement. Static navigation refers to the use of static surgical templates for the bone implant drilling and implant placement.[5,6,7,11] Static navigation surgery use stereolithographic templates supported by teeth, bone or mucosa whit metal tubes, during drilling and insertion of the implant (fully guide templates).[3,8]

The further development of computer technology and the associated computer-aided methods have increased the use of dynamic navigation in clinical practice in recent years.[9]

The purpose of this work is to summarize, in broad strokes, the advances in scientific research on dynamic navigation and summarize the general theoretical bases of the theoretical knowledge that we have today on this subject.

Methodology

An extensive research has been carried out in the english literature avaible on the main search engines; Pub Med and ScienciDirect to January of 2022 whit the keywords: Dynamic Navigation Implant and computer assisted implant surgery. After reviewing the publications found and eliminating duplicates, 15 studies were selected for their scientific relevance, their current scientific status, relevance to the subject, and whether or not they were journal publications on dentistry and implantology. It may still be possible that some grey literature was missed. Reports of clinical cases in vivo, cadaver or in vitro was excluded.

Navigation Surgery

Prosthetically driven planning has been shown to be suitable for achieving, the functional and esthetic rehabilitation, in an optimal and predictable way.[9] In both approaches, dynamic and static navigation, involves the same phases of implant planning in CBCT data with some software for 3D planning of surgery with a rehabilitative prosthetic approach.

DN uses a Navigation System, that can track in real time the position of surgical instruments on the CBCT, displaying it on a monitor whit the software of DN. This method differs from the static approach, does not require the use of surgical template and provides continuous and real-time feedback of the surgery in a monitor.[2] This virtual Reality device allows the surgeon to work dynamically on the patient and execute the planned implant surgery and any time the surgeon can change the plan based on the clinical situation.[7] This is not possible whit static approaches. The use of closed drilling templates can also lead to bone overheating due to the lack of access for cooling liquid.[9]

Surgical templates are not indicated on patients whit limited mouth opening or requiring simultaneous grafting procedures.[2] Is described in literature, that implants placed using mucosa-supported templates show greater deviations from the planned implant position to compare whit those placed using tooth-supported templates.[9] Although surgical templates are not practical for long drills and although no effective mechanism exist whit this approaches for zigomatics implants placement assisted by surgical guides as yet, DN has shown success when used for zygomatic implant osteotomy.[10,12]

Dynamic Navigation Surgery

The accuracy in transmitting the presurgical plan of the implant position to the patients mouth, is the most studied parameter in the field of Implant Navigation Surgery. In the systematic reviews studied on the subject, it reveals that DN has greater accuracy than free-hand approaches and is similar to the static fully guide.[1,2,3,4,5,6,8,9,10] However there is still little scientific evidence on Dynamic Navigation systems compared to Static Navigation.

Whit Dynamic Navigation Systems (DNS) exist the need to be calibrated to the patient's anatomical structures, the surgical instruments and CBCT images after the design. DNS continuously track the sensors or structures fixed from the patients mouth and surgical instruments trough the cameras and display the implanted drill and the surgical site on the computer screen, this can show any 3D deviation between the virtual planning implantation to the intraoperative procedure in real time.[4]

In Dynamic Navigation Surgery, tracking is a method of dynamically following the movement of an instrument in space, calculating the location of the instrument in relation to the patient and projecting that image in a screen.[12] DNS use optical tracking. There are two types of optical motion tracking systems, active and passive. Active tracking system arrays emit infrared light that is tracked to stereo cameras (*FIG 1)*. And passive tracking system arrays use reflective spheres to reflect infrared light emitted from a light source back to a camera, (*FIG*.2), the DNS then calculates the position of the patient and the instruments relative to presurgical time in the monitor in real time.[7] (*FIG. 1).*

Fig. 1: *(Courtesy of Nobel Biocare™) The Navigation System consist of two principal components:*

1. An infrared source of light, whit stereo cameras recording the tracking arrays positioned on the surgical handpiece, and on the patient.
2. A computer monitor, running the navigation software and displaying the 3D drill position and implant placement on the CBCT images

Traditional DN Workflow

The traditional DN workflow, consist of four steps:[7,11]

1. Preparation of a thermoplastic stent, required for fixation of a radiopaque fiducial marker on the arch to be treated.
2. Patient CBCT scanning with the fiducial markers (rigid object whit a known shape) in the mouth.
3. Prosthetically directed implant-surgery treatment planning.
4. Calibration of DNS with the patient and instruments. And guided implant placement, whit the stent and fiducials re-mounted on the arch, holding a tag with optical markers that provides a coordinate reference frame for the arch during surgery. (*FIG. 2 and FIG. 3).*

Fig. 2: *(Courtesy of Nobel Biocare™). Calibration of the chuck with the Go Plate perpendicular to the center target. We also see DN passive traking system, reflective spsheres in the handpiece, Go Plate and pacient arch. (The Calibration of the instrumentation occurs approximately 60 cm to 80 cm from the cameras).*[7]

Fig. 3: *(Courtesy of Nobel Biocare™). A computer monitor, running the navigation software and displaying the 3D drill position, in real time, for implant placement on the CBCT images.*

In the traditional DN workflow, it is essential to have fiducials (rigid objects with known shape). These must be kept in the mouth without altering their position at the time of CBCT and surgery or irreversible calibration errors may occur that generate inaccuracy, compromising the pre-surgical plan. Another disadvantage of the use of fiducial with stent is the need for an extra CBCT, which results in greater irradiation for patients, in addition to the fact that they can produce spatial interference with the surgical site. To overcome the aforementioned drawbacks, a technology called Trace Registration (TR) was recently introduced.[11]

Trace Registration Workflow

Instead of using fiducials with stents, TR uses fiducials for edentulous (screws) or in its absence, and preferably structures that are naturally visible in the CBCT, such as teeth, abutments, and some types of restorations. Unlike the fixed fiducials with a stent and with a known shape, the structures that will be used as reference for DNS calibration must be sensed by the DNS before surgery through a "surface contact scan" called Tracer, used to trace between 3 to 6 short paths over regions within the arch, then the information obtained with the Tracer ball-tips are aligned with the CBCT data through the DN software.[11]

The TR protocol consist of three stepts:[11]

1. Plan: Prosthetically directed implant-surgery treatment planning with the CBCT data and 3D implant software.
2. Trace Registration: Based on tracing structures marked on the CBCT. The surgeon can then clinically verify the registration accuracy by touching the tracer's balls tip on the patient structures for TR and comparing the actual physical location of the tracer tip with its representation on the DN monitor.
3. Place: Navigated implant placement according to the plan. In real time, the depth, angulation, entry point of the drills and implant placement.

Trace Registration is at least as accurate as traditional registration methods involving a fiduciary marker and thermoplastic stent in DN surgery.[11]

Results and Discussions

The computer-assisted implant planning and surgery, based on computer-aided design (CAD), is possible thanks to the software that allows the data from the DICOM files (Digital Imaging and Communication in Medicine) of the CBCT scanner to be combined in a virtual environment with the data from the STL files (Surface Tessellation Language) of the intraoral scanner.[13,14]

Currently there is little information available in the literature that considers the time and costs of Dynamic Navigation versus Static Navigation and freehand approach. However, current evidence shows that the cost of DN is significantly higher than other available approaches.[13] Also we should consider that as technology advances, the costs associated with it are also decreasing and that these equipments are not yet, so widely used. DN technology is completely virtual, without the need to make templates or take analogous impressions, which makes it more environmentally friendly. There is also a learning curve with the application of a new technology for all levels of technological comfort.[3,5,7,8,9,11]

There is still little literature, however was generally reported that DN is at least as accurate as tooth-supported surgical guide systems for implant drilling and implant placement, and considerably more than the freehand approach. [1,2,3,4,5,8,9,10.] The advantage of DN are that any implant system can be used thanks to the open-sourced system.[9] While DNS can be visualized and remain stable, even in edentulous patient. More research should be conducted to confirm whether DN can be a better choice for the implant placement method than static guidance. [4]

Trace Registration technology provides a completely digital workflow, it removes the time consuming and technique-sensitive step of fabricating a custom stent before the surgical procedure, minimizes the need of second CBCT scan whit fiducials markers and improved the access to the surgical site, because surgery is not performed with thermoplastic stent in place. Thanks to this technology DN is more efficient and widely applicable.[11]

The biggest benefit of DN is that it allows you to check the accuracy all the time during the surgery which does not allow the static approach.[7] In 2020, robot-assisted dental implant placement has been performed with promising results, with small deviation (apical global deviation of 0.8mm, coronal global deviations of 0.9mm, and angular deviation of 0.53°)[15]

Conclusions

DN is a technology that has been advancing in its development to allow clinicians to work based on pre-surgical 3D planning and bring it to the mouth of our patients with high accuracy. This allows us to treat in a predictable way in terms of prognosis and with optimal results.

There is currently a great concern for the environment and all the digital technology that is already being used in dentistry today is a step in favor of eliminating polluting waste.

Studies are still needed to validate DN technology as the first choice for its results, for patient care versus static approaches.

Conflict of Interest

The author declares no conflict of interest. No funding was received for this review.

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I expressly declare that there is no personal or financial interest or conflict of interest of any kind between the author and the Nobel BiocareTM.

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