Future of Pediatric Dentistry: A Review

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ABSTRACT

It is time for analysis and reform in our dental schools and teaching. If Pediatric Dentistry is to meet the needs of our time. Even the most thoughtful and probing analysis will be imperfect; even the most earnestly pursued remedies will not be entirely successful. Although we cannot reach the ideal, we can move towards it. A bright future lies ahead in the dental field, but we shall all have to work very long and very hard to make it come to pass. Future of dentistry has become one of the unique resources and providers of this oral systemic approach. Hence, this present article describes a brief review on some of the breakthrough advances in dentistry which includes smart materials, tissue engineering, dental implants and ozone therapy.

KEYWORDS: Pediatric Dentistry, Smart Materials, Tissue Engineering, Dental Implants, Ozone

INTRODUCTION

In understanding the patient's unique needs and to fully assess the individual requirements of the patient before, during, and after dental care, it has becoming increasingly important for the dentist to work with other cutting-edge, integrative practitioners. It's a rare opportunity to witness the beginning of truly groundbreaking advances in technology. Uncertainty is a natural reaction when we are presented with a radically new method and its potential uses which help us filter the valuable from the worthless, the permanent from the short-lived, and the rational from the ridiculous. Smart materials, Tissue engineering, Dental implants and Ozone therapy will change dentistry, healthcare and individual life more greatly than many precedent progress.1

SMART MATERIALS

Today the most promising technologies for life span efficiency and improved reliability include use of “Bio-Active Smart Materials”.2

The term ‘smart materials’ refers to a class of materials that are highly responsive and have the inherent capability to sense and react according to changes in the environment. For that reason, they are often also called ‘responsive materials’. The use of biocompatible smart materials has revolutionized many areas of Dentistry. These innovations in the material science have marked the beginning of an era of Bio-Smart Dentistry, a step into the future!3

Properties of Smart Materials: A key feature of smart behavior includes an ability to return to the original state after the stimulus has been removed. Smart material sense changes in the environment around them and responds in a predictable manner. In general, their properties are:

- Piezoelectric- Structures made from these products can be made to change shape or dimensions when a voltage is applied. Likewise, a change in shape can be used to generate a voltage which can be used for the purpose of monitoring.
- Shape memory- They can remember their original shape after deformation and return to it when heated.
- Thermochromic and Photochromic- These materials change color in response to change in temperature and light.
- Magneto-rheological- these are fluid materials becomes solid when placed in a magnetic field.
- pH-sensitive- swell/collapse when the pH of the surrounding media changes.
- Biofilm formation- Biofilms formed on the surface of materials in the mouth may enhance the smart behavior of materials containing fluoride releasing salt phases.
- Role of water- Many types of smart behavior are related to the ability of a gel structure to absorb or release solvent rapidly in response to a stimulus like temperature.
- Smart thermal behavior- The vast majority of materials respond to a temperature change in a predictable manner characterized by the coefficient of thermal expansion.
- Fluoride release and recharging- Even products with high initial fluoride release tend to rapidly lose the ability to release fluoride in a significant amount. There is evidence that the fluoride released from salt phases can be replaced when the material is bathed in a high concentration of fluoride as may occur in
toothpaste or mouthrinse.  

**Classification of Smart Materials:**

**a) Passive Smart Materials:** These materials respond to external change without external control. Example: Glass ionomer cement, Resin-modified glass ionomer, Compomer, Dental Composites.

**b) Active Smart materials:** These materials sense a change in the environment and respond to them. It also utilizes a feedback loop to enable them to function as a cognitive response through an actuator circuit.

i) **Smart composites:** It is a light-activated alkaline; nano-filled glass restorative material. It releases calcium, fluoride and hydroxyl ions when intraoral pH values drop below the critical pH, i.e., 5.5 and counteracts the demineralization of the tooth surface and also aids in remineralization. Example: Ariston pH control.

ii) **Smart ceramics:** These are metal-free biocompatible life resembling restorations that allows them to blend well with the surrounding natural dentition. Example: Cercon Zirconium Smart Ceramic System.

iii) **Smart impression materials:** These materials exhibit more hydrophilic properties to get a void-free impression. Example: Aquasil ultra (Dentsply).

iv) **Shape Memory Alloys:** These alloys have exceptional properties such as super-elasticity, shape memory, good resistance to fatigue and wear and relatively good biocompatibility. Example: Nitinol.

v) **Smart Glass Ionomer Cement:** The smart behavior of GIC is due to the ability of a gel structure to absorb or release solvent rapidly in reaction to a stimulus like temperature, change in pH, etc. Resin modified Glass Ionomers Cement, Compomer or Giomer also exhibit these smart characteristics. Example: GC Fuji IX.

vi) **Amorphous Calcium Phosphate (ACP) releasing pit and fissure sealants:** ACP is an antecedent in the biological formation of hydroxyapatite (HAP). At neutral or high pH, ACP remains in its original form, but when the surrounding pH drops to or below 5.5 (critical pH), ACP converts into crystalline HAP, thus replacing the HAP crystal lost to the acid.

vii) **Nickel-Titanium (Ni-Ti) rotary instruments:** The introduction of Ni-Ti in rotary endodontics has made instrumentation easier and faster. The advantages are fewer chances of file breakage, less fatigue, less transportation, decreased incidence of canal aberration and minimal post-operative pain. Example: Ni-Ti rotary files.

viii) **Smart prep burs:** These are polymer burs that cut only infected dentin. The affected dentin is left intact which has the ability to remineralize. Example: SS White.

ix) **Smart sutures:** These sutures are made up of thermoplastic polymers that have both shape memory and biodegradable properties. Example: Novel MIT Polymer.

x) **Smart antimicrobial peptide:** A pheromone-guided “smart” antimicrobial peptide is targeted against the killing of Streptococcus mutans which is the principal microorganism responsible for dental caries. Example: Pheromone guided “smart” antimicrobial peptide.

xi) **Smart Seal Obturating System:** Obturation of root canals should prevent reinfection, and this may be achieved by three-dimensional filling. The C Point system is a point-and-paste root canal filling technique that consists of premade, hydrophilic endodontic points and an accompanying sealer. The C Point is designed to expand laterally without expanding axially, by absorbing residual water from the instrumented canal space. Smart paste bio is a resin-based sealant designed to swell through the addition of ground polymer. Addition of bioceramics gives the sealer exceptional dimensional stability and makes it nonresorbable inside the root canal. It also produces calcium hydroxide and hydroxyapatite as by-products of the setting reaction, rendering the material both antibacterial and biocompatible.

xii) **Smart Coatings for Dental Implants:** “Smart coating” helps surgical implants bond more closely with bone and ward off infection. A crystalline layer next to the implant and amorphous outer layer that touches the surrounding bone is created by the coating. The amorphous layer dissolves over time, releasing calcium and phosphate, which encourages bone growth. “As the amorphous layer dissolves, the bone grows into the coating, resulting in improved osseointegration or bonding.” Also, silver nanoparticles have been incorporated throughout the coating to ward off infections.

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**TISSUE ENGINEERING**

Tissue engineering is an interdisciplinary field that coalesces the principles of engineering, material and biological sciences toward the progress of therapeutic strategies and biological substitutes that replace, restore, improve or maintain biological activities. It is a new frontier in Clinical Dentistry that deals with the interactions between cells, growth factors and the scaffolds to produce the intended tissue or organs. Important advances have been reported in Dentistry aiming the regeneration of temporo-mandibular joint, periodontal ligament, dentin, enamel, pulp and integrated tooth tissues.

**Design for Engineering Tissue Structures and Functions:** To engineer functional tissues, cells (host and/or donor) must be provided with appropriate spatial and temporal cues to enable growth, differentiation, and synthesis of an extra-cellular matrix (ECM) of sufficient volume and functional integrity. Most Tissue engineering approaches are based on the tissue engineering triad, which are derived from the three major parts of tissues: cells, their ECM, and a signaling system. With the use of one or more of these components, a functional tissue can be developed. A variety of biomaterial ‘scaffolds’ have been developed as ECM analogs capable of supporting cell attachment (e.g., conduction) and, in some cases,
providing the cues necessary for controlled temporal and spatial development (e.g., induction).7

**Key Elements of Tissue Engineering:** The classical cell-based tissue engineering approach involves the seeding of biodegradable scaffolds with cells and/or growth factors, then, implanting it in order to induce and conduct the tissue growth.

The three tissue engineering fundamental elements:6

a) **Stem Cells:** Stem cells are undifferentiated, immature cells that can multiply and divide for an extended period of time, differentiating into various types of cells and tissues.

i) **Embryonic stem cells (ESC):** Embryonic stem cells are derived from embryos generated by in vitro fertilization. They are pluripotent and give rise to all derivatives of three primary germ layers.8

**Adult stem cells (ASC):** These are undifferentiated cells that occur in a differentiated tissue.9 These are multipotent.9 Source of ASC can be from dental or non dental tissue. ASC from dental tissues includes Dental pulp stem cells (DPSCs), Stem cells from human exfoliated deciduous teeth (SHEDs), Stem cells from the apical papilla (SCAPs), Dental follicle stem cells (DFSCs), Periodontal ligament stem cells (PDLSCs). ASC from non dental tissue are Bone marrow-derived mesenchymal stem cells (BMSC), Adipose-derived adult stem cells, Umbilical cord stem cells, Amniotic fluid-derived stem cells, Induced pluripotent stem cells.8

**Scaffold:** Scaffolds are temporary frameworks used to provide a three dimensional micro-environment where cells can proliferate, differentiate and generate the desired tissue.6 To provide a spatially correct position of cell location and regulate differentiation, proliferation, or metabolism, an appropriate scaffolding is necessary.

Scaffolds can be either natural or synthetic. Examples of natural scaffolds include collagen, glycosaminoglycans, demineralized dentin matrix and fibrin. Whereas example for synthetic materials include polyactic acid (PLA), polyglycolic acid (PGA), polyactic co-glycolic acid (PLGA), poly-epsilon caprolactone, hydroxyapatite/tricalcium phosphate, bioceramics, titanium and, hydrogels such as alginate or variants of polyethylene glycol (PEG).10

**Cell Signaling:** Cell signaling is part of a amalgamated system of communication that controls cell activities and organizes their interactions.6 They coordinate interactions with cell populations and the extracellular matrix (ECM).

Growth Factors (GF) are primary signaling molecules, play important roles in regulating cell activities such as chemotaxis, migration, adhesion, proliferation, and differentiation. The strategy of tissue regeneration is to utilize GFs to induce and optimize the growth and differentiation of various cell types towards specific phenotypes. Following GFs are therapeutic candidates for periodontal regeneration: Bone Morphogenetic Proteins (BMPs), Transforming Growth Factor-β (TGF-β), Platelet Derived Growth Factor (PDGF), Fibroblast Growth Factor (FGF), Insulin-Like Growth Factor (IGF), Enamel-Matrix Derivatives (EMD) and Growth/Differentiation Factor-5 (GDF-5).11

**Dental and Craniofacial Tissue Engineering Applications:**

**Pulp/Dentin Tissue Engineering and Regeneration:** Dental pulp tissue engineering was first tested by Mooney et al. (1996). Bohl et al. (1998) reported that culturing pulp cells grown on polyglycolic acid (PGA) in vitro resulted in high cell density tissue similar to the native pulp.12

Gronthos et al. (2004) demonstrated both in vivo and in vitro in animals that dental pulp stem cells (DPSCs) were able of forming ectopic dentin and related pulp tissue.9

**Bioroot Engineering: Tooth regeneration:** Ikeda et al. (2009) explored in an adult mouse that by the interaction between the dental epithelium and mesenchymal cells, fully functioning tooth replacement can be achieved by transplantation of a bioengineered tooth germ into an alveolar bone of a lost tooth region. The bioengineered tooth, which had erupted and reached occlusion, had hardness of mineralized tissues for mastication and the correct tooth structure.8

**Tissue engineering in endodontics: root canal revascularization:** By the use of certain simple clinical protocols, Root canal revascularization attempts to make necrotic tooth alive. Earlier apexification was the treatment of choice for treating and preserving immature permanent teeth that have lost pulp vitality. However, with the success of root canal revascularization to regenerate the pulp-dentin complex of the necrotic immature tooth, apexification treatment may become obsolete.13 As regeneration of the tissue takes place by the patient's own blood cells, revascularization process offers negligible chances of immune rejection and pathogen transmission.8

**Periodontology and tissue engineering:** Entire regeneration of the periodontium has always posed a challenge due to its difficult structure (having hard and soft tissues). Hasegawa et al. (2007) confirmed that periodontal ligament cells cultured in vitro were effectively reimplanted into periodontal defects in order to endorse periodontal regeneration.9

**Uses in oral maxillofacial surgery for craniofacial reconstruction:** According to Pittenger et al. (1999) bone marrow-derived Mesenchymal stem cells (MSC) are now under consideration for the repair of craniofacial bone and even the replacement or regeneration of oral tissues. Using stem cells, vascularised bone grafts are also been developed, and reconstruction of a patient's resected mandible has been carried out using this method.5

**Neural regeneration:** Both dental and non dental MSCs are mainly derived from neural crest stem cells (which also give rise to neuronal cells). With neuronal
stimulations, human dental MSCs (DPSCs, SHED, and SCAP) could differentiate into neural lineage in vitro. It has been found that when transplanted into the injured site of the DPSCs and SHED enhanced neuronal recovery in animal models with CNS injuries. The improvement of DPSCs and SHED on neuronal recovery is likely due to their neurotrophic products.14

Bone regeneration: Dental and non dental MSCs are able to differentiate into chondroblasts and osteoblasts under inductive conditions in vitro. Aquino et al. (2009), found that DPSCs and collagen sponge scaffold formed a bio complex that could completely restore mandible bone defects in patients.

Muscle regeneration: Yang et al. (2010) verified that DPSCs were able to differentiate into dystrophin-producing muscle cells in cardiotoxin-paralyzed muscles in a mouse model, which has implications for the treatment and study of muscular dystrophy.

Tendon and cartilage regeneration: Tendons have very limited ability for self-repair after injuries. Since periodontal ligaments are similar to tendons (they both have the ability to absorb mechanical forces of stress and strain), PDLCs show a more organized structure, with more extracellular matrix and collagen, suggesting PDLCs have better potential for tendon regeneration.14 15

Salivary Gland and tissue engineering therapy: Salivary glands are the unusual but valuable target site for multiple clinical gene transfer applications. It can be used to repair damaged salivary glands following irradiation in Sjogren’s syndrome and for gene therapeutics, systematically by way of the blood-stream and locally in oral cavity.15

The future of Tissue Engineering in Dentistry is exciting. It is certainly possible that, once dentist-scientists bring together the new discoveries in material’s sciences, genetics, molecular and cell biology, new alternatives for regeneration of bone and soft tissues, management of periodontal disease and restorative procedures to regenerate enamel, dentin and pulp will become available for clinical application.6

OZONE

It is a gas composed of three atoms of Oxygen and occurs naturally in the upper layer of atmosphere in abundance. It absorbs the harmful ultra-violet rays from the sun thereby protecting the living creatures. It has got a high oxidation potential which is 1.5 times greater than chloride when used as an antimicrobial agent. It also stimulates the immune response and blood circulation. 16

Ozone, which is used for medical purposes, is of 95 to 99.95% oxygen (O2) and 0.05 to 5% pure ozone (O3). Edward Fisch (1950) used ozone for treating gangrenous pulpitis.17 Studies have shown that 99% of all the bacteria was causing tooth decay have been eliminated after 10 seconds of ozone exposure and 99.9% bacteria elimination after 20 seconds of exposure.1 Routes of Ozone Administration includes Gaseous ozone, Ozonated water and Ozonized oil.18

Mechanism of Action of Ozone:

Anti-Microbial action: It results from oxidation of microbial cellular components. Healthy human body cells because have free radical scavengers like superoxide dismutase, catalase, hydrolase, Vitamin C, E, beta-carotene, selenium, methionine, glutathione, hence they are not destroyed. Only unhealthy cells such as cancer cells that have lost this protective mechanism and organisms such as bacteria, viruses, fungi, parasites which are devoid of these antioxidants and scavengers are destroyed.

Anti-inflammatory and Analgesic action: The infection or inflammation is positively charged (acidic) and ozone is negatively charged (basic), so the chemistry of infection and inflammation attracts ozone to the area.

Immune-stimulating action: The electromagnetic action of ozone stimulates and modulates immune system particularly lymphocytes producing interleukins. It also activates the function of macrophages and increases the sensitivity of microorganisms to phagocytosis.

Anti-hypoxic action: Ozone brings about the rise of Partial pressure of Oxygen (PO2) in tissues and improves transportation of oxygen in the blood. Ozone acts as a super-oxygenator, bringing oxygen to tissues, assisting the body in its natural healing process.

Bio-energetic and biosynthetic action: Ozone activates mechanisms of protein synthesis, increases amount of ribosomes and mitochondria in cells, elevating functional activity and regeneration potential of tissues and organs.19

Ozone Therapy as Applied to Pediatric Dentistry:

Treatment of Dental Caries: Treatment of caries with ozone is simple, fast and involves little preparatory work. The loose debris is first cleaned away, until a leathery base is reached. This can be done with hand instruments. Ozone is applied, the lesion wetted with the CurOzone remineralizing wash and then the glass ionomer can be applied.

Restoration of large cavitations along with conventional conservative measures: The fundamental protocol is; the soft debris is removed along with any unsupported enamel. If feasible, denatured dentine is removed to the leathery layer. Ozone is used for 40 seconds or longer. Some practitioners are using 2 to 3 minutes for large deep lesions that extend on x-ray almost to the pulp chamber. Then, the remineralizing wash is applied. The lesion is restored using a mineral-releasing glass ionomer.

Remineralisation of pit and fissure, root and smooth surface caries: In early pit and fissure carious lesions or superficial root caries, ozone alone may be sufficient to treat these lesions. However, in situations where a severe breakdown of tooth structure has occurred, ozone may be used initially to promote remineralization and when this
take place the cavity may be restored with a suitable restorative material.

**Bleaching:** In root canal treated teeth, after placing the bleaching agent the crown is irradiated with ozone for a minimum of 3-4 minutes. This ozone treatment bleaches the tooth within minutes and gives the patient a happy and healthier-looking smile.

**Endodontic treatment:** When irrigating with the usual irrigant solution, ozone can be applied along with hypochlorite solution in the root canals. This technique will allow the root canal system to get thoroughly disinfected and possibly sterilized.20

Ozonated water in decontamination of avulsed teeth before replantation: Two-minutes irrigation of the avulsed teeth with non-isotonic ozonated water not only provides mechanical cleansing, but also decontaminates the root surface, with no negative effect on periodontal cells remaining on the tooth surface before replantation.

**Antibacterial effect of ozone on plaque biofilm:** Ozone may be useful to control oral infectious microorganisms in dental plaque. Ozonated water strongly inhibited accumulation of dental plaque. Healing and bactericidal properties make it useful as a subgingival irrigant.

**Ozone for treatment of peri-implantitis:** For the prevention of peri-implantitis, an adequate and steady plaque control regimen must be ensured. Ozone, a powerful antimicrobial kills the microorganisms causing peri-implantitis.17

**Ozone and soft tissue lesions:** Soft tissue lesions such as cheilitis, candidiasis, cysts, herpes, aphthae, removable denture ulcers, cuts and traumatic wounds can be treated with either ozonated water or oils. The healing and disinfectant properties help in the healing of such lesions.

Scientific support demonstrated by various studies shows ozone therapy as a potential therapy in the field of medicine and dentistry.19

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**DENTAL IMPLANTS**

Traumatic injuries and disease conditions such as Ectodermal Dysplasia, congenital absence of teeth or oligodontia can lead to edentulous conditions in children. This can be a source of immense psychological trauma to the child as well as affect the orofacial development.21

The use of implants in children or in individuals where growth is not completed is a controversial one. Before placement of an implant, it is essential to understand growth, development and the dynamics of a placed implant in a biologic environment of a growing patient.

Placement of implant in children is still under critical evaluation as there are two major concerns:

1. If implants are present during several years of facial growth, there is a danger of them becoming embedded, relocated or displaced as the jaw grows.
2. The second area of concern is the effect of the prosthesis on growth.22

**Recommendation According To Areas For Placing An Implant**

**Anterior Maxilla:** Vertical growth in this area exceeds growth in other dimensions and continues to a later age.23 According to Krant (1996), the placement of implants in the anterior maxillary quadrant before the age of 15 in female and 17 in the male with the possibility of future implant replacement.

**Posterior Maxilla:** According to Cronin (1998) placement of osseointegrated dental implants in the maxillary posterior quadrant is best delayed until the age of 15 years in females and 17 years in males.24

**Anterior Mandible:** The symphysial area causes the least problem with implant placement, since it is closed in early childhood and sagittal growth primarily occurs in the posterior part of the mandible.23 Therefore, it is the best site for the placement of an osseointegrated implant before skeletal maturatation.24

**Posterior Mandible:** In the posterior mandible, large amounts of transverse, sagittal and vertical growth occur. A conservative approach in the posterior mandible dictates that implants should not be placed until skeletal growth is completed.23

**Recommendation for an Implant placement according to length of edentulous span by Sharma & Vargervik (2006):** The authors divided adolescents with partial and complete anodontia into 3 groups:

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<th>GROUP</th>
<th>RECOMMENDATION FOR AN IMPLANT PLACEMENT</th>
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<td>GROUP 1: Children with congenitally missing single tooth and having adjacent permanent teeth.</td>
<td>Skeletal development is more vital than chronologic age. The implant will become submerged relative to the adjacent teeth, if it is placed before dental/evolar growth is complete. If the implant crown is remade to the appropriate length, the crown-implant ratio may be compromised. It is recommended that implants should not be placed until 2 consecutive annual cephalograms show no change in the position of alveolus and the adjacent teeth.</td>
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<td>GROUP 2: Children with missing more than few teeth but having permanent teeth present adjacent to the edentulous sites.</td>
<td>Treatment of patients in this group can be the most complicated with regard to the location of the implant and timing of implant placement because these patients may have ectodermal dysplasia or a nonsyndromic partial anodontia. The removable prosthesis should be used until implant placement. The best approach is to wait until dental/evolar development is complete, as determined by no change in lateral cephalograms taken 1 year apart. It is important that the patient and the family understand that when growth is complete, either surgical repositioning of the implant segment and/or a replacement of the prosthesis will be needed.</td>
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<td>GROUP 3: Children with completely edentulous one arch or having only 1 or 2 teeth in poor positions in the arch.</td>
<td>In this group, because no teeth are present, the main concern is related to jaw discrepancies as the mandible grows downward and forward. Implants may be placed in this group of children as this will not affect the position of the implant. However, when the growth is complete, surgery may be necessary to correct the jaw size discrepancy. Because of the oral-hygiene requirements, implants should not be placed in patients below &lt;7 years.25</td>
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**Table:** Group-wise recommendations for implant placement

**CONCLUSION**

Modern pediatric dentistry must take advantage of all new advances and once tested and proven useful, apply...
them to improve the standard of care of children and adolescents. The challenge to our profession today is to improve the quality of oral health while overcoming both extrinsic and intrinsic factors which may adversely affect our progress toward this goal. Let us show the world that the future of dentistry matters to us and that we move toward the future with great anticipation and optimism.

REFERENCES


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