Acta Scientific Dental Sciences (ISSN: 2581-4893)

Volume 5 Issue 2 February 2021

Review Article

A Journey from 3D to 4D in Orthodontics – A Review Article

Mamta Phogat[1] and Tulika Tripathi[2]*

[1]Senior Resident, Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences, Delhi University, India

[2]Senior Professor and Head of Department, Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences, Delhi University, India

***Corresponding Author:** Tulika Tripathi, Senior Professor and Head of Department, Department of Orthodontics and Dentofacial Orthopaedics, Maulana Azad Institute of Dental Sciences, Delhi University, India.

DOI: 10.31080/ASDS.2020.05.1031

Received: January 11, 2021

Published: January 30, 2021

© All rights are reserved by **Mamta Phogat and Tulika Tripathi.**

Abstract

Orthodontic records are one of the main milestones in orthodontic therapy. Records are essential not only for diagnosis and treatment planning but also for follow-up of the case, communicating with colleagues, and evalu¬ating the treatment outcomes. Various 3D techniques such as 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) has created the potential for comprehensive facial evaluation. Recently, with the emergence of 4D a new dimension (motion) has been added to the imaging filed which has enabled capturing of dynamic facial movements. However, more elaborative and interdisciplinary research work needs to be done to explore the scope of 4D techniques. Therefore, the aim of this study is to review advances in 3D and 4d imaging with in the field of orthodontics.

Keywords: Three-dimensional; Imaging; Orthodontics; Laser Scanner; Stereophotogrammetry; Computed Tomography; 4D Printing

Introduction

The traditional foundation of orthodontics has mostly relied on two-dimensional (2D) imaging to recreate the three-dimensional (3D) facial intricacies. However, due to lack of depth of structures in 2D the field of dentistry, particularly orthodontics witnessed the rise of 3D imaging in early 1990s [1]. Some main applications of 3D imaging include pre- and post-orthodontic assessment of dentoskeletal relationships and facial aesthetics, preparation of treatment plans, soft and hard tissue prediction (simulation), customization of arch wires and maintenance of facial, skeletal and dental records [2].

Historical Background

In 1895, W. C. Roentgen discovered X-rays and provided a vast scope for it in the field of dentistry and medicine. This was followed by introduction of cephalometric radiographs (2D) and various standardizations to diagnose and plan effective treatment by Broadbent and Hofrath [3]. Despite of many limitations in cephalometry such as lack of precision, positioning error and difficulty in landmark location many radiographic analyses were given to evaluate dental and skeletal discrepancies [4]. However, the introduction of 3D imaging enabled more precise evaluation of craniofacial structures. In 1944, Thalmann-Degan presented one of the earliest data on stereophotogrammetry [5]. Later in 1980s, advanced techniques such as CT scanning, CBCT, MRI etc. were introduced which enabled clinicians to assess different craniofacial anomalies in detail [6]. Recently, with the emergence of 4D a new dimension (motion) has been added to the imaging filed which has enabled capturing of dynamic facial movements [7].

3D imaging in orthodontics

3D imaging of face

- 3D Cephalometry
- 3D CT Scanning
- 3D Laser Scanning

Vision based scanning techniques

- Morie Topography
- Structural Light Techniques
- Stereophotogrammetry
- 3D facial morphometry
- Magnetic Resonance Imaging

New dimension- 4D and its applications

4D PRINTING

3D imaging in orthodontics

3D imaging of face

3D Cephalometry: It is based on manual techniques for abstracting 3D coordinates from 2 biorthogonal head films, i.e., lateral and anteroposterior radiographs [8]. Despite several improvements in 3D cephalometric research with advanced armamentarium there are still some drawbacks in terms of patient exposure to radiation, difficulties in accurately locating the same landmarks in 2 biorthogonal radiographs, lack of soft tissue contour assessment and the time-consuming nature of the procedure [2]. Pittayapat., *et al*. evaluated the diagnostic efficacy of 3D cephalometry in terms of measurement accuracy and reproducibility of landmark identification and arrived at the need for more standardized studies [9].

3D CT scanning

CT/CAT[1] contains 3D cross-sectional images which are primarily used to assess hard tissues [10]. There are two types of CT devices: Fan beam and Cone beam (CBCT) [11].

Fan beam

Under conventional Fan beam technique one or multiple cross-sectional images of the body parts are reconstructed. It can achieve 64 and/or 128 sections at one time.

Applications - Mainly used to assess airway volumes following rapid maxillary expansion. Other uses include diagnosis of maxillofacial pathologies, temporomandibular joint (TMJ), trauma and fractures, implant applications, craniofacial syndromes and for salivary gland pathologies [12-15].

Disadvantages

- High dose of ionizing radiation
- Poor resolution of soft tissues
- Artifacts due to foreign objects
- Expensive

Cone beam (CBCT)

Also known as CBVT[2] uses different source detectors and acquisition than conventional Fan-beam CT. Based on 360 degrees rotational sweep, it realigns 2D images into coronal, sagittal, axial planes in a single turn [16,17].

Applications

- It is widely used for diagnosis and treatment planning of impacted teeth including exact localization, assessment of proximal structures, pathology, root resorption and evaluation of surgical access.
- It is used to analyze the nasopharyngeal airway in different malocclusions
- It provides valuable information in cleft patients for determining alveolar defect volume, location, proximity, eruption status, and paths of the teeth near the cleft site
- It is helpful in assessing the surrounding tissues and anatomical structures such as tooth roots, sinuses, and nerves,

[1]computerized axial tomography

[2]Cone beam Volumetric Tomography

preventing any complications while placing temporary anchorage devices.

- It also plays crucial role in treatment planning of the patient with syndrome such as Cleft lip and palate, orthognathic surgery, syndromes, and facial asymmetries as these may present with supernumerary teeth
- It helps in assessing the etiology of the malocclusion related to TMJ disorders [18]

Advantages

- CBCT devices emit up to 98% lesser radiation and are quicker than conventional devices.
- 3D data can be reconstructed and arranged in personal computers
- Images obtained can be processed in various comprehensive software for implant placement and orthodontic measurements.
- The cost of CBCT imaging is very low compared to computerized tomography
- It provides more accurate information from one CBCT scan than the multiple 2D views.

Disadvantages

- Image artifacts can deteriorate the image quality
- The actual color of tissue images cannot be determined.
- Unwanted patient movement may cause image disorder.
- Price of these devices is more expensive than conventional X-ray equipment, and these devices require more space.
- Radiation scattering may occur

Micro computerized tomography (MCT)

MCT is a non-invasive technique which has micro focus X-ray source, a CCD camera, and a personal computer. This can produce nano sized cross-sections reconstructed which are bounded to a much minor area with 10,000 times more resolution in comparison to conventional CT [19].

Applications

This is primarily used to assess alveolar bone remodeling, root resorption and osseo-integrated implants for anchorage [20]. Other uses include researches related to wound healing and micro vascular in orthopedics, endodontics, prosthetics and TMJ [21].

Tuned-aperture computer tomography (TACT)

TACT is a simple, faster and low dose 3D- imaging system developed by Richard Webber. It processes 2D radiographs obtained from different projection angles into 3D volume. However, it does not provide precise control and information of the imaging parts [22].

Applications: This method is used to assess alveolar bone volume, root resorption and evaluation of the TMJ related disorders in orthodontics. Other uses include diagnosis of dental caries, impacted teeth and assessment of implants [22].

Spiral CT

Spiral CT/Volume acquisition CT is the most recent technique which presents with various advantages in comparison with conventional CT such as short scan time, more accurate cross-sectional images. Presence of artifacts due to simultaneous patient translation through the x-ray source with continuous rotation of the source-detector assembly limits its usage [23].

3D laser scanning

Laser scanning is a less invasive and less expensive method that captures the morphology of face. This is mainly used to assess facial symmetry, to evaluate soft tissue changes following orthodontic treatment and as a result of growth, to assess soft tissue defects in cleft patients, to scan dental casts and to produce digital models [24,25].

Advantages

It is less expensive and user-friendly technique. It provides quite high accuracy in capturing soft tissues with maximum measurement error of <1 mm.

Disadvantages

As the procedure is slow it can lead to image distortion and make it difficult to use in pediatric patients. This also imposes safety concern due to exposure of eyes to laser. Also, it is unable to record surface texture of soft tissues which makes the surface landmarks difficult to identify as they are based on surface color.

Vision based scanning techniques

These techniques are non-invasive and quite user-friendly. Among all the vision-based techniques, stereophotogrammetry has been shown to be the most frequently used in the orthodontics.

Moiré topography

It provides three-dimensional information on the basis of contour fringes and fringe intervals. It produces better results in smoothly contoured surfaces while presents difficulties in sharp surfaces. Special attention is needed while head positioning, as a small change in head position produces a large change in fringe pattern.

Motoyoshi., *et al*. proposed a 3D facial measuring system, but this system does not capture the normal facial texture making subsequent landmark identification more difficult [26].

Structured light techniques

This technique enables the co-relation of facial esthetics with underlying skeletal tissues. In this technique, the face is illuminated multiple times with only one camera in order to obtain high density image which is needed to locate 3D coordinates on the face model [27]. Two variants have been reported in the literature for this technique. In the first one, Techalertpaisarn and Kuroda used two LCD projectors, camera, and a computer to generate a 3d image of face which can be easily manipulated in any direction [28]. In the latter variant, Curry., *et al*. used two cameras and a projector. A color-based light pattern is projected to obtain an image which helps the software to determine an accurate 3D model [29].

This technique can be used to assess bracket position more precisely. Ora-Scanner which is the first 3D intra-oral scanner, is primarily based on this technique [27].

Disadvantages

Due to more chances of head movement due to increased capture time and requirement of multiple cameras reduce the applicability of the technique.

Stereophotogrammetry

This technique provides a more elaborative evaluation of captured objects. This is based on capturing images of the 3D object with the help of two cameras from two different planes to generate a 3D model [10]. In 1944, Thalmann-Degan evaluated the facial changes following orthodontic treatment [5]. Later, Ras., *et al*. also presented a system to compute 3D coordinates for any facial landmarks [30]. More recently, this is also used for 3D skull mapping. With the advent in technology, a new generation of computerized stereophotogrammetric techniques have evolved which make the capturing and building procedures faster, simpler and more precise. Certain applications of the technique include 3D md stereo photogrammetric scanner (3dMD) which produces the 3D facial model and C3D® system which is used in diagnosis, treatment planning and assessment of treatment outcome [31].

Advantages

As this technique is non-invasive, contactless, without any ionizing radiation, short capture time, user friendly, it produces good soft tissue changes and can be collaborated with CBCT which makes it a good communication means among orthodontists. This holds peculiar importance in patients with ortho-surgical needs and craniofacial anomalies as 3d images can be seen from all the directions.

Disadvantages

Certain facial structures such as eyebrows, hair and head movement deteriorate the image quality. Also, highly curved surfaces cannot be penetrated by light which results in their poor image.

3D facial morphometry

This technique is used in clinical practice as an adjunct to cephalometric analysis. The system consists of two infrared cameras which capture the subject, hardware for the identification of markers and a software for the 3D reconstruction of landmarks coordinates. After placing the landmarks on face and covering them with reflective markers, these are enlightened with the help of an UV stroboscope. In order to capture the full face, 2-sides should be determined [32].

Disadvantages

Landmark placement and their reproducibility is a lengthy and difficult process. Moreover, models produced by this technique don't have natural facial details. Due to these shortcomings, it is not advisable to use this technique as a communication tool between clinicians and assessment tool for treatment outcome.

Recent technique i.e. active shape model facilitates automatic 3D landmark extraction by collaborating stereo assisted features and surface map interpolation [33].

Another application of the above technique is 3D tele motion tracking (3D-TMT) which allows dynamic and prognostic evaluation of the facial structure following growth of the patient without exposure to ionizing radiation [33].

Magnetic resonance imaging (MRI)

MRI is a non-invasive technique which provides good contrast between hard and soft tissues. This is mainly imaging of water in the tissues [34].

Applications

This is mainly used for airway analysis, assessment of velopharyngeal incompetence particularly in cleft patients and temporomandibular joint disorders.

Advantages

It provides accurate information about articular disk morphology and its position.it also shows osseus tissue and inflammatory changes in detail on changing the signal intensity. This is a safe alternative for the patients who are allergic to contrast agent and no repositioning is required to produce images [35].

Disadvantages

Along with little expensive, it has long capture time and it is contraindicated in claustrophobic patients.

Applications of 3d imaging in orthodontics

3D planning in orthognathic surgery

Comprehensive treatment plan for ortho-surgical cases is the key to achieve best esthetics and stable occlusion. While planning for orthognathic surgery, soft tissue envelope, skeletal tissues and dental structures are to be considered. In order to assess the hard and soft tissue together, three-dimensional image and CBCT are combined to recreate virtual 3D patient [36]. These 3D models can be easily manipulated to make more comprehensive diagnosis and treatment plan and these models are also a good communication tool between maxillofacial surgeon and orthodontist. After the 3D models are constructed, virtual orthognathic surgery which includes osteotomy, repositioning of bones, virtual distraction osteogenesis, surgical predictions, post-surgical outcomes can be simulated. Later, CAD/CAM technology can also facilitate fabrication of surgical splints [37]. These surgical splints then directly be used during surgical procedure. Predictions of soft and hard tissues also help the patient to make decision for the treatment.

Intraoral scanning

This system is made of an intraoral camera, software and a computer. It can generate 3D scans of teeth, dental cats or dental impressions. Various uses of this technique are to fabricate 3D models for diagnosis and virtual storage of data, communication tool among dentist, patient and lab person, virtual treatment planning, fabrication of clear aligners and customization of brackets and arch wires. Moreover, disadvantages of conventional impression technique such as dimensional inaccuracies of alginate and plaster, storage of dental casts are also overcome with the advent of intraoral scanning [38]. Certain studies have found that various intraoral parameters such as overjet, overbite, molar and canine relation should be evaluated and verified using virtual digital models [27]. However, long scanning time is one of the discouragements for this new technique.

Digital study models

Recent technologic advances allow the plaster models to be digitized, measured with software tools, stored electronically, and retrieved with a computer. There are many softwares available to generate digital models. They also serve as good communication tool among dentist, patients and laboratory. Moreover, digital study models also overcome the drawbacks associated with conventional plaster models such as dimensional errors and their storage [33].

Customized wires

These are also known as robotic archwires which are fabricated with the help of 3D virtual setup. SureSmile™ is one such technology based on CAD/CAM which enables the orthodontist to diagnose and plan the treatment followed by customisation of archwires with the help of digital software [39]. Various studies have proven the effectiveness of customized wires as reduction in treatment duration was seen on using these archwires. However, studies have also shown that treatment results in terms of mesio-distal tooth movement were fine but less accurate in relation to tip and torque [40].

Customized brackets

These brackets were found to be more efficient in comparison with conventional brackets at the start of treatment, but a follow-up study has found no significant difference in the treatment outcome with both type of brackets [41].

Insignia software is among one of the earliest software which enables the clinician to alter the virtual setup to further refine individualized teeth positions three-dimensionally maintaining the proper arch form, smile curve and stable dental occlusion [42].

New dimension- 4D

Video camera (4D Imaging and Video Stereophotogrammetry)

The above-mentioned methods mainly assess the craniofacial structures in 2D or 3D. As the face is a dynamic structure involving movements of lips, jaws, eyes and nose, it necessitates the requisite for a four-dimensional(4D) method i.e. 4D video capturing to evaluate dynamic movements of facial structures and biomechanics of facial expressions [7]. With the introduction of this new technology, 4D virtual patients have been created with the collaboration of hard and soft tissues and dynamic facial movements [43]. As the literature is scanty in reporting the real-time virtual patient generation using 4D imaging, more such studies need to be conducted.

Application

4D printing

This process is based on self-folding of the microstructures of 3D-printed models which can undergo transformation of shape spontaneously under the influence of thermal and humidity changes. Selective light curing of 3D materials is responsible for motility in 4D objects. This has 2 essential steps: processing and programming. The model is firstly processed into an original shape which is then temporized intermediately into another shape and finally programmed to convert to another shape under the influence of a particular stimuli which can be human body temperature or body moisture in a self-folding manner [44].

The application of 4D printing in dentistry is also extended into the field of orthodontics. Recently, 3D orthodontic software provide data for the manufacturing of both the removable and fixed orthodontic appliances. The introduction of 4D printing concept enables the manufacturing of self-straining wires or self-folding removable appliances as this makes the appliances to undergo constant movement with time resulting in desirable positioning, angulation and alignment of teeth in the arch [45].

Conclusion

Various applications of three-dimensional imaging include comprehensive diagnosis, 3D treatment planning, and 3D soft and hard tissue prediction (simulation), pre-treatment and post-treatment evaluation of dental and skeletal relations and facial aesthetics in relation with soft and hard tissues. Three-dimensionally fabricated custom-made arch wires, archiving 3D facial, skeletal and dental records for in-treatment planning, research and medico-legal purposes are also among the benefits of using 3D models in orthodontics. With the advent of 4D printing, clinicians are provided with more precise diagnostic and treatment options which will further improve the future of dentistry. More elaborative and interdisciplinary research work needs to be done to explore the scope of 4D techniques in dentistry and further prospective analyses of its applications need to be discussed.

Bibliography

1. Standardization of Records in Orthodontics Part 2: Craniofacial Imaging Techniques.
2. Hajeer MY., *et al*. "Applications of 3D imaging in orthodontics: Part 1". *Journal of Orthodontics* 31 (2004): 62-70.
3. Hans MG., *et al*. "History of imaging in orthodontics from Broadbent to cone-beam computed tomography". *American Journal of Orthodontics and Dentofacial Orthopedics* 148.6 (2015): 914-921.
4. Han UK., *et al*. "Consistency of orthodontic treatment decisions relative to diagnostic records". *American Journal of Orthodontics and Dentofacial Orthopedics* 100.3 (1991): 212-219.
5. Burke PH and Beard FH. "Stereophotogrammetry of the face. A preliminary investigation into the accuracy of a simplified system evolved for contour mapping by photography". *American Journal of Orthodontics* 53.10 (1967): 769-782.
6. 3D Imaging in Medicine, Second Edition - 2nd Edition - Jayaram K. Udu.
7. Hallac RR., *et al*. "Dynamic facial asymmetry in patients with repaired cleft lip using 4D imaging (video stereophotogrammetry)". *Journal of Cranio-Maxillofacial Surgery* 45.1 (2017): 8-12.
8. Grayson B., *et al*. "The three-dimensional cephalogram: Theory, technique, and clinical application". *American Journal of Orthodontics and Dentofacial Orthopedics* 94.4 (1988): 11.
9. Pittayapat P., *et al*. "Three-dimensional cephalometric analysis in orthodontics: a systematic review". *Orthodontics and Cranio-*

facial Research 17.2 (2014): 69-91.

10. Hajeer MY., *et al*. "Three-dimensional imaging in orthognathic surgery: The clinical application of a new method". *The International Journal of Adult Orthodontics and Orthognathic Surgery* 17 (2002): 318-330.
11. Aboudara CA., *et al*. "A three-dimensional evaluation of the upper airway in adolescents". *Orthodontics Craniofacial Research* 6 (2003): 173-175.
12. Zilkha A. "Computed tomography in facial trauma". *Radiology* 144.3 (1982): 545-548.
13. Ito K., *et al*. "Clinical application of a new compact CT system to assess 3-D images for the preoperative treatment planning of implants in the posterior mandible A case report". *Clinical Oral Implants Research* 12.5 (2001): 539-542.
14. Westesson PL., *et al*. "CT and MR of the temporomandibular joint: comparison with autopsy specimens". *American Journal of Roentgenology* 148.6 (1987): 1165-1171.
15. Görgülü S., *et al*. "Nasal cavity volume changes after rapid maxillary expansion in adolescents evaluated with 3-dimensional simulation and modeling programs". *American Journal of Orthodontics and Dentofacial Orthopedics* 140.5 (2011): 633-640.
16. Kau CH., *et al*. "Three-dimensional cone beam computerized tomography in orthodontics". *Journal of Orthodontics* 32.4 (2005): 282-293.
17. Scarfe WC., *et al*. "Clinical applications of cone-beam computed tomography in dental practice". *Journal of the Canadian Dental Association* 72.1 (2006): 75-80.
18. Kapila SD and Nervina JM. "CBCT in orthodontics: assessment of treatment outcomes and indications for its use". *Dento Maxillo Facial Radiology* 44.1 (2015): 20140282.
19. Keleş A., *et al*. "Oval-shaped canal retreatment with self-adjusting file: a micro-computed tomography study". *Clinical Oral Investigations* 18.4 (2014): 1147-1153.
20. Karadeniz EI., *et al*. "Physical properties of root cementum: part 20. Effect of fluoride on orthodontically induced root resorption with light and heavy orthodontic forces for 4 weeks: a microcomputed tomography study". *American Journal of Orthodontics and Dentofacial Orthopedics* 140.5 (2011): e199-210.
21. King AD., *et al*. "Physical properties of root cementum: part 21. Extent of root resorption after the application of 2.5° and 15° tips for 4 weeks: a microcomputed tomography study". *American Journal of Orthodontics and Dentofacial Orthopedics* 140.6 (2011): e299-305.
22. Webber RL., *et al*. "Tuned-aperture computed tomography (TACT). Theory and application for three-dimensional dento-alveolar imaging". *Dento Maxillo Facial Radiology* 26.1 (1997): 53-62.
23. Wang M., *et al*. "Application of Low Dose Spiral CT in Diagnosing Impacted Teeth in Children and Adolescents". *Sichuan Da Xue Xue Bao Yi Xue Ban* 46.5 (2015): 777-782.
24. Kau CH., *et al*. "Reliability of measuring facial morphology with a 3-dimensional laser scanning system". *American Journal of Orthodontics and Dentofacial Orthopedics* 128.4 (2005): 424-430.
25. Kusnoto B and Evans CA. "Reliability of a 3D surface laser scanner for orthodontic applications". *American Journal of Orthodontics and Dentofacial Orthopedics* 122.4 (2002): 342-348.
26. Motoyoshi M., *et al*. "A three-dimensional measuring system for the human face using three-directional photography". *American Journal of Orthodontics and Dentofacial Orthopedics* 101.5 (1992): 431-440.
27. Nguyen CX., *et al*. "Three-dimensional imaging of the craniofacial complex". *Clinical Orthodontics and Research* 3.1 (2000): 46-50.
28. Techalertpaisarn P and Kuroda T. "Three-dimensional computer-graphic demonstration of facial soft tissue changes in mandibular prognathic patients after mandibular sagittal ramus osteotomy". *International Journal of Adult Orthodontics and Orthognathic Surgery* 13.3 (1998): 217-225.
29. Curry S., *et al*. "Integrated three-dimensional ciraniofacial mapping at the Craniofacial Research Instrumentation Laboratory/ University of the Pacific". *Seminar on Orthodontics* 7.4 (2001): 258-265.

30. Ras F., *et al*. "Quantification of facial morphology using stereophotogrammetry--demonstration of a new concept". *Journal of Dentistry* 24.5 (1996): 369-374.

31. Nanda V., *et al*. "Quantitative analysis of 3-dimensional facial soft tissue photographic images: technical methods and clinical application". *Progress in Orthodontics* 16.1 (2015): 21.

32. Ferrario VF., *et al*. "Facial three-dimensional morphometry". *American Journal of Orthodontics and Dentofacial Orthopedics* 109.1 (1996): 86-93.

33. Varghese SC and Kumar S. "3d Imaging and Its Implications in Orthodontics.- A Review". *Biomed Pharmacology Journal* 8 (2015): 283-291.

34. Mah J and Hatcher D. "Current status and future needs in craniofacial imaging". *Orthodontics Craniofacial Research* 6 (2003): 10-16; discussion 179-182.

35. Hall RK. "The role of CT, MRI and 3D imaging in the diagnosis of temporomandibular joint and other orofacial disorders in children". *Australian Orthodontic Journal* 13.2 (1994): 86-94.

36. Plooij JM., *et al*. "Digital three-dimensional image fusion processes for planning and evaluating orthodontics and orthognathic surgery. A systematic review". *International Journal of Oral and Maxillofacial Surgery* 40.4 (2011): 341-352.

37. Aboul-Hosn Centenero S., *et al*. "3D planning in orthognathic surgery: CAD/CAM surgical splints and prediction of the soft and hard tissues results - our experience in 16 cases". *Journal of Cranio-Maxillofacial Surgery* 40.2 (2012): 162-168.

38. Goracci C., *et al*. "Accuracy, reliability, and efficiency of intraoral scanners for full-arch impressions: a systematic review of the clinical evidence". *European Journal of Orthodontics* 38.4 (2016): 422-428.

39. Larson BE., *et al*. "Effectiveness of computer-assisted orthodontic treatment technology to achieve predicted outcomes". *Angle of Orthodontics* 83.4 (2013): 557-562.

40. Sachdeva RCL., *et al*. "Treatment time: SureSmile vs conventional". *Orthodontics: the Art and Practice of Dentofacial Enhancement* 13.1 (2012): 72-85.

41. Brown MW., *et al*. "Effectiveness and efficiency of a CAD/CAM orthodontic bracket system". *American Journal of Orthodontics and Dentofacial Orthopedics* 148.6 (2015): 1067-1074.

42. Gracco A and Tracey S. "The insignia system of customized orthodontics". *Journal of Clinical Orthodontics JCO* 45.8 (2011): 442-51; quiz 467-8.

43. Joda T., *et al*. "Systematic literature review of digital three-dimensional superimposition techniques to create virtual dental patients". *International Journal of Oral and Maxillofacial Implants* 30.2 (2015): 330-337.

44. Chae MP., *et al*. "Four-Dimensional (4D) Printing: A New Evolution in Computed Tomography-Guided Stereolithographic Modeling. Principles and Application". *Journal of Reconstructive Microsurgery* 31.6 (2015): 458-463.

45. Hamza H. Dental 4D Printing: An Innovative Approach CTOR Press (2018).

Assets from publication with us

- Prompt Acknowledgement after receiving the article
- Thorough Double blinded peer review
- Rapid Publication
- Issue of Publication Certificate
- High visibility of your Published work

Website: www.actascientific.com/
Submit Article: www.actascientific.com/submission.php
Email us: editor@actascientific.com
Contact us: +91 9182824667