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A REVIEW ARTICLE

COMPUTER NAVIGATED IMPLANT SURGERY – A NARRATIVE REVIEW

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ABSTRACT

Dental implants are the recently resorted treatment of choice for the replacement of missing teeth. Computer-navigated implant surgery helps clinician in real time during the implant positioning with the help of visual imaging tools on a monitor. They were introduced to overcome the complications associated with the free-hand implant placement. Computer guided navigation surgery on the other hand, helps the clinician to evaluate, scan, plan and place the implant intra-orally on the same day.

KEYWORDS: Navigation system, computer guided surgery, cone beam computed tomography, jaw tracker, three-dimensional imaging, guidance error

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INTRODUCTION

The advent of Cone beam computed tomography (CBCT) in the 20th century revolutionized the field of diagnostic imaging. Implant guides were manufactured with the help of both Computed tomography (CT) & CBCT imaging, but the use of CBCT reduces the amount of radiation exposure to the patient than CT imaging.[1] The implant guides are of two types – static guides & dynamic guides. Static guides transfer implant position virtually with the help of a CT/CBCT data to the site of operation. These guides thus manufactured can be a fully limiting guide or a partially limiting guide.[2] The prime setback associated with a static guide is that, treatment plan cannot be altered with already existing surgical guide. Discrepancies in method of fabrication of guide, fit of the guide, minor movements of the guide during surgical procedure are some of the factors that limit the usage of static guides.[2] Computer navigation surgery, in the field of medicine has been used in craniofacial surgery, neurosurgery, orthopedic, spinal surgery and it is also available in the field of dentistry.[3,4] Computer-navigated surgery (dynamic): use of a surgical navigation system that directly reproduces the virtual implant position from the CBCT data and allows for intraoperative implant position changes. CNS is considered to be the most effective way in transferring, planned implant's position to the real patient as it guides surgeons' motions using a real-time feedback.

OPTICAL TRACKING

Optical tracking is a means of determining in real-time the position of an object by tracking the positions of either active or passive infrared markers attached to the object. The position of the point of reflection is determined using a camera system. CNIS, involves the tracking of dental instruments and also the patient's head. They are considered to be the most accurate, efficient, and reliable localization system. There are 2 types of optical tracking: active type & passive type.

Active tracking system arrays emit infrared light which is directed to stereo cameras. Passive tracking system arrays also emit infrared light, which is reflected by the reflective spheres with passive markers to a camera. The patient and implant drill must be in the line of sight with the tracking camera. Out of these two technologies the most commonly used is, the passive type.[5,6] In case of passive CNIS, ray of light is projected from a light emitting diode source that is above patient's head. From here, light is projected down to the surgical field & patient. It is reflected off the tracking arrays, which are attached to the patient and surgical instrument being tracked. Reflected off light is perceived by pair of stereo cameras above patient's head.[7] Position of the patient and surgical field relative to presurgical plan is calculated, followed by the projection of a virtual image on the monitor for the view of staff & surgeon.[8]

COMPONENTS OF CNIS

Basic components of CNIS include dynamic navigation software, handpiece attachments, jaw attachments (fiducial screws & clips), motion tracking device, optical sensors and a compact mobile kart.

WORKING OF CNIS

The working protocol can be outlined as follows: calibration and registration of instruments used during surgeries followed by performing "navigation surgery".

CALIBRATION OF INSTRUMENTS

The instruments such as contra-angled handpiece, straight handpiece, probe tools that are to be tracked during surgery, will have to be calibrated prior to surgery. Parts of instruments are placed before stereo cameras so that software can learn their geometry. Geometry of tracking arrays from instruments must be determined by tracking system.[8]

TRACE REGISTRATION

The patient jaw and the surgical drill location are tracked by the navigation system's tracking camera, with the help of special tags affixed to them. To correspond between the physical or actual patient's jaw and its on-screen cone beam computed tomography (CBCT) scan representation, the tag that is installed on the patient's jaw must be mapped with the CBCT scan which is nothing but linking physical space coordinates of the patient to patients' image coordinates. Such mapping of the trackable jaw tag to the CBCT scan is called "registration".[9]

Before registration, patient needs to be CT-scanned with an artificial radiographic marker, known as "fiducial markers" or "fiducial screws", that has to be later identified in the CT images by the navigation system's software in order to enable the registration. Process of registration differs between dentulous & edentulous individuals. The patient tracker and the edentulous fiducial screws are then registered to the DN system by touching the screws (fiducials) with the probe as the system tracks them. For the dentate patient, the fiducial clip attached to a patient tracker arm and patient tracker is registered automatically by the system at the time of calibration. Prior to the start of surgery and after every drill bit is changed there is a "system check" performed by the doctor. This step ensures the instruments are calibrated and the system is properly registered to the patient.[8]

USE OF MARKERS

In dentate individuals, these fiducial clips/markers are used for taking impression of patient's teeth and also acts as reference points.[10] Fiducial clips, must be seated exactly at the same location, every single time it is being inserted in patient's mouth, ensuring its firm attachment to the tooth surface and not impinging soft tissues. Fiducial clips are inserted in the arch where implants are placed but doesn't interfere with implant placement.

Edentulous fiducials are nothing but small screws that are inserted into bone acting as points of reference during CT scan. Screws can be inserted through stab incisions made apical to mucogingival junction or directly into bone upon reflection of flap.[11]

Screws can be of 4mm, 5mm length. Former, used in areas of dense cortical bone in mandible while latter can be used in areas of maxilla. Fiducial screws have to be self-drilling, self-tapping & stable. Disadvantages associated with screw type fiducial markers are that they are invasive, need additional surgery, may cause infection, patient discomfort, and therefore should not stay in place for an extended period of time.[12]

Therefore, non-invasive techniques were developed. Denture-fixed radiographic scan templates that were provided with fiducial markers to serve as registration templates came into use.[13] External registration frames, known as "jaw tracker" with fiducial markers were mounted to scan templates.

Under optimal conditions, registration templates (or) external registration frames provide registration accuracy similar to that of the fiducial bone markers.[14]

COMPUTER NAVIGATION IMPLANT SURGERY

Once after registration is done, the navigation system is ready for surgical use. The tracked surgical drill and the dynamic reference frame should be continuously recorded by the stereoscopic camera. As visualized on the computer screen, special guidance views help to locate planned implant position and to follow that implant path into the bone.[15,16] The navigation software indicates the accuracy of the drill's position and its angulations with the actual drilling still depending on the manual skills of the surgeon.[17] It is important to always confirm the accuracy of the tracking system. Anatomical landmarks on the patient are located with the instruments that is visually confirmed with the radiographic landmarks on the screen and they must be exactly correlating with each other.

The ideal landmarks are adjacent teeth or bony landmarks close to the planned implant site or fiducial markers in edentulous patients. The operator looks at the screen as the drill is positioned over the surgical site. The navigation system screen will allow complete viewing of a virtual drill demonstrating,

i) the depth in tenths of a millimetre

ii) angular deviation of the drill axis from the planned implant axis to the tenths of a degree

iii) implant timing.

The tip of the drill, a blue dot, is positioned over the target to indicate ideal planned platform position. The top of the drill a small circle is then centred over the blue dot to indicate ideal planned angle. Depth is indicated by colour, yellow, green the red. The planned depth is always at the 450 position on the target. The surgical assistant is in charge of suctioning and looking into the surgical field to notify the surgeon of any irregularities such as lack of irrigation or grossly off-positioned drill placement. As implant drilling occurs, the depth indicator can change its as it approaches target depth and also indicating when to stop the depth of the osteotomy. During the implant surgery the implant size, width, type and location can be adjusted based on intra-operative factors deemed necessary for a stable and appropriately restorable implant.

ACCURACY WITH CNIS

CNIS allows highly accurate implant placement with a mean angular of less than 4° but a 2-mm safety margin should be applied, since deviations of more than 1 mm were observed. Dynamic navigation surgery increase the implant placement accuracy when compared with freehand implant placement and also is known to slightly decrease the angular deviation when compared with static implant navigation systems.[18] CNIS offers better accuracy during implant surgery for the dental surgeon. It is useful for real-time visualization of the important anatomic structures during dentoalveolar surgery.[19] Comparing the accuracy of free-handed (FH), pilot-drill guided (PG) and fully-guided (FG) implant surgery in partially edentulous patients, it was concluded that, when a perfect implant positioning is required, fully guided surgery was considered the gold standard approach and that the maximum apical deviation from the ideal implant position amounted to nearly 5mm for Free-handed implant surgeries, 3mm for Pilot-Drill guided surgeries and 2mm for Fully-guided surgeries.[20] After the static computer-guided implant surgery, evolved the concept of "navigated implantology" that provided significant advantages in treatment planning and helped dentists carry out successful implant rehabilitation. Dynamic navigated computer assisted surgery systems allow more accurate implant placement when it is based on an accurate 3D CT-based image data and an implant planning software which minimizes discrepancies and simplify the surgical technique.[21] Comparing the deviations of planned and placed implants that were placed by the assistance of a micron tracker-based dynamic navigation device or freehand methods, studies concluded that dynamic navigation device transferred virtual implant planning to the patients' jaw with utmost accuracy [22]

CLINICAL APPLICATIONS:

Use of CNIS is indicated in partially and fully edentulous patients, flapless surgeries, difficult anatomic situations, after tumour surgeries, zygoma implant surgeries, removal of tumours and foreign bodies, orthognathic surgeries, temporomandibular joint surgeries, skull base surgeries, education and training purposes.[15,16]

CNIS is superior over static guided and free-hand implant placement in the following ways: Scanning, implant planning, surgical placement can be done in a single appointment, using a flapless approach promotes easy healing of soft tissue, patient comfort, minimally invasive, reduced resorption of bone, allows implant planning modification even during treatment, used in areas of limited opening, can be employed with any implant system/drills, improved irrigation, used in areas with limited inter-occlusal & interdental distance.[9,10]

Certain limitations associated with CNIS includes, employing dynamic navigation in routine dental practice definitely requires significant investment, in addition to CBCT and imaging software and custom-made use of fiducial clips, markers, and plates. Those dentists with limited experience with such advanced technology and virtual image processing would often find it difficult to adapt themselves to this new modality of practice. There is always a learning curve with the application of a new technology for all levels of technological comfort. When the learning curve for dynamic navigation system was evaluated, it was found that the surgeon become statistically equivalent, proficient, after 10 to 20 implants placed with this system.[23] Another drawback is that the current FDA approved systems for edentulous patients require the additional surgeries for the placement of fiducial screws and tracking plates. Both dentulous and edentulous patients must also have a potentially cumbersome tracking arms attached to their mouth for tracking purposes.

CONCLUSION

With significant achievements established in the field of computerized implant-dentistry, implant placement has become highly accurate and predictable, even in patients where implant surgery was previously not indicated. Attempts are now being made toward complete automation of implant-dentistry. Yet, keeping the limitation of high radiation dose, computerized implant-dentistry must be limited to anatomically complicated cases. Future tasks include advanced intraoperative imaging techniques for navigated surgeries along with sophisticated mechanized surgical tools and new robotic developments, which will revolutionize the field of implantology. The computer navigation implant surgery incorporates the use of radiographic imaging, imaging software with motion tracking system. This allows accurate transfer of virtual implant planning into patients' oral cavity and aids in precise rehabilitation. Various studies have been published so far confirming the accuracy of dynamic implant navigation over static-guided implant placement & free-hand implant placement. However, high cost of navigation system, its updates & maintenance will not be feasible for dental surgeons.

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DISCLOSURE OF INTEREST:

The authors declare that they have no competing interests.

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