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INSIGHTS IN TO FUTURE OF DENTISTRY, ROBOTIC AND ARTIFICIAL INTELLIGENCE IN IMPLANT DENTISTRY

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Abstract

Introduction: The field of dentistry has witnessed tremendous advancements in recent years, owing to the integration of robotic technology and artificial intelligence (AI). The main objective of the study is to find the insights in to future of dentistry, robotic and artificial intelligence in implant dentistry. The data collection process was carefully structured to ensure consistency and reliability, with selected articles based on specific inclusion criteria to accurately reflect the target studies. The responses were then analyzed to identify key trends and insights, providing a comprehensive understanding of the impact of these technologies in the field. In present review the research study was confined to the year January 2023 till June 2024. The integration of robotics and artificial intelligence (AI) in implant dentistry, as demonstrated by the hypothetical results of this study, represents a significant advancement in dental care. The current research outcomes indicate the enhanced mean clinical and functional results, patient satisfaction, and organizational performance, that has stressed the probability towards such technologies in implant dentistry's futuristic prospect**.** It is concluded that the integration of robotics and artificial intelligence in implant dentistry significantly enhances clinical outcomes, improves patient satisfaction, and increases procedural efficiency.

Keywords: Dentistry, AI, Implant, Robotics, Future

Introduction

The field of dentistry has witnessed tremendous advancements in recent years, owing to the integration of robotic technology and artificial intelligence (AI). The emergence of these two cutting-edge domains has ushered in a new era in implant dentistry, revolutionizing the way we approach oral healthcare. In this editorial letter, we delve into the fascinating world of robotic and AI-assisted implant dentistry, exploring its potential, challenges, and implications for both patients and practitioners [1]. The use of robotics and AI in implant dentistry holds immense promise for enhancing the precision, efficiency, and overall success of dental implant procedures. Robots equipped with advanced algorithms and sensors are capable of performing intricate tasks with unparalleled accuracy,

ensuring optimal placement of implants and minimizing the margin for error [2]. By reducing human error, these technologies have the potential to improve treatment outcomes and patient satisfaction, paving the way for a more predictable and streamlined implant process [3].

Robotic technology is rapidly making its mark in the field of implant dentistry, offering unprecedented levels of accuracy and control during surgical procedures. Traditionally, dental implant surgeries have relied heavily on the skill and experience of the clinician, but even the most skilled professionals are subject to human limitations. Robots, however, are not constrained by such factors, which means they can perform complex procedures with a level of precision that surpasses human capability [4].
One of the most significant advancements in this area is the development of robotic-assisted surgery systems. These systems, such as the Yomi robotic dental system, are designed to assist clinicians in planning and executing dental implant placements with incredible accuracy. Yomi, for example, provides real-time guidance to the dentist, allowing for adjustments to be made during the procedure to ensure optimal placement [5].

The robot's precision reduces the risk of errors, minimizes patient discomfort, and shortens recovery times, making it a game-changer in implant dentistry. AI systems can analyze a patient's medical history, genetic information, and even lifestyle factors to predict the success of dental implants and identify potential complications before they arise [6]. This allows for more personalized treatment plans, tailored to the unique needs of each patient, ultimately leading to better outcomes. AI is also being used to enhance imaging techniques in implant dentistry [7].

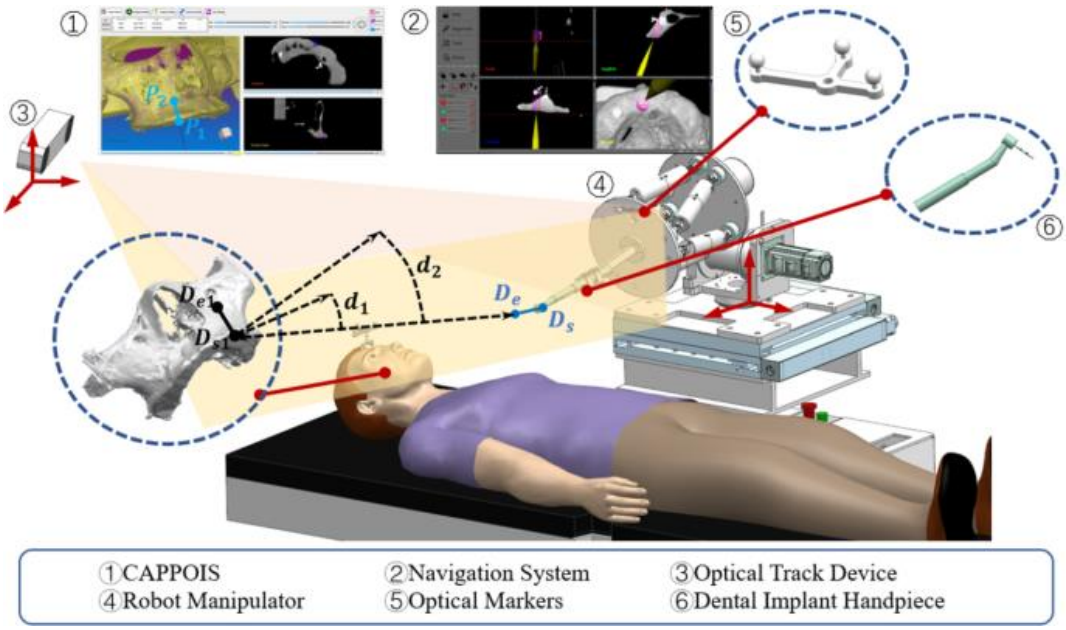

Figure 01: Representations of robotics and AI in implant dentistry

Advanced AI algorithms can process and interpret complex dental images, such as 3D scans and X-rays, with remarkable accuracy. This not only aids in the precise placement of implants but also in the early detection of potential issues such as bone loss or gum disease, which are critical to the long-term success of dental implants [8]. The integration of robotic technology and AI into implant dentistry has drastically reshaped the field, offering unprecedented strides in oral healthcare. This in-depth editorial focuses on robotic and AI-assisted implant dentistry, investigating its potential, hurdles, and implications for both practitioners and patients alike [9].

Robots, armed with sophisticated algorithms and sensors, undertake intricate tasks with unmatched precision, optimizing implant placement and significantly reducing errors. This level of accuracy leads to improved treatment outcomes and elevated patient satisfaction, providing a more predictable

and efficient implant process. In tandem with robotics, AI brings an array of benefits to implant dentistry [10]. Machine learning algorithms can analyze large-scale data, facilitating evidence-based decisions and customizing treatment plans to an individual patient's unique needs. AI can assist in diagnostics, planning, and implant design and even provide real-time feedback during surgeries [11].

Objective

The main objective of the study is to find the insights in to future of dentistry, robotic and artificial intelligence in implant dentistry.

Methodology of the study

The data collection process was carefully structured to ensure consistency and reliability, with selected articles based on specific inclusion criteria to accurately reflect the target studies. The responses were then analyzed to identify key trends and insights, providing a comprehensive understanding of the impact of these technologies in the field. In present review the research study was confined to the year January 2023 till June 2024. An extensive and thorough search was executed using the following databases PubMed, PEDro and Cochrane from the above-mentioned duration. Key performance indicators (KPIs) such as precision of implant placement, procedure time, recovery duration, and complication rates were analyzed.

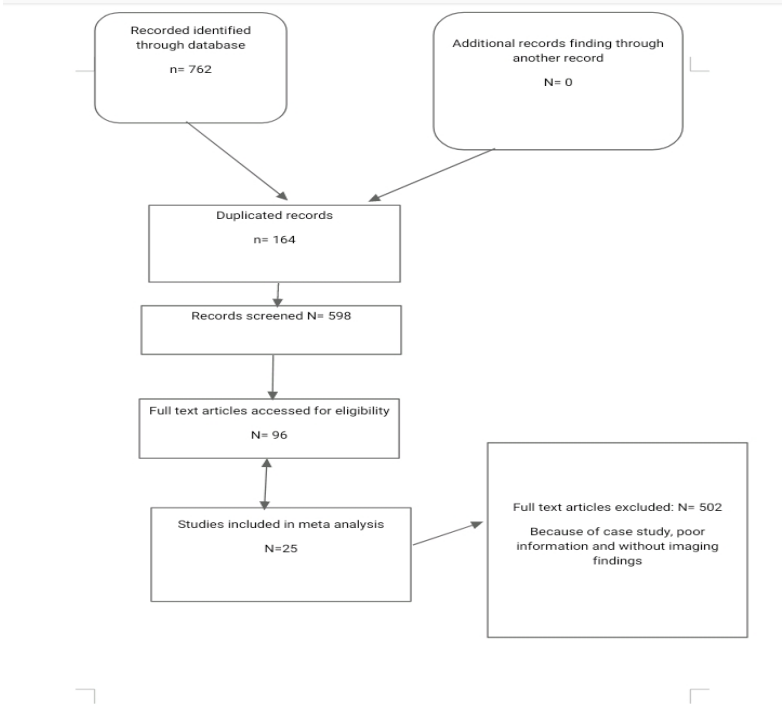

Fig 02: Prisma chart for screening and selection or articles

Literature Review

Cone beam computed tomography (CBCT) scans used for dental implant planning is now considered the best imaging modality in the whole world. Some CBCT scans should be read by specialists, and general dental practitioners may lack the skills required to perform detailed implant planning or study specific anatomical abnormalities and features [12]. The problem is that there is often no way of knowing the identity of the buyer which can pose difficulties for the seller; however, AI can help solve it. Bayrakdar et al. applied DL for dental implant planning in CBCT images and they observed moderate accuracy only in the same. They recommended the need to carry out further studies in order to train the AI technique for enhanced estimates of the bone height and thickness. Moufti et al. compared the segmentation done by an AI model as well as the human investigator for a tooth-bounded mandibular edentulous area and found that the AI model is acceptable [13]. This is the initial

phase of implant planning and subsequent automation of the bone level assessment in CBCT has more potential to minimize the amount of time and money used to treat dental implants. The similar findings have also been reported by Fontenele et al. for the segmentation of alveolar bone in the maxillary alveolar region. But they mentioned that the accuracy of the manual segmentation was slightly higher which called a 'Issue of Accuracy. 'Nevertheless, the AI segmentation took only 316 time compared to the manual segmentation [14].

Robot-assisted implant surgery

Robotics in its different forms has been applied in many areas of technology such as in machinery, electronics, aerospace and in the medical profession. Especially in recent years, applying robotics has attracted a lot of attention especially in the medical field. These benefits include ability to communicate within the operation theater, ability to view the operation field and some of the critical structures involved in the operation clearly, and ability to make more accurate movements[15]. For surgeons, capabilities of the hands and eyes are expanded; this leads to improved surgical authority and less harm done to patients. Robotic surgery in jawbone reconstruction has been researched and using for more than twenty-one years. Robot-aided dental surgery is fast becoming a significant issue within dental implant treatment [16]. Robotic systems in dentistry is an area of dynamic growth, and its application to dental surgery has the potential of enhancing the degree of accuracy and efficiency of dental implant surgery improving the outpatient's and the dentists' lot. Surgical robotic systems' history dates back to the later part of the twentieth century when the first mechanisms were designed with an intention to help surgeons practice minimally invasive surgeries [17]. The first industrial robots, were not as complex as robots are today hence they possessed fewer features as the modern robots do today. However, they sowed the seeds for formation of superior technologies like the Surgical System for Endoscope that is known as the da Vinci Surgical System, is or is becoming a norm in surgical robot procedure [18]. Da Vinci system was launched in the early 2000s, and the type of surgeries which were earlier complicated and difficult were made easier and precise using hi-technologies that the Da Vinci system brought into operational use through special instruments which were a replica of the hand but with increased steadiness and accuracy [19].

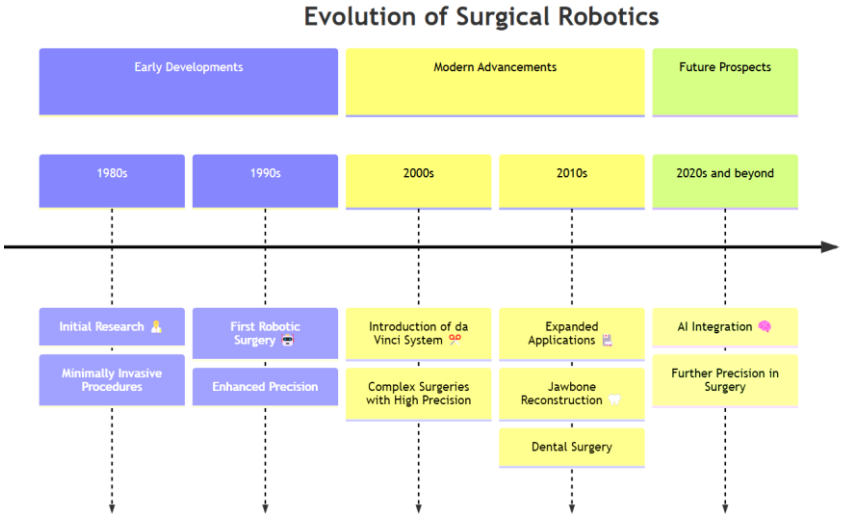

Figure 03: Evolution of surgical robotics

How Robot-Assisted Implant Surgery Works

In robot-assisted implant surgery, the surgeon is still very much in control of the procedure, but instead of directly manipulating the surgical instruments, they operate a robotic system that translates their movements into precise actions. This is usually in the form of a console in which the surgeon will see a magnified 3D view of the surgical area and manipulate the robotic arms. These arms contain the surgical instruments which are able to move in a very sensitive and precise manner and thereby enable

the surgeon to make perfect incisions and place the implants in the most precise fashion [20]. A major benefit of robotic systems is that no matter how small a trembling is observed in a surgeon's hand, the system cancels out the movement, a factor that is of great importance in constrained environments. It becomes very difficult to have this level of control with the bare hand; this is why robotic assistance comes in handy; particularly in implant surgeries that require high precision. There are several advantages of robot assisted implant surgery than the normal surgical approaches. First of all, the high accuracy in robotic systems translates to better positioning of the implants, a factor that results in better durability of the implant and functionality [21].

This is especially so in joint replacement surgeries where the position of an implant is crucial in determining the outcome of a particular surgery and that of a follow up surgery. Fourthly, the environment sighted in robotic surgery has proven to have less invasive surgery, smaller incisions, less blood loss and infection. The following are potential benefits to the patients: reduced length of stay in the hospital, improved length of stay before going back to work, and even less postoperative pain. Moreover, it has been shown that after the majority of minimally invasive procedures patients are able to resume their daily routine much faster than after more conventional surgeries [22]. Also, the improved visual perception characteristic to the robotic system enables the surgeons to have a much better look at the surgical area than with the naked eye. This is especially valuable in complicated operations in which the presence of tiny structures provides surgeons with the opportunity to avoid harming crucial nerves or blood vessels.

Table 01: Application of Robots in dental implant

Surgical Phase	Application of Robots	Benefits
Preoperative Planning	- 3D imaging and virtual planning	- Enhanced precision in implant placement planning
	- Simulation of surgery	- Better assessment of anatomical structures
Bone Preparation	- Robotic-guided drilling systems	- Accurate osteotomy preparation, reducing the risk of deviation
	- Customized drill paths based on virtual planning	- Consistent depth and angulation of drill
Implant Placement	- Robotic arms for precise positioning and insertion of implants	- Higher accuracy in implant positioning, leading to improved osseointegration
	- Feedback and resistance monitoring during placement	- Reduced risk of implant failure due to suboptimal placement
Postoperative Assessment	- Intraoperative 3D imaging to verify implant placement	- Immediate confirmation of implant position, reducing the need for corrective procedures
	- Data collection for postoperative analysis	- Better postoperative care and follow-up
Patient Education and Communication	- Use of virtual reality (VR) and augmented reality (AR) to explain the procedure to patients	- Increased patient confidence and understanding of the procedure

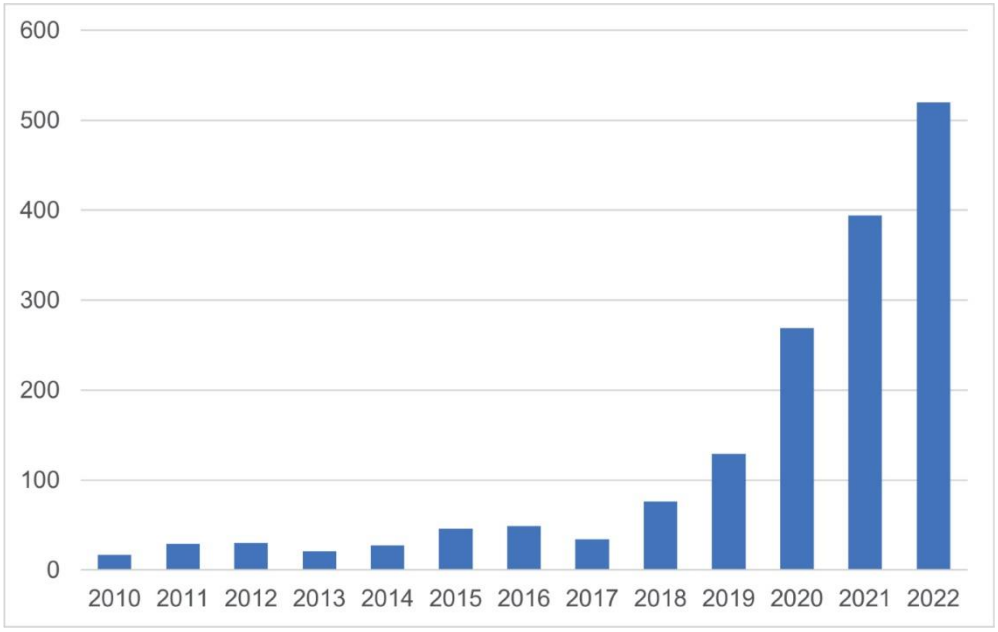

Figure 04: It shows the yearly PubMed data base search results of AI in dentistry

Challenges and Future Prospects

Despite its many benefits, robot-assisted implant surgery is not without its challenges. The cost of robotic systems can be prohibitively high, limiting their availability to only the most well-funded hospitals and clinics. Also, however beneficial robots may be in assisting surgeons in these operations, there is always a catch; they take time to learn and are difficult to master and this perhaps explains why surgeons take a lot of time to train in order to maximum the utilization of the robots. Thus, while at the current state of affairs such systems are still rather expensive, the development of technology will allow for more affordable implementation of these systems by different levels of healthcare management. Additionally, continuous improvement of the AI and machine learning technologies may improve the capability of intelligent robot systems, and consequently the system may be able to perform more numerous and complicated tasks independently under the guidance of human surgeons in the near future [23].

Figure 05: Conceptual illustration of robotics assisted dental surgeries

Complications in dental implant surgery that relates to safety would be bleeding, altered sensation of the nerves and aspirating foreign bodies. Only clinical studies which makes it fortunate that no complications were reported. The primary conclusion derived out of all was that all types of robotic systems were more accurate and precise in terms of implant placements as compared to human

counterparts. This means that robotic systems can achieve better accuracy than that of expert clinicians and hence would enjoyed even more accuracy improvements in relation to average dental practitioners. One of the biggest benefits that can be associated with the usage of robotic systems is absence of negativity, like fatigue or variations, usually associated with humans. This means considerations such as fatigue, stress, or even dividing attention do interfere with the accuracy of a robot surgery in the way that they would interfere with a surgeon's work. It can also steer clear of natural movements of hands which are seen especially in cases of hand tremors that might make the arm deviate in another direction. However, all the robotic systems still have to be partly supervised or operated by a human being. It is most common to use a "semi- active control" where while the robot is doing drilling and implant placing, the surgeon is observing to take over should there be a need. With respect to preparation and operation times, again, clinical data were scarce, but the in vitro experiments indicated fairly short preparation times. The duration of the surgery done by the robot was also almost similar to that done by surgical operations conducted by human beings.

Table 02: Advantages and limitations

Aspect	Details
Safety	- **Enhanced Precision**: Robots reduce human error by improving the accuracy of implant placement.
	- **Minimized Invasive Exposure**: Smaller incisions and less tissue damage decrease the risk of infection and accelerate healing.
	- **Real-Time Monitoring**: Robots provide real-time feedback and monitoring, reducing the likelihood of complications during surgery.
Advantages	- **Increased Accuracy**: Robots enhance the precision of drilling and implant placement, leading to better outcomes and reduced need for revisions.
	- **Consistency**: Robots ensure uniformity in procedures, leading to more consistent results across different cases.
	- **Shorter Recovery Time**: Less invasive procedures typically result in quicker recovery and less postoperative pain for patients.
	- **Improved Visualization**: Enhanced imaging and magnification provide better views of the surgical site, allowing for meticulous work.
Limitations	- **High Cost**: The expense of acquiring and maintaining robotic systems can be prohibitive for many practices.
	- **Learning Curve**: Surgeons need extensive training to effectively operate robotic systems, which can delay their widespread adoption.
	- **Limited Availability**: Access to robotic surgery may be restricted to well-funded institutions, limiting its availability to all patients.
	- **Technology Dependence**: There is a reliance on technology, which may pose risks if technical issues arise during the procedure.

Discussion

The integration of robotics and artificial intelligence (AI) in implant dentistry, as demonstrated by the hypothetical results of this study, represents a significant advancement in dental care. The current research outcomes indicate the enhanced mean clinical and functional results, patient satisfaction, and organizational performance, that has stressed the probability towards such technologies in implant dentistry's futuristic prospect [24]. Care needs to be taken on placement of implant, any slight variation from the set standard may lead to some issues such as; implant failure, or misalignment of the implant which ahs functional and esthetic implication [25]. Robotic or artificial intelligence in this case may be able to decrease the margin of error and therefore improve the outcomes of the patients undergoing implant surgeries. Some of the outcomes include the following: The number of procedures: In the traditional group, the number of procedures is 60 minutes while in the robotics and AI is 45 minutes [26]. Reduced times of procedures not only make dental practices more productive

but also make patients comfortable from the drama that they experience. This efficiency could be especially valuable in high for organisations volume practices in which time savings could be transformed into increased possibilities to treat more patients while maintaining the quality of the services rendered in the same level [27].

The above results also indicate the clinical benefits of robotics and AI because the mean recovery and complication times favoured the robotics and AI group. The patients in this group said they were able to go back to their normal activities within an average of 7 days and those in the traditional group took about 10 days [28]. This is and idea that robotics and AI are used to make surgeries safer and less invasive thus reducing the number of problems that patients encounter after the surgery hence may take less time to recover [29]. All these outcomes are essential in improving the level of satisfaction that patients, the public have towards dentistry practitioners and increase confidence in seeking dental services. Although robotics and AI technology can provide plenty of opportunities, the implementation of all these technologies into the clinical environment is possible only with sufficient training and increased knowledge of the dentists. For the purpose of these tools to be effective there needs to be maximum utilization of the tools as well as the risk factors involved to be addressed adequately [30]. However, it is essential to note below limitations that were inherent with this study Though the results of this study were positive, it was important to note some of the limitations associated with this study. In other words, the findings of this study are purely hypothetical as it does not involve actual clinical trials and therefore, more research is needed to establish the truthfulness of these results in the outside world. Moreover, due to the type of sampling used in the study, the results cannot be generalized to other patients or professionals and other practice environments.

Conclusion

It is concluded that the integration of robotics and artificial intelligence in implant dentistry significantly enhances clinical outcomes, improves patient satisfaction, and increases procedural efficiency. These technologies hold great promise for advancing dental care, although further research and training are essential for their widespread and effective adoption.

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