

NEW ERA UNFOLDS WITH THE USE OF ROBOTICS IN DENTISTRY

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ABSTRACT

Robotics in dentistry is emerging as a transformative force in diagnosis, treatment planning, surgical execution, prosthetic fabrication, endodontics, orthodontics, and education. While many systems are still in proof-of-concept or early clinical use, advances in imaging, AI, haptics, and robotic control are bringing us closer to more precise, minimally invasive, and efficient dental care. Significant challenges remain in cost, regulatory approval, training, and safety. This review summarises the current state, key applications, evidence, and prospective directions of robotics in dental practice, drawing upon recent literature

Keywords: robotics, Dentibot, robotics in dentistry, 3D imaging, AI, CAD-CAM

INTRODUCTION

Dentistry traditionally relies heavily on manual dexterity, visibility, tactile feedback, and the judgment of the practitioner. However, limitations due to human error, operator fatigue, anatomical constraints, and access issues have motivated research into robotic systems that can augment or assist human dentists.^{1,2} Robotics in dentistry is an emerging field that enhances dental procedures using robotic technologies to improve precision, efficiency and patient outcomes. Robotics combined with digital imaging, CAD/CAM, AI, and sensor technologies promises enhancements in precision, predictability, and patient outcomes.²

TYPES AND COMPONENTS OF DENTAL ROBOTICS

Some key aspects in the design of robotic systems for dentistry include^{2,3}:

- **Mechanical platform / robotic arm** — degrees of freedom, precision, force feedback, rigidity vs compliant designs.
- **Sensors** — force/torque sensors, vision (2D/3D imaging, CBCT), tracking systems (optical, inertial, etc.), patient motion monitoring.
- **Control systems** — position control, hybrid position/force control, real-time compensation (for movement / deformation), autonomy vs human-robot collaboration.
- **Software / AI / planning tools** — pre-operative planning (CBCT, 3D scans), path planning, safety checks, intraoperative guidance, automation.
- **Integration with imaging / digital workflows** — CBCT, intraoral scanners, CAD/CAM, digital impressions.

APPLICATIONS OF ROBOTICS IN DENTISTRY^{4,11}

1. Implant Dentistry

- Yomi Robotic System (FDA-approved in the U.S.):

Assists surgeons in placing dental implants with high accuracy. They have many benefits like minimally invasive approaches, improved accuracy and reduced healing time.

2. Orthodontics

- Robotic wire-bending systems (e.g., SureSmile): Customize archwires using robotic arms with various benefits like more precise tooth movement, shorter treatment duration & fewer adjustments.¹¹

3. Endodontics (Root Canal Treatment)

- Microrobotic systems help navigate root canals with more precision. AI can assist in detecting canal anatomy using 3D imaging.

4. Prosthodontics & Restorative Dentistry

- CAD/CAM systems with robotic milling machines create crowns, bridges, inlays, etc. and allows same-day restorations with high precision.

5. Oral Surgery

- Robots assist in various procedures like Jaw realignment surgery, Biopsies and Tumor removal which not only improves safety and precision but also helps especially in complex surgeries.

6. Dental Education & Simulation

- Haptic robotic simulators help dental students practice procedures with realistic feedback. Some examples are Simodont & DentSim. Various technologies used are AI & Machine Learning, 3D Imaging & CBCT (Cone Beam CT), CAD/CAM Systems, Robotic Arms & Actuators, Sensors & Haptics & Navigation Systems.

BENEFITS OF VARIOUS ROBOTICS SYSTEMS

- Improved precision and reduced deviations in surgical placement like implants.
- Repeatability and consistency across cases.
- Reduced operator fatigue and possibly shorter procedure

times.

- Minimal invasiveness as has better access, more accurate cuts or drilling.
- Potentially better patient experience as is less time consuming and also causes less discomfort.
- Seen potential to integrate robotics with digital dentistry like CAD/CAM, AI& 3 D imaging.^{4,5,11}

CHALLENGES AND LIMITATIONS

Some of the main challenges and limitations are as follows:

- **Cost:** Equipment is expensive; maintenance, software, and calibration add recurring costs.
- **Training & Expertise:** Clinicians need to be trained not just in dental procedures but in using robotic systems, interpreting digital plans, handling emergent issues.
- **Regulation & Safety:** Ensuring safety under human movement, force control, sterilization, and precise mechanical behavior; addressing regulatory approvals (e.g. FDA, CE).
- **Tactile / Haptic Feedback:** Many robotic systems lack sufficient tactile feedback; surgeons/dentists feel “blind” in certain contexts. Some systems attempt to integrate haptics.⁷
- **Patient Movement / Tracking:** In vivo, patient movement, soft tissue, saliva etc complicate precise robotic operation. Preclinical models often simpler.
- **Clinical Evidence:** Lack of large randomized controlled trials (RCTs) comparing robotic vs conventional procedures in patient outcomes (long-term survival, complication rates, cost-benefit).
- **Acceptance:** Both among dentists (willingness to adopt new tech) and among patients (trust, perceived safety, cost) is variable.⁸

EMERGING & FUTURE TRENDS

- Hybrid control systems combining position and force control, patient tracking to accommodate movement (e.g. DentiBot a new robot designed for endodontic treatment featuring 6-DoF hybrid position/force control, patient tracking, force/torque sensing; preclinical evaluation on acrylic and resin models showing feasibility.⁶
- Integration of AI in diagnostics, planning, prediction (implant position, outcome prediction, detection of pathology). More clinical case reports, developing

protocols for robot-assisted surgeries in live patients. Enhanced imaging integration (CBCT, intraoral scans) + robotic guidance for precise minimally invasive surgery. Tele operation / remote robotic assistance / teledentistry possibilities. Standardizing metrics for robotic accuracy, safety, clinical outcomes.⁹

DISCUSSION

Robotics in dentistry is advancing rapidly, with tangible progress in implant placement, endodontic surgery, prosthetics, and orthodontics. However, the balance between promise and practical adoption remains delicate. For many clinics, especially in less wealthy settings, cost and infrastructure are major obstacles.^{9,10} Also, since many systems are still in early phases, long-term data (patient satisfaction, survival, complications) is limited. But there is always a question that will the robotics merely assist, or will some procedures become substantially automated? At present, entirely autonomous robotics are rare; most systems provide guidance and support, with the human clinician still central. As sensor and AI capabilities improve, we may see more autonomy, but with significant oversight and regulatory safeguards.^{10,11}

CONCLUSION

Robotics has strong potential to augment dental practice with improving precision, reducing human error, enabling minimally invasive approaches, improving consistency in restorative and surgical work. But more evidence, cost reductions, regulatory clarity, and clinician training are needed before robotics becomes routine in general dental practices.

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