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EDITORIAL

Translational dentistry: Integrating biomaterials, artificial intelligence, and oral–systemic pathways to accelerate patient impact

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Dentistry offers a uniquely tractable test bed for translational medicine. Oral tissues are accessible and highly innervated, implantable devices are commonplace, and saliva provides a rich, noninvasive biofluid for repeated, longitudinal sampling. At the same time, oral conditions are deeply interconnected with systemic health and health system priorities, now formalized by the World Health Organization (WHO) through WHA74.5 and the Global Strategy and Action Plan on Oral Health 2023–2030, which explicitly call for cross-disciplinary integration, data-driven prevention, and equitable implementation.[1,2] Positioning dentistry at the center of this translational agenda can accelerate patient-relevant impact across prevention, diagnosis, and therapy, while advancing the global oral health mandate.[1,2]

Biomaterials serve as rapid conduits from bench to chairside. This is particularly evident in the dental implant field, where materials science translates efficiently from surface engineering to clinical endpoints. Decades of research have demonstrated that implant surface chemistry and topography significantly modulate osseointegration and long-term stability. In general, moderately rough, isotropic microtopographies enhance early bone responses compared to minimally rough or excessively rough surfaces.[3] Classic and contemporary reviews converge on three dimensions of translational readiness: (i) reproducible characterization of surface roughness and chemistry; (ii) biologic plausibility (e.g., improved protein adsorption, osteoblast attachment, and wettability); and (iii) clinically meaningful outcomes such as survival and marginal bone level changes.[3]

Hydrophilicity and nanoscale features further influence protein conditioning films and early cell behavior, with emerging evidence supporting faster early bone apposition; nonetheless, reviewers rightly caution that superiority claims require consistent clinical corroboration and standardized metrology across platforms.[3] The dental arena's iterative loop—from benchtop surface modification to preclinical osseointegration assays, and short-interval clinical readouts—offers an efficient model for translation that other surgical specialties can emulate.

Salivaomics, which integrates transcriptomics, proteomics, metabolomics, and extracellular vesicle analytics, has evolved from a conceptual framework into a translational pipeline, providing robust evidence that salivary profiles reflect both oral disease biology and systemic conditions.[3,4] Foundational work established practical advantages and identified diagnostic signatures for oral cancer and periodontal diseases, among others. Contemporary reviews now emphasize the use of multi-analyte panels,

standardization, and clinical-grade validation to mitigate variability across collection devices, circadian influences, and comorbid oral inflammation.[4]

In a translational context, saliva offers several advantages: (i) compatibility with repeated sampling in community or primary-care settings; (ii) interoperability with digital health (e.g., home collection, remote triage); and (iii) suitability for multi-disease screening (e.g., cardiometabolic risk markers alongside oral-disease biomarkers) in alignment with WHO prevention goals.[2,4] The next step is pragmatic, prospective trials comparing salivary panels head-to-head with blood-based standards for defined indications, incorporating health-economic endpoints and equity considerations.

Artificial intelligence (AI) has moved from proof-of-concept to early regulatory adoption in dental radiology. A widely cited synthesis details opportunities (e.g., lesion detection, segmentation, and risk prediction), limitations (e.g., dataset bias and lack of external validation), and enablers (e.g., explainability and federated learning) for trustworthy clinical AI. Notably, the United States Food and Drug Administration's 510(k) clearances of dental AI systems—such as Overjet's software for assisting caries and bone-loss detection and measurement on two-dimensional radiographs and Pearl's "Second Opinion" for pathology detection and measurement assistance on intraoral radiographs and cone beam computed tomography—represent a practical inflection point for real-world translation.[5]

The translational obligations are clear: Curate diverse, well-labeled datasets; mandate external validation and drift monitoring; and prospectively evaluate their impact on clinician behavior, diagnostic accuracy, and patient outcomes. Implementation science should be integrated with randomized or quasi-experimental designs to demonstrate value in representative clinical settings and to define safe human-in-the-loop workflows.[5]

Contemporary evidence increasingly positions oral–systemic pathways as targets for precision prevention. Periodontitis is consistently associated with atherosclerotic cardiovascular diseases, and mechanistic studies suggest this link may involve low-grade systemic inflammation, bacteremia, endothelial dysfunction, and immune-metabolic crosstalk. In parallel, an updated Cochrane review indicates that periodontal therapy yields clinically meaningful improvements in glycemic control among individuals with diabetes (approximately 0.3–0.4% reduction in absolute hemoglobin A1c at 3–6 months), thereby strengthening the case for integrated dental-medical care pathways. Collectively, these data support bidirectional screening and coordinated management between dental and medical teams as integral components of chronic disease prevention and control.[1-5]

A translational blueprint in dentistry should include (Figure 1):

(i) Discovery and design: Materials and devices engineered with standardized surface metrology and biologic assays; saliva-omics panels derived from rigorous discovery/replication cohorts.[3]
(ii) Validation and regulation: Pre-specified endpoints and external validation; for AI, prospective, monitored deployment with post-marketing surveillance.[4]
(iii) Implementation and equity: Multicenter pragmatic trials incorporating cost-effectiveness, workforce impact, and access metrics; integration with primary care and community settings, aligned with WHO's 2030 targets.[1-5]
(iv) Feedback within a learning health system: Privacy-preserving data linkage enabling continuous improvement and personalized risk stratification.[5]

In summary, dentistry is positioned at the intersection of device innovation, diagnostic techniques such as fluid-biopsy, and chronic disease prevention. Establishing clear translational pathways, standardizing material measurement methods, validating salivary omics against clinical outcomes, and implementing validated AI systems in real-world settings can lead to tangible improvements in patient outcomes and advance broader oral health goals for 2030. The opportunity extends beyond individual disciplines to a systemic level.

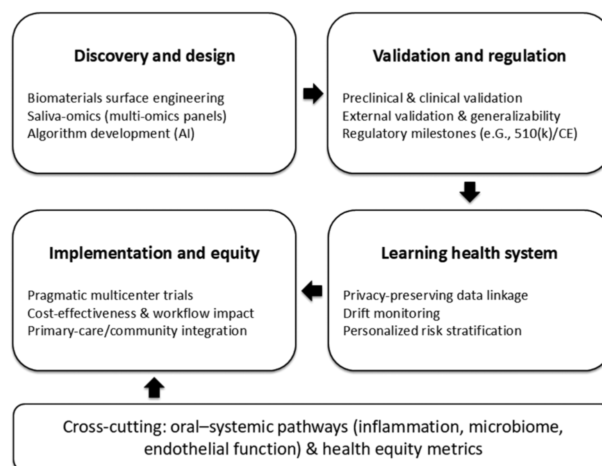

Figure 1. Schematic illustration of translational dentistry depicting the bidirectional flow among the bench (e.g., biomaterials, multi-omics, and algorithm development), bedside/chairside (e.g., clinical evaluation and regulatory milestones), and community (e.g., screening, prevention, and implementation), with oral-systemic pathways and health equity metrics spanning all phases
Abbreviation: AI: Artificial intelligence.

Conflict of interest

Luca Fiorillo is an Editorial Board Member of this journal. The author declares he has no competing interests.

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