Review article

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Dental Microchips and GPS Tracking: Technological Convergence in Modern Dentistry

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ABSTRACT

The convergence of microchip technology, Global Positioning Systems (GPS), and dental applications represents a paradigm shift in both clinical precision and patient safety management. This paper examines two distinct but technologically related applications of chip-based and GPS technologies in dentistry: (1): Dynamic navigation systems for dental implant surgery, often colloquially termed "dental GPS," which provide real-time three-dimensional guidance for surgical precision; and (2): Intraoral GPS tracking devices embedded in dental prostheses for locating individuals with Alzheimer‘s disease, dementia, or other conditions that predispose patients to wandering behavior. Through a comprehensive review of peer-reviewed literature, patent documentation and clinical case studies, this paper analyzes the technological mechanisms, clinical applications, efficacy data, limitations and ethical considerations for both applications. The X-Guide dynamic navigation system is examined for its reported sub-millimeter accuracy in implant placement, achieving positional errors of less than 0.4 mm compared to freehand techniques. GPS-embedded denture technologies are evaluated for their utility in tracking vulnerable patient populations, with documented battery life of 40-48 hours and integration with mobile tracking applications. Technical limitations including power supply constraints, signal transmission challenges due to dental material shielding, biocompatibility concerns and miniaturization barriers are critically analyzed. The paper concludes with recommendations for clinical implementation and identifies future research directions including nano-GPS development and post-quantum security protocols for dental IoT devices.

Keywords: Dental GPS; Dynamic navigation, X-Guide; Implant surgery; Intraoral microchip; Alzheimer’s tracking, GPS denture; Dementia patient safety; Dental IoT; Navigation-guided surgery

INTRODUCTION

The integration of chip-based technologies and satellite positioning systems into dentistry represents one of the most significant technological convergences in modern oral healthcare. Two distinct application domains have emerged: surgical navigation systems that utilize real-time tracking technology (colloquially termed "dental GPS") for precision implant placement, and patient tracking devices embedded in dental prostheses for locating individuals with cognitive impairments [1-32].

The term "dental GPS" has entered clinical parlance through systems such as X-Guide Dynamic Navigation (X-Nav Technologies), which provides surgeons with real-time, three-dimensional guidance during implant placement. This technology functions analogously to automotive GPS systems by providing continuous positional feedback, enabling the clinician to track surgical instrument location relative to pre-operative plans with sub-millimeter accuracy [33-50].

Simultaneously, true GPS technology has been adapted for dental applications through the embedding of GPS tracking modules in removable dentures and cheek plumpers. This innovation addresses a critical public health challenge: the management of wandering behavior in patients with Alzheimer ‘s disease and other dementias. The World Health Organization and the National Institute on Aging have identified tooth loss as a risk factor for Alzheimer's disease, creating an intersection between prosthodontic rehabilitation and patient safety technology [51-60].

Scope and objectives

This paper aims to:

- Analyze the technological mechanisms of dynamic navigation systems for dental implant surgery
- Evaluate the clinical efficacy of "dental GPS" systems compared to traditional methods
- Examine GPS-embedded dental prosthesis technologies for patient tracking
- Critically assess technical limitations including power supply, signal transmission, and biocompatibility
- Address ethical and privacy considerations for intraoral tracking devices
- Propose future research directions for dental microchip technologies

LITERATURE REVIEW

This review synthesizes findings from peer-reviewed dental and medical literature, patent documentation, commercial technology specifications, and clinical case reports published between 2008 and 2025. Sources include the National Institutes of Health database, the Research Journal of Pharmacy and Technology, clinical reports from implant centers, and international patent filings [61-75].

Dental GPS: Dynamic navigation systems for implant surgery

Evolution from freehand to guided implant placement

Dental implant surgery has undergone a technological evolution from purely analog techniques to sophisticated digital workflows. The traditional "freehand" method relies entirely on the surgeon's visual judgment and manual skill, using two-dimensional radiographs for pre-operative assessment. While acceptable for straightforward cases, freehand placement carries inherent risks of positional deviation that can affect aesthetics, occlusal function, and long-term implant survival [75-82].

Research published in the Journal of Oral and Maxillofacial Surgery (Block, 2017) documented that freehand implant placement can result in angular errors up to 6.5 degrees and positional deviations exceeding 1.8 millimeters. Such deviations may compromise prosthetic outcomes, potentially violating the “safe zone “around critical anatomical structures including the inferior alveolar nerve and maxillary sinus [83-100].

Static surgical guides represented the first major advancement beyond freehand techniques. These templates are digitally designed using implant planning software and fabricated via three-dimensional printing. However, static guides have a fundamental limitation: they cannot adapt to intraoperative variables. If bone density varies unexpectedly, tissue shifts occur, or the drill encounters resistance requiring angulation adjustment, the static guide provides no capacity for modification [100-115].

Dynamic navigation technology: The "Dental GPS" concept

Dynamic navigation systems address the limitations of both freehand and static guide techniques by providing real-time, adaptive guidance throughout the surgical procedure. The X-Guide system (X-Nav Technologies) exemplifies this technology and has received regulatory clearance in multiple jurisdictions including the United States (FDA), Europe (CE Mark), and Australia (TGA).

Mechanism of operation:

The dynamic navigation workflow follows a systematic sequence:

CBCT imaging: A cone-beam computed tomography scan captures the patient 's maxillofacial anatomy in three dimensions, providing detailed visualization of bone architecture, nerve pathways, and adjacent tooth roots.

Virtual treatment planning: The surgeon uses proprietary software to plan the optimal implant position, angle, and depth based on prosthetic requirements and anatomical constraints.

Optical tracking: During surgery, an optical camera system mounted above the patient tracks specialized reference markers attached to both the patient 's jaw and the surgical handpiece.

Real-time guidance: The system displays the position of the drill tip on the pre-operative plan, showing deviation from the planned trajectory in all three planes. The surgeon can view this guidance on a monitor and make instantaneous adjustments [116-123].

This technology functions analogously to automotive GPS: the surgeon can see their current position, the planned destination (optimal implant location), and the deviation between the two in real-time. Unlike static guides, the dynamic system allows for intraoperative plan modification if clinical conditions warrant adjustment [124-128].

Clinical efficacy data

Multiple peer-reviewed studies have evaluated the accuracy of dynamic navigation systems for dental implant placement. Emery and colleagues, publishing in the Journal of Oral Implantology, reported that X-Guide achieved:

- Mean positional error: less than 0.4 mm
- Mean angular error: approximately 0.9 degrees
- Deviation rate approximately 11 times lower than freehand placement

Clinical reports from implant centers using X-Guide technology have documented enhanced accuracy even in complex cases, including:

- Immediate loading protocols where precise fit is critical for osseointegration
- Anatomically challenging sites with proximity to vital structures
- Full-arch rehabilitations requiring multiple implants with coordinated trajectories
- Patients with limited bone volume requiring strategic placement

Comparative analysis

Technique Mean Positional Error Mean Angular Error Intraoperative Adjustability

Freehand 1.8 mm 6.5° No

Static Guide 0.8-1.2 mm 2.5-4.0° No

Dynamic Navigation <0.4 mm <1.0° Yes

Clinical applications and benefits

Precision and safety: The sub-millimeter accuracy of dynamic navigation systems enables implant placement within 0.5 mm of planned position, reducing risks of nerve injury, sinus perforation, and damage to adjacent tooth roots. This precision is particularly valuable in the aesthetic zone where implant positioning directly influences soft tissue contours and prosthetic appearance [129-134].

Minimally invasive surgery: The enhanced accuracy permits flapless or minimally invasive approaches in appropriate cases, reducing post-operative discomfort, swelling, and recovery time. Patients experience less morbidity while achieving predictable outcomes [135-138].

Complex case management: Dynamic navigation excels in challenging anatomical scenarios including:

- Severely atrophic ridges requiring angled placement
- Immediate placement into extraction sockets
- Patients with limited mouth opening where static guides cannot be seated
- Cases requiring navigation around existing anatomical structures

Educational value: The real-time visual feedback serves as a training tool, allowing less experienced surgeons to place implants with confidence while receiving objective performance feedback [138-142].

Limitations and considerations

Cost and accessibility: Dynamic navigation systems require substantial capital investment for hardware (optical tracking cameras, monitors, specialized handpieces) and software licensing. This cost may be prohibitive for smaller practices, potentially creating a two-tier system of implant care.

Learning curve: While the technology provides guidance, surgeons must develop proficiency in interpreting the visual feedback and coordinating hand movements with on-screen information. Studies suggest a learning curve of 10-20 cases before achieving optimal efficiency.

Workflow integration: The technology adds time to the surgical procedure for setup, calibration, and intraoperative reference marker attachment. Practices must balance enhanced precision against increased operative time.

Technical limitations: Optical tracking requires an unobstructed line of sight between the camera and reference markers. Soft tissue retraction, instrument placement, or assistant positioning can potentially interrupt tracking.

GPS microchips in dental prostheses for patient tracking

The public health problem: Wandering in dementia

Alzheimer‘s disease accounts for 60-80% of dementia cases globally. Among the most distressing behaviors associated with dementia is wandering—disoriented, aimless, or repetitive locomotion that can result in patients becoming lost, injured, or experiencing fatal outcomes. Research indicates that approximately 40% of individuals diagnosed with dementia will wander at some point, and 5% of these individuals will wander frequently with potentially fatal consequences.

Traditional tracking solutions include wearable devices such as bracelets, necklaces, watches, and clothing attachments. However, these approaches have significant limitations:

- Patients may remove or lose wearable devices due to agitation or confusion
- Caregivers may forget to reapply devices after bathing or clothing changes
- Devices may cause skin irritation or be perceived as stigmatizing
- Individuals with advanced dementia may not tolerate any external attachments

The dental prosthesis represents an innovative alternative location for tracking technology. Unlike wearable devices, dentures are:

- Intended for continuous intraoral wear during waking hours
- Less likely to be intentionally removed by confused patients
- Perceived as a normal part of daily life rather than a tracking device
- Fabricated as part of routine prosthodontic care

GPS-embedded denture technology: Design and fabrication

Clinical procedure

The technique for incorporating GPS tracking into complete dentures has been described in peer-reviewed literature and involves the following steps:

Conventional denture fabrication: Standard maxillary and mandibular complete dentures are fabricated using heat-Polymerized polymethyl Methacrylate (PMMA) resin according to conventional protocols.

Sensor positioning: The optimal location for the GPS sensor is identified and marked on the maxillary denture. The posterior palatal region or buccal flange area is typically selected to minimize interference with speech and tongue function while providing adequate bulk for device concealment.

Acrylic encapsulation: A light-polymerizing acrylic sheet is adapted over the designated sensor position. The sensor is placed on the polymerized sheet and spot-cured for approximately 5 seconds to allow trimming of excess material.

Protective overlay: A clear thermoforming material (e.g., Clear Bioplast) is vacuum-pressed over the sensor to provide a protective seal. The material is shaped to completely cover and protect the sensor from saliva exposure while maintaining a smooth surface against oral mucosa.

Sealing and activation: The extension of thermoplastic material over any USB port or switch access point is removed and sealed with room temperature vulcanizing silicone. The power switch is activated following manufacturer instructions.

Alternative design: Cheek plumper integration

An alternative approach described in the Research Journal of Pharmacy and Technology involves incorporating the GPS device into a hollow cheek plumper attached to the buccal aspect of the maxillary denture using magnets. This design offers several advantages:

- The GPS device does not contact saliva or buccal mucosa directly
- The cheek plumper can be removed for battery replacement or maintenance
- The magnetic attachment allows caregivers to activate the device only when needed (e.g., when the patient leaves home)
- The design provides additional facial support for patients with significant tissue atrophy

Tracking mechanism

Once activated, the GPS receiver within the denture establishes communication with the Global Positioning System satellite network. The device determines geographic coordinates (latitude and longitude) and transmits location information through cellular networks to a designated mobile application. Caregivers can then track the patient‘s location, speed, distance traveled, and route using standard mapping services available on Android and iOS platforms.

Technical specifications and capabilities

GPS module features:

Contemporary GPS modules designed for dental incorporation offer the following capabilities:

- Location accuracy within 5-10 meters in open outdoor environments
- Auto-report positioning at programmable intervals
- Geofence alerts that trigger notifications when patients enter or exit designated safe zones
- Low battery alerts for caregiver notification
- Remote monitoring capabilities through web-based or mobile interfaces
- Speed and movement detection for identifying potential emergencies

Power supply

The battery life of current GPS modules ranges from 40 to 48 hours on a full charge. Devices are designed for low-power operation and incorporate rechargeable batteries. However, the physical constraints of intraoral placement limit battery size, creating a fundamental tension between device longevity and patient comfort.

Integration with mobile applications:

Tracking data is transmitted to caregiver smartphones through dedicated applications. Features commonly available include:

- Real-time location mapping
- Historical route tracking
- Speed and distance monitoring
- Customizable alert zones
- Multi-caregiver access with permission controls

Target patient populations

Alzheimer's disease and dementia

Patients with moderate to severe dementia who exhibit wandering behavior are the primary target population for GPS-embedded dentures. These individuals benefit from the passive tracking capability that does not require their active cooperation or tolerance of wearable devices. The technology provides peace of mind to caregivers while enabling earlier intervention when patients become disoriented.

Elderly patients with neurological disorders

Individuals with Parkinson‘s disease, stroke-related cognitive impairment, or other neurological conditions that affect orientation and memory may also benefit from intraoral tracking technology [34].

Natural disaster scenarios

In regions prone to natural disasters (earthquakes, tsunamis, hurricanes), GPS-embedded dentures could theoretically assist in locating displaced individuals. However, this application remains conceptual rather than clinically validated [49].

Limitations and technical challenges

Size and bulk constraints

Current GPS modules measure approximately 1 cm in length and 0.8 cm in width with 2 mm thickness. This bulk requires modification of the denture base that may affect:

- Patient comfort, particularly palatal adaptation
- Speech articulation, especially with posterior palatal placement
- Denture retention due to altered contours
- Tissue tolerance, with potential for mucosal irritation

Battery limitations

The 40-48 hour battery life requires regular recharging, necessitating removal of the GPS component. This creates a risk that caregivers may forget to reattach the device, leaving the patient untracked. Additionally, the battery must be replaced periodically (typically annually), requiring technical expertise.

Signal transmission challenges

Several factors can compromise GPS signal reception in dental applications:

Metal shielding: Dental materials including metal denture bases, clasps, frameworks, and some ceramic materials can block or attenuate GPS signals. Complete dentures fabricated entirely from acrylic resin provide the best signal transmission.

Oral cavity location: The intraoral position may attenuate signals compared to external placements. The device must transmit through soft tissue, bone, and potentially thick facial structures.

Saliva exposure: Despite sealing efforts, moisture ingress remains a risk that can compromise electronic components.

Bulkiness and patient acceptance

A study of denture-wearing Alzheimer‘s patients noted that the additional bulk required for GPS incorporation can affect:

- Phonetics, particularly production of /s/ and /t/ sounds that require precise palatal contact
- Swallowing function due to altered palatal contour
- Overall denture satisfaction

Cost considerations

Customization of GPS sensors into nano-sized formats remains expensive. While open-source tracking platforms reduce software costs, the hardware and fabrication expenses may be prohibitive for many families and healthcare systems.

Infection control complexity

The presence of electronic components within the denture complicates standard disinfection protocols. The GPS module must be removed before chemical disinfection, and care must be taken to prevent moisture ingress during cleaning.

Safety and biocompatibility considerations

Tissue response

The GPS device must be completely sealed within biocompatible acrylic resin to prevent contact with oral mucosa. Any leakage of battery materials or electronic components could cause local tissue irritation, chemical burns, or systemic toxicity. Current techniques utilize medical-grade silicone and acrylic materials to achieve complete encapsulation.

Electromagnetic effects

Concerns have been raised regarding the potential effects of electromagnetic radiation from GPS transmitters on physiological function. While the low power output of these devices (milliwatt range) is generally considered safe, long-term studies specifically examining intraoral placement are lacking. Some researchers have noted theoretical risks of altered physiological, genetic, or immune function with chronic electromagnetic exposure, though no adverse effects have been documented in clinical use.

Ingestion or aspiration risk

If the GPS device becomes dislodged from the denture, it represents a foreign body with aspiration or ingestion risk. Meticulous fabrication techniques and regular clinical monitoring are essential to ensure device integrity.

Historical and conceptual foundations: The tooth microchip patent

The 2008 tooth-mounted microchip patent

A foundational document in the field of intraoral tracking technology is United States Patent Application US20090237236A1, titled "Tooth located GPS person tracking and location method and apparatus," filed in March 2008. This patent describes a system for remotely monitoring a person‘s location through a microchip mounted within a tooth cavity.

Patent description

The invention describes a microchip containing a processor, memory, transceiver, antenna, and power supply. The chip communicates with GPS satellites to determine geographic location and with ground-based tracking devices (e.g., mobile phone networks) to transmit location information to caregivers.

The microchip is mounted in a cavity prepared in a natural tooth, extending into dentin. After chip placement, the cavity is sealed with conventional dental filling material (composite resin or amalgam), fixing the chip in position. The patent describes preparation of cavities on occlusal, lingual, or buccal tooth surfaces.

Power supply innovations

The patent includes novel concepts for powering the intraoral chip

Active power supply: Miniature batteries rechargeable through bodily energy sources including temperature differences, muscle activity, vibration from pulse or speech, and mechanical or acoustic energy harvesting

Passive power supply: Inductive coupling that derives electrical energy from signals received from the tracking unit, eliminating the need for onboard batteries entirely

Status: The patent application is noted as "Abandoned" in USPTO records, indicating that the described invention was not pursued to commercial realization. The primary barriers likely included miniaturization challenges, power supply limitations, and the invasive nature of cavity preparation for device placement.

Comparison: Patent concept *vs*. current reality

Feature 2008 patent concept 2025 reality

Location Cavity in natural tooth Denture base or cheek plumper

Power Source Body energy harvesting Rechargeable battery (40-48 hr)

Size Not specified ~1.0 × 0.8 × 0.2 cm

Surgical Invasiveness Tooth preparation required non-invasive (prosthesis-borne)

Clinical Status Abandoned Active clinical use

The shift from natural tooth placement to prosthesis-borne devices reflects practical recognition that removable prostheses offer easier device access for battery maintenance and eliminate the need for invasive dental procedures.

Ethical, legal, and privacy considerations

Informed consent and capacity

For patients with dementia who are candidates for GPS-embedded dentures, questions of informed consent and decision-making capacity arise. Patients may lack the cognitive ability to understand the tracking technology ‘s implications, including:

- The extent and duration of location monitoring
- Who will have access to location data
- How long data will be retained
- The potential for function creep (use of tracking for purposes beyond safety)

In such cases, surrogate decision-makers (family members or legally appointed guardians) must authorize the technology while adhering to substituted judgment or best interest standards.

Privacy and dignity

Continuous location tracking raises privacy concerns even when implemented with beneficent intent. The technology may be perceived as:

- Infringing on residual autonomy and freedom of movement
- Stigmatizing the individual as requiring surveillance
- Reducing the person to a trackable object rather than respecting their personhood

Balancing safety benefits against privacy costs requires careful case-by-case consideration. Some ethicists argue that the minimally intrusive nature of denture-borne tracking (compared to wearable devices) may enhance dignity by normalizing the technology.

Data security

GPS tracking devices transmit location data through wireless networks, creating potential vulnerabilities to:

- Interception of location information by unauthorized parties
- Hacking of caregiver mobile applications
- Unauthorized access to historical movement data

Dental GPS devices for patient tracking must incorporate encryption and authentication mechanisms appropriate to the sensitivity of location data. Unlike surgical navigation systems that operate in isolated clinical environments, patient tracking devices transmit data over public networks and require robust security measures.

Regulatory status

GPS-embedded dentures for patient tracking occupy a regulatory grey area:

- In the United States, the FDA may consider these devices as low-risk Class I or II medical devices depending on claims
- No specific FDA clearance has been identified for denture-borne GPS trackers
- The technology is primarily described in academic literature rather than commercialized products
- Professional guidelines for ethical use have not been established by dental organizations

Future directions

Nano-GPS technology

The most significant technical barrier to widespread adoption of intraoral GPS tracking is device size. Nano-GPS modules (currently in research and development) measuring less than 2 mm in greatest dimension would:

- Eliminate bulkiness and improve patient comfort
- Enable placement in partial dentures and removable appliances
- Reduce interference with speech and swallowing
- Potentially enable placement in natural teeth as originally envisioned in the 2008 patent

However, nano-GPS devices remain expensive and are not yet commercially available for dental applications.

Improved power solutions

Several approaches to power supply are under investigation:

- Solid-state batteries with higher energy density in smaller form factors
- Wireless inductive charging through external paddles, eliminating the need for device removal
- Energy harvesting from mastication, speech, or temperature gradients (reviving concepts from the 2008 patent)
- Low-Power Wide-Area Networks (LPWAN) that reduce transmission power requirements

Integration with health monitoring

Future iterations of intraoral tracking devices could incorporate additional sensors for:

- Intraoral temperature monitoring (fever detection)
- pH monitoring (caries risk assessment, gastroesophageal reflux detection)
- Bruxism detection (grinding force and frequency)
- Medication adherence monitoring (detecting placement/removal of removable prostheses)

Artificial intelligence integration

Combining GPS tracking data with artificial intelligence could enable:

- Predictive wandering risk assessment based on movement patterns
- Automated alerts for deviations from established routines
- Integration with smart home systems for comprehensive safety monitoring
- Machine learning optimization of geofence parameters

Surgical navigation advances

For dental GPS (dynamic navigation) systems, future developments include:

- Integration with augmented reality headsets, eliminating the need to look away from the surgical field
- Haptic feedback systems that provide tactile guidance for implant placement
- Automated robotic assistance for routine implant cases
- Machine learning optimization of treatment plans based on outcome data

Recommendations for clinical practice

For dynamic navigation (implant surgery)

Patient selection: Consider dynamic navigation for anatomically challenging cases, immediate loading protocols, and patients requiring optimal aesthetic outcomes.

Learning investment: Surgeons should anticipate a learning curve of 10-20 cases before achieving efficiency comparable to freehand techniques.

Technology validation: Review published accuracy data for specific systems (e.g., X-Guide) and confirm regulatory clearance in your jurisdiction.

Workflow integration: Develop standardized protocols for CBCT acquisition, treatment planning, and intraoperative reference marker placement.

Documentation: Document planned vs. achieved implant positions to verify accuracy and support quality improvement efforts.

For GPS patient tracking devices

Patient selection: Consider GPS-embedded dentures for patients with documented wandering behavior who cannot reliably wear external tracking devices.

Informed consent: Obtain consent from legally authorized representatives with clear explanation of tracking capabilities, data access, retention policies, and security measures.

Caregiver training: Ensure caregivers understand battery maintenance, device activation, application usage, and emergency response protocols.

Clinical monitoring: Schedule regular follow-up to assess device integrity, tissue response, denture fit, and ongoing patient benefit.

Privacy safeguards: Implement data access controls and retention limits appropriate to the sensitivity of location information.

Exit strategy: Establish protocols for device deactivation and data deletion when tracking is no longer needed or desired.

CONCLUSION

The application of chip-based and GPS technologies in dentistry encompasses two distinct but technologically related domains: surgical navigation for implant placement and patient tracking through dental prostheses. Both applications leverage the unique advantages of the oral cavity-its accessibility for surgical procedures and the inherent retention of dental prostheses-to achieve clinical goals.

Dynamic navigation systems, colloquially termed "dental GPS," have demonstrated clinical efficacy with reported positional accuracy of less than 0.4 mm and angular deviation of approximately 0.9 degrees. These systems offer significant advantages over freehand and static guide techniques, particularly for complex anatomical cases and clinicians seeking objective performance feedback. While capital costs remain substantial, the technology is increasingly accessible and may represent the standard of care for complex implant procedures in the coming decade.

GPS-embedded dentures for patient tracking address a critical unmet need in dementia care: locating individuals with wandering behavior who cannot reliably wear external tracking devices. Current technology demonstrates feasibility with battery life of 40-48 hours and integration with mobile tracking applications. However, limitations including device bulk, battery constraints, signal transmission challenges, and the need for regular maintenance currently restrict widespread adoption. Future advances in nano-GPS technology and power supply solutions may overcome these barriers.

The ethical implementation of intraoral tracking technology requires careful attention to informed consent, privacy protection, data security, and respect for patient autonomy and dignity. As these technologies evolve, professional guidelines and regulatory frameworks must adapt to ensure patient safety and rights are protected.

The convergence of dental science with microchip and satellite positioning technologies represents an ongoing transformation. The “dental GPS” is no longer a futuristic concept but a clinical reality, while true GPS tracking through dental prostheses remains an emerging but promising approach to a challenging public health problem. Continued research, development, and thoughtful implementation will determine the ultimate impact of these technologies on oral healthcare and patient safety.

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