Futuristic trends in dental Implant surgery: Robotic assisted dental implant surgery with an autonomous dental implant Robot (ADIR)

The extensive application of robotics in the field of medicine owing to standardizing new approaches for better treatment has been undertaken since last few years. The field of Dentistry has also upgraded it's techniques for better efficiency in surgery with minimal invasiveness . Optimal implant positioning serves as the foundation for ensuring the extended viability of dental implants and achieving pleasing restorative results. Utilizing computer-assisted guidance techniques, both static and dynamic, has been employed to enhance the precision of implant placement[1]. One of the future trends in Oral and Maxillofacial surgery in India shall certainly unveil the application of Robotic assisted implant surgery technology as the latest technique for improved accuracy while performing conventional implant surgery keeping low invasiveness at it's best interest and also for extending surgical expertise .
Guided implant therapy has gained widespread popularity as a method for dental implant placement. Nevertheless, the technologies linked to guidance have undergone significant advancements in recent years[2].
Furthermore, the continuous expansion of surgical skills aligns with the pursuit of utilizing innovative technological solutions to ensure comprehensive precision and accuracy. It is imperative for healthcare professionals to harness advancements in imaging and planning technologies to meet patient expectations for efficient treatment processes and impeccable outcomes in terms of both function and aesthetics. In contrast, freehand implant surgery depends on the expertise of the surgeon, which introduces uncertainty regarding the accuracy of implant placement.

Digital Imaging

The benefits of digital imaging is highly undeniable while planning through surgical intervention for overall
precision

Methods of guidance :

Static and Dynamic navigation for implant placement

DDS Labs provides three distinct types of surgical guides designed to accommodate the unique requirements and personalized treatment plans of patients undergoing implant restoration surgeries. These options comprise the SAFE Guide, Universal Guide, and Pilot Guide. The static computed tomography (CT)-generated guide stent, when employed alongside a coordinated system of specific drilling procedures, generally results in deviations from the intended position of less than 2 mm at both the crestal and apical levels, as well as an angulation error of fewer than 5 degrees.
However, it's worth noting that navigation methods generally exhibit higher precision compared to conventional approaches[3]. While CT-generated static stents have considerations related to workflow time and cost, dynamic navigation offers a time-efficient approach for maintaining overall precision during implant placement. Nevertheless, it's important to acknowledge that there remains a possibility of error in implant placement, even with these advanced methods.
The major dubiety is about the choice of the practitioner to implement either of the Static system or Dynamic navigation system. Let's keep all the basics upfront:

* Navigation allows minimal invasiveness by allowing limited flap elevation, which lead to limited post-operative morbidity to the patient.

* The system enables precise spacing and angulation of implants, in contrast to the less precise nature of freehand approaches.

* Facilitates precise depth control but elevates the potential risk of damaging the Inferior Alveolar nerve.

* Utilizing virtual implant planning and subsequent navigated placement ensures that the implant is positioned with the correct angulation and depth for aesthetic scenarios.

* By using virtual implant planning and navigation, the prosthetic and surgical teams can collaborate precisely and execute the plan accurately, achieving results that are specific to each patient.

Nonetheless, to utilize CT-generated static stents, individuals must incur costs for both the software and the production of the guide stent. While in case of Dynamic navigation system, one has to pay for the computer system with arrays. The only recurring cost is the patient - specific clips, which is relatively cheap. Now let's move to the individual systems.

Static Guides :

A static system employs computer-aided design and computer-aided manufacturing, utilizing CT-generated data to produce stents equipped with metal tubes. This method involves the placement of implants through the use of a stent custom-designed and manufactured according to CT images of the patient(fig 1). The metal tubes guide the instruments to insert the implant in the exact position that was planned. Once the stent is in place, it is not possible to alter the implant's position(fig 2). Before conducting a cone-beam CT (CBCT) scan on the patient's mouth, it is essential to have a laboratory-crafted imaging guide aligned with the prosthetic plan. This guide serves as a crucial component in the creation of a CT-generated surgical guide for static navigation. This procedure has the potential to result in time inefficiencies and additional expenses for both the medical team and the patient. There is a possibility that digital approaches may eventually supplant the need for the imaging guide. The CT planning software requires access to CBCT Digital Imaging and Communications in Medicine (DICOM) data, and proficiency in its usage necessitates training. Certain clinicians may not achieve proficiency with the software and might opt to engage a third party to oversee case planning. The team subsequently uploads the finalized plan to the stent manufacturer, after which either a physical model or an optical scan of the arch is required to fabricate a precision-fitting dental guide. This process necessitates the creation of impressions, the use of stone, and the development of models, all of which contribute to the time and expenses associated with the static CT-guided approach. The stent manufacturer conducts a quality control assessment on the uploaded scan, although the clinician may need to repeat it if the guide does not align properly with the teeth or tissues. Following these steps, it typically takes two weeks before the surgical guide is ready, and the surgery can commence thereafter. The cost for static CT-generated guides varies by maker. The pricing of static CT-generated guides fluctuates depending on the manufacturer. These guides necessitate preoperative procedures and come with additional expenses. Furthermore, some clinicians may be reluctant to thoroughly acquaint themselves with the planning software. All of these factors combine to create a workflow obstacle when considering the adoption of static CT-generated guides. When employing a CT static guide, the surgeon must ensure they have the appropriate surgical kit tailored to the specific implant system. This is crucial because altering the implant choice becomes challenging once the CT guide stent is in use. In surgical procedures, it's important to note that the implant's position cannot be adjusted unless the surgeon opts to discontinue the use of the CT guide stent. Furthermore, the CT-generated guide stent complicates the irrigation of the drill during the process. Access to the bone is limited, potentially leading to increased heat generation.

Therefore, employing Static Guides presents challenges when patients have limited mouth opening or require implant placement in the posterior regions of the oral cavity. In such cases, the drill length and the extension needed for precise depth control may exceed the patient's mouth opening capacity, with this issue exacerbated in the posterior regions of the mouth.

(1) (2)

FIGURE 1. A static guide generated through computed tomography for a patient with edentulism.
FIGURE 2. Several implants were positioned in predetermined locations, following the guidance of the computed tomography-generated static guide. While the guide facilitated precise implant placement, it's important to note that the static nature of the guide stent meant that no adjustments could be made to the plan during the guidance process.

Accuracy Considerations:

CT-generated guide stents are generally more accurate in placing implants than less precise methods like bland or model-based non restricted guides, particularly concerning the implant's position, platform, and depth control. However, it's important to note that CT-generated guides are not entirely error-free. Deviation values typically fall within the range of 0.6 to 1.5 mm at the implant apex and 0.6 to 1.27 mm at the shoulder, with variations contingent upon whether the guides receive support from mucosa or teeth. Regarding deviations in implant angulation from the intended position, they often fall within the range of 2.5 to 5 degrees, typically leading to shallower placements than initially planned. The precision of CT-generated guides may exhibit variability among clinicians, with certain practitioners achieving greater accuracy in implant placements than their peers. Remarkably, when comparing experienced surgeons to their inexperienced counterparts, no notable disparity in implant placement accuracy was observed when employing CT-generated stents.

In scenarios that encompass guided surgery (both mucosa and bone-supported) as well as free-hand implant placements or surgical templates in fully edentulous jaws, the group that used guided implant placement typically displayed a 1.4 mm deviation at the entry point, 1.6 mm at the apex, and 3.0 degrees in angular deviation. Conversely, the free-hand techniques registered greater deviations, with 2.7 mm at the entry point, 2.9 mm at the apex, and a pronounced 9.9-degree angular shift. On the whole, CT-generated guidance approaches seem to adhere more accurately to the envisaged virtual positioning [3].

Advantages:

* Places implants accurately by using a flapless method.
* Moreover it is able to make fixed provisional restorations before surgery.
* Furthermore, static CT-generated stents typically necessitate less invasive surgical procedures, leading to reduced patient morbidity.

Indications:

In cases involving edentulism, a CT-generated static guide should be employed when:

* When opting for a method without the need for a surgical flap.

* The CT-generated static guide can facilitate the preoperative creation of a provisional prosthesis using models derived directly from the guide.

* When the clinician aims to employ a bone reduction guide to precisely allocate space for the intended prosthesis.

* Precise implant placement is paramount when considering a fixed crown and bridge type prosthesis for a complete arch.

Dynamic Navigation:

Dynamic navigation systems for dental implant placement use visual technologies to monitor the patient and the hand piece and to show images on a screen [3].

The visual systems use **PASSIVE** or **ACTIVE ARRAYS** of trackers.

Passive systems utilize arrays that bounce light from a source to stereo cameras, whereas active system arrays emit light that the stereo cameras track. In the instance of a passive visual dynamic navigation system, exemplified by X-Nav Technologies, Inc. in Lansdale, PA, the procedure necessitates the placement of fiducial markers on the patient's arch during CBCT scanning. (fig-3)[3]. These markers assist in synchronizing the arch with the cameras, and an array is affixed to them. Notably, this array is positioned outside the patient's oral cavity and links to the clip bearing the fiducial markers. Moreover, the implant handpiece is equipped with its own array. When integrated with the fiducial markers on the clip, this configuration allows for triangulation, ensuring meticulous guidance (fig 4)[3].

To achieve precise tracking and optimal visualization on the screen, it is imperative that both the drill and the arrays affixed to the patient stay within the field of view of the overhead stereo cameras[3].

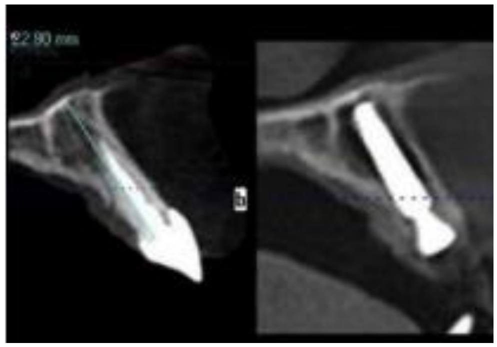
If necessary, the surgeon creates a minor flap to expose the crestal bone and then employs the standard drilling procedure for the implant site. Throughout this process, the surgeon primarily relies on the navigation segment for guidance, minimizing direct observation of the drill within the patient's mouth. The dynamic navigation procedure initiates with the fiducial markers positioned on the arch. A clip, equipped with three metal fiducial markers, is attached to the patient's teeth in a region not designated for surgery. Should an aesthetic plan be implemented, teeth containing radiopaque material can remain in the mouth, serving as an imaging guide to assist in determining the virtual implant position subsequently. A CBCT scan is conducted with the clip in place. After the scan, the clip can be removed and preserved for the surgery. This DICOM dataset is then transferred to the navigation system's computer. Subsequently, a virtual implant is positioned. This task is straightforward, ensuring that clinicians with minimal computer expertise can effectively handle it. The available implants are generic, characterized by platform diameter, apical diameter, and length adjustable in 0.1-mm increments. As needed, the implant's position can be adjusted.

During surgery, the clip housing the fiducial markers is equipped with an array. It's essential for the medical team to synchronize the clip, now attached to the array, and the handpiece, which possesses similar arrays, with the navigation system. Surgeons can administer conventional anesthesia and make minimal incisions with limited flap reflection. It's imperative that the clip array is securely reattached to the arch. Any drill lengths should have been predetermined and registered prior to this step. Finally, the surgeon positions the patient and arrays so they remain within the field of view of the overhead cameras[3]. Three-dimensional visuals on the display illustrate the optimal orientation for the drills, encompassing depth guidance. The surgical assistant should manage irrigation, retraction, and suctioning, following standard procedures. Depending on the clinician's preference, the implant can be inserted either entirely or partially by hand. (fig 5)[3].

FIGURE 3- A clip containing fiducial markers is positioned in the patient's mouth prior to the cone-beam computed tomography (CBCT) scan. These fiducial markers facilitate the registration of the patient's maxilla, enabling triangulation during the implant placement procedure.

(4A) (4B)

FIGURE (4A)-,Overhead lights emit blue light, which is then reflected by the arrays on the clip within the patient's mouth and on the handpiece back to two cameras.
FIGURE[4B)-, A line drawing illustrates the emitted light originating from the blue lights within the overhead array, subsequently reflected back to the two cameras positioned in the same overhead array. The resulting three-dimensional graphics are then showcased on the navigation screen.



(5A) (5B)

FIGURE [5A]. Cross-sectional images portraying the preoperative perspective.

FIGURE (5B), A genuine postoperative cross-section reveals the implant in its designated position. The implant site was meticulously prepared using the dynamic navigation system and then precisely placed under its guidance.

Accuracy Considerations:

Research conducted by Chiu et al, Kramer et al, Brief et al, and Casap et al suggests that dynamic navigation systems possess an entry error of approximately 0.4 mm and an angular deviation error around 4 degrees. While clinical studies have been limited, they indicate that the success rates of implants are comparable to those of traditional drilling techniques.

Advantages:

The dynamic navigation method has some benefits.

* It is accurate, saves time and money, and lets the clinician change the implant size, system, and location during surgery.
* Dynamic navigation, in addition to requiring less invasive flap reflection compared to free-hand methods, also offers advantages to the surgeon. This includes a more ergonomic posture, reducing strain on the back and neck.
* Dynamic navigation is applicable for patients who may experience difficulty in mouth opening or necessitate an implant at a challenging-to-reach site, such as the second molar area. It aids in precise implant placement by employing the navigation screen to guide the drills, obviating the need for direct visual inspection within the patient's mouth.

* Mastering the use of a dynamic navigation system involves a learning curve. Medical data suggest that clinicians may require 15 to 125 cases, contingent on the specific procedure and the utilization of surgical simulators, before achieving proficiency in novel surgical techniques.
Effective utilization of a dynamic navigation system also necessitates a collaborative team approach. The surgeon and the first assistant must establish a seamless working partnership to efficiently operate the dynamic navigation system.

Indications:

Dynamic navigation is recommended for any of the following scenarios:

*Placing implants in patients with a limited mouth opening.
* Dynamic navigation is advised when implant placement is scheduled for the same day as the CBCT scan.
* Placing implants in hard-to-reach locations such as the second molar.
* Dynamic navigation is recommended for implant placements in situations where direct visualization poses a challenge.
* Dynamic navigation is the preferred choice for implant placement in narrow interdental spaces when the use of static guides is precluded due to tube size limitations.
* Dynamic navigation is the favored option for implant placement in close proximity to natural teeth, especially when static guide tubes would obstruct the achievement of optimal implant positioning.

Propositions:

he selection of the most appropriate method for a specific situation becomes more evident as the clinician gains greater experience and surgical proficiency. As time progresses, dynamic methods may gain wider acceptance due to their streamlined workflow, which enhances both efficiency and cost-effectiveness.
Nonetheless, it is essential to acknowledge that dynamic navigation in dentate patients hinges on the presence of teeth, serving as stabilizers for the registration clip and array. Consequently, it should not be employed in cases involving provisionally cemented restorations or mobile teeth.
Furthermore, complexities arise when implanting molars in areas where direct visual access is limited, particularly in patients with restricted mouth openings or crestal bone depletion. Such circumstances frequently call for the incorporation of drill extenders. When aiming to position implants with precise spacing between them and adjacent teeth, both static and dynamic systems offer viable solutions. The clinician's decision between these two options hinges on their level of experience and the unique demands of the specific case. Dynamic navigation provides versatility, affording the clinician the capacity to adapt the surgical plan as circumstances require throughout the procedure. Furthermore, it obviates the necessity for laboratory procedures, facilitating real-time scanning, planning, and guidance, all attainable on the same day as the patient's initial consultation. It is imperative for clinicians to recognize that achieving proficiency in dynamic navigation entails a period of learning and adjustment.

Limitations of the above systems and the Advantages of ADIR technology for implant placement:-

Static guides and dynamic navigation represent two frequently employed methods aimed at improving the precision of dental implant surgery when compared to freehand procedures. Nevertheless, static guide technology does have its inherent limitations. It lacks the capability for intraoperative adjustments concerning implant position and angle, and there is the potential for the guide plate to disrupt the cooling process during surgery. Moreover, the accuracy of dental implant surgery using a template relies significantly on the operator's level of expertise.

On the other hand, dynamic navigation technology delivers real-time feedback regarding implant position, angle, and depth throughout the surgery. However, it's not without its challenges. For instance, it necessitates that the surgeon split their attention between a display screen and the actual surgical site, which might potentially influence their confidence and efficacy. Furthermore, dynamic navigation operates without physical constraints, and since the surgery involves the use of a hand-held instrument, the surgeon's precision could be at risk. Exploration into implant placement has also encompassed the realm of robotic assistance. In a 2021 animal experiment conducted in China, Bai, Ren, and Feng et al. developed and tested an autonomous dental implant robot (ADIR) to evaluate its viability and safety.

About the ADIR technology:

The technology works by a Robotic assisted dental implant surgery assisting the ARCHPOINT surgeons in guiding implant post into the correct spot while allowing same day surgery avoiding invasiveness for traditional implant surgery.

The **virtues** of this technology concerning the ARCHPOINT surgeon throughout the process include:-

1. Control with precision :
For obtaining better accuracy while maintaining trajectory, the Robotic assistant helps guide the surgeon's hand with precise controlled angles, including tracking patient's motion for overall decisiveness.
2. Perform Complex procedures:
Cases that do require efficiency and accuracy for their procedures with complex tooth problems adjure robotic assisted surgery.
3. Obtain Visual and Audio Data:
The enormous aspect of using Robotic assisted surgery include recuperating visual and audio clues during the treatment to counter the possibility of unintended movement.
4. Faster Recovery times:
Better decisiveness of the technique promotes the surgeon to make smaller incisions into the gum line to promote rapid recovery time overall.
5. Provide successful treatment:
Safe investment of Robotic implant with Robotic assisted aid and the cases which is indicated for minimally invasive surgeries is highly intended.
6. Extending surgical expertise.
7. Technologically Augmented Workflow[4]:
Robotic guidance ensures consistent surgical precision throughout the procedure, bringing the practice one step closer to achieving a genuinely digital workflow.

The subsequent flowchart illustrates the clinical workflow for implant placement using the ADIR (Autonomous Dental Implant Robot) system. [1] : —

Preoperative procedure:

Data acquisition

Preoperative planning

Accessories Fabrication

Intraoperative Procedure:

Registration

Path Recording

Osteotomies and implant placement

Accuracy Assessment

Immediate Restoration

Definitive Restoration

Postoperative procedure

Explanation of the procedure:

The process initiates with the retrieval of jaw data via a Cone Beam Computed Tomography (CBCT) scan, subsequently archived in Digital Imaging and Communications in Medicine (DICOM) format. Furthermore, teeth and soft tissues are subjected to scanning using an intraoral scanner, with options including CEREC Primescan, Trios 4, Medit i500, iTero Element 5D, and CS 3600, and the ensuing data is exported in Standard Tessellation Language (STL) format.

The DICOM and STL datasets are integrated into preoperative planning tools, such as the Yomi robotic guidance platform or DentalNavi, enabling three-dimensional reconstruction and alignment. Next, the alveolar ridge's height and width are assessed to verify their adequacy for the proposed procedure. Following this, a provisional prosthesis is crafted, and the drill sequence for osteotomies is established, considering surgical guidelines and the bone quality in the toothless area. Specific rotational speeds and feed rate parameters are designated for each drill, contingent upon the bone's quality. Prior to the surgery, surgical accessories such as holders, props, suction trays, and registration holes (fig 7A)[1] are pre-planned. These accessories serve a crucial function in the intraoperative registration process, facilitated by the utilization of 3-dimensional printing equipment. The surgical procedure is executed under local anesthesia. For the completion of the intraoral registration, a surgical marker is fitted into the holder, and the registration probe is strategically positioned within the designated registration holes. (fig 7B)[1]. The surgeon then positions the handpiece manually patient’s mouth who remains seated (fig 8)[1] that is connected to the robot's end effector which reaches the planned starting position of the drill.

FIGURE 6- Preoperative planning.A, Prosthesis and implant position. 6 B-steps showing osteotomy

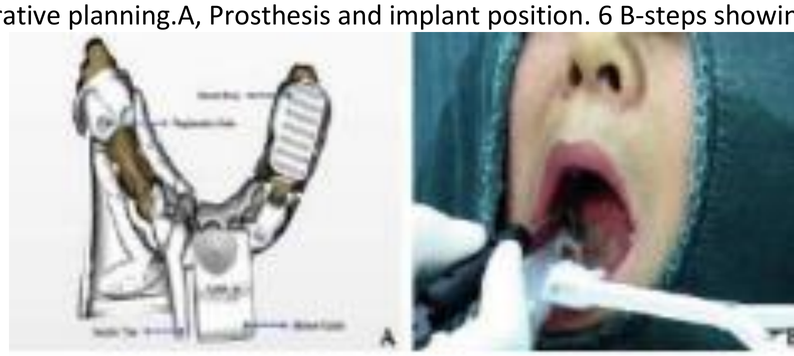


FIGURE (7A) Design of surgical accessories with registration holes. FIGURE (7B)- intraoral registration with probe

FIGURE 8- Surgical scenario of dental implant placement surgery with autonomous dental implant robot.

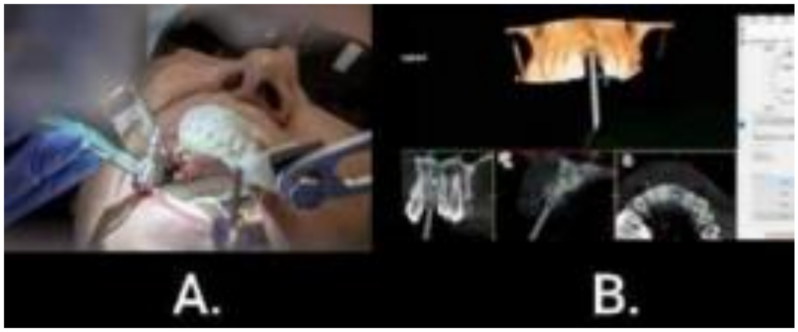
Subsequently, the handpiece is extracted from the patient's mouth, and the path is meticulously recorded within the robot's computer. This process involves the identification of the robot's end effector marker via an active optical pose tracking system. (fig 9A[5],B[4]).
The ADIR autonomously navigates the designated path, ensuring a safe exit from the mouth without making contact with teeth or soft tissues.

FIGURE [9A)- Yomi tracker arm attached to treatment guide to register the robot to patient's anatomy.
(9B) Picture illustrating Yomi patient tracker connected to splint .

Thereafter, the ADIR autonomously performs osteotomies stepwise (fig l0A[4],B[5]) and implant insertion without lifting a flap along the recorded paths (fig 11 A[4],B[5]). The screen shows the depth and angle of the drill while Subsequently, the ADIR takes autonomous action to methodically execute osteotomies (as illustrated in fig 10A[4],B[5]) and insert the implant following the pre-recorded paths (depicted in fig 11 A[4],B[5]) without the need for flap elevation. The display concurrently presents the drill's depth and angle, juxtaposed with the implant's planned position (as shown in fig 12A[5]), while the surgeon oversees and directs all robotic movements using a foot pedal.

FIGURE([10A)- Under Yomi Robotic guidance, osteotomies are meticulously drilled, with the surgeon's hand maintaining a firm grasp and control over the handpiece. Simultaneously, the patient tracker facilitates real-time updates to account for any patient movement.

(10B) Picture depicting Yomi guidance software providing physical, visual and audio guidance during ostectomy.



FIGURE[11A)- A- Implant placement procedure carried out with Yomi Robotic guidance.
(11B)- Picture illustrating Yomi guidance software subsequently providing physical, visual and audio guidance during implantation process.

FIGURE(12A)- Final implant placement
(12B)- Radiograph of final implant placement

In fact the surgical plan can be modified with respect to the convenience of the surgical procedure during the surgery.
Finally an immediate post operative radiograph is taken(fig 12B)[5].
The implant stability is checked and interim abutments are connected to the implants and seated.

Robotic guidance platform :

Yomi Robotic Guidance platform (Neocis , Miami FL)

Neocis, a firm with a specialization in dental robotics, has developed and introduced the software suite termed "YomiPlan Implant Surgery Suite." This suite equips clinical teams with the tools needed to devise accurate treatment strategies and execute procedures with remarkable precision and quality. The Yomi Robotic guidance platform amplifies the predictability of implant positioning in contrast to freehand surgical methods. By addressing the limitations inherent to static guides, it augments the overall patient experience through the enhancement of restorative outcomes.
In the pursuit of top-tier digital data, a spectrum of techniques is harnessed, encompassing facial scans, intraoral scans (IOS), and Cone Beam Computed Tomography (CBCT). These techniques are seamlessly integrated into a comprehensive digital workflow, complemented by software applications tailored for planning and robotic execution.
The Yomi procedure incorporates a three-dimensional orientation marker termed a "Fiducial Array" (Fig 13A, B)[4]. During the preoperative scan, this array is securely affixed to the patient using a splint (Fig 14)[5]. Subsequent imaging is refined through planning software, crafting a panoramic representation of the

oral structures and forging a surgical "blueprint" or “map” (Fig 15A, B)[5]. This integrated blueprint, when combined with Yomi Robotic guidance, amplifies the precision of implant placement and the predictability of restorative outcomes. The platform also furnishes visual and auditory feedback, equipping assistants with the ability to meticulously oversee the procedure and intuitively anticipate ensuing stages.

A B

FIGURE [13A] - Displaying the Yomi patient splint, accentuated with a contrasting insert and fiducial array.
(13B)- Yomi fiducial array which is shown connected to patient splint.

FIGURE 14- Placement of treatment guide with fiducial array.

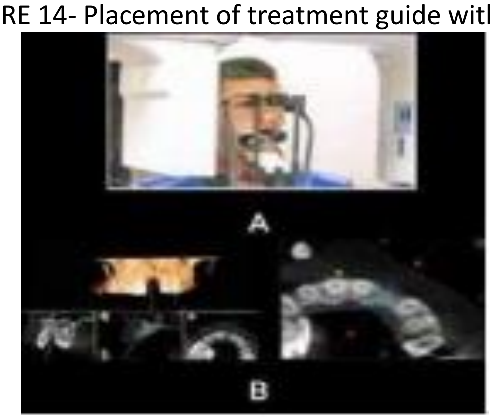


FIGURE (15A) 3D CBCT scanning with tooth mounted treatment guide and Fiducial array in place.
(15B) - Preoperative plan "map" showing planned implant placement

The Yomi Robotic arm functions to stabilize the handpiece, which responds to the ARCHPOINT surgeon's hand movements, thereby enhancing efficiency. This, in turn, provides tangible feedback, commonly referred to as "haptic boundaries" (as depicted in fig 16[4]), rooted in the drill's position relative to the surgical plan. It also serves as a deterrent against deviations from the intended surgical path while facilitating uninterrupted direct visualization of the surgical site throughout the procedure.

Although surgical guides might obstruct visual access during navigation, this challenge can be effectively managed through visual cues displayed on a monitor. The precise tracking of the patient's location in relation to the robotic arm is executed through Yomi's patient tracking system, which monitors the fiducial marker affixed to the splint.

FIG URE16- Yomi Robotic Operatory Configuration: The robotic guidance furnishes the handpiece with "haptic boundaries", enabling the surgeon to retain uninterrupted visualization of the surgical area. It's noteworthy that while the monitor offers visual reassurances when required, the robotic haptic mechanism ensures stability of the handpiece.

Consideration*: While Yomi provides guidance throughout the surgical process, it doesn't govern it. Based on clinical circumstances, the plan can be adjusted at any given moment.

General Considerations:

The potential to elevate the recognized advantages of guided implant placement using static resin guides lies in dynamic real-time clinical support, facilitated by emerging digital protocols. By overcoming the limitations of both static guides and dynamic navigation, implant placement with an ADIR offers several advantages. The surgeon can adjust the implant position according to the surgical situation, while only looking at the screen that shows the drill position and angle in real-time. The robotic arm controls and restricts the handpiece, so the surgeon does not need to hold it. This improves accuracy, reduces fatigue, and eliminates the effect of the surgeon’s skill level. This is also what distinguishes an autonomous robot from other robots that assist in dental implant placement. In contrast to guided implant surgery, the absence of a guide plate at the surgical site facilitates improved drill cooling. Additionally, the prop assists the patient in maintaining their mouth open for extended periods, while an efficient suction tray safeguards against liquid aspiration when seated. The method eliminates the need for an assistant to retract the cheek and evacuate saliva, thereby streamlining the osteotomies.
The ADIR system oversees implant placement under the surgeon's vigilant supervision, ensuring safety throughout the procedure. The robot adheres to pedal-based instructions, and the surgeon possesses the capability to swiftly halt the robot in emergency situations, such as unexpected patient movements. The implant is programmed to steer clear of vital structures, employing a low feed rate that enables the

surgeon to respond effectively. The pre-established path safeguards the patient's soft tissues and teeth from any contact with the surgical instruments as the handpiece autonomously moves in and out of the mouth.

Disadvantages of ADIR:

The procedure has some drawbacks, such as:

* The need to design several customized surgical accessories before surgery, which lowers the planning efficiency. This problem might be solved by using general accessories in the future.
* The robot devices occupy a lot of space in the operating room.
* Facilitating the process of robot calibration and spatial registration prior to surgery is essential.
* The precision of the implant placement using ADIR proved satisfactory for the present patient. However, it remains uncertain whether ADIR surpasses the accuracy of static guides and dynamic navigation. Additional clinical studies and case reports are imperative to assess the precision of ADIR comprehensively.

Conclusion:

ADIR represents a novel iteration of dynamic surgical guidance, amalgamating aspects from both static and dynamic guidance technologies for dental implant placement. Despite not having achieved widespread or customary clinical adoption, ADIR offers a compelling combination of high precision, adaptability, efficiency, and safety for various phases of implant treatment, including planning, osteotomy preparation, and implant placement.. It also reduces the demand for surgical accessories, assistants, and radiation exposure. However, ADIR faces some challenges, such as the need for high-quality digital data acquisition, robot calibration and spatial registration, and the space occupied by the robot devices in the operating room. Additionally, the accuracy of ADIR in relation to other methods of implant placement is still vague and requires more clinical studies and case reports. Therefore, ADIR is a potential technology that may improve the outcomes of implant therapy, but it also needs more development and evaluation to verify its clinical efficacy and reliability.

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