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RESEARCH ARTICLE

3D-DIGITIZATION; A PANORAMIC THRIVE IN ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS- A REVIEW OF LITERATURE

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ABSTRACT

Application of digital recording machines/gadgets provides more inventive, high quality dental restorations which in turn lead to utilize different types of dental scanners in contemporary dental practice. This review is aimed to provide the historical backgrounds of dental scanner and their various kinds; the benefits and pitfalls. An intensive search was performed in the available database with relevant keywords. Dental scanner used to measure the entire 3-dimensional (3D) of the external surface of a physical object either intraorally or extra orally from multiple directions. Implementation of the methods of 3D digitization in dental practice is a new methodology for dentistry which may revolutionize the routine techniques used commonly in dental practice. With this opportunity in hand-easier, faster, accurate and more predictable dentistry is anticipated.

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INTRODUCTION

The conventional orthodontics comprises of radiographs, photographs and study models. Preparation of models requires procurement of oral cavity impression. (Ola Al-Jubouri and Abbas Azari, 2015) mainly cephalogram is used in orthodontics. Though the conventional technique is very simple, but also holds a question on the precision and accuracy in difficult cases and so creates problem at the time of clinical application of the appliances made on cast. With the Introduction of new innovative modern technologies for manufacturing dental appliances, success rate of the treatment has increased to a significant level. Throughout the past decades, the expansion in the area of CAD/CAM systems has accelerated. In the process based on CAD/CAM technology, a series of the digital geometrical data exchanged occurred:

1. Outer surface digitization of the proposed area by 3D acquisition device (Dental scanner). (Andersson and Oden, 1993; Person *et al*., 2006) Digitizer term in dentistry means data collection tools that accurately measure three dimensional surface contours of oral structure/s and transform them into digital data sets (Azari and Nikzad, 2009).
2. Manipulation of the digital data with a software program to create a virtual model and freeform addition of the proposed restoration to it (CAD). (Hodolič *et al*., 2011)
3. A series of production process which translates the freeform model into the physical object (CAM). (Duret, 1988)

In 1971, first attempt for computer assisted production of dental restoration was made. (Quaas *et al*., 2007) In near the beginning days, the capturing mode was only made over the patient mouth but nowadays, the data acquisition may either performed directly in the patient's mouth (intraoral scanner) or indirectly on an poured cast model (Extra-oral scanner) (Budak Djordje Vukelic, 2012). Whatever technique used, the scanning process is one of the primary step for CAD/CAM technology. Various small and large machineries are requisites for this technology which differs from manufacturing companies to the upgraded technologies. The main aim and objective of this review is to assess the development of 3D digitization and outcomes of 3D digitization currently used in dental CAD/CAM technology.

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MATERIALS AND METHODS

The articles were searched in renowned major databases. Initially the search was performed in Pubmed for the keywords 3D Digitization, Cad/ Cam, Dental scanners, extra-oral scanners/ acquisition, intra-oral scanners/ acquisition. 111 articles were found on Pubmed Data base and 550 articles were found with other major data basis like Wileys online library, Google Scholar, Science Direct by manual search.

Inclusion criteria: Dental scanner, light scanner and dental digital impression utilized for digital model and or digital intraoral model and any other scanners utilized in the field of orthodontics were included

Exclusion criteria: 3DPhotography, Computed Tomography Scan, Magnetic Resonances imaging, Cone beamed Computed Tomography and other scanners which are used for engineering or medical purposes were excluded. The total articles collected as per the inclusion and exclusion criteria were 661 articles, out of which only 25 articles of them were included as relevant articles, the nearest but excluded articles were 8 (Table 1).The total articles collected from the manual hand search were 24; technical papers were also included for data collection. (Table 2)

Perspective of an Orthodontist

Orthodontist produces beautiful smile for patients and crafting smile is an onerous process. But with digitization, it has become more easy and accurate. 3D Digital Impression was introduced first by Cerec 1in 1987 using infrared camera along with powder on the teeth to form a virtual cast. Over the decades, there has been a great improvement observed in the field of computers replacing the conventional methods. There has been tremendous improvement in the scanning technologies which have accounted to a good comfort for doctors, staff and patients. These optical scanners have the capability of scanning both in vivo and in vitro models for creating 3D digital representation. After the 3-D scan is done, it is transferred to the computer to get 3-D images of patient's teeth. Either these fi les can be sent out to labs for fabrication or in office set up where the 3-D CAD fi le is dragged into the 3-D printer. Various companies have introduced compact 3-D Printers for clinical setup and small labs where 20 models per printer can be created. Various removable appliances, functional appliances, arch expansion appliances, clear aligners, retainers, arch wires, brackets, auxiliaries, trays for indirect bonding, set up models which will make lingual orthodontics and mock surgeries fast and easy, also study models.

Table 1. Nearest possible articles to the inclusion criteria, but were excluded

S.No.	Title of article	Type of article	Author	Summary	Year
1.	Quantitative 3Dmaxillary arch evaluation of two different infant managements for unilateral cleft lip and palate.	Original research	Author: Prasad *et al*,	Data acquisition (model digitization) and computer processing were performed for unilateral cleft lip patient	2000
2.	A three-dimensional evaluation of a laser scanner and a touch-probe scanner	Original research	Anna Person *et al*.	Dies of teeth preparation for complete crowns were fabricated in presintered yttria-stabilized tetragonal zirconia (Y-TZP) and digitized 3 times each with an optical or mechanical digitizer.	2006
3.	Optical stereo matching for digitizing edentulous jaws	Original research	Busch M, Kordass B.	The method of 3D digitization was used for edentulous arch.	2008
4.	A review of dental CAD/CAM: current status and future perspectives from 20years of experience.	Review article	Takashi Miyazazi *et al*.	Review of recent history of the development of dental CAD/CAM systems for the fabrication of crowns and fixed partial dentures (FPDs)	2009
5.	Calibrated segmentation of CBCT and CT images for digitization of dental prostheses.	Original research	Wouters V, Mollemans W, Schutyser F.	A 3D model is created using CT and CBCT	2011
6.	3D Soft Tissue Imaging: An Accurate and Economical Approach	Original research	Dehis HM, El-Sharaby FA Mostafa YA	A 3D video model was constructed based on facial measurements taken after patient positioning using custom made patient positioning assembly. A photographs were taken and digitalized to make a facial reconstruction	2015
7.	The Accuracy of Conformation of a Generic Surface Mesh for the Analysis of Facial Soft Tissue Changes.	Original research	Cheung MY *et al*.	The simulation was performed by deforming the actual soft tissues of the participant during image acquisition with 3D stereophotogrammetry.	2016

Table 2. Chronologically filtered manually hand searched articles with inclusion and exclusion criteria till 15th of may 2016

S.No.	Title of article	Type of article	Authors name	Summary& Conclusion	Year
1.	Assessment of the accuracy of a three dimensional imaging system for archiving dental study models.	Original research	A. Bell, A. F. Ayoub & P. Siebert	The models were captured in three dimensions using a photostereometric technique and stored in digital format. Conclusion: This study shows that it is possible to use 3D imaging to store dental study models for treatment monitoring and research with a satisfactory degree of accuracy.	2003
2.	Applications of surface-surface matching algorithms for determination of orthodontic tooth movements.	Original article	Keilig L, Piesche K, Jäger A, Bourauel C.	Tooth movement was analysed on casts before and after treatment. The casts were digitized either with a COMT or 3D laser scanning systems. Conclusion: The resulting transformations delivered three dimensional information on translations and rotations. An accuracy of 0.2 mm in translations and 1 degree in rotations could be demonstrated, showing the different efficiency of treatment schemes.	2003

3.	Accuracy of intraoral data acquisition in comparison to the conventional impression	Original article	R.G. Luthardt R. Loos S. Quaas	The comparison was done between intraoral/ extra oral digitization vs. conventional procedure. Which concluded that intraoral/ extra oral digitization is accurate in comparison Conclusion: Scanner D had a significantly higher accuracy than S ($p<0.05$), corresponding with the smaller pixel distance of the sensor. Both devices show adequate accuracy and reproducibility and have an adequate ability to detect the equator. The test is also suitable for calibration purposes.	2005
4.	Accuracy of dental digitizers	Original article	Simon T. Vlaar	Two laser light section scanners: DentaScope II and D200 were evaluated for validation	2006
5.	Reproducibility of facial soft tissue landmarks on 3D laser-scanned facial images.	Original article	M. Toma, A. Zhurov, R. Playle, E. Ong, S. Richmond	Facial landmarks were assessed with 3D facial images acquired for each subject by using two high-resolution Konica/Minolta laser scanners. Conclusion: The reproducibility of facial landmarks should be considered in the three planes of space. The majority of X-Y-Z coordinates taken to the 21 facial landmarks were reproducible to < 1 mm which is clinically acceptable. The accuracy of landmarks identification ranged from 0.39 to 1.49 mm. The reliability in identification depends on the clarity and definition of each landmark as well as gender characteristics. The different landmarks reproducibility should be considered when evaluating changes related to growth and healthcare interventions	2009
6.	Evaluation of a 3D stereophotogrammetric technique to measure the stone casts of patients with unilateral cleft lip and palate.	Retrospective research	Sforza C, De Menezes M, Bresciani E, Cerón-Zapata AM, López-Palacio AM, Rodriguez-Ardila MJ, Berrio-Gutiérrez LM.	Three-dimensional stereophotogrammetric systems have some advantages over direct anthropometry, and therefore the method could be sufficiently precise and accurate on palatal cast digitization with unilateral cleft lip and palate. Conclusion: Three dimensional stereophotogrammetric systems have some advantages over direct anthropometry, and therefore the method could be sufficiently precise and accurate on palatal cast digitization with unilateral cleft lip and palate. This would be useful for clinical analyses in maxillofacial, plastic, and aesthetic surgery	2012
7.	The iTero optical scanner for use with Invisalign: A descriptive review A Peer-Reviewed Publication	Review	Dr. Perry Jones	Education about accuracy of i- tero Optical Scanner is shown in this peer reviewed publication	2012
8.	Pre-processing of point-data from contact and optical 3D digitization sensors	Original article	Gor Budak DjordjeVukelic DragoBracun JankoHodolic MirkoSokovic	This paper presents an integral system for the pre-processing of point data using laser 3D digitizationsystems. Conclusion: This paper presents an integral system for the pre-processing of point data, i.e., filtering, smoothing and reduction, based on a cross-sectional RE approach. In the course of the proposed system development, major emphasis was placed on the module for point data reduction, which was designed according to a novel approach with integrated deviation analysis and fuzzy logic reasoning. The developed system was verified through its application on three case studies, on point data from objects of versatile geometries obtained by contact and laser 3D digitizationsystems. The obtained results demonstrate the effectiveness of the system.	2012
9.	The Digital Decade in Interdisciplinary Orthodontics	Review	ALEXANDRU OGODESCU	Discussion and evaluation of the major applications of computers in interdisciplinary orthodontics like three-dimensional craniofacial imaging, digital models or cone-beam computed tomography is done in this article Conclusion: The era of plaster models seems to come to an end. Today's orthodontic hardware and software facilitates rapid measurements on digital models without any distortion on the real morphology of the teeth. When we recommend a CBCT examination we have to compare between the increased amount of information obtained and the increased radiation dose for each person. Orthodontics is undergoing a gradual transition from plaster decade to digital decade, mainly due to advancements in computer technology, changing the dental specialists to a new way of imaging, diagnosing, documenting and communicating between them and with the patients. Each specialist in orthodontics and in other specialties from dental medicine should have good knowledge in bioinformatics and should be trained to use these new digital devices in order to provide better medical care for the complex cases All this digital technologies when applied correctly and in an interdisciplinary approach they fertilize each other, resulting in more precise diagnosis, improved treatment results and better communication..	2012

10.	Accuracy of digital models obtained by direct and indirect data capturing	Original article	Jan-Frederik Guth Christine Keul Michael Stimmermayr Florian Beuer Daniel Edelhoff	Sample was assessed with Lava Chair side Oral Scanner by digitizing polyether impressions and also by scanning the referring gypsum cast by the Lava Scan ST laboratory scanner. Conclusion: Within the limitations of this in vitro study, the direct digitalisation with Lava C.O.S. showed statistically significantly higher accuracy compared to the conventional procedure of impression taking and indirect digitalisation.	2012
11.	Creation of 3D Multi-Body Orthodontic Models by Using Independent Imaging Sensors.	Original Article	Sandro Barone, Alessandro Paoli * and Armando Viviano Razionale	In this paper, dental data captured by independent imaging sensors are fused to create multi body orthodontic models composed of teeth, oral soft tissues and alveolar bone structures. The methodology is based on integrating Cone-Beam Computed Tomography (CBCT) and surface structured light scanning. Conclusion: The 3D individual dental tissues obtained by the optical scanner and the CBCT sensor are fused within multi-body orthodontic models without human supervisions to identify target anatomical structures. The finalmulti-body models represent valuable virtual platforms to clinical diagnostic and treatment planning.	2013
12.	Research of 3D Virtual Design and Automated Bending of Oral Orthodontic Arch wire.	Original Article	Wenjun Zhang	The paper showed bending of orthodontics arch wire with the help of 3D virtual designing. Conclusion: The practice shows that the software and bending-machine can fit seamlessly into orthodontist's design and bending of orthodontic archware, replace effectively previous handmade methods used inorthodontics, and provide low-cost high-quality medical services for orthodontic patients.	2013
13.	Tooth model reconstruction based upon data fusion for orthodontic treatment simulation. [27]	Original article	Yau HT, Yang TJ, Chen YC	This paper proposes a full tooth reconstruction method by integrating 3D scanner data and computed tomography (CT) image sets.	2014
14.	Accuracy of Digital Models Prepared by Spiral CT in Comparison to Standard Cast Models	Original article	Marwa Shama et. al	this paper shows the comparison of the standard plaster models with their digital counterparts prepared by scanning the patients with a spiral CT (Light speed Pro, General Electric medical CT scan machine, Wakesha, Wis). Conclusion: In conclusion; digital models are acceptable replacement for plaster casts for the routine measurements made in most orthodontic practices.	2014
15.	Review: Intraoral Digital Scanners	Review	NEAL D. KRAVITZ	The paper reviews about all the intraoral digital scanners. Conclusion: Intraoral digital scanners are becoming integral to the modern orthodontic office, improving both practice efficiency and the patient experience compared to conventional alginate and PVS impressions. Open and trusted connections with orthodontic laboratories, merging of CBCT and DICOM files, increasing interoperability among manufacturers, and in-office 3D printing have opened limitless possibilities for this technology.	2014
16.	3D Archive in Dental Practice – A Technology of New Generation	Review	Miroslava Dinkova	The paper shows that instead of gypsum models storage, i.e. difficult for storage and maintainance, 3D digitization plays a best role to overcome this conventional method. Conclusion: The digitalization of plaster models is a step towards for increasing the efficiency and precision in the field of dentistry. Development and perfection of 3D printing technology allows a production of the 3D information with an accuracy of 0.1mm. 3D technology successfully replace archives for plaster models and so the clinician can easily find a model in a second, and if necessary, to reproduce it.	2014
17.	Comparative analysis on measuring performances of dental intraoral and extraoral optical 3D digitization systems	Original Article	Branka TrifkovicIgor BudakAleksandar Todorovic Djordje Vukelic Vojkan Lazic TatjanaPuskar	Comparison is done with intra oral and extra oral digital scanner.	2014
18.	A New DimeNsioN iN DiAgNostics, PlANNiNg AND treatment 3D imaging with gAlileos	catalogue	Sirona company	_	2015
19.	A new era in digital Orthodontics	Educational information byClinical and practice management orthodontics resoursre.	Dr Kozzlowski	_	2015

20.	An introduction to dental digitizers in dentistry; A systematic review	Systematic review	Ola Al-Jubou and Abbas Azari	The paper reviews about the accuracy of 3D digitization in the field of Dentistry. Conclusion: In the last several years, exciting new developments in dental scanner and computer technologies led to advance and success of contemporary dental CAD/CAM technology. Several highly sophisticated dental scanners have been introduced or under development. Implementation of the methods of 3D digitization in dental practice is modern and new option for dentistry creating an alternative technique to the method of conventional impressions, especially in the field of prosthodontics. Scanner device with digital technology made what were previously manual tasks easier, faster, accurate and more predictable.	2015
21.	3D Scanning, Imaging, and Printing in Orthodontics	Chapter- 9 Book issues in contemporary orthodontics	Emilia Taneva, Budi Kusnoto and Carla A. Evans	This chapter reviews the types, methods, uses, of 3D printing technologies in the field of orthodontics. Conclusion: With the rapid development and advanced research of diverse technologies and compatible materials, it is possible to obtain single scan digital impressions, virtually design, and 3D print different types of orthodontic appliances. 3D facial imaging further provides comprehensive analysis as an aid in orthodontics, maxillofacial, plastic, and esthetic surgery. Software integration of digital models, 3D facial scans, and CBCT facilitate treatment simulations and establish a meaningful communication with patients. Elimination of traditional impressions and dental-cast production stages enhance practice efficiency, patient and staff satisfaction for a fully integrated digital and streamlined workflow. Patient digital impressions are stored in a more convenient way and can be easily transferred to any lab or an in-office milling machine for a simpler, faster, and more predictable appliance fabrication. New companies, scanner and printer models are emerging daily which result in significant decline of systems cost and enhancement of material qualities. From imaging to product design and manufacture, technologies will offer more affordable and feasible diagnostic and treatment applications beyond the current methods.	2015
22.	Accuracy of a three-dimensional dentition model digitized from an inter-occlusal record using a non-contact surface scanner.	Original study	Kihara T *et al*.	The occlusal and incisal morphology of participants was registered in the intercuspal position using a hydrophilic vinyl polysiloxane and digitized into 3D models using an optical scanners Conclusion: The digitization method in this study provides sufficient accuracy to visualize the dental morphology, as well as the position and inclination of these teeth.	2015
23.	Reliability and validity of measurements on digital study models and plaster models.	Original study	Reuschl RP *et al*.	Analyses were performed with a diagnostic calliper and computer-assisted analysis after digitization of the plaster models.	2015
24.	Applications of 3-D Printing in Orthodontics: A Review.	Review Article	Shahnaz Mahamood *et al*.	Paper shows the importance and usage of Three-dimensional (3-D) printing application in orthodontics. Conclusion: Automated model-making with the 3-D printer dramaticallyreduces fabrication times and exponentially increasesoutput per technician. Thus by transitioning to a fully digital process, there is no need to store bulky physicalmodels and keep all your cases digitally, for as long as you need.	2016
25.	White light or laser-what makes the best dental 3D scanner?	Technical paper	Karl Hollenbeck Mike van der Poel	_	2016
26.	Dental Lab 3D Scanners-How they work and what works best.	Technical paper	Karl Hollenbeck Thomas Allin Mike van der Poel	_	2016

The process requires less physical storage. There are various implications of intraoral scanners, but the best utilization is in digital storage of models, cast analysis and marking the landmarks on the cast (Kravitz *et al*., 2014).

Conclusion

From the comprehensive search it can be concluded that there has been a lot of improvement done in the field of 3D digitization in orthodontics, but still there has been a lot of studies that contradicts. This is due to lack of concrete and robust evidence. Although, automated model-making with the 3-D printer has dramatically reduces fabrication times and exponentially increases output per technician, considering its accuracy is also important. Thus, more studies are required to prove the accuracy and effectiveness of the digitization in orthodontics in order to cater best outputs.

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