REVIEW ARTICLE

ADVENT OF ROBOTICS IN DENTAL IMPLANTOLOGY

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ABSTRACT

BACKGROUND: Robotics have ushered in the era of disruption that would revolutionize the face of treatment planning and spearhead a precise programmed outcome. For the drilling and installation of the implant, the Static-Computer Assisted Implant Surgery technique used a surgical implant guide supported by teeth, bone or mucosa whereas the Dynamic-Computer Assisted Implant Surgery devices follow the drills and implants in real-time using an optical marker.

METHOD: Neocis (USA), patented the first robot assisted implant, YOMI in 2017. In 2021, an autonomous robot-assisted surgery system, 'Remebot' was introduced by Baihui Weikang Technology (China). Literature search was done for studies that were conducted including these two systems. A comparative evaluation of the means of the global coronal deviation, global apical deviation and angular deviation was articulated in this study.

RESULT: For Autonomous robotic implantology the means of the global coronal deviation, global apical deviation and angular deviation were 0.59±0.24 mm, 0.61±0.23 mm and 0.89±0.38 degrees respectively, whereas for dynamic assisted implantology the means were 1.04±0.7 mm, 0.95±0.73 mm, 2.56±1.48 degree respectively.

CONCLUSION: Robot-assisted implant surgical devices can pave the way for precise, minimally invasive patient-specific operations in dental implant surgery.

KEY WORDS

Robotics, Yomi, Remebot, Robot assisted implant placement, Autonomous Robot Surgery.

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INTRODUCTION

Precise implant location has now been successfully achieved using digital 3D planning, what was left was the precise positioning of the implant, which have been made possible with the tip-toeing of Robotics in the field of implantology. Utilizing cone beam computed tomography (CBCT) or three-dimensional imaging, the real state of the alveolar bone is documented and combined with the target of a digital prosthetic planning goal. Digital implant planning is made possible by computer-assisted processes. Drill templates are used in static navigation to carry out the planning. How drill templates are used for implants had been thoroughly investigated. This method has demonstrated clinical accuracy and produces repeatable outcomes. Dynamic surgical techniques are additionally offered in addition to static ones. A surgeon navigates the mouth cavity while preparing the implant bed and inserting the implant while viewing a three-dimensional image of the actual implant bed on a screen. Using optical tracking systems and predetermined reference markers, the positions of the instruments are tracked in real time and shown on a screen. Real-time visualisation was used during the implantation, allowing for intraoperative changes to the strategy. In contrast to drill templates, dynamic navigation can be employed when there is little vertical space. However, due to the complexity of the surgical technique, adequate training is necessary, and there might be a learning curve.

Yomi, the first robotic surgery system, received approval from the US Food and Drug Administration in 2017[1]. The haptic robotic guidance is a semi-active robot assistance system that consists of a coordinate measurement machine arm and an operational arm that gives the surgeon tactile (haptic) feedback and visual guidance during implant osteotomy. The surgeon still uses the working arm to manually conduct the implant osteotomy. The National Medical Products Administration in China authorised the use of the "Remebot" autonomous robot-assisted surgery system for dental implant surgery in 2021[3]. This system was categorised as a semi-active and task-autonomous robotic system. Robot-aided, image-guided technologies are used to automatically conduct the implant osteotomy and placement.

During surgery, surgeons may keep an eye on the performance of the robots.

MATERIALS AND METHODS

Robot-Assisted Implant Placement

(Haptic Guidance)

YOMI (Picture I) is a system that offers dynamic guiding and planning software. DICOM and STL files are accepted by Yomi planning software. The contralateral side of the arch is placed with an intraoral splint following a comprehensive examination and diagnosis.

The intraoral splint had a variety of fiducial indicators magnetically fastened to it. The intraoral splint with the fiducial markers was then used to take a CBCT. The Yomi programme incorporated the DICOM file to plan the best 3D implant location.

The intraoral splint was connected to the patient-tracking arm during surgery in order to track the patient's movements in real time. The robotic arm that stabilized the handpiece enables haptic guidance. The surgeon could move the handpiece towards the drilling location thanks to the movements of the robotic arm. It only permited movements within the implant's intended position (position, angulation, and depth). Any variation from the plan resulted in the arm being locked, preventing errors and inaccuracies. In order to provide visual confirmation of the procedure, real-time tracking tools like dynamic navigation are also available on the monitor (Grant 2019). Flowchart-I Workflow for robot-assisted (haptic guidance) implant placement.[2]

Autonomous robot-assisted surgery

According to Picture II, the autonomous robotic surgery system (Remebot) primarily consisted of a robot arm, an optical tracker, a positioning marker, and an operational software system. The manufacturer gave information about the robot arms' accuracy, stating that the trueness (or average positioning accuracy) was 0.156 mm (range: 0.071-0.204 mm) and the precision (or average repeated positioning accuracy) was 0.033 mm (range: 0.028-0.038 mm).[3] Flowchart- II : Workflow of Remebot.

Pre-operativeplanning

The patient must first undergo a cone-beam computed tomography exam with a voxel size of 0.2 mm for the preoperative planning. The picture file was exported to the DICOM format. The file was then entered into a computer programme for virtual implants. The surgical plan would be eventually transferred to a DICOM file and designated as the first DICOM data. Using Exocad software, a customised template with a positioning marker will be created. To decrease template fixation mistakes, a second tooth- supported guide template would be created.

Metal pins will be used to fix both templates. The templates will be made with a 3D printer utilising surgical guide material. After the ceramic balls are glued to the template, the operator will calibrate a positioning marker. The distances between the optically marked point and several ceramic balls will be measured and recorded. The ceramic balls represent the extremely radiopaque indicators. As a result, it is easier for the optical marker to recognise three-dimensional entities using previously recorded distances. The teeth will be fitted using both surgical templates. Under local anaesthesia, the marker template affixation will next be carried out. The second DICOM file with a surgical marker template was exported after the patient had a CBCT scan[4].

Intra-operative planning

Prior to the procedure, the first and second DICOM files-one for implant planning and the other for the patient with the positioning marker-would be transmitted and integrated to the robotic surgical system.

This procedure could aid in the preoperative design of prosthetically driven implant placement, cutting down on intraoperative time. We would segment the 3D regions of interest, including the maxillary sinus and alveolar ridge. The goal implant position and the osteotomy plan would be prepared and visualised. The optical tracker would also be installed above the patient's head in position. It was done to register the robotic arm and the positioning marker. Furthermore, the calibration process was automatic.

During the surgical phase, the physician positioned the robotic arm close to the oral cavity. The robotic arm's three-dimensional location was then automatically modified to match the planned implants. In a flapless operation, the implant osteotomy was automatically carried out by the robotic arm in accordance with the surgical and osteotomy planning.

The surgeon could see the drilling feedback information (direction, depth, and force), as well as the actual drilling position, in the coronal, transverse, and sagittal planes, based on the real-time surgical system. Dental implants were put in place at the sites automatically following implant site preparation. when the final implant location was completed. The robotic arm would move to the following site for the implant osteotomy and insertion once one implant site had been completed. The values of the implant stability quotient (ISQ) would then be determined. Finally, a postoperative CBCT scan evaluation would be performed on the patient.

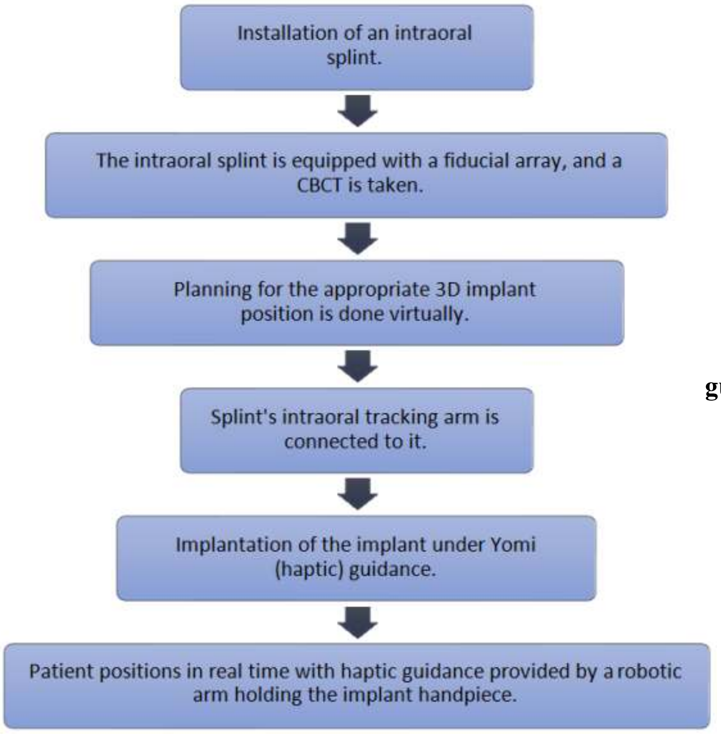
RESULT

Comparative evaluation between Robot-Assisted Implant Placement (Haptic Guidance) and Autonomous robot-assisted surgery system[4,5,6].

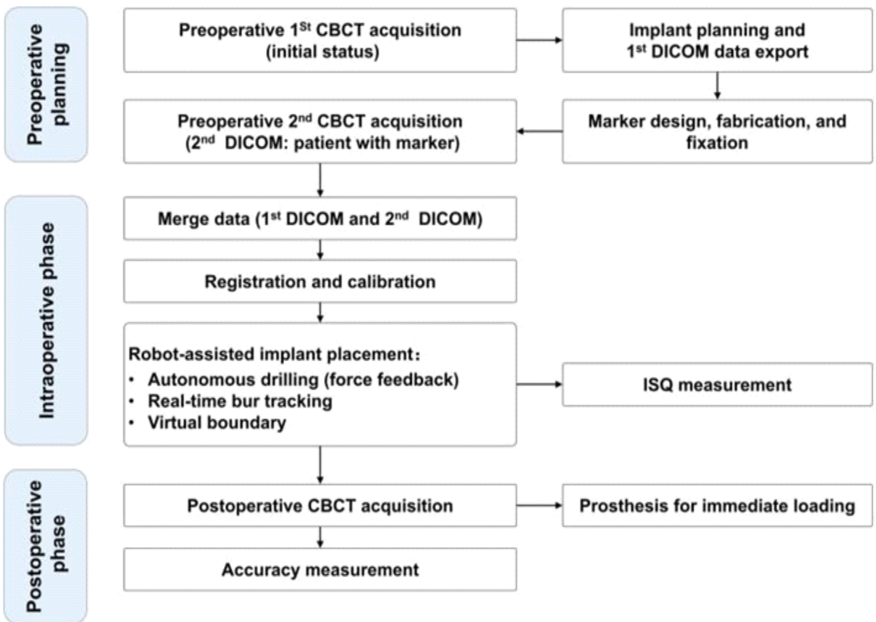
	GLOBAL CORONAL DEVIATION	GLOBAL APICAL DEVIATION	ANGULAR DEVIATION
AUTONOMOUS ROBOTIC IMPLANTOLOGY	0.59±0.24mm	0.61±0.23mm	0.89±0.38degrees
ROBOT GUIDED IMPLANTOLOGY	1.04±0.7 mm	0.95±0.73 mm	2.56±1.48degree

PictureI - Yomi : Hapticguidedsystem.[1]

Picture 2 : Remebot : Autonomous Robot-Guided Implant[2]



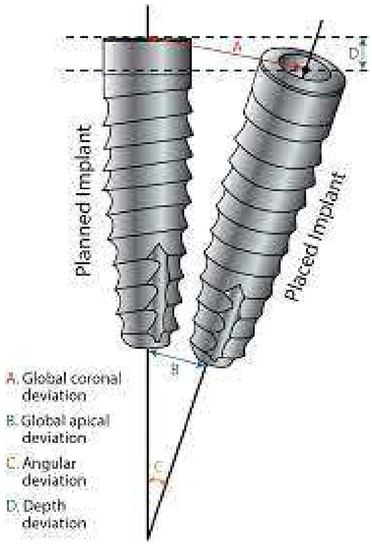
Work flow-I Workflow for robot-assisted (haptic guidance) implant placement.[3]



Workflow 2: Workflow of Remebot, autonomous robotic system.[4]

DISCUSSION

Computer-assisted implant surgery(CAIS) allowed for flapless surgery to speed up postoperative recovery and delivered prosthetically driven, safe implant placement. Prior to surgery, prosthetic parts could be made, cutting down on the number of appointments and the amount of time required to achieve the complete restoration. CAIS will become a crucial component of the accepted standard of treatment in the quickly developing field of digital dentistry. To ensure safe placement, one should be aware of potential errors and take into account the greatest inaccuracies that had been documented. The placement of implants should not be permitted by CAIS, especially for untrained doctors. Even if completely CAIS is being taken into consideration, a considerable learning curve must be anticipated, and proper training is required. Predictable, functionally appropriate, and aesthetically pleasing outcomes could be achieved by having the knowledge and skills necessary to recognise errors made during the data collecting and implant planning processes.



GLOBAL CORONAL DEVIATION
3D deviation between the planned and the placed implants at the center of implant platform

GLOBAL APICAL DEVIATION
3D deviation between the planned and the placed implants at the center of implant apex.

ANGULAR DEVIATION
Deviation of implant axes between the planned and placed implants.

Fig: 3 Parameters of comparative evaluation.[4,5,6]

CONCLUSION

Dental implant surgery might witness new developments owing to robot-assisted implant surgical systems, which could allow for precise and minimally invasive patient-specific operations. To offer concrete clinical data, more trials must be conducted.

REFERENCE

1. Chen J, Bai X, Ding Y, Shen L, Sun X, Cao R, Yang F, Wang L. Comparison the accuracy of a novel implant robot surgery and dynamic navigation system in dental implant surgery: an in vitro pilot study. BMC Oral Health. 2023 Dec;23(1):1-9.

2. Bolding SL, Reebye UN. Accuracy of haptic robotic guidance of dental implant surgery for completely edentulous arches. The Journal of prosthetic dentistry. 2022 Oct 1;128(4):639-47.

3. Yang S, Chen J, Li A, Li P, Xu S. Autonomous robotic surgery for immediately loaded implant-supported maxillary full-arch prosthesis: A case report. Journal of Clinical Medicine. 2022 Nov 7;11(21):65-94.

4. Li C, Wang M, Deng H, Li S, Fang X, Liang Y, Ma X, Zhang Y, Li Y. Autonomous robotic surgery for zygomatic implant placement and immediately loaded implant-supported full-arch prosthesis: a preliminary research. International Journal of Implant Dentistry. 2023 May 19;9(1):12-8.

5. Yang S, Chen J, Li A, Deng K, Li P, Xu S. Accuracy of autonomous robotic surgery for single-tooth implant placement: A case series. Journal of Dentistry. 2023 May 1;132:10 44-51.

6. Li Z, Xie R, Bai S, Zhao Y. Implant placement with an autonomous dental implant robot: A clinical report. The Journal of Prosthetic Dentistry. 2023 Mar 22 S22-3913(23) 124-5.

