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Transforming dentistry

By Rob Morgan, VP Medical at Sagentia

Dentistry has a long history of reinventing and repurposing technologies from other branches of medicine. In the digital age, this increasingly extends to technology transfer from wider industries. Rob Morgan considers innovations set to transform dental systems, products and instruments, improving practice efficiency and patient outcomes.

Innovation in dentistry has to strike a fine balance. On the one hand, there's increasing demand for patient-centricity, practice differentiation and workflow efficiency. On the other, any developments need to offer tangible benefits for the sole practitioners or dental groups adopting them. In short, they need to be economically viable.

The pace of change in the digital economy means manufacturers of dentistry products, systems and instruments must go beyond incremental innovation to achieve this equilibrium. They need to identify emerging market opportunities, then quickly address them with cost-effective solutions to gain competitive advantage.

This paper explores five areas where strategic adoption and adaptation of non-core technologies could transform dentistry and give manufacturers the edge over competitors.

Biomaterials and biologics

Biomaterials and biologics offer new routes to the repair of dental tissue, providing an alternative to the use of restorations and implants. Dental tissue regeneration will drive a transformational shift in dentistry, avoiding the need for tissue replacement. And the augmentation of existing treatments with tissue regeneration, such as restoration of bone stock for dental implants, will lead to further changes.

The repair of both hard and soft tissue continues to advance in other branches of medicine, and progress is being made in dental tissue regeneration research. The options can be broadly categorized into three technology disciplines: advanced biomaterials and scaffolds, biologic molecules including recombinant proteins, peptides and small molecules, and cell therapies.

Much can be learnt from the approaches taken in orthopaedic surgery, sports medicine, spine surgery and wound care. The technical approaches trialled in these clinical settings and the commercial models which have and haven't been successful provide valuable lessons.

Advanced biomaterials must provide more than mechanical properties and biocompatibility. They also need to interact with the host environment to induce tissue healing and regeneration.

Researchers have demonstrated the efficacy of some advanced biomaterials. But, in general, biologic molecules or cell therapies are required to achieve significant tissue regeneration, for example in bone healing to achieve osteoinduction or osteogenesis rather than just osteoconduction. Recombinant proteins such as bone morphogenic proteins have gained widespread adoption in spine surgery as osteoinductive agents for vertebral spine fusion. Cell therapies already enjoy widespread use in sports medicine to treat articular cartilage defects through the culture of autologous chrondrocytes onto biomaterial scaffolds. They've also been used extensively to treat dermal wounds such as diabetic foot ulcers and burns through the culture of allogenic cells.

Dentistry can take key learnings from these approaches. From the pre-clinical and clinical pathways required to launch commercial products, to side effects and risks identified during widespread clinical use, and the production models required to deliver therapies at required price points. Drawing on existing evidence and insights can accelerate innovation.

Additive manufacturing

Additive manufacturing – or 3D printing – unlocks new possibilities for chairside manufacture of dental components. It's now used extensively in many commercial applications, with complex objects produced quickly and cost-effectively from 3D digital models. In the medical sector, maxillofacial surgeons use the technology to create personalized titanium implants for victims of serious facial injuries. Hearing aid design can be customized using a scanned impression of the user's ear. And surgical cutting guides are routinely printed to provide accurate, patient-matched bone cuts for surgeons conducting knee replacements.

Today, more than 20 manufacturers offer 3D printing solutions for dental applications including models, provisional restorations, implant drill guides and night guards. This is likely to be the start of an enduring movement, which will gather pace as technology advances and a wider range of products – such as orthodontic and restorative devices – can be manufactured. As with CAD/CAM machines, upfront investment can be high. But manufacturing costs per unit may be lower, making this a more attractive proposition than current onsite machining methods.

Ongoing activity in the biomaterials sector is set to add a new dimension to this trend, through the development of new 3D printing materials. For instance, a research group at the University of Groningen in the Netherlands is working on the creation of 3D-printed teeth made from an antimicrobial plastic that kills the bacteria responsible for tooth decay.

Furthermore, various research groups are exploring 3D printing of cells onto scaffolds. This could offer new potential for dental bone graft indications such as sinus floor and alveolar ridge augmentation. Current treatment options are limited to traditional autologous, allogenic or synthetic bone graft materials or the high-cost bone morphogenic protein formulations.

Digital dentistry and advanced manufacturing techniques open new clinical possibilities and promise cost-effective solutions for in-office restorations.

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Such innovations may involve significant upfront investment in equipment, maintenance and training. However, producing customized devices chairside will reduce iteration times, improve the patient experience and accelerate throughput.

Advanced imaging for monitoring and diagnosis

Digital 2D and 3D x-rays provide fast, accurate dental imaging that encompasses bone structure and root position as well as teeth. However, while 2D x-ray imaging is well-established, 3D techniques such as Cone Beam Computed Tomography (CBCT) have had limited uptake. The machine's six-figure price tag is prohibitive for many dental practices. What's more, both techniques involve the exposure of patients to ionizing radiation. So, are there alternatives that could be developed?

One area that's ripe for further innovation is the intraoral cameras used for dental inspection and creation of digital patient records. These devices leverage existing imaging technology from the consumer electronics industry, reducing the associated development costs. There is scope to extend and enhance their functionality with dual imaging channels and improved dynamic range.

For instance, existing intraoral scanning technologies offer surface-only optical imaging, but alternative imaging modalities could be integrated to provide subsurface information. The most prominent of these are fibre optic trans illumination (FOTI) and fluorescence imaging, both of which are already used in standalone inspection devices to detect caries lesions.

FOTI devices, such as CariVu, emit a high-powered white light source which makes enamel appear transparent while porous lesions trap and absorb light. Fluorescence imaging devices, such as DIAGNOdent, also provide enhanced detection of caries, albeit with a limited imaging depth of a few millimeters. Such devices have also been developed for the detection of intraoral cancer during oral mucosal examinations, e.g. the VELscope.

Use of fluorescence imaging is limited in dentistry to date, but it's enjoyed widespread adoption in other branches of medicine when combined with

Advanced imaging offers new possibilities for chairside diagnosis and monitoring.

fluorescence markers. The most widely used marker is indocyanine green (ICG), which provides contrast between blood vessels and their surrounding tissue for applications including angiography and ophthalmic imaging. It's also used to provide enhanced, real-time data during surgery. The da Vinci Robotic Surgery System incorporates an option for fluorescence imaging and a range of new markers is being developed for solid tumor and critical structure visualization during surgery.

Ultrasound imaging also has potential for some dental applications. It's non-invasive, relatively low cost, and can be used to image both hard and soft tissue. Clinicians currently use ultrasound for diagnostic purposes and for real-time imaging during invasive procedures, such as laparoscopic surgery and percutaneous needle placement. Several research projects have given favourable evaluations of its use in dental diagnostics and in temporomandibular (TMJ) disorders, which fall within dental clinical practice.

These techniques clearly have the potential to improve routine dental imaging. And they could enable dentistry to benefit from real-time imaging to guide caries lesion removal or endodontics procedures.

One to watch for the future is magnetic resonance imaging (MRI). It's worth noting that MRI is already considered by many as the gold standard for diagnosing TMJ disorders. And GE Global Research and the Mayo Clinic have published work regarding a 3 Tesla head-only system for neuroimaging. While the cost would currently be unrealistic for individual practices, this development indicates that lower-cost MRI could become a reality for dentistry. Centralization of care models could drive widespread use more quickly.

Effective clinical imaging relies on a raft of powerful modalities, sometimes used in combination. In the hospital environment, MRI, ultrasound, enhanced fluorescence imaging and optical coherence tomography are among many techniques used across a wide range of applications. They offer multiple benefits without the risks attached to ionizing radiation.

However, the centralized patient care model of hospitals makes it easier to accommodate instruments with a high capital outlay, since they're involved in the treatment of many conditions. It's harder for dental practices to achieve an adequate return on investment.

Can manufacturers harness proven imaging modalities in new, cost-effective ways to enhance diagnosis and monitoring of caries, periodontal disease and other conditions? Those that do have an opportunity to corner this aspect of the dentistry market.

Biomarkers and in vitro diagnostics

In vitro diagnostics (IVD) tests are routinely used by medical professionals to diagnose and monitor a wide range of conditions. They typically involve the analysis of blood or urine samples in central laboratories or point of care (POC) settings, using clinical chemistry, immunochemistry and molecular diagnostic methods.

Salivary analysis holds promise for diagnosis of systemic conditions, with HIV and oral cancer currently detectable. The OraQuick Advance test is a CLIA-waived, POC test which provides HIV test results in 20 minutes from an oral swab sample. Tests for oral cancer include the SaliMark OSCC, which analyzes six mRNA markers from a saliva sample.

There is scope to apply similar methods in dentistry, and analysis of saliva to diagnose periodontal disease is a particular area of interest. Research to date has included assessment of the inflammatory response and specific bacterial species involved.

Recent advances in salivary diagnostics have been enabled by the characterization of biomarkers and the mapping of the salivary proteome. Understanding the proteins present in human saliva offers much potential for clinical applications. Commercially available tests will follow, and an immediate target is Sjorgen's syndrome, the autoimmune disease causing dry eyes and dry mouth. Researchers are also studying the use of salivary analysis to determine caries risk and detect salivary gland diseases.

As evidence from basic research grows, dentists are likely to want to use salivary testing to assess and monitor oral health during routine examinations. This will introduce new device requirements. Dentists may choose to send samples to a central lab for analysis, as do many primary care physicians with blood and urine samples. However, POC diagnostics would bring added convenience and the opportunity for immediate treatment decisions.

Commercialization of POC diagnostic devices for the dental office will require collaboration across multiple disciplines. Development capabilities from the IVD industry, scientific knowledge of dental researchers and the established distribution networks of dental equipment providers will all have a role to play. Consumers would also benefit from home use monitoring devices to assist in oral health management, just as diabetes patients use blood glucose meters. The commercialization of home use kits will require a similar combination of dental and IVD capabilities, transferring technology into dentistry from other medical markets.

Connectivity and new care models

Connectivity has transformed the consumer electronics industry, and shifted consumer expectations in all aspects of their life. The digital health trend is set to accelerate in the coming years, and many medical device manufacturers are moving into this space. Orthopaedic implant manufacturers are looking beyond joint replacements and providing connected systems which assist the entire patient care cycle, from presurgical planning to post-operative support. Pharmaceutical companies are embracing digital health to improve patient adherence to chronic disease medication. Chronic cardiac conditions are being managed at home using a combination of remote monitoring and telemedicine.

There is great potential for connectivity to bridge the gap between daily oral care performed at home and the less frequent care administered by dentists. Smart toothbrushes are already available for keeping track of brushing habits and alerting a user when they've missed a spot. As technology progresses, smart tooth brushes or home use tests could be used to signal the emergence of conditions requiring professional treatment. Alternatively, these devices might transfer data to the cloud for automated analysis and periodic inspection by the dentist. Device manufacturers are already experimenting with smartphone imaging. Using an app, a patient records images of their teeth and gums for a dentist to inspect. This enables the dentist to monitor enamel white spots, gum disease and other slow-progress conditions.

The emergence of IVD methods for dental issues, combined with connectivity, introduces the possibility of radical new care models. If salivary diagnosis becomes a reality for dentistry, people may not need to visit their dental practitioner for a regular check-up. Health clinics and pharmacies could offer saliva testing, enabling patients to have a remote dental check-up when collecting a prescription or getting a flu shot. Patients might provide a saliva sample, then receive the result on their smartphone a little later. Depending on the result, they're either good for another six months, or need to make an appointment with their dentist.

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Medical device manufacturers are also exploring the use of connectivity to improve operational efficiency. They're looking to cut sales and distribution costs through remote monitoring of product inventory, and reduce capital equipment maintenance costs through remote diagnostics.

Remote tracking of product use and inventory location might change the dynamics of manufacturer/distributor relationships. Manufacturers of dentistry products, systems and instruments would do well to consider such developments, which embrace modern ways of working to boost efficiency, productivity and profitability.

When will transformation happen?

This is the million-dollar question. Advances in biomaterials, additive manufacturing, diagnostic imaging, salivary diagnostics and connectivity have exciting potential. Yet, while digital health offers many advantages, to date it has only enjoyed extensive uptake in relation to life-threatening conditions like Type I diabetes. And salivary diagnostics still has some way to go before it evidences the specificity and sensitivity required for use as a standalone test.

Change is certainly on the cards. But there always needs to be a clear economic case for the adoption of new technologies. Dental practices that invest at the right time will benefit from improved efficiencies, more effective patient care and competitive differentiation.

However, they will have to reconcile themselves to the fact that the days of upgrading equipment every ten years or so are over. They may have to purchase new equipment much more frequently to stay relevant.

Dental device manufacturers with the acumen to pinpoint new technologies with the greatest potential to drive cost-effective improvements will perform best in the digital economy. They will be at the forefront of exciting and disruptive changes in dentistry treatments and patient care models. Those that embrace transformation strategically, intelligently and shrewdly are set to thrive.

Biography

Dr Morgan is Vice President of Medical at Sagentia

A science, technology and product development company with clients from across the dental, pharmaceutical and medical technology sectors. Prior to joining Sagentia Dr Morgan held various positions in research & development and strategic marketing for the Orthopaedics and Biologics & Spine divisions of Smith & Nephew. During his career he has worked on biomaterials, regenerative medicine, sensor enabled implants, in vitro diagnostics and surgical robotics.

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