Abstract

Dental caries, periodontal disease, malocclusion and dentofacial anomalies are the major global oral health problems. Twenty first century has brought revolutionary changes in quality of human life in many ways, including oral health care. The changing life style, food habits and increasing number of elderly patients have become more challenging for oral health care providers. The future of dentistry depends on its ability to incorporate new, better diagnostic and treatment modalities into clinical practice, to ensure a sufficient supply of well-trained manpower, to fulfill the consumer demands, to maintain a strong research focus and to provide quality health care to those who do not have easy access to dental care. The developments in the field of dentistry occurred in unison with other fields like material sciences, Biotechnology, Imaging technology and stem cell biology etc. Newer technologies and materials are coming up every day which has helped in newer strategies for diagnosis, prevention and quality treatment outcome.

Key words: Dentistry, 3D imaging, Stem cell biology, Dental implantology, tissue regeneration.

Introduction:

Dental caries and periodontal disease have historically been considered the most important global oral health problems. Malocclusion and dentofacial anomalies form the 2nd largest burden of oral health related needs after dental caries among children. The treatment of these oral diseases requires restoration and rehabilitation of mutilated dentition.

Origin of Dentistry dates as back far as about 7000 B.C. Since those ancient times the quest for ideal dental material and treatment procedure have began. Queen Elizabeth I (1533-1603) used cloth fragments to fill the cavities in her teeth. Fauchard (1678-1761), the father of modern dentistry introduced tin foil/lead cylinders as a restorative material for filling tooth cavities. Historically wide variety of materials were used for restorative purpose, gold, Ivory, human teeth, turpentine resin, cork, gums, and metal foils. Major breakthrough in restorative material occurred with the invention of silver amalgam in France by Taveau in 1816 and it is used till date. The necessity for new dental material has been increased, since
evolution of the different specialties within dentistry, in the early 20th century. Introduction of casting methods, cast and base metal alloys, stainless steel and polymers resins has changed the face of dentistry in the early half of this century. Adhesives and tooth colored restorative materials eliminated some of the drawbacks of conventional restorative and preventive dentistry and entirely replaced the orthodontic banding.

Branemark introduced Titanium implants in 1965 and paved way for implant dentistry. It is one of the significant scientific breakthroughs in dentistry. Implant dentistry plays important role in modern dentistry especially in Orthodontics and Prosthodontics specialties. Bone regenerative materials like acidic extract of enamel matrix proteins (EMPs), Emdogain and Recombinant amelogenin are playing major role in regeneration of tooth-supporting tissues, alveolar bone and periodontal-ligament. Stem cell biology, an emerging field of research, has shown promising future application in medicine and dentistry. Stem cells are a promising tool for regeneration of tissues such as bone, dentin, periodontal ligament, cementum and dental pulp tissue.

Also recent advances in technology, such as nickel-titanium (NiTi) rotary instrumentation, digital radiography, irrigation systems, ultrasonics, apex locators, magnification, illumination, and the surgical operating microscope (SOM), Mineral Trioxide Aggregate (MTA) and more efficient instrumentation and obturation methods have added new dimension to efficient endodontic care.

3D intraoral scanner, 3D printing and CAD-CAM technology are proven to be better alternative for conventional impression and model methods and will replace them in near future. The use of three dimensional imaging utilizing cone beam computed tomography (CBCT) is the newest innovation and it has multiple application in dentistry, from analysis of root canal anatomy to orthognathic surgical planning and evaluation of treatment outcome. The major advantage of CBCT over conventional CT is lesser radiation exposure. The field of view for the CBCT imaging can be as small as 4x4 cm, directly related to radiation exposure, thereby better definition and more radiation safety to the patient.

Nanodentistry is a science & technology of diagnosing, treating & preventing diseases, using nanoscale structured materials. With developments in materials science and biotechnology, nanotechnology is especially anticipated to provide advances in dentistry and innovations in oral health-related diagnostic and therapeutic methods. Various potential nanotechnology application in dentistry includes Nanocream- Nano Aluminium Oxide Fibres, Nano Filtration, Oral Anesthesia Induction, Nanorobotics, Dental Hypersensitivity, Tooth Repositioning, Digital dental imaging. More and more applications and possibilities are continually evolving. These technologies promise to enhance dentistry for the clinician and patient alike.
Diagnosis of caries

Dental caries is still a major oral health problem, even in the most industrialized countries, affecting 60-90% of school children and the vast majority of adults. Today, because of scientific advances and new technologies, dentistry is developing new strategies for managing dental caries. These strategies emphasize prevention and early intervention.

Early identification of the incipient lesions: Traditionally, caries detection has been done using intraoral mirror and a sharp explorer. However, use of a probe on an incipient area of decalcified enamel can lead to cavitation, and hence, is not in clinical practice anymore. A variety of innovative technologies have been developed and introduced in the last few years to aid clinicians not only in early caries detection but make a firm diagnosis and to treat cases conservatively. However, the detection of incipient lesions is not easy in routine clinical practice and many clinicians end up missing them.

Newer tools like Fiber-optic transillumination, Digital imaging fiber-optic transillumination, DIAGNOdent laser system, Electrical caries monitor, Polarization-sensitive optical coherence tomography, CarieScan, Frequency-domain infrared photothermal radiometry and modulated luminescence, Cone beam computed tomography are being increasingly used to identify difficult proximal lesions hidden from sight.

We have yet to invent a robust, reliable and cost effective tool for early diagnosis of dental caries in hidden region and much early, before it can be visible as chalky spots on enamel.

Periodontal disease

Periodontal disease affects both the young and the adults with variable frequency, which is closely related to level of oral hygiene. The main concern of periodontal treatment is prevention of periodontal diseases, resolution and regeneration of lost periodontal support. Recent advances in material science and stem cell biology have opened new and exciting scenarios for nonsurgical and surgical therapy of periodontal diseases.

Periodontal ligament and alveolar bone regeneration: One of the most interesting and intriguing aspects of dental research is periodontal ligament and alveolar bone regeneration. Current research is yet to find a foolproof way for regeneration of periodontal ligament, alveolar bone and tooth attachment apparatus. Although experimental regeneration of alveolar bone has been shown to be possible in animal models using stem cells, its expansion to humans is yet to be accomplished with concreteness. Studies have shown that induced mesenchymal cells when implanted into periodontal defects may significantly increase the amount of regeneration and newly formed mineralized tissue present. These stem cells may be sourced from various body tissues like dental pulp and the umbilical cord. Current research is
focusing in harvesting stem cells from adipose tissue\textsuperscript{11}. Efforts are needed to further explore the role of stem cells in periodontal regeneration.

**Orthodontics (Malocclusion and deformities)**

The rapid advances in other fields have larger impact in all branches of dentistry, orthodontics is not an exception to this. Skeletal anchorage systems, 3D imaging and virtual treatment planning, 3D surface scanning, CAD-CAM bracket customization and robotic wire bending are the few recent advances in field of orthodontics. These are likely to revolutionize the current orthodontic clinical practice in next decade.

**Temporary anchorage devices and Skeletal anchorage system**

Temporary anchorage devices (TAD) have been used increasingly in the orthodontic field. Because of their small size, they can be used in many places in the maxilla and mandible\textsuperscript{12}. Accurate mini-implant positioning reduces problems such as loosening of the implant or root surface\textsuperscript{13}. Surgical guides have been used to place implant accurately in desired site and in proper angulations. Recently new surgical guide system that uses CBCT images, an implant-positioning program (SimPlant), and stereo lithography to make a surgical guide for accurate placement of orthodontic mini-implants were used by Kim et al\textsuperscript{13}.

The skeletal anchorage system (SAS) which uses titanium miniplates and screws\textsuperscript{14,15} has brought new dimension in orthodontic treatment. SAS can be placed in piriform rim, zygomatic buttresses, and any regions of the mandibular cortical bone and it has been used successfully for skeletal class III malocclusion, correction of severe open bite and distalization of mandibular molars.

![Figure 1. TAD used as indirect anchorage for enmasse anterior teeth retraction. A. Pre, Mid and Post treatment intraoral photographs. Arrow in middle photograph indicates TAD (miniscrew implant). B. Pre and Post treatment extraoral photographs.](image)
Digital models, 3D skeletal imaging, and Virtual Treatment planning

In near future digital models will entirely replace the conventional plaster models. Virtual study models introduced to orthodontic market in 1999\textsuperscript{17} and proven to be used successfully for orthodontic diagnosis and treatment planning\textsuperscript{18}. These digital models are obtained from 3D scanning of impressions/plaster models or direct Intra-oral digital scanning. These technologies are one of the most exciting new areas in dentistry. There are almost ten intra-oral scanning devices have been developed for various specialties in dentistry\textsuperscript{19}. Recently Kau CH et al\textsuperscript{20} showed that digital models obtained from CBCT are as accurate as conventional digital models in making linear measurements.

Craniofacial imaging is a crucial component of an orthodontic patient’s record. Computerised cephalometrics utilizes computers to perform cephalometric analyses, where the orthodontists mark landmarks manually and computers do perform the measurements. Fully automated computerized 2D cephalometric analyses have been introduced recently, since its full potential in clinical practice yet to be tested. Autoceph is one of the such indigenous cephalometric analysis software developed jointly by AIIMS, New Delhi and CSIR-CSIO, Chandigarh. Its application have been field tested in AIIMS and proven to be reliable tool in orthodontic practice.

![Figure 2. Lateral cephalometric analysis (Autoceph® cephalometric analysis software, AIIMS, New Delhi and CSIR-CSIO, Chandigarh)](image)

3D imaging techniques like computed tomography (CT), magnetic resonance imaging (MRI) and cone beam computed tomography (CBCT) are recent advances in craniofacial im-
aging. Although CBCT was introduced two decades after CT imaging, it has undergone very rapid development and it is used extensively in orthodontics. These are going to be valuable aid in diagnosis, treatment planning and assessment of treatment outcomes in patients with impacted teeth, facial deformities, craniofacial anomalies, obstructive sleep apnea (OSA).

Figure 3. Analysis of CBCT image using Dolphin 3D™ imaging software 11.5(Dolphin Imaging, Chatsworth, Calif) shows root resorption of left lateral incisor due to impacted canine.

Figure 4. Measurement of volume and area of maxillary air sinus (Dolphin 3D™ imaging software 11.5(Dolphin Imaging, Chatsworth, Calif))
Figure 5. Analysis of area and volume of oro-pharyngeal airway on CBCT image using Dolphin 3D™ imaging software (11.5, Dolphin Imaging, Chatsworth, Calif)

The importance of soft tissue in orthodontic diagnosis and treatment is emphasized since Angles’ era. The 2D photographs provide less information of 3D face regarding facial depth, symmetry, and shape. Various technologies such as laser scanning, stereo photogrammetry, an optoelectronic device are available to create 3D images. As a complementary technology to 3D skeletal imaging, 3D facial surface scans and digital models are being constantly improvised for virtual treatment planning. Virtual treatment planning has wide range of application, from simple orthodontic tooth movement and implant placement to planning for functional jaw orthopedics and orthognathic surgery. It can be carried out in an orthodontic clinic or from a remote station and sent to remote area as a digital data. Virtual treatment planning and digital records reduce the need for extensive storage space required to store files and plaster models. Thus more data can be stored, effectively managed, communicated and transported when required. Apart from being used as an orthodontic/surgical treatment planning tool it can be used to educate and motivate the patient and parents.

Orthodontic treatment without orthodontic brackets

Traditional fixed appliances with wires, bands, and brackets are efficient and versatile treatment method. The idea of invisible appliance was first introduced by Kesling in 1945. As an alternative to the bracket system the invisible method of orthodontic tooth movement was introduced in 1999 by Align Technology Inc with the trade name of
Invisalign\textsuperscript{27}. This is a major area with tremendous possibilities. These are sequential clear, removable plastic aligners. This invisible appliance uses the principles of Kesling set-up through virtual digital models and computer aided design and manufacturing process (CAD-CAM). Series of clear aligners are capable of incremental tooth movement of 0.25-3mm, over a period of 2 weeks. The Clear Aligner is especially indicated for treatment requiring minor tooth movement and in cases of relapse. The main indications are minor crowding, rotation control, expansion (non-skeletal), intrusion, space closure, less than 4 mm; passive/active retainer.

\textbf{Figure 6. Clear aligners, alternative removable appliance system}

\textbf{Customized Brackets and robotic wire bending}

In 1928 Edward angle introduced edgewise system which has three dimensional controls on the teeth. Andrews\textsuperscript{28} modified Angles' edgewise appliance by incorporating predetermined first, second, and third order compensation in brackets(straight wire appliance (SWA)). The SWA rarely accomplish the treatment goals only with straight arch wires, as its name implies, and it requires bends incorporated in arch wire at certain treatment period to accomplish desired treatment goals. It is because of the inter-individual variation of the teeth is not taken into consideration in the process of standardization of brackets. If the straight wire approach should be followed, the bracket would have to be custom made\textsuperscript{29}. With the recent advances in computer and imaging technology this problem may solved by combination of computer assisted virtual treatment planning and bracket placement, customized brackets individualized to each tooth, robotic wire bending and indirect bonding procedures to create the ultimate orthodontic appliance.

\textbf{Biological Mediators to facilitate orthodontic treatment}

The synthesis and release of various inflammatory mediators, neurotransmitters, growth factors and other cytokines in response to applied mechanical forces was identified to be the cause of cellular differentiation during tooth movement\textsuperscript{30}. Extensive research still continues to
identify the mediators and signaling molecules responsible for tooth movement. These chemical molecules are believed to initiate, maintain and cessation of the orthodontic tooth movement. The use of inflammatory and other mediators may also accelerate the tooth movement as these mediators strongly influence the bone remodeling. Gurton AU et al.\textsuperscript{31} showed that prostacyclin (PGI2) and thromboxane A2 (TxA2) analogs increased the number of multinuclear osteoclasts, osteoclastic bone resorption, and rate of orthodontic tooth movement in rats. Local administrations of prostaglandins E1 or E2 combined with orthodontic tooth movement can approximately double the rate of tooth movement\textsuperscript{32} and the main side effect of PG is hyperalgaligia. Also the local injection of echistatin and arginine-glycine-aspartic acid (RGD) peptides prevent tooth movement, thereby enhancing anchorage and also echistatin showed inhibitory effect on root resorption\textsuperscript{33,34}. Alteration of speed of tooth movement in orthodontics through gene modulation but has great potential in future.

Summary

Technological innovations are crucial for the advancement of the art and science of clinical dentistry. The challenge to our profession today is to improve the quality of oral health while satisfying the developing needs. The combined efforts of dental education, dental research, and dental practice will be needed to maintain the quality of our present system and to meet new challenges. The time is not far when there will be no impressions, no plaster models, no tracing papers, and no pliers in the orthodontic office. However it is important that these tools should be cost effective, so that benefits of these technologies can be extended to all sections of society including economically disadvantageous population and those living in remote locations.

References


