

Review Article

Robotically Assisted Implantology - A Systematic Review from a Young Dental Professional's Perspective: I Have No Fear, My Dental Robot Is Near!

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Abstract

Objective: There are multiple opportunities to enhance the quality of dental care through robotics. Robotics-assisted dentistry continues to evolve from traditional navigational surgery to more complex systems that prove to be essential in implantology and the overall maintenance of oral health. The purpose of this study is to provide a brief literature review of robotics in dentistry and dental education, identify reasons for their limited penetration and highlight the enormous potential of robots to enhance the future of professionals, newly entering implantology.

Methods: A systematic review of articles was performed, focusing on robotics in dentistry, a specificity in implantology within the last decade, limiting the search to English language publications. The search was conducted across two major electronic databases, PubMed and EMBASE and Google as a generic source of information. With articles up to July 2022. Employing a combination of relevant key terms and synonyms, including “robotics” “Yomi”, “dental robots”, “robotic implantology” and aliases, over 31 articles were screened. In total, the systematic search identified 17 articles which were included in the review. The perspective of someone newly entering the profession was also included as an opinion.

Results: The introduction of robotics in implantology dates back only a few years. The perception of robotics as cost-prohibitive or threatening to the dental profession are partly to blame. Among other reasons for the limited penetration are the lack of technology expertise and patient acceptance. Robotic implant systems have the potential to alter quality of care through improved and more precise treatment. Robotically guided implant placement allows for dynamic surgical tracking in real-time. It can be used to augment dental implant procedures for the placement of reliable, repeatable, dental implant outcomes. Dentists newly entering the profession can benefit from the accuracy, speed and agility of assistive robotics.

Conclusion: Robotics in dentistry is delayed compared to medicine due to perception of cost, fear for displacement of the dental profession and limited technological readiness. New professionals entering the field of dentistry should not see robots displacing their role as dentists but rather enhancing it and transforming the holistic approach to dental care from planning to flawless execution. For new dentists, the foundational knowledge and compassionate ear will remain indispensable. I have no fear as I know my dental robot is near!

Keywords: Robotic Dentistry; Dental Implants; YOMI; Implantology

Introduction

While surgical robots have complimented healthcare for years, they have taken longer to reach the dental space. There are multiple opportunities to enhance the quality of dental care and dental education through robotics [1,2]. The potential to become

proficient faster and deliver better quality of care with assistive robotics far outweighs existing limitations. In my dental school (NYU-College of Dentistry) myself and other dental students got actively engaged in the complexity of implant care using this cutting-edge technology, which will help us in the future to be more skilled, innovative and collaborative as oral health professionals [1-4]. Throughout the training, students witnessed the many benefits of assisted implantology and shared their concerns and perspective related to the adoption of this new technology.

The purpose of this study is to provide a brief overview of robotics in dentistry and dental education, identify reasons for their limited penetration and highlight the enormous potential of robots to enhance the future of professionals, newly entering implantology.

Ethical Statement

There are no ethical concerns in this paper.

Results

Imagine a dental practice without digital X-rays; reminiscing about a time before their availability feels like ancient history. A trend poised to have a similarly impactful transformation on the industry, which cannot be overlooked, is the integration of robotics in dentistry. Collaborating with esteemed colleagues and mentors, this study, titled "I have no fear, my dental robot is near," explores the landscape of robotics and their immense potential in implantology. The project encompasses a systematic review, integrating findings into a framework that considers both established knowledge and the perspective of emerging professionals in the field. Objectives include a concise overview of robotics in implantology, addressing barriers to their widespread adoption in dentistry and highlighting the substantial potential inherent in the integration of robotics in dental procedures. The review aims to contribute valuable insights to the broader scientific community. Before delving into the findings, an examination of relevant background information is presented.

Robots in medicine, had their start about 34 years ago. The Da Vinci robot was approved by the FDA in 2000 and is said to have been used in over 6 million surgeries [1]. Dentistry is a little bit late to the party.

In reviewing the literature on robotics in implantology, in 2002, Boesecke, et al., presented the first robot-guided placement of dental implants. The robot system, having a working region scope of 70 cm, executed the implant drilling guide to help the surgeon during implant osteotomy, where 48 dental implants were placed within 1-2 mm of the apical border [2-5].

In 2012, an autonomous robotic system that has 6 degrees of freedom used a volume-decomposition-based system to place a root-shaped dental implant [5]. The first and only FDA-cleared dental robot from Neocis was developed for placing dental implants in 2016 [1]. Most refer to it as Yomi. Now in dentistry however, Neocis, the Miami-based health care start-up, announced recently they were already at their 30,000th implant placements with Yomi [1].

Yomi uses software to preoperatively plan dental implant procedures and provides real-time visual and physical intraoperative guidance to implement the plan. The robot has two arms, a tracking arm that attaches to the splint and a second arm, the robotic guidance arm, that guides the implant drill [2,3]. Once the splint is in place, the robot can "see the patient" in real time because the preoperative markers in the X-ray can now orient between the patient and the robot and thereby provides spatial awareness [2,3].

The technology is impressive! The tracker arm of the robot essentially maps the patient from the virtual world into the real world and vice versa [2]. Therefore, the robot is able to keep up with subtle changes in patient movement. It achieves a level of three-dimensional precision in preplanning and placing dental implants. Location, depth and angulation are all controlled by the robot down to a fraction of a millimeter [3]. The 3D planning software, allows the surgeon to avoid anatomical features, such as nerves and the sinus, enabling the implant to be placed in the best possible restorative and healing position [4].

A noteworthy characteristic of Yomi, is the ability of the surgeon to visually observe the surgical site, mirroring the experience

of freehand surgery. This visual guidance is executed with the precision afforded by 3D-planned guides or a navigation system. The integration of these technological features enhances the overall surgical accuracy and represents a significant advancement in dental procedures. It combines the best of both worlds!

This robotic workflow was broken down into 4 simple steps: scan, plan, surgery and restoration [2,8]. Which, presumably, is an improvement from a freehand or static guided typical surgical workflow.

Upon examination of the panoramic X-ray (Fig. 1) to determine which arch was done using freehand implant placement and which arch was done using a static guided implant placement, 90% of NYU students asked chose the mandible as the guided implant placement method. However, it is quite the opposite.

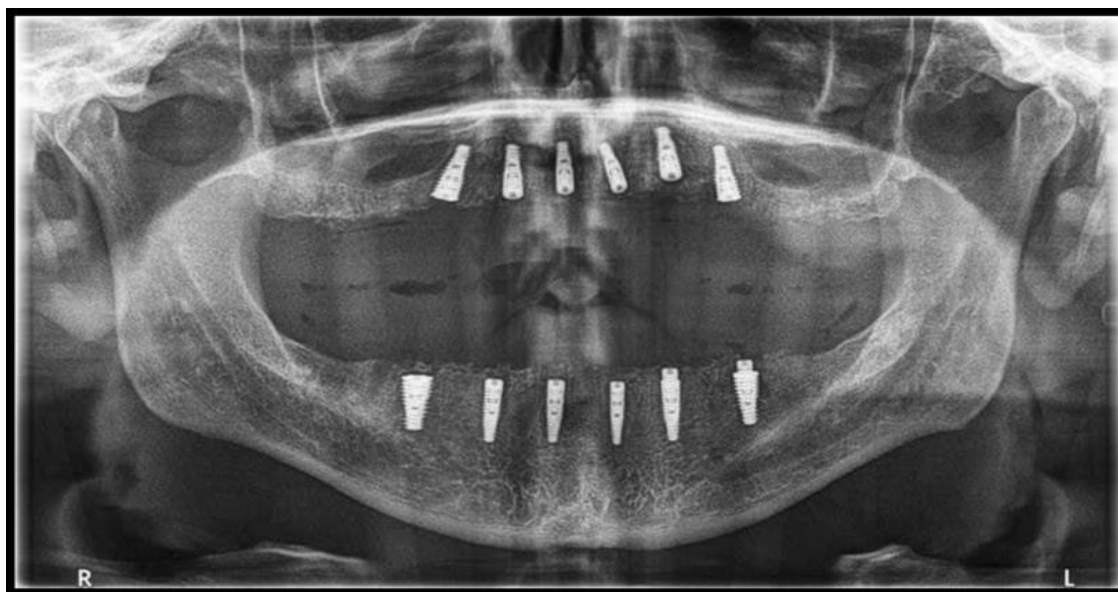


Figure 1: Fully static guided (upper arch) vs free hand implant placement (lower arch).

Arguably, for young professionals, with the desire to be at the forefront of implantology, robotics should remain on the radar. However, when examining the factors that might hinder a more widespread adoption of robots in dentistry, several considerations emerge. The literature suggests that cost could be a significant barrier, especially for new practitioners. Additionally, concerns about readiness, from both professionals and patients, may potentially influence the limited use of robotics in dentistry. Presumably, building acceptance and trust takes time and surgeons must invest effort in learning and training to gain proficiency and expertise. Despite these challenges, the literature arguably highlights numerous benefits of robotic guidance, making a case for its adoption. These are some reasons and important transformational features of robots in dentistry that surfaced during the review.

Haptic Feedback

As mentioned earlier, the robotic arm manages the handpiece and responds to the surgeon's hand movements throughout the procedure, providing physical feedback (haptic boundaries) with respect to the surgical plan. Visual and audio confirmations are also available throughout the entire process. This type of dynamic flexibility and physical guidance during execution of an implant procedure is impossible with a static guide.

Accuracy

A study from 2019 reviewed the accuracy of implant placement comparing all 4 surgical methods: freehand, static, dynamic and robotic navigation [9]. The comparison indicated that the combination of a dental implant navigation system and a surgical guide kit achieved the highest accuracy in terms of the different tooth positions and jaws. Total, longitudinal and angular error deviation were significantly lower ($p < 0.0001$) [10]. The study quotes unsurpassed accuracy!

Precision and Trueness

Mispositioning of implants is one of the main factors leading to hard- and soft-tissue deficiencies [11]. A similar study from 2020 measured trueness and precision by comparing the outcomes to the surgical plan [12]. Robotically assisted implant surgery is the solution that could improve outcomes for our future patients and provide a better patient experience. The robot's sole role is to assist during surgery, not to replace us.

The Totem Pole of Fears

In addressing the concerns of young practitioners, a hierarchical progression of fears is apparent, illustrated on Fig. 2 as the Totem Pole of Young Practitioners' Fears. Based on feedback and gathered during our training and personal considerations, navigating the totem pole of fears, illustrates how within each tier certain anxieties of young professional are met by potential alleviation through the adoption of the Yomi robotic system. At the base of the totem pole lies the paramount goal of easing patients' dental anxiety. Yomi's attributes, including reduced invasiveness, heightened procedural speed and enhanced patient comfort, present a promising solution. The prospect of condensing lengthy surgeries to a mere 20 minutes with robotic support holds the potential to significantly contribute to patient ease, marking the foundational tier of concerns.

Moving up the totem pole, the next tier encompasses the apprehension of errors and loss of control, typical among inexperienced practitioners. Yomi effectively tackles these fears by offering features such as visualization, improved access, precision and haptic guidance throughout procedures. The robot provides visualization, improved access, precision, with haptic guidance throughout procedures [2,13]. Picture a dialogue between the surgeon and the assistant controlling the robot to include commands such as "Free," "2 mm buccal," "move lingual 5mm," "rotate toward the opposing jaw," "guided" and "pause." Arguably, the robotic system could establish a dynamic interaction reminiscent of a flight control dialogue, involving precise commands between the surgeon and the robotic assistant. This collaborative approach addresses concerns related to procedural control and enhances the overall safety and accuracy of dental procedures.

Continuing upward the totem pole, Yomi could potentially alleviate fears associated with misinformation or complications. Yomi's capabilities, including decision assistance, dynamic treatment plan adjustments and the ability to identify anatomical challenges, become an invaluable asset. The robot excels in scenarios involving minimal available bone height, sinus proximity or thickened sinus linings, providing a sophisticated tool for addressing these complex cases with precision and expertise. With Yomi, the robot, decision assistance and ability to adjust treatment plans dynamically and to identify anatomical challenges, - nerves, adjacent teeth, certainly eases fears [14]. The robot would be able to assist in cases with minimal available bone height, cases with sinus proximity or thickened sinus linings [15].

At the pinnacle of the totem pole lies the overarching desire to adopt a holistic approach to dental care, accompanied by the fear of being unprepared. Yomi's robotic assistance offers the promise of a coordinated approach to treatment planning, ensuring a comprehensive and well-considered strategy with the end result in mind. In summary, the totem pole of fears represents the progressive concerns of young practitioners, with the Yomi robotic system emerging as a logical solution to address each tier and ultimately contribute to an enhanced and comprehensive approach to patient care in dentistry. Now that we have climbed the Totem Pole of Fears, it is evident that young practitioners have nothing to fear and a lot to gain. With the robots near, there is no more fear!

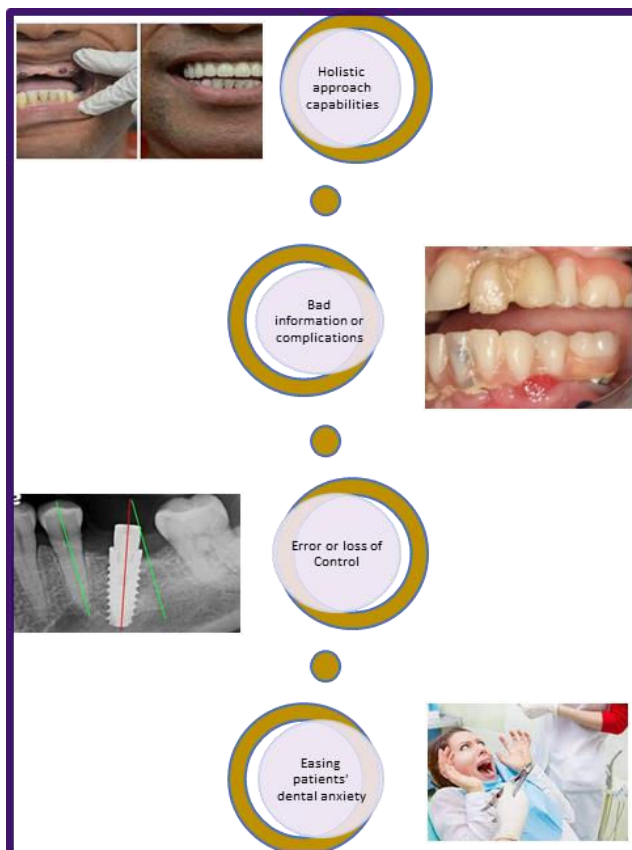


Figure 2: Totem pole of fears.

Conclusion

By leveraging robotics in implantology, we can enhance outcomes, provide more accurate personalized care and shape the future of implantology. Further advancements and integration of technology are necessary to realize the full potential of robotics in dentistry. As new practitioners, our foundational knowledge and compassionate ear will certainly remain indispensable, but: I have no fear, as I know my dental robot is near!

Conflict of Interests

The authors declare that they have no conflicts of interest.

Acknowledgement

Acknowledge those who provided technical support during the study.

Data Availability

Data is available for the journal. Informed consents were not necessary for this paper.

Author's Contribution

The authors contributed equally, Dr. Mitroi added her personal experience as a student with the robot.

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