JAZ INDIA

Journal of Advanced Zoology

ISSN: 0253-7214
*Volume **44** Issue **04 Year 2023** Page **1002:1008***

Dynamic Navigation: Paving The Way for Accurate Implant Placement

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Article History

Received: 06 June 2023
Revised: 05 Sept 2023
Accepted: 04 Dec 2023

Abstract

Dental implants have become one of the most accepted treatments for the replacement of missing teeth over the last decade. Conventional or static guided approaches are almost arbitrary approach that are heavily dependent on the clinician's experience. Over the past several years, computer-aided implant placement (CAIP) protocols, which are based on digital workflows aimed at maximizing implant placement accuracy, have expanded the landscape of existing surgical options. The development of the dynamic navigation systems for placing dental implants is paving a way to overcome their drawbacks and provide reproduces the virtual implant position directly from computerized tomographic data and allows intra-operative changes of the implant position.

Keywords: *Dental Implants; Dynamic Navigation; Static Guided Approach; Conventional Approach; computer aided implant placement; 3D guided implant placement*

1. Introduction

Dental implants have been a common solution in clinics for restoring missing teeth. (1). Precise placement of implants is associated with favorable prosthetic results as well as extended stability of the peri-implant tissues and considerable implant longevity. (2). Recent advancements in dental implantology concepts have included computer-aided implant surgery (CAIS) to reduce variations from the virtually preplanned implant placement procedure (3). Compared to the free-hand approach, guided implant placement involves a less invasive surgical procedure, lowers surgical time and postoperative morbidity, and assists the clinician in avoiding major blood vessels, nerves, the nasal cavity, and the maxillary sinuses during the intervention. This method could support the long-term stability of the peri-implant soft and hard tissues while ensuring the prosthesis's best function, aesthetics, and biomechanics. (4)

History:

In the late 1997 dynamic navigation was introduced for oral maxilla-facial surgical procedures on the basis of contribution done by Enisilidis G, Wagner G and Ploder (11). In 2000 VISIT a new dynamic implant navigation system was introduced for implant placement. (12) The first dental implant navigation system to hit the market was the RoboDent® system (fig.1) (Berlin, Germany, 2001), which changed the course of dynamic surgery. It is currently unavailable for purchase 5.

fig.1-

The Canadian business ClaroNav produced the Navident® dynamic navigation system (Toronto, Canada, 2015), which is based on the same motion tracking technology as the Navient brand used in neurosurgery, otolaryngology, and orthopaedic surgery. (5)

In 2016, Robert W. Emery, Scott A. Merritt, Kathryn Lank, and Jason D. Gibbs carried out the first model study, placing implants in models under clinical simulation using a dynamic navigation system (X-Guide, X-Nav Technologies, LLC, Lansdale, Pa).

In 2017, Michael S. Block, Robert W. Emery, Kathryn Lank, and James Ryan conducted the first in vivo study in which implants were placed in the mandible and maxilla of patients using a dynamic navigation system (X-Guide, X-Nav Technologies).

Most recent dynamic navigation system is Navident 4 evo system (Toronto,canada)2022.(fig.2)

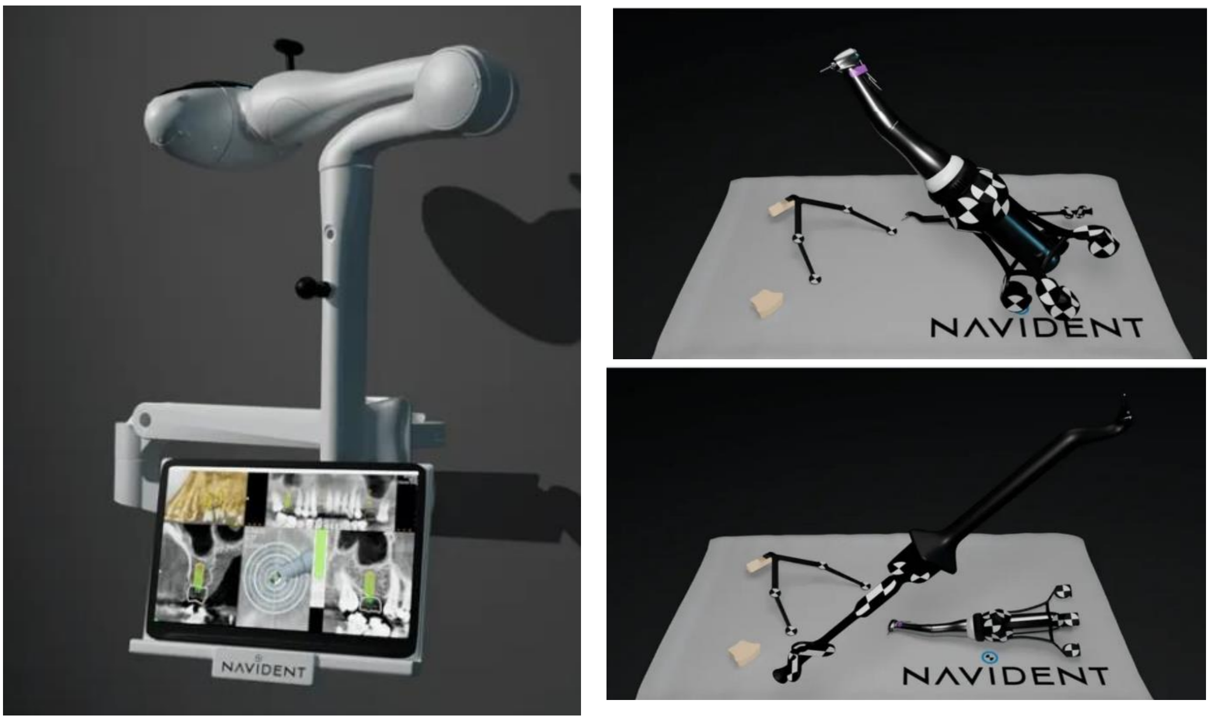

Fig.2-

Types of implant approaches

Conventional free-hand (8,9)

Panoramic and periapical radiographs are utilized in free-hand surgery to gauge the width and alveolar bone profile available for implant placement, investigate the surrounding anatomy, and ultimately rely on CBCT imaging.

The adjacent teeth may also be utilized as a reference to aid in position the implant precisely.

Static Guides

Static navigation systems enable the predefined implant position to be reached without real-time visualization by employing computer-aided design and computer-aided manufacturing (CAD/CAM) technology to create stents to guide drill instrumentation. (6)

Stents with metal tubes are created by a static system using CT-generated computer-aided design and manufacturing, while a surgical system inserts implants using the guide stent through coordinated instrumentation. (7)

Dynamic Navigation

The dynamic navigation systems that are currently in use track the patient and the hand piece using optical technologies and project images onto a monitor. Either active or passive tracking arrays are used by the optical systems.

Tracking arrays are used in passive systems to return light from a light source to the stereo cameras. (fig.3)

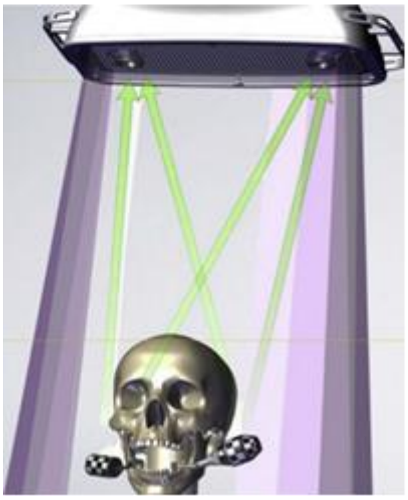

Fig.3

Stereo cameras track the light emitted by active system arrays. (7)

General components of the dynamic navigation system (10)

1. Graphic processor on computer.
2. Monitor: A visual aid for the staff and surgeon.
3. Volumetric surgical tracking cameras.
4. Fiducials in the digital-analog interface.
5. Dynamic reference frame: Patient tracking array.
6. Patient effectors in the instrument array.
7. Software for Tracking.

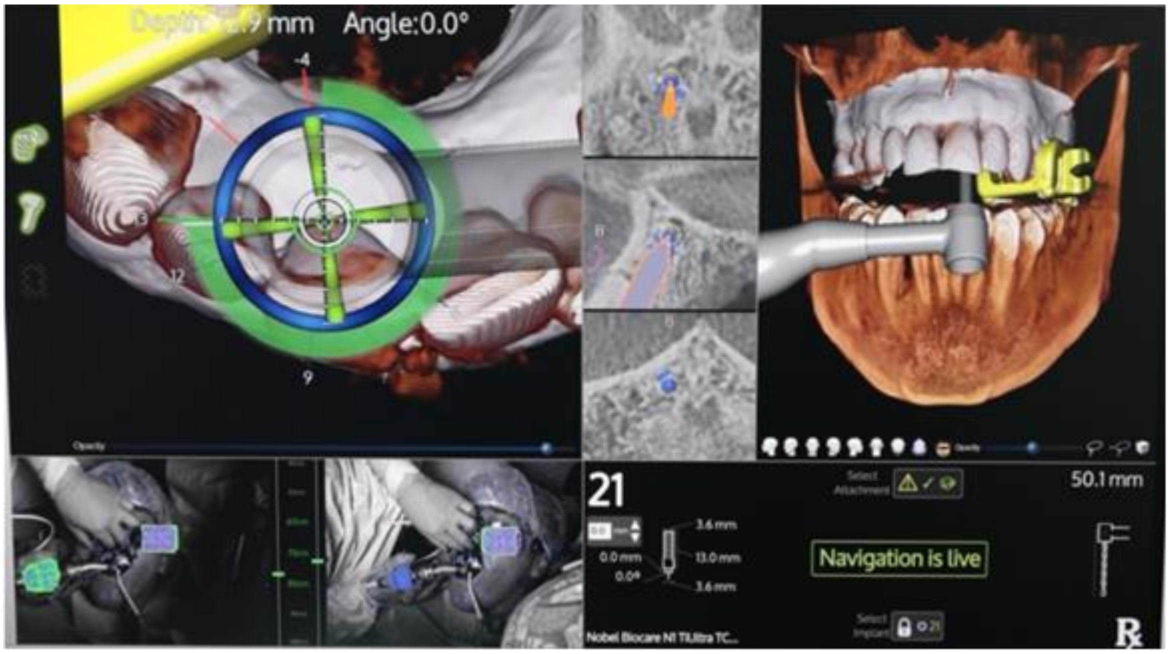

Fig.4

Steps:(7) (fig.4)

1. Fiducial markers that are securely affixed to the patient's arch must be used by a passive optical dynamic navigation system during CBCT scanning.
2. With the addition of an array, the device containing the fiducial markers enables the registration of the arch to the cameras.
3. An extraoral joining of the clip containing the fiducial markers to the array is made. Accurate navigation is made possible through triangulation using the array on the implant handpiece and the fiducial markers on the clip.
4. To precisely follow the drill and patient-mounted arrays on the monitor, they must be in the line of sight of the overhead stereo cameras.
5. If required, a small flap could be made to expose the crestal bone.
6. The standard drilling procedure for implant sites is followed.

Indication (15)

1. It is recommended for individuals with restricted oral opening who are inaccessible.
2. It is beneficial in areas with narrow interdental spaces where static guides are impractical due to the tube's size in close proximity to the natural teeth.
3. In situations where static guide tubes will interfere with ideal implant placement.
4. to achieve the best possible implant placement, angulation, and esthetics right away. (16)

Adv and drawbacks over free and static:

Advantages:(7,13,14)

1. The patient can have a single visit that includes planning, scanning, and surgery all on the same day.
2. Better guidance with respect to anatomical considerations.
3. When clinical circumstances demand it, the plans can be modified in-situ, giving the surgeon the ability to modify the system's size and configuration.
4. Access to posterior teeth is made simple by the constant visualization of the entire field.
5. Accuracy can always be confirmed, which enhances accuracy. Allows for complete treatment in one location.
6. Reduces multiple guides and visits are no longer necessary.
7. Minimal trauma to the surgical site as it involves a less invasive approach.

8. Overcomes inherent inaccuracies of human vision.
9. Provides good ergonomics by eliminating the need to bend the neck or back while placing the implant.

Drawbacks (14)

1. Investment of the equipment is required.
2. Cost is high.
3. The process has a learning curve.
4. In edentulous patients, additional surgery required for the placement of fiducial marker and tracking arrays.

Types of Dynamic navigation system available (21-32):

Dynamic navigation system	manufacturer	Year of launch	Mode of tracking	Studies	Result (horizontal apex deviation)
VISIT	University of Vienna, Austria	2000	passive	Wittwer G et al. Int J Oral Maxillofac Implants. 2007	0.7 mm
Robodent	RoboDent, Garching, Germany	2001	passive	Cecchetti F et al.J Biol Regul Homeost Agents. 2020	
IGI system (AKA DenX)	DenX advance system,israel	2001	active	1. Casap N et al. J Oral Maxillofac Surg. 2004 2. Casap N et al J Oral Maxillofac Surg. 2008	less than 0.73 mm less than 0.5 mm
Medtronic StealthStation Treon	Medtronic, Minnesota,US	N.A	passive	Wittwer G et al.Int J Oral Maxillofac Implants. 2007	Error 0.9 mm
Taiwan- dental navigation system	AQNavi, TITC Ltd., Taiwan	2014	passive	1. Kasten et al 2018 2. Sun, Ting-Mao et al. International Journal of Environmental Research and Public Health 2017	0.4mm 0.73 ± 0.13 mm
Navident	Claronav, toronto	2014	passive	1. Böse MWH et al. J Dent. 2022 2. Jorba-García A et al. Med Oral Patol Oral Cir Bucal. 2019	0.32 ± 0.22 mm 0.5mm*
X-Guide	X-Nav technologies	2014	passive	1. Ma et al. BMC Oral Health 2023 2. Stefanelli LV et al. Int J Oral Maxillofac Implants. 2019	1.60±0.94 mm 1.00 (0.49) mm
Dcarer DNS system	Suzhou Digital-health care Co., Ltd.®, Suzhou, China)	N. A	active	1. Bin-Zhang Wu et al, Journal of Dental Sciences, 2023	1.086 ± 0.667 mm
ImplaNav	BresMedical, australia	2016	passive	1. Gerargdo et al ,2019 2. Pellegrino G, Bellini P et al. Int J Environ Res Public Health. 2020	1.35 ±0.56mm 1.61 ± 0.75 mm.

4. Conclusion

is Accurate positioning of the implant is a necessity for the prolonged stability and functioning of dental implant. Ultimate aim of which is to rehabilitate the patient in with respect to suitable profile, aesthetics, health and phonetics. The dynamic navigation system certainly aids in achieving this aim with novel techniques, using advanced imaging and tracking arrays, minimal invasiveness with high regard for dental hard and soft tissues, and precise anatomical considerations. With effective learning curve and experience of operator's dynamic navigation can increase the success rate of the implant prosthesis.

Future prospects:

Emerging technology known as augmented reality (AR) has demonstrated a growing number of uses in various medical fields. When utilizing AR in conjunction with dynamic navigation instead of 2D navigation techniques, Jiang et al. showed a reduced error in the incisive and canine regions implant placement. (33)

The first computerized navigation robotic system in the world, YOMI offers physical guidance of the drill's depth, orientation, and position, preventing the need for the operator to stray from their hand and fabricate surgical guides on-site. (34)

The term "four-dimensional (4D) printing" refers to the process of creating intricate, spontaneous structures that adapt to external stimuli in predictable ways over time. This process includes the growingly popular bioprinting technique. (35)

Additionally, 4D-printed materials are adaptable to the various forces present in the oral cavity, regardless of their direction or type. 4D-printed prosthetic materials can have good dynamic properties and consistent fitting and retention because of their self-folding nature.

4D printing can be utilized to swiftly create intelligent dental implants. Without undergoing any post-processing steps, a high-power laser beam is focused to fuse metal particles to a powder bed, creating the proper implanter design layer. During the 4D impressions, materials like hydrogels and polymers may be used. (36)

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