

# "A Century of Orthodontic Progress" – Innovations in Orthodontics

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## ABSTRACT

Innovation is the roadmap towards improvement .Creation, implementation and execution of new ideas, methods and technology aiming at efficiency and improvement is known as innovation. Innovation is the roadmap towards improvement. The speciality of orthodontics has obtained new dimensions due to innovations such as holistic orthodontic approach, Laser assisted orthodontics, digitization in diagnosis and treatment planning, nanotechnology, genetically driven orthodontic treatment plans with gene therapy, interactive self ligating bracket and flash free adhesive coated appliance system, robotic wire bending, 3D bioprinted scaffolds to treat osseous defects of the craniofacial complex, forensic orthodontics, mobile apps in orthodontics and dentoalveolar distraction modalities. These innovations have lead to an accurate treatment with reduced clinician efforts, enhanced treatment precision and better patient compliance. The future of orthodontic speciality with these adjuncts is bright and progressive. With reduced clinician's efforts and improved patient's compliance these advancement are certainly a boon to our orthodontic speciality.

**KEYWORDS:** Bio printed Scaffolds, Dentoalveolar distraction, Forensic orthodontics, Gene therapy, Holistics, Nanotechnology, Robotics

## INTRODUCTION

"Oral health is a reflection of physiological, social and psychological factors that are essential to our quality of life". Poor oral health reflects an impaired general health. Innovation is the creation, development and implementation of a new product, process or service with the aim of improving efficiency, effectiveness or competitive advantage. Dentistry is an ever evolving industry. Digital technology is transforming the conventional designing and manufacturing in clinical practice. Digitization has added to the precision and accuracy with which treatment can be imparted to the patient. 3D assisted diagnosis and treatment planning has helped the clinician to reduce post operative complications to minimal. Holistic treatment approach works to activate the body's natural healing power towards an ailment. Holistic dentistry goes beyond teeth and gums, it aims at curing entire body physically, mentally emotionally and spiritually. New solutions to old problems have resulted in advancements in orthodontic materials and their cascade effect on the

appliance design and treatment modalities. Interactive self ligating brackets are yet another innovative prescription in orthodontics. Flash free adhesive coated appliance system has reduced errors in bracket placement and orientation.

Genetically driven treatment plans in the form of Gene therapy have allowed orthodontists to replace faulty gene causing a malocclusion and curing craniofacial anomalies that show a genetic predisposition. Homeobox genes such as MSX and BARX play a key role in development of dentition though odontogenic homeobox code model responsible for patterning the dental arches. Implication of Smart phones to orthodontics is indispensable as it offers downloadable apps for patient education and motivation, treatment progress and reminder apps, diagnosis apps etc. Forensic Orthodontics is another big innovation utilizing orthodontic records for facial reconstruction and identification of the dead. Bite mark analysis is specific of a particular dentition enables

orthodontics to provide valuable information in case of assaults. Nanotechnology is manipulating matter at nanometer level, when applied to dentistry it is called as nanodentistry. With special consideration to orthodontics nano designed orthodontic bonding materials, nanovector for gene delivery to stimulate mandibular growth, nano-lipus devices, smart bracket with sensors, nano coated arch wires, nano particles in orthodontic adhesive and nano particles delivery from elastomeric ligature have improved the outlook of orthodontic practice all over the globe.

Robots play an important role in providing physical subordinates and even companionship in today's clinical practice. Orometrix and LAMDA wire bending robot system are yet another innovation incorporating robotics. Robotic orthodontic appliance fabrication is more precise and saves clinicians time and effort. Conventional reconstructive procedures have limitations which generated the urge of research and innovation in this field. With the development of rapid prototyping methods, biomodels have become inseparable tool for craniofacial osseous reconstruction. Restoring bony defects using 3D bioprints involve fabrication of mimetics architectures containing osteogenic and vasculogenic niches .The effect of dentoalveolar distraction on dentofacial structures is evident. Canine retraction using distraction osteogenesis is a useful adjunct to the retraction mechanics providing good results in a shorter span of time.

Innovation originates from necessity and gives birth to improvement and betterment. Innovations in the speciality of orthodontics have revolutionized the clinical practice many folds. With these advents we can confidently say that the future of orthodontics is bright and progressive.

### **FUNCTIONAL JAW OTHOPEDICS -HOLISTIC ORTHODONTICS**

Holistic approach means to provide support to entire system rather than just a part of it. A holistic treatment aims at providing physical, emotional, social and spiritual well being rather than merely curing an illness .In simple words entirety of something must be considered rather than just considering its parts. This philosophy is called holism. Pertaining to speciality of orthodontics the aim is not only to focus on the alignment of teeth but also underlying bone, jaws and anatomy of the craniofacial complex and how they affect the normal

functioning of the body. This explains how orthodontics have come to play a key role in obstructive sleep apnea, temporomandibular joint disorders, headaches, snoring and other unrelated conditions. The orthodontic consideration on the patient's airways, psychological and emotional development is a holistic orthodontic practices. Orthopedic orthodontics better known as Functional Jaw orthopaedics focuses on the structural foundation of the underlying jaws, minimizing the need for extractions. Holistic orthodontics uses natural biological forces of the patient such as natural bite, chewing force, tongue pressure to promote anterior face and jaw development . More growth and development means more space for the teeth to fit straight and align in balanced occlusion. Holistic orthodontics has taken orthodontics at a new heights.

### **LASER ASSISTED ORTHODONTICS**

LASER is "Light Amplification through Stimulated Emission of Radiation". It has been widely used in orthodontic practice because of the enormous benefits such as reduced pain, less wound contraction, reduced bleeding and swelling. Laser assisted acid etching and debonding is certainly an asset. Low level laser therapy (LLLT) offers key supportive role in accelerated tooth movement and pain control<sup>1</sup>. Many of the applications of LASERS in orthodontics includes mini-implants stability, bonding and debonding procedures, osseous regeneration, uncovering temporary anchorage devices (TADS ), exposure of impacted teeth, pericision and soft tissue surgeries etc<sup>2</sup>. Improved patient cooperation, reduced treatment time, efficient pain management have proved this innovation a boon to the orthodontic practice. Lasers assisted soft tissue surgeries is much efficient and beneficial than conventional scalpel surgeries as LASERS coagulates blood vessels, seals lymphatics and maintains wound sterilization during ablation. It vaporizes minor aphthous and herpetic ulcers, resulting in improved patient compliance<sup>3</sup>. Diode and Erbium soft tissue lasers offer extra advantage of aesthetic finishing post surgery. Bio stimulant effect on the desirable orthodontic tooth movements and softening of bonding adhesive during debonding procedures prove that LASER therapy has many folds benefits to the speciality . High intensity Laser therapy (HILT) has proved to be useful in controlling the soft tissue complications associated with orthodontic procedures.

## DIGITIZATION IN ORTHODONTICS

3D Digital models constructed using stereophotogrammetry and LASER technology, bracket placement using Ortho CAD software, 3D image capturing system for facial profile, CBCT for clefts and impactions, MRI imaging for TMJ, smile analysis by smile mesh programme, rapid prototyping and clear aligners are some of the leading implications of digitization in the field of orthodontics.

Digital models measures precise tooth positioning in 3D. These models can be sectioned and positioned to long axis inclination specific to each individual tooth. Mapping of the tooth movements can be successfully carried out by superimposing the digital casts.<sup>4</sup> CBCT (Cone Bone computed Tomography) along with digital models facilitates the creation of the surgical guides, exposure of impacted teeth, plan orthognathic surgeries and site of insertion for TADS (Temporary Anchorage Devices). Hand held scanners can be used successfully to capture 3D information of the dentition and the underlying anatomical structures to provide adequate information about treatment planning and appliance fabrication. Complex antero posterior lingual bonded retraction appliance can be fabricated with CAD/CAM technology useful in intrusive retraction of maxillary anteriors<sup>5</sup>. Digital adjuncts such as digital photographs, virtual reality softwares and video imaging are powerful tools for pre surgical orthodontic procedures and mock surgeries. Dentofacial planner is a computer aided diagnostic and treatment planning software for orthodontics and orthognathic surgery<sup>6</sup>. Based on the triangulation and fringe projection method the 3D facial scan is used to measure aesthetic facial parameters, to orthodontic diagnosis and to evaluate the craniofacial growth and development. Digigraph is a synthesis of video imaging, computer technology, and three-dimensional sonic digitizing. It offers sonic digitizing electronics and computers that enable the clinician to perform non-invasive and non-radiographic cephalometric analysis. The digigraph uses sonic digitization technology to calculate the tooth size arch length discrepancy(TSALD) and lateral cephalometric measurements<sup>7</sup>.

A 3D occlusogram (3-DO) performs image scanning and settling, occlusal processing, lateral cephalometric processing and occlusogram construction<sup>8</sup>. There are many different morphometric methods available for the evaluation cephalometric data. The main objective

of the computer program developed for this goal is transformation of these methods into ones which are both interesting and usable for the clinical orthodontist. Centre of resistance is an essential aspect of planning orthodontic tooth movements. Finite element method is helpful in numerically determining CR for upper anterior teeth<sup>9</sup>. Finite element also supports the analysis of serial, lateral cephalometrics radiographs. It is a powerful adjuncts to achieve accurate results .

## ORTHODONTIC MOBILE APPS

Smart phones are the latest and most widely used application of technology offered at our finger tips. They have surely revolutionised everyone's lives. Smart phones offer many useful applications to informate, educate and entertain us. Keywords like braces, orthodontics, teeth alignment speciality can be used to search the apps related to orthodontics. In today's date, more than 350 downloadable apps can be utilised for patient management, orthodontic education, diagnostic apps, apps for patient reminder, public information apps, model analysis apps, reviewed journal apps and many more<sup>10</sup>. Easy downloadable apps like Remind Align app, Smart Smile app, diagnostic apps such as Ceph Ninja S and iModel analysis app are utilised by both clinician and patients.

WaMBCO app for appointment and treatment progress. Certain cephalometric measurement apps are also available such as SmartCeph Pro and CephNinja which provides ease of cephalometric tracing of the patients<sup>10</sup>. Patient education and motivation apps like Brace mate and Braces booth pro have also gained popularity recently. Orthodontic community apps help the orthodontist to connect to each other world wide<sup>11</sup>. Orthotown is a leading community orthodontic app. The orthodontic product apps offer an efficient and easy means to order products online saving clinician's time and effort. The infusion of smart phones with the speciality of orthodontics is truly a boon for both patient and the orthodontist.

Though, they are not as reliable and precise than the digital imaging systems but being user friendly and affordable makes them an in demand innovation of today's time.

## FORENSIC ORTHODONTICS

Forensic odontology is an interdisciplinary approach of dentistry towards the detection and solution of

crime and in civil proceedings. Teeth are useful tool for both defense and offense. Teeth being fire resistant are powerful medico legal evidence in cases where face is completely disfigured. The specific pattern of dental arches, alignment of dentition, head form, facial form and profile are key points in the identification of the victim or deceased. The basis of dental based identification is based on the fact that every oral cavity is unique and specific of an individual<sup>12</sup>. Bite marks are also peculiar for every individual. Bite mark analysis can be used as a determining factor in cases of assaults. Orthodontists contribute by maintaining dental records to provide vital informations to legal authorities when needed. Lateral cephalogram can aid in reconstruction of facial soft tissue, to aid in the identification of the dead<sup>13</sup>. Photographs in addition to cephalogram superimposition yield high grade accuracy in facial recreation. In case of mass destruction, identification of deceased is of utmost relevance to hand over the bodies to the relatives. Orthodontic Scars such as white spot lesions, gingival recession, dark triangles, lacerations and signs of wire impingement act as potential identification tool as they are specific to the individual. Retainers such as lingual bonded retainers also provide identification related information. The disasters caused by nature like earthquakes and landslides or mankind related like terrorism yield many unclaimed bodies whose face is need to be reconstructed for identification. The orthodontists with his softwares and records can contribute immensely. Dental records like cast models, photographs and craniofacial anthropometric measurements are certainly a strong evidence base in for forensic related studies and identification.

#### **GENETICALLY DRIVEN TREATMENT PLAN WITH GENE THERAPY**

Genes are the structural and functional unit of heredity traits. Malocclusion is no exception to this. Dentofacial phenotyping deals with explaining the soft and hard tissue anomalies in acquisition to genomic data explaining the genetic mechanism responsible for such variations<sup>14</sup>. The classic example is inheritance is prognathic mandible(habsburg jaw) in royal family of Germany. Absence of teeth and apparent reduction in tooth size are controlled by the same or related gene loci. The tooth size fits the polygenic multi factorial threshold model. Lidral (JDR 2002) concluded that a mutation in MSX-1 gene in chromosome 4 is the causative factor for oligodontia involving the absence of all second premolars and third molars. Missing first

and second molars linked with a substitution mutation of MSX-1 gene. Also mutation of PAX-9 transcription factors has been observed in familial tooth agenesis and also in missing mandibular second premolars and central incisors. Alvesalo & Portin (1969) provided substantial evidence supporting the view that missing and malformed lateral incisors may be the result of a common gene defect. Neubuser et al (1995) found that PAX-9 transcription factor is associated the genetic mechanism for tooth displacement anomalies, such as palatally displaced canines and canine transposition.

Gene therapy is a technique for correcting defective genes responsible for disease development with several approaches for correcting faulty genes<sup>15</sup>. In the case of craniosynostosis, surgical implantation of a functioning, tissue-engineered suture could replace the multiple surgeries often required today. Selective seeding of HLA-haplotype-matched, embryonic-stem-cell-derived osteoprogenitor cells on an appropriate matrix could produce a functional suture. Hagg and colleagues have demonstrated the use of functional appliances causes transient up regulation of a number of genes in condylar cartilage. A clear understanding of the genes responsible for mandibular growth and safer methods of transducing healthy genes into the altered tissues may become the novel standard of care for treatment of mandibular deficient malocclusion. Genetics indeed has a very important role in orthodontics. Knowledge in this regard can help the orthodontist to make an accurate diagnosis and plan and execute his treatment with the special strategies and considerations pertaining to clinical demands.

#### **NANOTECHNOLOGY IN ORTHODONTICS**

The manipulation of matter at nanometer level is nanotechnology. Implication of nanotechnology to dentistry is called nanodentistry. Nanocomposite has filler particles of size 0.005-0.01 micron which enhances the compressive and tensile strength with increased resistance of fracture. The shear bond strengths of nano ionomers and nanocomposites are at acceptable levels making them good candidates for bonding of brackets and orthodontic auxiliaries. The novel innovation of elastomeric ligatures having nanoparticles embedded in its matrix which are anti inflammatory, antibiotic drug molecules and anticariogenic particles are a boon in orthodontic practice<sup>16</sup>. The Shape memory nanocomposite polymer are used in fabrication of esthetic archwires. With percentage elongation of

upto 300%, shape memory appliance can produce continuous forces over a long range to produce desirable tooth movements. Combining dental materials or coating surfaces with metal nano particles have antimicrobial benefits as a large surface to volume ratio offers an increased microbial interaction . Silver is used as the metal adjunct with nanoparticles due to its antimicrobial properties against streptococcus mutans found in the oral cavity<sup>17</sup>. Enhanced orthodontic tooth movement can be obtained by combining mechanical forces with electricity with the nano electromechanical systems (NEMS) which are nano devices integrating mechanical and electrical functionality at the nanoscopic levels. Nano LIPUS ( Low intensity pulsed ultrasound) are very efficient in liberating preformed fibroblast growth factors from macrophage cell lines and promotes angiogenesis during wound healing . Pertaining to orthodontics it supports the osseous growth after distraction osteogenesis and upon the insertion of titanium porous surface coated implants. It is also successful in reducing the root resorption associated with the orthodontic therapy. Newer smart bracket system for multidirectional force and moment control have integrated nanomechanical sensors into the base of the bracket. These provide favourable tooth movement within biological range and minimal side effects. Nano materials offer friction free orthodontic archwire which aids the treatment modality<sup>18</sup>. The implication of nanotechnology in orthodontics is many folds highlighting the success of this innovation .

### **3D BIOPRINTED SCAFFOLDS FOR CRANIOFACIAL OSSEOUS DEFECTS**

There is a greater demand for biocompatible materials for repair of bony defects and new bone regeneration .Conventional calcium phosphate porous bio ceramic offer low flexure resistance and very limited mechanical strength. Bioactive CSi-Mg 10 porous scaffolds maintain their properties in aqueous medium for good amount of time. 3D printed CSi-Mg 10 scaffolds are excellent choice for craniofacial deformities like alveolar bone defects because of their appropriate mechanical strength and good bioactivity . Appropriate pore size and porosity are useful to construct good 3D structures for cancellous bone ingrowths (Otsuki et al.2006 ). Scaffolds with square pore of size 200-300 micron meters (Choi et al 2010) and greater porosity are better suitable for vascular endothelial cell ingrowths that provides nourishment to the novel bone formation(Karageorgiou and Kaplan 2005). Bioprinting

is a step ahead of conventional 3D printing as the viability of the cell is maintained. Key parameters of 3D bioprinted scaffolds comprises of cell positioning , bio ink selection and mechanical strengths .The scaffolds should possess compatible micro architecture , porosity and specific pore size<sup>19</sup>.

Osteogenic regeneration by resident cells and osteo inductive materials such as autogenous grafts and bone morphogenic proteins aids in restoring bone defects. The mechanical properties of these scaffolds is in hormony with the tissue being regenerated. Selective layer sintering of polycaprolactone fabricates porous cylinders providing a stiffness of 15 MPa to the bony scaffold. Osteochondral and cartilage tissue are also engineered using cell laden hydrogel<sup>20</sup>. Bio printed scaffolds are certainly a novel and innovative method to restore osseous deformities.

### **INTERACTIVE SELF LIGATING BRACKET SYSTEM AND FLASH FREE ADHESIVE COATED APPLIANCE SYSTEM**

The self ligating bracket system offer added advantage of efficient and better wire placement and removal with reduced treatment time and enhanced patient comfort as impinging ligature wires are eliminated<sup>21</sup>. The one piece self ligating system with CAD-CAM computer technology has a rigid curve arm that wraps occlusogingly around labial part of bracket body. These brackets were innovated to overcome the limitation of conventional self ligating brackets requiring heavy forces to slide open the clip during subsequent visits. Interactive self ligating system are indeed a new and improved orthodontic philosophy.

The recent innovations provide the clinician with the brackets that are already available with bonding agent already placed so that brackets can be directly picked, positioned and cured .It is the only orthodontic bonding system that pre coats each bracket with adhesive . It eliminates bracket handling problem as it offers each individual bracket clearly identified and pre oriented on a special foam liner which virtually eliminates bracket rotation in transit. Apart from the advantage of being flash free. Flash free adhesive system uses moisture tolerant and colour change adhesive making them more clinician friendly .The absence of flash around the brackets brings about significant reduction in the formation of white spot lesions associated with excess of adhesive<sup>22</sup>.

## ROBOTICS IN ORTHODONTICS

Robotics is a human computer based interaction technology to eliminate human errors and increase the precision and reproducibility of the results. Insignia and Sure smiles are the commonly used techniques to implement the newer robotic arch wire bending in orthodontic practice to yield improved accuracy and precision. The Insignia system is a software that enables practitioner to construct final desirable occlusion using customized arch wires, transfer jigs and brackets. These customized wires are fabricated by a printing robot that uses a system to bend and trace wires according to the patient's specifications. An arch wire bending robot utilizes the scanned digital images of the mouth along with estimated position of the brackets and the arch wire. The robot with the aid of two automated pliers bends the arch wire aiming to position teeth into the favourable position. LAMDA (Lingual arch wire manufacturing and design aids) bends the arch wire in a closed loop fashion by understanding the biomechanics in two planes along the XY axis.

The robot component is an arch wire bending compartment comprising of a base, feed, tuning and bending die. A solid work software is used to fabricate the structure of the arch wire bending robot<sup>23</sup>. The orthodontic wire bending procedure is executed using cartesian type wire bending robot resulting in good precision and desirable tooth movement. Arch wire spring back property and planning of bending points are the mainstay of the robotic wire bending technology. The future of fixed orthodontics combined with robotic arch wire fabrication is progressive as it not only reduces the treatment time and clinicians efforts but also improves the accuracy, efficiency and precision in bringing the desired biomechanics.

## DENTOALVEOLAR DISTRACTION TECHNIQUES

Long duration of treatment time is one of the major reason for reduced patient compliance. The effect of dentoalveolar distraction on dentofacial structures is evident. Canine retraction using distraction osteogenesis is a useful adjunct to the retraction mechanics providing good results in a shorter span of time. Distraction surgical procedures are performed after the extraction of the first premolars using rigid tooth borne distraction devices, as a result canines moved into at a rate of 0.8mm per day in 8-14 days<sup>24</sup>. Moreover the anchorage teeth shows minimum anchorage loss in reaction to the retraction forces.

This technique is useful in reducing the treatment time by 6 – 9 months in subjects requiring extraction with reduced need for any kind of anchorage reinforcement<sup>25</sup>. The dento alveolar distraction is yet another leading innovative technique that has reduced the treatment duration to almost half with no undesirable effects on the surrounding structures. Improved patient compliance and considerable reduction in duration of treatment makes this a widely acceptable technique by the orthodontists.

## CONCLUSION

- The innovations in orthodontics have taken conventional practices to newer dimensions with improved patient compliance and reduced treatment time.
- From advent in diagnosis and treatment planning, digital photographs and video imaging, nano particle coated appliance, robotic wire bending, gene therapy, interactive self ligating brackets, flash free adhesive coated appliance system and bio-mimetics in bonding agents have revolutionised the treatment modalities entirely.
- With increased precision, accuracy, efficiency and reproducibility of treatment results and highly improved patient compliance with reduced treatment time, these advancements are certainly a boon for the speciality of orthodontics.
- Genetically driven treatment plans prevent the onset and aggravation of a familial predisposing abnormality by replacing faulty genes. Understanding an abnormality from its origin helps in bringing perfect treatment results naturally.
- Whenever improved materials and leading technologies come together the outcomes are promising.
- When these innovations are applied to clinical practice, the entire outlook of orthodontic treatment is very bright and progressive from both clinicians and patient's point of view.

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