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# Advancements in Technology in the field of Orthodontics

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**Abstract:**

In the very fast paced current day society, it is no surprise that the various technologies in the field of Orthodontics as well have seen tremendous advancements. Orthodontics as a field, is indispensable to dentistry, as it is not just cosmetic cover-ups, and is much more. Directing growth modulation, resolution of functional problems, treatment for multidisciplinary cases like cleft and such, and so on. From the very primitive wires and horseshoe shaped metal bands that were used to splint teeth to bring them to position, to the current aligner and lingual orthodontics, there has been a massive evolution, both in orthodontic systems and the various technologies that are an essential part of the field of orthodontics as they facilitate the orthodontic treatment which has become more efficient with time. This review article aims to cover the following areas: Digital radiography, 3D scanners, NiTi and CuNiTi wires, TADs, Aesthetic orthodontics (Lingual orthodontics, Self-ligating braces, Clear Invisible braces, Ceramic brackets, aligner/Invisalign systems-Customised smile designing), Accelerated treatment periods (PROPEL, AOO), Lasers in Orthodontics.

**Keywords:** TAD, mini-screw, mini-implant, Invisalign, aligner, Wilckodontics, Digital radiography, lingual braces.

## INTRODUCTION:

Orthodontics is that science, in the field of dentistry that deals with the alignment of mal-aligned teeth, growth and development of the jaws to correct functional discrepancies, it consists of not only the aesthetics par of it, but also for cases of cleft and syndromes, to be managed synergistically with surgery. In all, it is the branch of dentistry responsible for the prevention and correction of malocclusion. The history of orthodontics, is a very old one, and the attempts to align teeth with appliances can be traced back to the Egyptians. However, it was first discussed on paper by Norman Kingsley. He published a paper on 1879, which had the first formal text discussing Orthodontics, “A Treatise on Oral Deformities as a Branch of Mechanical Surgery” and at the time, he had introduced the use of extra oral force to move the teeth.[1] In 1900, it was declared a specialty, by Edward H. Angle, and was in-fact the first dental specialty. After founding the American Association of Orthodontics (AAO), he started the first independent school of orthodontics and made the original Angle’s classification of Malocclusions. [2] It was Angle’s belief system that when teeth were brought into optimum positions, it would result in good facial aesthetics. He was opposed to the idea of extractions preceding orthodontic treatment and carried out all his treatments non-extraction, in order to achieve ideal occlusion. With time, with the subsequent development of cephalometrics, the relationship of teeth with surrounding soft tissues and bone were studied. During the early 1930’s, Calvin S. Case controversially, was in favor of, or rather advocated the use of extractions in Orthodontic treatment, along with the use of retainers for the maintenance of achieved results. [3] Change is the only constant, and with the passage of time, there have been tremendous technological advancements and an evolution in the way orthodontic treatments are carried out. The efficiency of treatments, the time taken for the treatment, the discomfort experienced by the patient, the time efficiency for the dentist: the number of patients they can see per unit time due to overall reduced appointment times, the efforts they have to put in, or any kind of manual work that was previously mandated, has now boiled down to fewer, simpler procedures. A host of patient factors are considered to individualize the treatment, and tailor it to the requirements of each patient. There are various improvements in the field, like improved orthodontic systems, from the initially used horseshoe shaped arches and wires to hold teeth in place, through the various advancements orthodontic systems, skeletal anchorage to achieve results like never before, mini implants(TAD) and the auxiliary technologies like digital radiographs, CBCT (Cone Beam Computed Tomography). There is an array of options available for the patient to make the treatment more acceptable, less conspicuous, aesthetic, quicker, less painful and more efficient. The various areas of development that will be briefly overviewed in this article include Digital radiography and 3D imaging, NiTi and CuNiTi wires, TAD (Temporary Anchorage Devices), Aesthetic orthodontic systems (ceramic brackets, lingual orthodontics, self-ligating braces, Invisalign/aligner systems), and accelerated treatment systems, and the application of LASER in orthodontics. Where we are right now in terms of advancements and developments is not the final destination, and there will definitely more and more changes, as there is constant evolution, which is but a rule and not an exception.

## DIGITAL SCANNERS, DIGITAL X-RAYS AND 3D IMAGING

Digital Scanners have a variety of applications in Orthodontics, which include applications for treatment planning [4], indirect bonding tray fabrication, custom appliance design and construction(palatal and lingual orthodontics) [5], aligner orthodontics [6], Orthognathic surgery simulation and wafer construction [7], evaluating surgical outcomes for cleft lip and palate patients [8]. This eliminates the disadvantages associated with the technique-sensitive impression taking [9], unpleasant patient experience [10] reduced allergy risk [11] and the

various inaccuracies that could be due to the material properties, shrinkage, undercuts, time discrepancy before casting, storage, mixing, and temperature sensitivity.

Study models are most often preferred in the digital format today because of their increased accuracy [12]. Good alginate impressions along with bite registrations can be used to generate computer assisted digital models. Various digital scanners are available to create digital models. (iTero, 3D shape Trios). These digital models can then be used to generate stereolithography (.stl) files that may be used as and when needed to 3D print digital models. Digital models are a great development in the sense that they can be stored with much ease, reduce the physical storage space required enabling cloud storage, easy transfer, improved communication among practitioners and the ease in diagnosis. [13] Evidence based research shows similar accuracies of linear measurements in digital models as well as stone models [14]and hence makes them quite useful in the analysis of arch length tooth-material discrepancy, occlusal characteristics and the relationship of teeth within the arch as well as the inter-arch relationship.

CBCT is used for comprehensive imaging of orthodontic patients. CBCT images may be used for the generation of digital models (Anatomage, CareStream) but the accuracy of the same hasn't been fully explored. CBCT generated scans may also be used, in the diagnosis of impacted teeth, craniofacial anomalies, suspected temporomandibular jaw pathologies, and skeletal asymmetries [15]. It is used for a 3D analysis and can be customized to the requirement specific to the case, to include just the maxilla or mandible, or the part of the arch to be evaluated, a part of the head or the entire head. Compared to the other radiography methods, there is lesser overall radiation exposure in a CBCT as it can be used to extract all the other views required (lateral cephalogram, OPG, or a PA view) with a single revolution around the patient, and it is also time effective and operator-friendly. It is more accurate, quicker, and has lesser artifacts. It is priceless for diagnostic purposes like the assessment of skeletal and dental structures, 3D evaluation of impacted teeth, location of pathology, presence of root resorption, and treatment planning[16], to reliably assess cervical vertebrae maturity as an evaluation of skeletal maturity[17], for an enhanced airway assessment[18] and may be significantly useful in the diagnosis of Obstructive Sleep Apnea[19], TMJ analysis[20,21], cleft palate assessment (bone defect evaluation, presence of supernumerary teeth, alveolar bone morphology) for the effective rehabilitation. [22,23] CBCTs may also be used in the planning of surgical treatments, for optimizing surgical outcomes and to assess occlusal relationships, hard and soft tissues and their spatial relationships and achieve good facial aesthetics. They can be used to plan for the placement of TADs or mini implants [24,25] and 3D CBCT based stereolithographic surgical stent guides have been proven to be more effective than 2D surgical guides in micro implant placement.[26] CBCTs may also used in assessing the space requirements for an impacted tooth, for arriving at the best surgical access for bonding and efficient extrusion path, to circumvent collateral damage, fabricating custom orthodontic appliances[27] (for eg. SureSmile System [28]), assessing treatment progress and outcomes [29] with lesser overlapping of anatomical structures for a better assessment [30] but the superimposition of 3D images is highly operator sen sitive [31]. It may also be used in the assessment of neuropraxias following orthognathic surgery [32] and moreover, the frequency of supplementary incidental findings (Cervical vertebrae clefts, endodontic lesions, TMJ aberrations, sinus pathologies) from a CBCT apart from what one was looking to diagnose are around 25% and are always very valuable.[33]

Lateral cephalometric radiographs, Orthopantamograms, are taken digitally, instead of the conventional X-ray film, and this is highly advantageous for a number of reasons, that include: decreased radiation exposure, easier to repeat, easy record keeping and maintenance, decreased distortions, magnification errors, decreased processing and developing errors. Cephalometric analysis is done by identifying key anatomical points on the radiograph and measuring linear and angular measurements using that, which are then compared to evaluate skeletal, dental and soft-tissue relationships. It usually carried out using tracing on acetate paper after printing the film. With the current advances pertaining to digital radiography, various softwares (QuickCeph, Dolphin Imaging) have been developed to complete various analyses, choose different points and adjust magnifications in just a matter of a few clicks. [34]

**NiTi AND CuNiTi WIRES**

In the period of over 40 years NiTi wires have come a long way in that there have been various improvements to enhance their clinical performance. NiTi wires were first developed at the Naval Ordinance Laboratory of Silver springs, USA. The first developed NiTi alloys were aimed at orthodontic use. [35] Unitek Corporation produced the stabilized NiTi alloy under the name Nitinol (Nickel Titanium Naval Ordinance Laboratory) for clinical use. It consisted of 45% Titanium and 55% Nickel, first used in 1972. Initially they had excellent elastic recovery but no significant shape memory or superelasticity. Super elastic NiTi was produced in japan in 1978 by Furukawa Electric Co. Thermodynamically activated NiTi wires emerged in the 1990s and they had the property of Shape memory. [36] They were NiTi wires are known because of their super elasticity and shape memory [37]. Nickel Titanium wires have revolutionized orthodontic treatments because of their ability to deliver light continuous mechanical forces over a wide range of displacements for optimal tooth movement [37, 38] when compared to the conventionally used stainless steel wires. Materials that provide ideal forces for the tooth movement, lesser patient and clinician care, and longer intervals between the orthodontic treatment visits have been gaining preference. Ideal orthodontic wires must exhibit low stiffness, good formability, high-energy storage and a good spring-back [39]. Other factors include the resistance to corrosion, ductility, [40] biocompatibility [41] and low surface

friction, and the ability to be soldered or welded [42]. However, NiTi wires cannot be soldered or welded. NiTi wires, because of their low load/deflection ratio (elastic modulus) provide desirable force and control of the magnitude of the same [43]. Superelasticity is attributed to the fact that on unloading the wire returns to its original shape prior to loading. It can withstand upto 7-8% deformation, almost times as much as stainless steel wires. During the process of loading, the periodontal ligament is deformed, as the deactivation ensues a plateau of light forces that facilitate optimum biological tooth movement as the wire returns to its original arrangement[44, 45, 46] Another characteristic feature of NiTi alloys is its shape memory, by virtue of which it can remember its original shape after being elastically or pseudoplastically deformed by increasing the temperature. The shape memory can be attributed to the thermoplastic martensitic transformation. [47] The Austenitic phase (body centered cubic parent phase) is transformed to the martensitic phase (orthorhombic or monoclinical phase) on decreasing the temperature (cooling through the critical-transformation temperature), this may have an intermediate tetragonal phase (R) [48,49] The austenite phase is more stable at higher temperatures. The phase change typically occurs while receiving or releasing thermal energy. [50] This transformation may result in changes in the alloy in terms of its modulus of elasticity(stiffness), yield strength and electric resistivity due to changes in the inter-atomic bonding and it alters the physical properties of the alloy [51] and allows features of shape memory[52] Not just thermal change, stress can also transform the material from austenite to martensite, when shear stress is applied, leading to a martensitic transformation to relieve the excess stress applied, and the material will remain in the martensitic phase as long as the stress is maintained. When the stress is removed, the material becomes unstable and transforms back to the austenitic state. Pseudoplastic behavior is observed when plastic behavior is recoverable without the material actually entering the plastic stage. Such intense deformation and its corresponding reverse transformation at a lower stress is called superelasticity or pseudoelasticity. Copper when added as a ternary alloy element, CuNiTi is formed. These wires emerged in the mid-90s and because of the addition of a good heat conductor (Cu), to the NiTi, they had better transition temperatures, ensuring a homogenous loading and effective tooth movement.[53,54] Copper It consists of 5-15% Copper as a substitute for Nickel, and the transformation occurs in two steps from cubic to orthorhombic and then to monoclinic. When the concentration of copper is increased, the transformation start temperature for the change of austenite to orthorhombic martensite doesn't change, but it decreases for the transformation of the orthorhombic to monoclinic (Cu content below 15%). Adding Cu at more than 10% embrittles the alloy and spoils the formability [55]. For the purpose of orthodontic treatment, the NiTi arch wires transform into their original austenite form when they are at their transformation temperature in the oral cavity, helping align the teeth. The martensitic phase is more ductile, and hence the arch wire can be cooled and adapted to crowded or rotated teeth, for ease of adaptation.

**TAD (MINI IMPLANTS, MINI SCREWS, PALATAL IMPLANTS)**

Various anchorage devices have been used over the century. Extra-oral anchorage like face-masks and headgear are very powerful but have a shortcoming, because their effectiveness depends directly on the patient compliance. Intermaxillary elastics also have to be worn religiously by patients and hence might not be as effective. Other intra-oral anchorage methods like trans-palatal arch, lingual arch etc, are not absolute though they don't depend on patient compliance. In the 1980s the concept of skeletal anchorage was introduced to the orthodontic field by Creekmore and Eklund [56], where a titanium screw was placed in the nasal spine that was used as intermaxillary fixation after orthognathic surgery and intruded the maxillary incisors. Later, an implant placed in the retromolar area, with a canine connected to the fixture using a bypass wire used to mesialize the mandibular molar towards the edentulous space.[57] In the 1990s, anchorage devices for orthodontic use were developed in East Asia and were adopted for use worldwide. [58-62] They are currently known as TADs or Temporary Anchorage Devices. [63] Though various miniscrews are marketed and are commercially available, those that are made from Ti-6V-4Al are preferred alike by the patients and the orthodontists, due to their biocompatibility, minimal discomfort, relatively non-invasive nature and fewer limitations with respect to their placement. [64,65] Miniscrew anchorage has really expanded the avenues for orthodontic treatment. It is highly advantageous due to the provision of stationary anchorage for various tooth movements without patient compliance, and make it possible to facilitate previously impossible orthodontic movements. As opposed to previously used conventional anchorage from solely the molars, which can possibly result in movement of the anchorage segment forwards along with the retraction of the anterior segment, and anchorage loss, mini screw placement in the alveolus can be very efficient and advantageous when done rightly. Despite the fact that they are short and have a small diameter, they can be used to facilitate various tooth movements like intrusion, retraction, protraction[66,67] According to a recent study, the success rate in 4987 miniscrews is 86.5%[68] It does have disadvantages like screw fracture, failure, patient discomfort and must be used by trained professionals.

**ESTHETIC ORTHODONTIC SYSTEMS (self-ligating braces, Customised smile designing systems: Clear/invisible aligner orthodontics, clear brackets, Lingual Orthodontics)**

Over the past 2 decades, there has been a massive paradigm shift with regards to patient preferences for orthodontic treatment. Around 30% percent of the patients are adults and know clearly what they want out of the orthodontic treatment and have specific expectations. Also, most of them have certain esthetic requirements.

Long gone are the ages of metallic smiles with elastics plastered on to the teeth giving the patients a rather unsightly brace-face appearance. Ceramic brackets have been developed that use a clear alternative bracket that may be used with clear elastics and coated wires for a more camouflaged esthetic appearance. Ceramic and lingual braces are constantly advancing and are preferred by patients for a less conspicuous appearance. Self-ligating braces are also available, so that the use of elastics or ligatures can be bypassed for a more aesthetic appearance. Another option for esthetic orthodontic therapy is aligner orthodontics offered by companies like Align Technology, with Invisalign that consists of a series of custom-made Smart Track plastic (developed by Align Technology Inc.,) aligners that are used to bring teeth into desired positions. They are digitally designed, and handed over to the patient. Impressions are made by intra-oral scanning (eg. iTero scanner) The practitioner's knowledge and patient compliance are very important factors for the success of aligner orthodontic treatment.

In 1726, the possibility of using an appliance by bonding it lingually was discussed by Pierre Fauchard. In 1841 the first lingual arch for expansion and alignment was designed by Pierre Joachim Lefoulon. The lingual appliance was first used in Japan, pioneered by Kinja Fujita, in the 1970's for the patients who were involved with the practice of martial arts, in order to protect their buccal and labial soft tissues. He was also the first to develop the lingual multi-bracket technique with the mushroom shaped arch wire. It has slowly developed with time. The development of indirect bonding has significantly reduced chairside time, and made things easier for the orthodontist. Other important developments include the customization of the bracket with composite to conform to the contours of the tooth surface allowing the laboratory to include the biomechanics into brackets and their positioning reducing the need for wire bending. [69] Lingual Orthodontics were an enigma in the early 80s but it was a difficult technique, but years later, presently there have been developments with the brackets, the wires, lab procedures, and patient comfort. The main goal of orthodontic treatment is to achieve an esthetic appearance [70], and the means to the end is usually rather unaesthetic and lingual placement of the brackets [71] is advantageous for extremely appearance-conscious. With the evolution of the systems and the advancements this sector has seen, the clinical results achieved are at par with labial orthodontic systems, and its acceptance in the profession has grown rapidly. [72] There are also various associated advantages like sparing of the facial surfaces from the process of etching, bonding, debonding and polishing to remove the adhesive which may lead to inadvertent loss of tooth material. Facial soft tissues are not affected and the true contours can be appreciated during treatment itself. It does have disadvantages like tissue irritation, speech difficulties, gingival impingement, oral hygiene difficulties, high expense involved, technique sensitivity, difficulty in rotation corrections.

Retention after orthodontic treatment is of paramount importance, and is traditionally achieved by the use of Hawley's retainers and permanent retention by the use of lingual bonded retainers. Clear or vacuum formed retainers are now available, that are less conspicuous and hence, may encourage prolonged wearing, by the patient. VFRs (Vacuum Formed Retainers) perform better in maintaining arch length and the labial segment alignment, which is most important from the patient's standpoint, for an esthetic appearance. [73]

## TIME EFFECTIVE ORTHODONTIC TREATMENTS AND LASER IN ORTHODONTICS. (cosmetic corrections, PROPEL, AOO-RAP, WILCKODONTICS)

The time old concept that never grows old, is time itself, and anything that can be done to accelerate the treatment process within the physiological limitations, is always welcome. Research in the pursuit of the same has led to the development of periodontally aided rapid orthodontic treatment procedures aka, Alveolar corticotomies, before applying orthodontic forces, so that the enhanced inflammatory process aids in faster teeth movement. This synergy which is a result of interdisciplinary orthodontic and periodontics specialties in orthodontic treatment. This tooth movement with periodontal tissue regeneration principles help facilitate rapid tooth movement and help overcome its side-effects.[74] Orthodontic tooth movement is due to increased metabolism in the alveolar bone and increased turnover rate, which directly influence the quality and quantity of tooth movement. [75-77] the various types of damage that can be inflicted to the bone in order to accelerate the treatment process are : Osteotomy( complete cut through the cortical bone to medullary bone), corticotomy (partial cuts to the cortical bone without penetrating the medullary bone), ostectomy(removal of a portion of cortical and medullary bone), corticotectomy (removing an amount of the cortex without involving the medulla)[78,79] This surgical wounding of the alveolar bone leads to tissue reorganization and healing by way of a sudden burst of transient localized soft and hard tissue inflammation triggered remodeling.[80]

Wilckodontics was patented by the Wilcko brothers. [81] surgically assisted tooth movement has been around since the 1800's. Cunningham presented "Luxation, the immediate method in the treatment of irregular teeth" at the International Dental Congress at Chicago in 1893. Tooth movement facilitated by corticotomy was described by LC Bryan in 1893 published in the textbook by SH Guiliford. Henrich kole's publication set the stage for corticotomy facilitated orthodontics in 1959. [82] It was Kole's belief that the thick layer of outer bone(cortex) if disrupted, will lead to a movement of the blocks of bone in which the teeth were embedded. This was named "bony block movement" [83] Orthopedist Herald frost coined the cascade of physiological events following the surgical wounding as RAP (The Regional Acceleratory Phenomenon)[84,85] RAP is a local tissue regeneration process to noxious stimuli, which is normally faster than a normal regeneration process[86] but the response is dependent on the magnitude of stimulus, tissue type. It usually lasts for about 4 months in human bone. It is

around 10-50x faster than the regular bone turnover.[87] It begins after a few days of the intervention, peaks at 1-2 months and takes 6-24 months to completely subside. [85] There is a decrease in the overall bone density but the bone matrix volume remains constant. [84] Orthodontic movement triggers RAP and vice versa, also when it is combined with selective decortication, the effects are manifold. [87,88] The catabolic osteoclast activity is a limiting factor in the movement of the tooth and is crucially assisted by the periodontal ligament. [89] This process is considered an intermediate between conventional orthodontic treatment and orthognathic surgery. [82,83] As opposed to osteotomy, when corticotomy is employed, the spongiosa maintains the nutrition though the bone is exposed and the possibility of a bone aseptic necrosis is avoided. Devitalization of tooth is prevented along with shortened treatment time. [82,83] It can be used in cases of crowding, where conventional orthodontic treatment is cumbersome and time consuming, for canine retraction to close the premolar extraction spaces, dis-impaction of impacted teeth, slow orthodontic expansion, molar intrusion, open bite correction and enhancement of post orthodontic correction stability. [90]

Most adults with crowding or spacing that seek out a cosmetic correction, to just align the teeth that are unpleasant to their aesthetic may have their requirements fulfilled without the actual bite correction, to make the occlusion ideal, which may take two years at minimum. It can be employed in the correction of rotations, crowding, spacing, overbites, open bites, etc, but if the issue is serious and the degree of misalignment is high, with a not so ideal bite, or bite issues, full blown orthodontic treatment is always the better choice as it will deal with the underlying issue rather than just the symptoms for a cosmetic appearance. Piezoelectricity assisted corticotomies may be used to further accelerate the process, along with placement of bone grafts to increase the alveolar bone volume and prevent bone dehiscence. [91] It has proven to be effective in the correction of various skeletal malocclusions. [92, 93, 94, 95] However it should be avoided patients with periodontal disease, untreated endodontic issues, corticosteroid therapy, and those on medications like NSAIDs and Bisphosphonates that slow down the bone metabolism. [79]

Recently, Lasers have been used in LASER assisted flapless corticotomy, as a non-invasive procedure that brings down the effective treatment time and damage to the periodontium, enhancing orthodontic tooth movement by virtue of the cortical layer reduction following ER-Cr: YSGG laser irradiation (Erbium, Chromium doped Yttrium Scandium Gallium Garnet) without flap elevation. [96] Apart from this lasers can also be used for other auxiliary procedures like gingivectomy, frenectomy, operculectomy and for the flattening of the inter-dental papilla following treatment.

Other Novel approaches include MTDLD (Monocortical Tooth Dislocation and Ligament Distraction Technique) wherein, vertical and horizontal microsurgical corticotomies are performed with a piezo-electrical microsaw to eliminate bone resistance on the surface that corresponds to the direction of movement. This is followed by the immediate application of strong biomechanical forces that will lead to the movement of the unit as a whole. (root+cortical bone) On the root surface opposite to the direction of movement, the force produces rapid distraction of the PDL fibers. Osteogenic movement ensues as normal orthodontic biomechanics occur. [97] A piezosurgical technique may be used to perform microsurgical corticotomy around each root and the immediate application of a biomechanical force that prevents the PDL involvement and bone resorption which are staples of traditional orthodontic movement. The first 30% of treatment time with MTDLD exhibits maximum movement. [98,99]

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