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RESEARCH ARTICLE

DIGITAL DENTISTRY: AN OVERVIEW ON RECENT ADVANCEMENTS IN INTRAORAL SCANNER

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Abstract

New devices are continuously introduced in the clinic and the dental laboratory. The first phase of the digital workflow is to obtain an image with the help of intra-oral scanner. These devices are replacing conventional impressions techniques with the digital scanners. Impressions which are recorded using scanners are more accurate as compared to conventional technique. Intra-oral scanners are time efficient, decrease the patient's discomfort and make clinical procedures easier. Over the last few years, there has been new advances in dental scanners for comprehension of computerized work process. Presently in market there are several brands of the scanners with better features to obtain digital impressions, to record the accurate Data in comfortable working time for the dentist and patient. Therefore, it is convenient to analyze the most used IOS systems based on the available scientific data.

Introduction:-

In Mid-twentieth century there was a rapid movement in digital technology sweeping across different industries worldwide from the military to aviation and ultimately to the health care field. Modern dentistry has entered in most of the dental offices where clinicians are using digital techniques over conventional technique.[1]

Computerized digital technologies has significantly progressed and have come with innovations such as digital extra-oral and intra-oral scanners, cone beam computed tomography, three-dimensional printers, laser sintering units and milling machines.[2] CAD/CAM technology is employed in the fabrication of restorations, especially inlays, onlays, bridges, veneers, ceramic crowns and implant abutments.[3]

According to GPT 9 the Dental Impression is a negative likeness or copy in reverse of the surface of an object; an imprint of the teeth and adjacent structures for use in dentistry.[4]

The aim of dental impression is to record the accurate details of the patient's intraoral structures and translate it into a model. Various types of materials and impression techniques have been performed throughout the years to attain desired exactness. Enhancement of a dental impression is measured by its precision.[5]

Formerly impressions were made using impression plaster. To overcome the disadvantages of impression plaster, reversible hydrocolloid Agar was developed in 1937. Due to complex handling technique of Agar was then replaced by irreversible hydrocolloid Alginate. Elastomeric impression materials were developed to overcome hydrocolloid

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problems in 1950. Yet, there is inaccuracy in impressions. To overcome the imprecision, digital intraoral scanners were invented.[6]

The development of CAD/CAM is based around three elements: Data Acquisition unit, Data Processing and Design unit, and Manufacturing unit. In the CAD phase Data acquisition and Data processing of the system play roles, while the Manufacturing unit works under the CAM phase. With the help of CAD/CAM technology clinician can record the digital impressions, design the restorations and also mill the fixed restorations along chair-side operating in-office milling units.[9]
Based on digital data sharing capacity CAD/CAM systems is alienated into two types: open system and closed system. This article explains the characteristics of some major intraoral digital impression devices currently available and focuses on categories, working principles, and operation.

Some major Intra-oral digital scanning devices are:
1. CEREC system
2. Lava C.O.S. system
3. 3M true definition scanner
4. iTero system
5. E4D system
6. PlanScan
7. TRIOS system
8. CS3500 intraoral digital impression scanner
9. IOS FastScan
10. DENSYS3D
11. DPI - 3D
12. 3D PROGRESS
13. DIRECTSCAN
14. Cara i500
15. Bluescans-I

CEREC System (Sirona, Bensheim, Germany, 1987):[11]
First intraoral digital impression and CAD/CAM device used in the dentistry. Works on the principle of "Triangulation of Light". An opaque powder of Titanium dioxide is coated before the scanning to produce even light dispersion which ultimately increases scan accuracy. Employed with blue light-emitting diodes (LEDs) the shorter-wavelength, intense, blue light. The scanned images are distortion-free, so that stitching of multiple images is possible with great accuracy. It is a closed system, exports the digital impression data with only Sirona's supporting CAM devices like CEREC MC and CEREC In-Lab. It takes 1 minnute to scan one quadrant and few seconds to scan opposing quadrant of arch.

In 2012 CEREC AC Omnicam, was launched in the market and can be used for a single tooth, quadrant, or full arch. Most prominent features of Omnicam are scanning does not require opaque powder and 3D images are obtained with natural colour. Chair side unit so the dentist can scan the teeth digitally and also fabricate the restoration in a single visit, or can transfer the data to the dental laboratory by CEREC ConnectR, where the restoration design is selected virtually and later milled in laboratory. Four axis milling machine used for fabrication of prosthesis.

For fabrication of implant crowns, abutment or a scan body can be scanned.[12]

Newer inventions in CEREC devices are CEREC MC X and CEREC MC XL combined with

CEREC AC Omnicam.
The modern versions of the CERECs system can fabricate single crowns, bridges, veneers, laminate, inlays and onlays.

CEREC in Labs MC XL can mill a restoration within 4 minutes.

Earlier with CEREC Bluecam, chair-side milling was not possible also bluecam was not capable of milling high strength ceramics but in recent advanced systems it is possible to mill the chair-side restoration including Zirconium oxide.[13]

Lava C.O.S. system (Lava Chairside Oral Scanner; 3M ESPE, Seefeld, Germany 2006):[14]
Brontes Technologies manufactured The Lava™ Chairside Oral Scanner (C.O.S.) and in October 2006 it was developed by 3M ESPE .

The Lava C.O.S. system works on the principle of active wavefront sampling with structured light projection. 3M ESPE designated it as '3D in-Motion technology'. Three sensors scans the structure from diverse angles consecutively and generate surface patches as in-focus and out-of-focus data by proprietary image-processing algorithms.

The Lava C.O.S. has scanner tip of only 13.2mm wide diameter. It requires a powder coating spray (lava^{tm} powder) on the tooth surface before scanning is sprayed on the tooth surface to form a homogeneous layer. Automatic bite registration is possible with the captured scans. A stereolithography model is created by the manufacturer and delivered to the laboratory. All types of finish lines can be replicated on the SLA dies and allows any type of crown to be fabricated by the dental laboratory.

Scanning of implant crown is done by Biomet3i. It utilizes Encode; Biomet 3i healing cap which is attached to the implant before making an optical impression. Lava C.O.S. is a Semi-Open system as it is compatible with other software's such as DWOS

For fabrication of prosthesis 3- axis milling machine is used.

Advantages of the system: Aallows capturing 3D data in a video sequence and models the data in real time if there are holes in the scan, the dentist scans that specific area and the software patches the hole.

3M true definition scanner (3M ESPE 2013):[12,15]
Lava™ chair-side oral scanner presented an updated version which is 3M True Definition scanner in 2013. 3M scanner works on the "active wave-front sampling" principle to captures 3D images. The system is installed with a rotating aperture element which is placed off-axis in the optical apparatus either in the imaging or the illumination path that measures the defocus blur diameter. For scanning system requires coating of an opaque powder (Titanium dioxide) so the scanner can locate the reference points. Scans are stored in video format which captures 20 frames per second and a complete full mouth scan with a bite registration over all time required is 5 to 8 minutes. It is an Open system so that Data exportation with third-party providers became easy.

iTero system (Cadent Inc Carstadt, NJ, 2007):[12,16]
This system works on the principle of Parallel Confocal Scanning. During one scan a total of 100,000 points of laser light at 300 focal depths of the tooth structure can be obtained. iTero system does not require powder coating while scanning. Capable of recording virtual bite registration. Cadent industrial 5-axis milling machine is used for the fabrication of prosthesis. iTero is an open system. It exports digital image files as an STL format, which can be shared by any other lab equipped with a CAD/CAM system. For an optical impression of the implant position, iTero partners with Straumann.

Straumann applies implant components according to CAD software DWOS. To determine correct implant positioning a specific transfer is attached to the superior surface over the implants with three spheres.

Recent Advancements: capable of generating a coloured 3D virtual model, captures each prepared tooth in 15 or 20 seconds, able to convert the output files in STL format, powder free scanning.

E4D system (D4D Technologies, LLC (Richardson, TX 2008):[12,17]
D4D technologies introduced the E4D system in 2008. The intraoral scanner is organised with Optical Coherence Tomography or confocal sensor. The laser digitizer consist of a laser source attached to fiber optic cable, a coupler and a detector. The coupler splits the light source into two paths, one path leads to the imaging optics and other path directed towards the optical delay line and to the reflector. It uses red laser as a light source and micro-mirrors that

vibrates at a speed of 20,000 cycles per second. The software builds a library of images. Does not require powder coating for scanning the intraoral structure. Scanning is performed at a particular angle and series of images are integrated into 3D impression. The 3D digital impression data can be exported into STL format, so it is a Semi-open device. In case of closed format, the data is sent to specific DentaLogic software for CAD work. The E4D system file can also be converted to an STL file by D4D technology, which makes Thus, the digital impression data can be used by other CAD/CAM systems. This system can work with a chair-side milling device. This system provides the relative motion effects can be tracked mathematically and removed in subsequent analysis offers in office milling units.

PlanScan (Planmeca,driven by E4D Technologies 2015): [18]

Launched in the market on 4th February 2015. System uses blue laser light with real-time video-streaming technology to capture the dental data, and it is powder-free. Chair-side design and milling system. As this system exports and imports STL files, so is an open system. Captures both hard and soft tissues of various translucencies, dental restorations, models, and conventional impressions. Removable scanner tips with built-in heated mirrors allow for no down time between patients, as well as high-level disinfection. Processing, designing, and manufacturing of the restorations can also be done into the laboratory or PlanMill 40 milling machine (Four-axis dual spindle machine) can be used for chair-side milling of the restoration. The digital casts can be used to design inlays, onlays, crowns, bridges, and veneers. Different scanners available are Planmeca Emerald™ S, PlanmecaRomexis.

TRIOS system (3Shape Copenhagen, Denmark 2010):[12,19]

3Shape launched the TRIOS in 2010 and bought to market in 2011. Works on "ultrafast optical sectioning and confocal microscopy" principle. Uses red laser light and scans are stored in multiple image format. A quick scanning speed of up to 3000 images per second reduces the influence of movement between scanner probe and teeth. While scanning o need of coating the intraoral structure with an opaque powder or spray.

TRIOS has the property of telecentricity. The 3D profiles of teeth and gingiva are generated simultaneously, while the dentist moves the scanner gradually above them.

TRIOS system has 2 parts: TRIOSR Cart and TRIOSR Pod.

It is an open system that is able to convert 3D data into STL file format. TRIOS is comprised with a digital impression acquisition and CAD system, and does not incorporate CAM milling device.

Upgradation: variation of the focal plane without moving the scanner due to its property of Telecentricity.

CS3500 intraoral digital impression scanner(2015): [20]

CS3500 is the portable digital impression system launched at the end of 2015. System works on the "confocal laser scanner microscopy" technique which allows to capture the true-color 2D and high-angulation 3D scans of up to 45º angle with a depth of -2 to 13 mm. No need to use opaque powder for scanning. Resolution of captured images is 1024 x 728 pixels and the accuracy is upto 30 microns. Mirror fogging while scanning is prevented with the help of built-in heater streamlines. The green light during scanning indicates a successful scan while the amber light shows that a rescanning of the area of the interest. About 10 minutes are required for scanning of the full arch. CS 3500 is well-matched with open source software or it can also work with Carestream CAD/CAM dental restorations system.

IOS FastScan – by IOS TECHNOLOGIES, INC.5. (US 2007):[12,18,20]

IOS technologies launched IOS FastScan in 2007. This system works on the principle of "active triangulation".The light from two perspective is combined onto a single camera using passive or active triangulation. Glidewell Laboratories (CA) is the main clinical testing facility for IOS technologies'. In this system camera moves within the wand. Probe of the 3D scanner sweeps a sheet of light across one or more surfaces of teeth, where the sheet of light projector and imaging aperture within the scanner probe rapidly moves back and forth along all or part of the full scan path, and displays the real-time, live 3D preview of the digital 3D model of the scanned intraoral structure. A 3D preview provides information about the position and orientation of the probe according to the intraoral structure that is to be scanned.

Stores the scanned data in STL format, an open source data format that all the laboratories can recognize and manipulate it accordingly. IOS FastScan™ includes a scanner to captures the data along with the three dimensional shape of dentition. The system has inbuilt CAD module to store the colour and translucency information and the 3D shape, to concentrate a coloured accurate representation of the prosthesis. The colour, translucency and surface information are combined in a single digital prescription, which is electronically transferred to a laboratory or CAD/CAM system for fabrication.

DENSYS 3D MIA3d (IL)(Migdal Ha'Emeq, Israel, February 2009):[21]
MIA3d launched Densys 3D which is a separate chair-side scanner. Works on the "active stereophotogrammetry" principle with structured light projection. The intra-oral scan is illuminated by a 2D array of structured illumination. Files are saved into ASCII format which are formed with visible lights. This system requires contrast medium before scanning procedure.

Densys scanning system is the easy to use software, the fastest calculation and the most accurate and robust wand in the market, with full interproximal scan coverage. The aim of this system is to duplicate the 3D intra-oral structures for dental uses such as veneers, laminates, inlays, onlays with minimal apparatus. Minimize the effect of movement of the patient, the practitioner, and the apparatus, during the procedure of 3D intra-oral imaging.

DPI - 3D BY DIMENSIONAL PHOTONICS INTERNATIONAL, INC. (US 1990s):[12,20,22]
DPI-3D is the leading developer of innovative 3D measurement and shape capture technology. Firstly it is considered at Massachusetts Institute of Technology (MIT) Lincoln Laboratory in the late 1990s. This system is the most precise and multipurpose 3D scanning technologies. DPI - 3D works on an "accordion fringe interferometry" principle. It extends traditional linear laser interferometry to three dimensions.

The MIT Lincoln Laboratory performed original work on AFI. AFI has many benefits over older "white light" scanners as lower sensitivity to ambient light, noise, good accuracy, large projector depth of field and has greater ability to scan shiny surfaces. The device has the 350 nm to 500 nm wavelength which reduces the measurement errors. It is an Open system as the files are saved in STL format. Scanned data can be stored in multiple image format. No need of coating the teeth surface with powder or spray.

Advantage of this system is wavelength of the light source enables lower sensitivity to ambient light variations and noise which enhances the ability to scan shiny and translucent surfaces.

3D PROGRESS (2015):[12,20]
MHT Optic Research AG and MHT S.P.A. launched 3D Progress which is a light-weight, portable digital impression system. The technology of the 3D progress is the confocal microscopy combined with the detection of the effect Moiré (The Moiré patteren appears as a result of an interaction between transparent layers of repeated structure, when superimposed layers are viewed through), a kind of structured light. Data collected is shown in real time on computer screen. Scanning of oral tissue without use of opacifiers. Real time automatic stitching of scanned images is possible. 3D Progress takes impression less than 1/10th of a second for a single scan and scans a full-arch in under 3 minutes. 3D Progress does not require powdering of the translucent surfaces.

While scanning highly reflective surfaces requires the coating of opaque powder for example, implant scan abutments and markers. A smart Pixel Sensor that enables fast and accurate scanning, each single scan is automatically stitched. This system is capaale of an automatically (or semi-automatically) detects the margin line or finish line. 3D Progress works as a confocal microscope combined with Moiré effect detection.

DIRECTSCAN BY HINT – ELS GMBH (DE, 2011):[18]
Directscan by HINT is based on the principle of human stereoscopic vision and on the principle of the linear projection. By the end of 2010 the company Hint-els® announced, for the first quarter of 2011, the launch of its Directscan.

Scans are taken in a speedy sequence from various angles every 200 milliseconds, recording the surface and shape of every tooth or gap. The images are stored into 3D software, which conducts a pixel-precise comparison to map the intraoral structures.

Captured Data is stored in STL format and can be processed with both the CAD/CAM components and with other open systems. Software includes a virtual articulator and allows the modelling of fully anatomical inlays, crowns and large span bridges.

Cara i500 (Kulzer's Developed in partnership with Medit 2018):[20]
This scanner has Cloud based workflow management system, greater precision and improved accuracy ease of use, scaling work routines, increased efficiency, quick and easy operation.

A more integrated workflow - digitized data can be easily imported into any CAD software, print with cara Print 4.0 and dima Print Materials, Small tip and powder-free scanning make the process comfortable for the patient. Medit scanners can store scans either Raw format or Processed called MeditMesh.

Double focus: Two high-speed cameras ensure fast results and high-resolution images thanks to rapid, video-based scans. The open system can export the .stl, .ply, or .obj files for more convenient processing and design, Vivid, precise colored scans for easy differentiation between soft tissue, plaque, and teeth.

Wide range of indications fabrication of single custom abutment, inlays and onlays, single crown, veneer, 3 unit implant bridge upto 5 units, implant guide, denture workflows.

Functionalities:
Installed with iScan features, with the help of which functions like automatic and manual margin line creation and editing options. During scanning the patient's arch or teeth, dentist can add or edit control points to the prepared teeth scan data to create the true margin line. HD intraoral Camera is used to take HD pictures.

Bluescans-I:[20]
Bluescan-I has been developed in co-operation with the largest, independent Austrian Research Institute (AIT) and is a highly complex optic measurement-system which takes 8–15 stereo images per second.

In this system, taking impressions of teeth is like taking a video with an easy and free-moving hand piece with integrated optics an anti-shake protection, the camera does not have to be held still and calibrated.

The camera head is warmed by body heat and internal electrics to prevent fogging; it produces high-definition and very high resolution real-time images in just milliseconds with.

The wand is really small and light. Low size STL file is available for further process.

No spray or powder is required with the Bluescan-I.

Bluescan-I operates according to active stereoscopic vision principle oral scans are performed by a camera system that consists of two cameras, which record stereoscopic images for the three-dimensional measurement of the object.

This system incorporated with a very small wand and is portable and connects to PC via USB 2.0 cable.

Conclusion:-

Digital technology has affected and is affecting the profession of dentistry. Patients are also prefer digital dentistry, as it is more comfortable compared to traditional impressions. Besides, it minimizes chair and office time, making the office significantly more efficient, reduces remakes, reduces seating time of restorations, and lowers or eliminates laboratory bills.

Studies have shown that digital impressions are at least as accurate as conventional impressions. Retakes are quick, easy and inexpensive. Digital impressions are easier to store because they do not take up space. There is no need for disinfectants, pulls, bubbles, tears and practitioners want to know which intraoral scanning device is the best one. This article gives a review on different types of scanners available in the market. Also a lot of the examined devices are not commercially available and they are not still presented to the market. The advanced upgrading of the intraoral digital impression technique will lead to its extensive use in dentistry.

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