Review Article

Three dimensional (3D) imaging techniques in orthodontics-An update

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Abstract

3D imaging is a technique which develops or creates the impression of depth within an image by deploying 2D data into 3-dimensional format. To aid in quality regulating processes for industrial purposes, 3D imaging has become an extremely valuable factor. Owing to their various drawbacks, a wide range of investigative methods formulated for demonstration of facial structures and the dentition were dilapidated. Currently in medicine, the most prevalent method is perhaps 3D imaging technique renders thorough and problem specific information regarding hard and the soft tissues, such as Computerized Tomography (CT), Cone Beam Computerized Tomography (CBCT), Micro Computerized Tomography (MCT), 3D laser scanning, structured light technique, stereophotogrammetry or 3D surface imaging systems (3dMD), 3D facial morphometry (3DFM), Tuned Aperture Computed Tomography (TACT), and Magnetic Resonance Imaging (MRI). 3D imaging techniques in orthodontics plays an important role by facilitating more elaborated diagnostic information on the precise cases like patients having craniofacial anomalies. Hence, the aim of this study was to review advances in 3D imaging with in the field of orthodontics.

Keywords: Advances, imaging, orthodontics, techniques

Introduction

3D imaging is a method which develops or creates the impression of depth within an image by deploying 2D data into 3-dimensional format. To aid in quality regulating processes for industrial purposes, 3D imaging has become an extremely valuable factor. Many one of a kind technologies are available which could render help with this technique rendering 3-Dimage for inspection and testing purposes.[1]

The past of imaging and orthodontics could be a saga of biology receiving information by technology. The mechanics of dentistry and particularly orthodontics has been influenced by the advancements in bands, brackets, and arch-wires. Developments in imaging modified our cognition. This can be as a result of imaging offers the discipline a scientific tool to check prospective craniofacial growth and also the effect of treatment on this dynamic method. Suitably, the recent 3-dimensional (3D) scanner utilizes less ionizing radiation as compared to traditional cephalograms and panoramic views, and today we get more detailed information with less radiation exposure.[2]

Among all the investigative procedures, the best among all is Imaging and it is of utmost essential tools for orthodontics to appraise and document dimensions and anatomy of the structures in the craniofacial region.[3] The utilization of 2-dimensional (2D) static imaging procedures is often done by Orthodontists for recording the craniofacial anatomy, however obtaining depth of the structures is not possible with 2D imaging. Development of 3D imaging was done in the start of 1990's and has attained a valuable position in the dental field, fraternity of orthodontics and oral surgery (orofacial surgeries)

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are benefitted the most. In 3D investigative imaging, anatomical data in series is congregated by means of advanced high-tech equipment, managed by computer and subsequently confirmed on a 2D monitor to exhibit the misapprehension of deepness.[4]

The triad of teeth, the facial soft and the hard tissues has an extensive role in making plans related to orthodontic treatment.[5] Hence, imaging of those anatomical sites is one of the beneficial diagnostic gear for clinicians for assessment in therapeutic modality.[6] For orthodontic reasons 3D imaging specifically comprise before and after treatment appraisal of dento-skeletal and craniofacial associations and facial looks along with beauty, reviewing treatment outcomes in terms of hard and soft tissues, formulating investigative selections and therapeutic planning besides 3-D treatment projections.[7]

Owing to their various drawbacks, an array of investigative methods developed for demonstration of structures like facial and within the oral cavity like dentition were outmoded.[8-10] The foremost well-liked technique in the current scenario is probably 3D imaging technique giving elaborated and downside adjusted information regarding soft and onerous tissues, like computed axial tomography (CT), small computed axial tomography (MCT), Cone Beam computed axial tomography (CBCT), sterophotogrametry or 3D surface imaging systems (3dMD), 3D laser scanning, structured light technique, 3D facial morphometry (3DFM), Magnetic resonance Imaging (MRI), and Tuned Aperture CT (TACT).[11-14] Hence, the aim of this study was to review advances in 3D imaging with in the field of orthodontics. The study proposal was submitted to the research center of Riyadh Elm University and Institutional review board approval was obtained (FRP/2019/191/61/64).

3D imaging strategies may be recapped as follows:[15]

1. Convention computed and cone-beam computed tomography (CT/CBCT)
2. Laser scanning (3D laser scanning)
3. Vision-based scanning techniques
4. 3D orthognathic surgery planning
5. Intraoral scanning
6. Magnetic resonance imaging (MRI) and surface scanning
7. Video camera (four-dimensional (4D) imaging and video stereo photogrammetry).

3D Imaging Methods

Computed tomography (CT)

Images of the body which are cross-sectional in nature are obtained by using special X-ray instrument in CT imaging, known as computerized axial tomography (CAT) imaging. Basically, CT devices are grouped into two categories namely Cone and Fan beam. X-ray source and circular metal frame detectors rotate around patient in the conventional fan beam CT devices. In a horizontal manner firstly, the patients are positioned upon a table and then CT scanner works. Through the middle of a big X-ray machine, the table gradually moves. The entire process is painless, however certain tests need a contrast medium to shape some anatomical components seem higher within the image.[16] The practice of CT is sort of extensive in odontology, yet there are few shortcomings of CT that are:

1. High-priced,
2. Unobtainability in all the hospitals,
3. Distant lesions from the sections are missed,
4. Creation of artifacts from certain entities like restorations and various prosthesis,
5. Compared with different soft-tissue imaging systems, data of CT is insufficient.[17]

Cone beam computerized tomography (CBCT)

CBCT (Craniofacial) equipment got designed to beat restrictions of usual CT scanning devices.[18] The CBCT devices comes with tons of variations together with positioning of the patient, scan period, resolution and the radiation emission amount.[19] Additionally, some CBCT devices are capable of scanning all head space, others have the ability of scanning solely the chin space. Dental therapists are able to do 3D (volumetric) data with extremely small radiation dose at just single occasion with the cone beam systems.[20] the added advantage of the CBCT is that it allows to view the 2 dimensional images to be viewed in either sagittal, oblique, or coronal planes and numerous other inclinations at the same-time.

In CBCT, as compared to CT, patients' visualization with reduced radiation quantity is quite feasible.[19,21] It is estimated that radiation dose of conventional CT scanners is 15 times more than CBCT devices and approximately dosage of CBCT equals tothe12 panoramic radiographs dose.[12]

In orthodontia, the images of the craniofacial region received with CBCT devices, offer valuable information in many categories. Complicated areas of craniofacial treatment data can be obtained or elucidated as a self-determining solution in single or more of the subsequent groups[17]:

1. Identifying typical and atypical anatomy
2. Decision pertaining to length of root and alignment
3. Calculating jaw size along with distance of teeth examined
4. Determining the association between arch size and surveyed teeth size
5. Finding 3D relationship of maxilla-mandible
6. Detecting TMJ status
7. For determining the impact of orthodontic management in craniofacial surgeries.
8. Recognition and exact locating the supernumerary or impacted tooth.

The capability of delivering 3D descriptions of structures within the craniofacial region with least magnitude of alteration has boosted the provision of this particular procedure.[12,17]

Benefits of CBCT in orthodontics:[22]

a. Cost: The expense of CBCT imaging is enormously small

related to CT. Restriction just to the head and face leads to simpler image process. There is relatively less maintenance value of CBCT devices.

b. Decreased radiation dosage: findings of the various reports shows that, 98% fewer radiation is emitted by CBCT devices. CBCT devices emit on an average, 1.320 to 3.324micro-sievert (μSv) for the mandibular bone and 1.031 to 1.420 μSv for maxillary bones.[23]
c. Speedy scan: With the CBCT equipment, all information is obtained in just one flip. The method enhances the patient satisfaction and also reduces the period of stay within the hospital.
d. Dimensional reenactment feature: the foremost vital aid of CBCT is that it becomes feasible to show and prepare 3D information in own computers.
e. Image processing: numerous wide-ranging software's for implant position and in orthodontics calculations can be made with the use of this device.

Demerits of CBCT in orthodontics: [22]

a. The artifacts caused by metal brackets and restorations leads to weakness in image.
b. Unable to determine the particular authentic skin color and of the images of the soft tissue.[12]
c. Image distortion resulting from unanticipated or unnecessary patient movement.
d. The surplus cost and space is required for these devices when compared with conventional X-ray apparatus.
e. Constant image monitoring could be not permitted by radiation scattering.

CBCT procedure is also haunted by its inadequate capability in demonstrating soft tissues, nevertheless fortunately also has a debatable issue for hard tissue investigation of the facial structures and head.

1. Airway assessment: The disorders of airway are a characteristic reason for mal-alignments of teeth and may lead to the typical presentation of adenoidal face. 3D CBCT images provide correct illustrations of the airway space. The utilization of various software's by CBCT data permits superior visualization, volumetric dimensions and patency analysis of the airway.[24]
2. CBCT-generated Cephalograms or Digital Cephalometry: Cephalometry may be an essential instrument in orthodontics for investigation of craniofacial structures, identification of exact growth pattern, designation of abnormalities predicting potential upper and lower arch relationship, treatment planning and assessing the growth outcomes and treatment efficacy.[25] Heikovesser *et al.*[26] studied and compared the radiation exposure and dose between typical cephalometry and digital cephalometry. They concluded that digital cephalometric radiography reduces the radiation dose to almost half in comparison with conventional screen film technique. JiaKuing Liu *et al.*[27] studied the accuracy of computerized identification of landmarks utilizing various angular and linear measurements. They concluded that computerized identification of various landmarks is questionable and more studies are required to substantiate their accuracy. One of the important studies done by Geelen *et al.*,[28] wherein he tried to reproduce all the cephalometric landmarks on the conventional film, the monitor displayed images and the hard copy which was obtained by a technique called as storage phosphor.

Recent Advances in 3D Imaging

Laser scanning (3D laser scanning)

For capturing facial morphology and soft tissue Laser scanning is considered as a non-invasive technique. Several researches have confirmed validity of this method.[29,30] They are relatively less expensive and has ease of handling as well as fabricates accurate 3D facial models.[31]

Vision-based scanning techniques[15]

These are also non-invasive and quite easy techniques. Few examples of these techniques are Moiré topography, stereo photogrammetry, and structured light and 3D facial morphometry. Among these, the foremost employed method in orthodontic practice is Stereo photogrammetry.

3D planning in orthognathic surgery[15]

Capturing the 3 vital tissues—facial soft tissues, facial skeleton, and dentition—for orthognathic surgery treatment planning will solely be accomplished through "image fusion".[5] CBCT images combined with 3D facial image capture could be utilized to shape a "virtual 3D patient" thus assisting in valuating patient's craniofacial skeleton and along with the soft tissue by the orthodontists and oral surgeons. These 3D models may be spun to every possible view for comprehensive diagnosis as well as treatment planning. Entire gathered data can be saved and stored in the computer files which might be simply operated on-line.

Intraoral scanning[15]

Intraoral scanner is basically a device comprising of computer, software system, and an intra-oral camera. Digital 3D model is produced of scanned items like teeth, or impression. The typical drawbacks of impression techniques like dimensional alterations in the impression materials, storage difficulty, and dental stone errors have been overcome by the intraoral scanning technique. Orthodontists can now manage the positioning of brackets, establish the treatment on the digital model, and superimpose afore and later models.

MRI and surface scanning

These are again non-invasive imaging techniques. MRI is been engaged in craniofacial imaging since a long time as it delivers precise and elaborate data on abnormalities and conditions of hard and soft tissues of this region, particularly the TMJ.[15] MRI

is generally employed for upper airway evaluation and3D imaging of TMJ morphology.[32]

Video camera (4D imaging and video stereophotogrammetry)

4D video will document the facial movement dynamics and modify to investigate the dynamics of expressions of face. Dynamic facial expressions, and variations in facial motion between people with and without repaired cleft lip using 4D imaging (video stereophotogrammetry) have been studied.[33] These latest technologies paves way for performing new attempts to construct virtual patients by superimposing soft tissue, facial skeleton, and/or dentition.[34] Well-designed studies in the future are required for the creation of a real-time 4D virtual patient in action.

The basic foundation of any specialty is correct diagnosis. This just not helps to plan an accurate treatment planning but also helps to plan the preventive modalities also. The unnecessary and avoidable complications can be reduced thus improving the prognosis of the treatment. Productive patient communication also becomes easy as the 3D images gives compressive information. The application of advanced technology in the healthcare sector will prove be a boon, just not for treatment but also in primordial and primary prevention also.

Conclusion

3D imaging techniques in orthodontia plays a vital role in facilitating additional investigative evidence on the particular cases like patients having craniofacial incongruities. Overall, if all 3D imaging techniques become a routine practice of orthodontists, then the chair time for full dental and oral records, loss of record, and storage of these dental and oral records get reduced, thereby leading to a possibility of increase in the knowledge base for interdisciplinary communication. Although evidence-based guidelines for 3D imaging is still needed to get it into commonplace dentistry, the long run of 3D imaging offers the health professionals a dynamic 4D virtual patient in action. The present study didn't get any funds from Saudi Arabia or abroad.

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Conflicts of interest

There are no conflicts of interest.

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