Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/12758
DOI URL: http://dx.doi.org/10.21474/IJAR01/12758

RESEARCH ARTICLE

DIGITAL ORTHODONTICS- A CONTEMPORARY VIEW OF FUTURISTIC PRACTICE

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Manuscript Info

Manuscript History
Received: 20 February 2021
Final Accepted: 24 March 2021
Published: April 2021

Abstract

The world is going digital and so is the speciality of orthodontics. The knowledge of computers is no longer rudimentary and the application of technology in orthodontics has grown exponentially. Conventional methods of running an orthodontic practice were limited and associated with multiple drawbacks. Owning and running a digital orthodontic practice is the need of the hour and necessity of the future. The aim of this review article is to encourage and promote the orthodontic community to integrate digital elements in their practice. This review article discusses in detail about the various aspects of digital orthodontics involving digital office, study models, three-dimensional imaging, rapid prototyping, virtual treatment planning, artificial intelligence and role of robots. This review article provides an insight into the capabilities and clinical application on currently available digital orthodontic technological systems.

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Introduction:-

As science and technology multiplies around us, we can observe the future more closely. The advancement in internet, globalization and the recent coronavirus pandemic has prompted the world to become paperless. In the recent decades, the speciality of orthodontics has digitally evolved significantly.[1] Right from the moment when the patient thinks about having their teeth corrected to the time when their treatment is over, the arsenal of digital technology has enabled the orthodontist to approach more wisely, efficiently and accurately.

Presently, all paper based records are being replaced by software-backed, centrally stored practice management programs. Conventional physical imaging had been taken over by digital radiographs and digital photographs. Plaster models are now being replaced by digital models.[2] Similarly, the digital revolution has taken over cephalometric analysis, simulation/virtual treatment planning, treatment alternatives, outcomes and follow-ups. This digital revolution in orthodontics has enormously assisted in overcoming previous communication hindrances, improving treatment outcomes and subsequently increasing productivity. The objective of this review article is to highlight the scope, merits and demerits of various digital technological advancements which are or can be used in the field of orthodontics.

A Digital Orthodontic Office -

Scope –

A paperless orthodontic office can be a reality for progressive orthodontists. It involves upgrading office with new hardware and software to improve the efficiency of your practice.[3] Patient management software can be used for

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maintaining the demographic records of the patients.[4] The diagnostic records such as digital photographs, radiographs, models can be stored. The treatment plan, sequence, alternatives and notes can be readily available to review at regular appointments. The software can also store and communicate with the patient about their appointment schedule and fees on their smartphones.[5]

Merits-
-All the records go digital, hence space is preserved, manpower is reduced and efficiency is improved
-The risk of cross-infection reduces as the physical form of data is eliminated
-All the data and record is available centrally which can be communicated easily with patient or other practitioners by any staff member
-Patient review, progress and other notes can be updated outside office on weekends and holidays
-Overall the ease of doing practice and productivity increases in the long run

Demerits-
-Transition can be difficult for not so technologically friendly doctors
-Establishing new hardware and software equipments can be a financial strain
-Back-up for records is mandatory as computer systems are prone to crash and virus-attack.
-Regular upgradation of software and equipment is required to be abreast with latest advancements.

Digital Models -
Scope-
In the past decade, most of the orthodontic practice has been revolutionary barring the replacement of plaster models with digital models. Orthodontist have been reluctant in adapting and adopting this component of digital patient record. Only 10% of orthodontist used digital programs for dental models in Spain.[6] Similarly in USA and Canada, only 10% of orthodontist used digital study models in their practice.[7] Digital models can be acquired by indirect or direct methods. In indirect method, a high quality impression and bite registration is required from which a plaster model is made and optically scanned to obtain a digital model. In direct method, the impression is not required. The images are obtained directly from the patients mouth by intra-oral scanners, lasers, structured light or CBCT.[8] Software such as Orthocad, Geodigm, Unitek TMP are available to acquire, mange and store digital study models. Recent software are enabled with articulation feature to evaluate TMJ functions, stimulate various movements and provide with most effective treatment plan.

The accuracy and reliability of digital models have been contentious in the orthodontic literature. Some studies have found no statistically significant difference in the measurements between the plaster and digital models[9,10] whereas some studies have found the digital models to be larger[11,12] and some have found digital models to be smaller than the plater models.[13] Nevertheless, digital study models are the new gold standard in orthodontic practice and hence an orthodontist should be aware of the clinically acceptable accuracy, acquisition techniques, use of software and printing of 3D models in their orthodontic office.

Merits-
-Storage space for physical models is no longer required
-Transfer and communication of files is easy and instant
-Discussion and visualization with patient is effective and interesting
-Digital models can be accessed anytime and anywhere for diagnostic and clinical purposes

Demerits-
-Scanners and software required for digital acquisition of models can be costly
-Lack of proper training, familiarity and tactile sense with the scanner and software
-Incompatibility issues of digital model files with other software programs due to proprietary formats
-Legal acceptance of digital models is still questionable which refrains many orthodontists from using it.

Digital Imaging
Development and incorporation of three dimensional (3D) tools in orthodontics has been the most significant achievement of the speciality in this century. Moving ahead from conventional two dimensional radiographs, the world of orthodontic practice has progressed to better and accurate system of diagnosis and treatment planning. Three dimensional imaging techniques is the umbrella term used to describe an array of digital imaging modalities

like Cone Beam Computed Tomography (CBCT), Computed Tomography (CT), Micro Computed Tomography (MCT), Tuned-aperture Computed Tomography (TACT), 3D laser scanning, structured light technique, 3D stereophotogrammetry, 3D Facial Morphometry (3DFM) and Magnetic resonance imaging (MRI). Although the advances are many, a competent orthodontist should be aware of the specific clinical indications of these 3D imaging techniques in routine clinical practice.

Cone-Beam Computed Tomography (CBCT)

CBCT was first described in the year 1978 and became commercially available in late 1990s.[14] The first CBCT for dental purpose was used in 1998.[15] In 2001, FDA approved NewTom CBCT was commercially available for head and neck imaging.[16] Since then, CBCT has been a boon to orthodontics. CBCT used a cone-beam that passes from patient and is captured on a two-dimensional flat plane metal detector. These two-dimensional images are converted into three-dimensional images by the computer based-software programs.

Specific indications of CBCT in orthodontics-

Patient selection is important and should be based on the risk-benefit ratio and golden laws of ethics. The potential benefits of outcome must outweigh the risk of increased radiation dose.[17] Following are the specific indications of performing CBCT in orthodontic practice:

Localization of impacted teeth-

CBCT provide accurate localization of impacted teeth. It can supplement panoramic radiographs when impacted canine inclination exceeds 30 degree, the root apex of canine is not visible clearly or when the root resorption of adjacent lateral incisor is suspected.[18] Precise localization of impacted teeth can affect the diagnosis and treatment planning of the case but its role in reducing the treatment time and facilitation of surgical exposure can't be confirmed.[17] CBCT improves the clinician's confidence about their treatment decisions. Also clinicians have rated higher proportion of teeth with root resorption on CBCT images.[19]

Skeletal deformities-

The use of CBCT to predict or evaluate the outcome of treatment for dentofacial abnormality cases like syndromes, facial asymmetry or orthognathic surgery is the most researched application. Planning of realistic surgical movements, virtual stimulation and prediction of soft-tissue adaptation can be done by collaborating CBCT with specific surgical planning software and 3D study models.[20] Preference should be given to patients older than 16 years of age.[21]

Cleft lip and palate-

CBCT can be used to asses the maxillomandibular anatomy, size, volume and location of the bony defect, canine displacement, presence of supernumerary teeth.[22] CBCT can also be helpful in evaluating the post-surgical outcome like bone volume post-alveolar grafting and morphology of alveolar bone.[23] CBCT in cleft patients provide better insights into the problem and is an accepted indication for the problem.

Temporomandibulat Joint (TMJ) assessment-

CBCT evaluates both the right and left TMJs in a single 360 degree rotation compared to tomography which usually requires four cuts in frontal and lateral plane.[24]This cumulatively reduces the radiation exposure. CBCT images provide superior view of condylar morphology, erosions and structural deformity.[25]Nevertheless, it is pertinent to understand that CBCT is not recommended in TMJ problems like myofacial pain dysfunction syndrome (MPDS) or internal disk derangements. MRI is usually recommended in such cases.[26]

Bone Assessment-

CBCT can be used to assess both the quality and the quantity of bone. Buccal and lingual bone plates thinner than 0.2 mm can be measured and assessed easily which is not possible with multi-sliced computed tomography.[27]

Temporary Anchorage Devices (TADs)-

CBCT is usually not indicated for placing TADs in orthodontics. It is indicated only in cases where critical space is left for the placement of TADs. Here the CBCT is useful in evaluating the quality, quantity of bone and proximity of important anatomical structures. This helps in improving the stability and success of mini-implants. Moreover, surgical guides can be prepared using CBCT scans which provide accurate placement of TADs in the desired aspect of bone.[28,29,30]

Airway analysis-
CBCT of airway doesn't affect the orthodontic diagnosis and treatment planning. Lateral cephalograms can evaluate the area whereas CBCT is required for volumetric assessment.[17] Role of CBCT in diagnosing obstructive sleep apnoea (OSA) is controversial. Ideally, polysomnography is the standard method to diagnose OSA instead of CBCT. Nevertheless, certain studies have highlighted the importance axial CBCT cuts in diagnosing OSA owing to their better soft-tissue assessments.[31,32]

Evaluation of treatment outcomes-
CBCT derived 3D overlays and colour coded displacement maps assist in quantitative evaluation of growth and treatment outcomes in cases involving maxillary protraction and rapid maxillary expansion.[33]

Other arenas where CBCT can be handful is to assess the growth or skeletal maturity by evaluating the cervical vertebrea[34] and fabrication of custom orthodontic appliance in tandem with 3D printing.[35] Certain conditions like orthodontic treatment induced mental nerve paraesthesia,[36]buccal, lingual and interproximal bone defects,[37] centric occlusion, centric relation (CO/CR) discrepancies[38] can be evaluated with CBCT for improvised diagnostic information.

Advantage of CBCT in orthodontics-
In comparison to conventional lateral cephalograms, the CBCT is more accurate, reliable and provide three-dimensional view. As compared to conventional computed tomography (CT), the CBCT is cost-effective and easy to maintain. The radiation exposure in CBCT is four times lower than that of CT.[39] Overall CBCT involves exclusive dentofacial imaging, beam is limited, images are accurate, easy to use, scan is rapid i.e. obtained in a single turn and compatible to various computer-based planning software.[40]

Disadvantage of CBCT in orthodontics-
CBCTs provide poor soft tissue contrast thereby leading to limited display of soft-tissues. They are costlier than conventional radiographic equipments and require more space. Radiation exposure can be more in comparison to conventional radiographs but it outweighs the risk-benefit ratio. Image artefacts such as brackets and restorations can reduce the image quality.[40,41]

Computed Tomography (CT)-
These devices use fan beam and line detector to generate cross-sectional images in the sagittal, axial and coronal plane. The slice thickness of 2 mm and 64 or 128 sections can be captured in one time.[42] In orthodontics, CT scan is recommended in diagnosis and treatment planning of dentofacial deformities as it provide excellent hard and soft tissue details. CT is expensive because of increased number of sensors and also have a high radiation dose. Hence its application in orthodontics is limited to conditions in which the benefits outweighs the risks.[43]

Micro-Computed Tomography (MCT)-
MCT involves nano-sections and has 10,000 times more resolution than CT. In orthodontics, this property can be used to analyse micro-bone architecture. MCT can be useful in evaluating alveolar bony remodeling, bone dihescence, osseo-intergration of mini-implants and root resorption.[44]

Tune-Aperture Computed Tomography (TACT)-
TACT is a low dose, three-dimensional imaging technique which involves the use of reference markers for synthetic reconstruction of the image. In orthodontics, TACT can be used to assess the bone volume, root resorption and TMJ disorders.[45,46]

3D Laser Scanning-
In orthodontics, direct scanning of face can be used for treatment planning and evaluating the outcome of orthognathic surgical treatments. It has been reported as a reliable soft-tissue imaging modality with measurement error of less than 1 mm. But this modality has not garnered much support as the process of scanning is slow, requires patient to be motionless, distortion of images frequently occur and rendering of soft tissue surface texture is unsatisfactory. Also there is a safety risk of eye exposure to laser especially in the growing children.[41,47]

Structured Light Technique-
This technique can be used to capture the face at surface level only using non-ionizing radiation. Usually a single image is sufficient to create 3D facial analysis and superimpositions. High concentration image of face and radiographic information from other sources combine to produce 3D views for diagnosis, treatment planning and outcome of results in orthodontics. It can also be used to determine the position of bracket on teeth.[48,49]

3D Stereophotogrammetry-
The three-dimensional surface imaging technique is a powerful, non-contact tool to acquire and quantify craniofacial soft-tissue morphology. It is a minimally invasive, rapid, accurate and reliable way of replicating the geometry, colour and texture of face.[50]Stereophotogrammetry involves capturing the face from two different coplanar planes to acquire lifelike rendering of facial images.[51] Like other surface imaging techniques, stereophotogrammetry in orthodontics can be used for facial reconstruction, diagnosis and planning of treatment and evaluating outcome of surgical procedures.[52] In this method, the hair and eyebrows are difficult to capture. The subnasal and submental region is prone to data loss. Movements during image acquisition can lead to production of less accurate images.[50] Nevertheless, due to its quick capture speed and expanded coverage of facial surface, the 3D stereophotogrammetry technique is being employed extensively in clinical and research settings. It is most frequently used in cleft lip and palate cases for soft tissue evaluation.[53]The small capture time and simple equipmentsfavours its utilization in small children.[54]

Magnetic Resonance Imaging (MRI)-
MRI is non-invasive, non-ionizing technique which has huge potential but limited application in orthodontics.
MRI is indicated for the imaging of TMJ morphology and disk problems.[55] Recently, MRI has been used to evaluate velopharyngeal incompetence[56], tooth germs and mesio-distal tooth measurements.[57]It offers excellent soft and osseous-tissue description along with examination of inflammatory lesions and scar. Still, the usage is limited, equipments are expensive and there is lack of training amongst orthodontists regarding its use. Also it is contraindicated in patients with claustrophobia, pacemaker and pregnancy.[58]

Intra-Oral Scanners-
Intra-oral cameras along with software is used to capture images to create digital dental models, examine inter-arch relationships, virtual treatment set-up, 3D fabrication of arch-wires, printing of aligners, fabrication of customized brackets, appliances and indirect bonding. Overall, 3D intra-oral scanning is a medium of acquiring 3D images which can subsequently be used for myriad of orthodontic applications.[59,60]

Rapid Prototyping-
Rapid prototyping (RP) is a novel and fascinating technique of printing three-dimensional objects by using computer aided manufacturing (CAM). A computer-based software is used to design images which can be brought into physical structures by using 3D printers or stereolithography machines.[61] The various methods by which RP models are created include stereolithography, selective laser sintering (SLS), Inkjet based system and fused deposition modeling (FDM).[62] RP has a vast and promising application in dentistry. In orthodontics, RP technique can be used to diagnose the exact anatomical location of impacted canine and fabricate attachments for canine traction.[63]Inorthognathic surgical cases, an anatomical replica model of the patient can be constructed using RP technique. This RP model model can be helpful in planning and performing surgery more conveniently and accurately. Evaluation of asymmetrical discrepancies and pre-operative mock surgery can be performed on the RP model. Surgical splints which are placed post-operatively can be fabricated using stereolithography techniques.[64,65] CAD-CAM techniques can be used to print clear aligners which can be offered as an alternative to conventional braces. These aligners can assist in correcting relapse after fixed orthodontic treatment.[66] 3D mandibular distractors can be fabricated using RP technique for performing distraction osteogenesis.[67] RP can also be employed to fabricate customized lingual brackets[68,69] and surgical template for accurate and precise insertion of mini-implants in orthodontics.[70] RP seems a promising modality but comes with some major disadvantages. The cost associated with printing 3D models is too high to be integrated into routine clinical practice for every orthodontist. It requires complex equipments, proper training, is labour-intensive and time consuming. Nevertheless, the scope of rapid prototyping for digital fabrication in dentistry and orthodontics is expansive and bright in the near future.

Virtual Treatment Planning (VTP)-
Conventional orthognathic surgical procedures are often encountered with inadequate radiographic imaging and inconsistent anatomy of the patient. This lead to over-reliance on judgement and experience of the surgeon. In the

present times, VTP is a modality which collaborates the patient's photographs, 3D imaging scans and CAD-CAM software to plan the surgery pre-operatively. VTP involves 4-stages: planning, modelling, surgery and evaluation.[71]

Planning:
The CBCT or CT scans and 3D reconstruction images of the patient are submitted in a treatment planning software. Here the virtual surgery is performed on the computer screen. Yaw, pitch and roll movements in the 3 plane are observed. The clinical effect of bone resection, osteotomy and grafting is evaluated in this stage. Surgical splint to achieve ideal occlusion and facial symmetry are designed as required.

Modelling:
The software along with CAD-CAM, stereolithography and rapid prototyping machines prints the 3D model, guides, plates and splints for that particular case.

Surgical:
In this phase the actual surgery is performed with the help of 3D templates. These customized pre-fabricated templates and models improves the overall accuracy of the procedure, the surgery is performed in less time and the patient discomfort is greatly reduced. This effectively increases the surgeon and his team's confidence of performing aorthognathic surgical procedure with predictable and promising outcome.

Evaluation:
Here the 3D models are overlaid with CBCT or CT scans and 3D reconstruction images to compare the pre-operative and post-operative outcomes.

Studies have shown that the patient satisfaction, functional and aesthetic outcomes are greatly improved in VTP cases as compared to conventional surgical procedures.[72] The VTP is cost-effective and reduces the operation theatre (OT) time of the patient.[73] The main drawback of this technique is the unwillingness of older and experienced surgeons to adapt to this new technology.

Artificial Intelligence (Ai) And Machine Learning (Ml) In Orthodontics
The buzz word of AI and ML has made its presence felt in the speciality of orthodontics too. Artificial Intelligence (AI) is the ability of computer programs to perceive data information and convert it into reasonable and intelligent actions. Machine Learning (ML) is an application of AI commonly used in dental and medical fields. In orthodontics, AI and ML can be used for diagnosis and treatment planning, growth assessment and prediction of treatment outcomes.[74] Artificial Neural Networks (ANNs) can be used to predict extraction decision, extraction patterns and anchorage requirements in fixed orthodontics.[75] ML can be used for landmark identification and cephalometric analysis on digital cephalograms.[76] ANNs can estimate the dental age[77] and can predict canine impaction from panoramic radiographs.[78] AI can also be utilized to predict the post-treatment soft-tissue changes such as lip position in extraction vs non-extraction cases.[79] AI can also be used to quantify facial attractiveness,[80] predict post-treatment peer assessment rating (PAR) index[81] and treatment outcome in untreated Class III orthodontic cases.[82] AI and ML in orthodontics can play a substantial role in eliminating subjectivity, reduce variability and practice more efficiently. The drawback of this technology lies in the fact that the algorithms are based on assumptions thereby leading to misleading information. Hence is it prudent for an orthodontist to not substitute their orthodontic knowledge, judgement and experience for such non-human software-backed programs.[74,83]

Role Of Robots In Orthodontics-
Robotic technology in medical field has been extensively researched in developed countries. Robots in dentistry can be employed to bring convenience, improve accuracy and provide economic growth. Although in a nascent stage, robots in orthodontics can be used for inserting a mini-implant with precise insertion depth, insertion angle, proper torque and achieving primary stability.[84] Robots have also been employed to bend arch-wire and is known as SureSmile arch-wire bending robot.They provide with customized arch-wire and brackets allowing simulation of different treatment plans and detailed treatment planning.[85] The scope of robotic technology in vast and unlimited but will require extensive research to promise practical clinical benefit in this field.

Conclusion:-
Digital orthodontics has been there around a decade, but the recent advancements in technology and the inherent desire of orthodontist to go paperless has dramatically turned the tables in favour of digitalizing the practice. Beginning from the initial patient communication, to record keeping, photographs, radiographs, treatment planning and outcomes, everything under the practice of orthodontics can be digitalized. The heart of any good orthodontic treatment lies in its diagnosis and treatment planning. Incorporation of three-dimensional digital technology for radiographic imaging, 3D reconstruction of face, fabrication of study models, construction of 3D stereolithographic models, prediction of treatment outcome, virtual surgical planning and artificial intelligence has lead to correct diagnosis and better clinical outcomes. All this begins with the collection of digital data and this trend will continue to dominate the practice of orthodontics in coming future.

Data is the new currency in today's digital world. Large chunks of data acquired from any source can create opportunities for unending technological advancement in the field of dentistry and orthodontics. It is a duty and collectively responsibility of the orthodontic community to harness the power of this 'big data' to improvise the clinical outcome and refine personalized care for our patients. The collaborative efforts of the government, corporates and dental researchers can dramatically shape the future of orthodontics. Moving towards a fully dedicated digital orthodontic practice can be a daunting task initially both in terms of finance and psychology. In the long run, the merits of the practice are positively effected exponentially. Average treatment times are reduced, appointments are streamlined, treatment outcomes are better leading to enhanced patient experiences. Overall, progressing towards a digital orthodontic practice will only generate more revenue, increase profession liking amongst peers and bring an immense sense of satisfaction to the orthodontist.

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