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THREE DIMENSIONAL IMAGING: AN IMPACT IN ORTHODONTICS – A REVIEW

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ABSTRACT

This article reviews the various methods of three-dimensional (3D) imaging in orthodontics including the origin and history. Various technologies of 3D imaging applicable to the field of orthodontics such as Structured light ,Stereophotogrammetry, 3D Facial Morphometry, Dynamic stereometry, Laser scanning,Magnetic resonance imaging, Computed tomograghy, Cone beam computerized tomography.Present and future perspectives of 3D imaging in orthodontics

KEYWORDS: 3D Imaging, MRI, CT, CBCT

INTRODUCTION

Three-dimensional (3D) imaging has evolved greatly in the last two decades and has found applications in orthodontics, as well as in oral and maxillofacial surgery.The basic concept in 3D medical imaging, a series of data is collected using diagnostic imaging materials, which are then processed by a computer and then displayed on a 2D monitor to give the illusion of depth.Depth perception causes the image to appear in 3D[1]. The development of integrated 3D tools for diagnosis and treatment planning is one of the most exciting developments in orthodontics as the specialty moves into the 21st century. But as valuable as these new advances are, a strong cautionary note is in order. No one of these methods and indeed no combination of them will treat malocclusions by itself. The key element in orthodontic treatment remains a skilled orthodontic specialist with an understanding of the biological and biomechanical knowledge base that our specialty has painstakingly acquired in more than 100 years of collective.

History: The introduction of X-rays in 1895 furthur revolutionized orthodontics by allowing the visualization of hidden anatomy. In the 1960s and 1970s, a number of investigators sought to implement the use of stereophotogrammetric methods, originally developed for aerial mapping to measure the skull and other anatomical systems. Prominent among these investigators were Rune, Sarnas, and Sevik [2-3]. In the late 1970s, computerized axial tomography (first referred to as CAT and later as CT) became available. For a brief period it was thought by many that CT and the magnetic resonance imaging modality that followed soon afterward (first referred to as NMR and later as MRI) would replace conventional projection radiology. Although both technologies have an enormously important role in

medicine, they have not proved useful for routine diagnosis and treatment planning in orthodontics.

***3 Dimensional technologies*:** Analysis in 3D begins with the examination of the form of the facial soft tissues, the teeth and the skeleton. Modeling uses mathematics to describe the physical properties of an object.Texture mapping adds some shading and lighting which brings more realism to the 3D object. Rendering in which the computer converts the anatomical data collected from the patient into a life-like 3D object viewed on the computer screen.3D images consists :

- x-axis (or the transverse dimension),
- y-axis (or the vertical dimension), and
- z-axis (the anteroposterior dimension 'depth axis').

Stereophotogrammetry: This refers to the special case where two cameras, configured as a stereopair, are used to recover 3D distances of features on the surface of the face by means of triangulation.[4] The technique has been applied clinically by using a portable stereometric camera optically linked with a simple plotting instrument.[5] This method has evolved from old photogrammetric techniques to provide a more comprehensive and accurate evaluation of the captured subject.

This has been used in Craniofacial imaging for more than

50 yrs. Two or more cameras can capture a pair stereo image of the topographic surface from the patient face. Through sophisticated stereo algorithms geometric calculation performs a triangulation against the known position of camera sensors. A sequence of x-y-z coordinates becomes the geometric foundation for 3D model displayed as polygonal mesh, a point cloud or CAD/CAM data. An acquisition time of less than 2 milliseconds minimizes data errors caused by patient movements. After the 3D model is generated it contains 45,000 – 90,000 polygons per data set. A 24 bit full color texture data are then mapped onto the 3 D model. This method has been used to assess the outcome of Twin Block treatment,[6] and the combined orthodontic-surgical corrections of Class II or Class III patients.[4]

3D Facial Morphometry: This is not a 'true' imaging system; it employs two CCD cameras that capture the subject, real time hardware for the recognition of markers and software for the 3D reconstruction of landmarks *x*, *y*, *z*, coordinates relative to the reference system.[7] Landmarks are located on the face and then covered with 2 mm hemispheric reflective markers. An infrared stroboscope is used to light up the reflective markers. Two-side acquisition is usually needed to capture the whole face. 3DFM technology in different orthodontic and allied fields.[8] The results of facial changes have been reported in different ways. Landmarks' displacements,[9] inter-landmark distances and angles,[10] color-millimetric maps[11] and volumetric changes[12,13] have been described.

Drawbacks:

- Placement of landmarks on the face is time- and labor consuming.
- Reproducibility of landmarks
- Change of facial expression between the two acquisition sessions increases the magnitude of error.
- No life-like models can be produced to show the natural soft-tissue appearance of the face.

Dynamic stereometry: This technique allows us to analyze the variation of the relationship between the articular surfaces, providing indirect insight into disk deformation during function and parafunction as well as TMJ loading. Movement of the condyles in thier respctive fossae can be visuaized by this method and hence helps in understanding for the complexity of condylar movements.Dynamic stereometry also helps to empower our knowledge of TMJ biomechanics and therefore of the etiology of degenerative joint diseases and possibly also of internal derangement.

Laser scanning: 3D imaging of the surface of the soft tissues of the face.they can scan human face range from 2 – 20 seconds to provide a surface image map. The topographic image can be viewed on a computer monitor.Laser scanners can be caliberated with a color camera to provide a super imposed high resolution photo quality image. However, this technique has several shortcomings for facial scanning. Optical laser scanning has been used to assess facial soft-tissue changes following functional treatment,[14] following extraction and non-extraction orthodontic treatment,[15]following orthognathic surgery,[11] and in cleft lip and palate patients.[16]

They include:

- The slowness of the method, making distortion of the scanned image likely.
- Safety issues related to exposing the eyes to the laser beam, especially in growing children.
- Inability to capture the soft tissue surface texture, which results in difficulties in identification of landmarks that are dependent on surface color. Even with the new white-light laser approaches that capture surface texture color, the shortcomings persist.[4]

Structured light techniques:In the structured light technique, the scene is illuminated by a light pattern and only one image is required (compared with two images with stereophotogrammetry). The position of illuminated points in the captured image compared to their position on the light projection plane provides the information needed to extract the 3D coordinates on the imaged object.[17] However, to obtain high-density models; the face needs to be illuminated several times with random patterns of light. This increases the capture time with increased possibility of head movements. In addition, the use of one camera does not provide a 180° (ear to ear) facial model, which necessitates the use of several cameras or rotating the subject around an axis of rotation, which is not practical and has resulted in reduced applicability of this technique.[18] Studies have been demonstrated where they use two LCD projectors, charge-coupled device (CCD) cameras, and a computer to produce a three-dimensional image of the face that can be edited, shifted or rotated easily in any direction[19]. This system needs at least 2 seconds to capture an image, which may be too long to reliably avoid head movements, especially when dealing with children. Another variant of this technique was reported which consists of two cameras and one projector. A color-coded light pattern is projected onto the face before each image is acquired[20]. The displacement of the pattern enables the software to compute an accurate 3D model. Another image is acquired without any accompanying light pattern, to be used for texture mapping. Three acquisitions are needed (one frontally and two obliquely) to cover the whole face. In a further step, the three stereo-images are 'stitched' together using specific software. The produced 3D facial maps are integrated with other 3D skeletal and 3D dental maps.

Magnetic resonance imaging: On July 3, 1977, an event took place that would forever alter the landscape of modern medicine where the first MRI exam was

performed on a human being. At that time of the event it took five hours to produce one image and these images were, by today's standards, quite bad and cannot be compared to latest standards. Dr. Raymond Damadian, a physician and scientist, along with Dr. Larry Minkoff along with Dr. Michael Goldsmith, worked for seven long years to reach this point . Orthodontists should have an understanding of MRI techniques in order to understand how orthodontic appliances in situ may affect the diagnostic quality of these scans and should a patient wearing fixed orthodontic appliances require an MRI scan.

Computed tomograghy*:* The first commercially viable CT scanner was invented by Sir Godfrey Hounsfield in Hayes, United Kingdom at EMI Central Research Laboratories using X-rays. Hounsfield gave his idea in 1967,and later it was published in 1972. Allan McLeod Cormack independently invented a similar process, and both Hounsfield and Cormack shared the 1979 Nobel Prize in Medicine.This technique has become an important method for diagnosing medical diseases. It is also known as **CAT Scan** i.e. Computer Axial Tomography Scan. CT Scan is an X-ray technique that produces images of our body visualizing internal structures in cross section, rather than the overlapping images typically produced by other conventional X-rays. CT scanning has been used to assess surgical outcome and soft to hard tissue displacement ratios in orthognathic surgery.[21-22]

Cone beam computerized tomography (CBCT): CBCT was developed in the 1990s as an evolutionary process resulting from the demand for three-dimensional (3D) information obtained by conventional computerized tomography (CT) scans. this technique were designed to counter some of the limitations of the conventional CT scanning devices. There are currently four main system providers in the world market:

- NewTom 3G (Quantitative Radiology, Verona, Italy),
- i-CAT (Imaging Sciences International, Hatfield, USA),
- N CB MercuRay (Hitachi Medical Corporation, Tokyo, Japan),
- N 3D Accuitomo (J Morita Mfg Corp, Kyoto, Japan).

Cone beam CT scanner does not image slices, instead its cone shaped beam scans a complete volume at once. By rotating the beam around the subject and making an image every few degrees, the area of interest is observed from a number of different angles. The result is what is promising to be the future of CT scanning, real time 3-D images of the internal organs of the body, including the heart. The technology allows scan times to vary typically from 10 to 40 seconds and the exposure dose to be about 50mSv.The voxel size of CBCT is between 0.1 and 0.4 mm in x, y, and z planes. The image data output can be sliced in various planes or viewed as 3d volume. CBCT-synthesized cephalograms can successfully replace conventional headfilms[12] .

CONCLUSION

The knowledge of the third dimension to our radiographic records is now a reality. The future in orthodontic imaging seems exciting as we discover new frontiers, by using various three dimensional technologies mentioned in this article for diagnosing and treatment. Tele-orthodontics' is one of the promising applications of having complete 3D records of patients, especially in cases where inter-disciplinary treatment is required.

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