ORIGINAL RESEARCH PAPER

Prosthodontics

A LIGHT ON THE TREND OF DIGITALIZATION - CAD/CAM - A REVIEW

KEY WORDS: CAD/CAM systems, operational parts, 4D imaging, materials used.

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ABSTRACT

CAD/CAM called as Computer Aided Design/Computer Aided Manufacturing, was first introduced in mid 80's. In dentistry, conventional methods of fabrication of prostheses have been considered the gold standard for several years. The development of computer-aided manufacturing and its application in dentistry have provided an alternative way of fabricating oral prostheses. CAD/CAM technology was developed mainly to ensure adequate strength of the restoration, to create restoration with a naturally pleasing appearance and to make the restoration easier, faster and more accurate. This narrative review aims to evaluate the development of various CAD/CAM systems, operational components and restorative materials commonly used.

INTRODUCTION:-

Conventional fabrication methods involve recording an impression, pouring cast and fabricating a wax pattern. Later, wax pattern is invested and casted. Aforementioned steps require considerable human intervention and may also lead to increased processing errors and inaccuracies, as well as increased time and cost. CAD/CAM technology is a strongly emerging prosthesis fabrication method in dentistry which produces accurate, esthetic and strong prosthesis. Innovation of CAD/CAM has enabled the dentists and laboratories to make use of power of computers to automated design and fabrication techniques which facilitated the production of more reliable and durable prostheses by reducing the reliance on the human variable.[1]

With the continuous development, CAD/CAM technology have revolutionized dentistry and became an integral approach for Prosthodontics and other disciplines dentistry. This article reviews on various CAD/CAM systems, its components and restorative materials commonly used in dentistry.[2,4]

HISTORY AND EVOLUATION OF CAD/CAM SYSTEMS:-[2,3,5]

1971, Dr. Francosis Duret introduced CAD/CAM device in dentistry. Using optical impression, he first fabricated restoration by numerical controlled milling machine. In 1983, Sopha system developed by Duret, became landmark for CAD/CAM current devices.

1st Generation:- In 1987, Mörmann and Brandestini invented CEREC system,(chair side economical restoration of esthetic ceramic) which was the first dental system to combine digital scanning with the milling unit.

2nd generation - In 1994 CEREC(2) system developed by Siemens Corporation.

3rd generation- In 1999 CEREC(3) system developed by Sirona, Benheim, Germany.

Sirona system (3rd generation) had several technical improvements over 2nd generation, including the three-dimensional (3D) CEREC(3) intraoral camera, manipulation of the picture, and the grinding unit.

In 2008 E4D Dentist system was introduced that permits same day in office restorations along with CEREC system.

Historically, the early application was crude and the so obtained prosthesis were associated with compromised quality and precision. Continuous improvements of computer-aided manufacturing and a gradual shift towards wider acceptance of the new technology for prosthesis fabrication resulted in accurate restoration. To date, the application of computer-aided manufacturing in Prosthodontics is attributed to continuous systems development and refinement,greater ability for quality control, along with material growth. With improved scanning technology, modelling software, and production systems, CAD/CAM is becoming more user friendly.[1]

OPERATIONAL COMPONENTS OF CAD/CAM:-[5,10]

It includes scanner, software and technology scanner.

SCANNER:-

OPTICAL SCANNER	MECHANICAL SCANNER
Triangulation procedure - collects the three dimensional structures. Source of light (e.g:- laser) and the receptor unit are set in a definite angle in their relationship to one another and this angle helps in calculating three dimensional data from image on receptor unit. Ex: Lava Scan ST (3M ESPE, white light projections) and es1 (etkon, laser beam).	The three-dimensional structure of master cast is read mechanically line-by-line by means of a ruby ball and is measured. This is differentiated by a high scanning accuracy, whereby the diameter of the ruby ball is set to the smallest grinder in the milling system, with the result that all data collected by the system can also be milled. Ex: Procera Scanner.

Drawbacks of mechanical scanner over optical scanner include:- complicated mechanics, expensive, long processing time.[5]

Software of designing based on milling axis which include:- 3 axis milling, 4 axis milling and 5 axis milling devices.[10]

3 axis milling	4 axis milling	5 axis milling
Degrees of movement in the three spatial directions. All 3-axis devices used in dentistry turn the component by 180° in the course of processing the inside and the outside. Advantages – less milling time and good control , cost effective. Ex: InLab (Sirona), Lava (3M ESPE), Cercon brain (Degu Dent).	Three spatial axes + the tension bridge for the component, can also be turned infinitely. It saves material and milling time by adjusting bridge constructions with vertical height displacement into the usual mould dimensions . Ex: Zeno (Wieland-Imes).	Three spatial dimensions + rotatable tension bridge (4th axis) + the possibility of rotating the milling spindle (5th axis). This helps in making the milling of complex geometries with subsections. Ex: Everest Engine (KaVo) .

SCANNING TECHNOLOGY:-

D700 and Q700 scanning series are combination of most advanced 3D scanning technology and management software.

D700 SERIES	Q700 SERIES
Optimized for impression scanning, and is capable of scanning full dental gypsum models up to 40% faster along with greater details. The 3-axis – helps model to be tilted, rotated and translated so as to be scanned from any view point, corresponding to a dental model.	Makes use of 2 scanners - the Q700 with 1.3MP camera resolution and the Q740 with 5.0MP resolution. For quality control of small objects through greater detail level, high scan speed and accuracy

CAD/CAM systems :- [2,5,6]

Different CAD/CAM systems include Cercon, Everest, Lava, Procera, DCS precident, CICERO , CEREC SYSTEM, CEREC in lab, E4D dentist system.

Everest system:-

It has scanning unit (CCD camera in a 1:1 ratio with an accuracy of measurement of 20 µm), a reflection free gypsum cast is fixed . Detailed morphology and precise margins from a variety of materials are produced by machining unit with 5 axis movement. Ex:- Titanium, Lucite etc..

Cercon system:-

CAD component is absent. It scans wax pattern made of 0.4 mm thickness. Later this scanned wax pattern is milled using zirconia blocks. Afterwards coping is sintered at 135^{0}C for 6-8 hrs in cercon heat furnace.

Lava system:-

Yttria stabilized tetragonal zirconia polycrystals (Y-TZP) which has greater fracture resistance than conventional ceramic are used. Laser optical system to digitaliize information.This software automatically recognizes and suggests the margin and pontic. 20% larger framework is designed to compensate for sintering shrinkage.

Procera system: [6]

It combines Pantographic reproduction + electrical discharge (spark erosion) machining. Alumina and zirconia copings are produced using innovative concepts.

Master die 3D images are produced using scanning stylus sent to processing center via modem designs enlarged dies (compensate for the shrinkage of the ceramic material) .

Using dry pressing, copings are manufactured by high-purity alumina powder (> 99.9%) against the enlarged dies which are then milled to the desired thickness. The restorations of procera system obtained have excellent clinical longevity and strength.

DCS Precident:

It has Preciscan laser scanner and Precimill CAM multi tool milling center. Scans, 14 dies simultaneously and also mills up to 30 framework units in one fully automated operation. Porcelain, Glass Ceramic, In- Ceram, Dense Zirconia, metals, and Fiber-reinforced Composites are different materials used along with titanium and fully sintered dense zirconia.

CICERO System:

Developed by CICERO Dental System B.V. (Hoorn, The Netherlands). This method used for production of ceramic restorations by using official scanning, ceramic sintering, and computer assisted milling techniques with maximal static and dynamic occlusal contact relations. This system also makes use of other techniques like optical scanning, ceramic sintering, near net-shaped metal and computer-aided fabrication techniques .

CEREC SYSTEM:- [2,5]

<table>
<tr><th>CEREC 1</th><th>CEREC 2</th><th>CEREC 3</th></tr>
<tr><td>Ceramic block could be turned on the block carrier with a spindle and fed against the grinding wheel. Optical scan of the prepared tooth is made with a couple charged device (CCD) camera, and a 3D image is generated on the monitor. Then restoration is then designed and milled.
Ceramic block grind into a new contour with a different distance from the axis at each feed step.</td><td>Additional cylinder diamond helps the grinding of partial and full crowns. Occlusion in three modes is designed by : extrapolation, correlation and function. (Still the design was projected two-dimensional- 2D)</td><td rowspan="2">Introduced Two bur system. The diameter of the top 1/3rd of the cylindrical bur to a small- diameter tip is reduced by step bur. Using intraoral camera(significant factor of 3D) tooth preparations for all points of interest can be seen from a single viewing line, representing the preparation and insertion axes, respectively.</td></tr>
<tr><td colspan="2">Optical scan of the prepared tooth is made with a couple charged device (CCD) camera, and a 3D image is generated on the monitor. Then restoration is then designed and milled.</td></tr>
</table>

CEREC in Lab (Laboratory system):-

In this, working dies are laser-scanned and a digital image of the virtual model is displayed on a screen. While designing the coping or framework, the technician inserts the VITA In-Ceram block, into the CEREC in Lab machine for milling which is verified later.

E4D Dentist System:

Besides CEREC system, currently E4D system permits same day in-office restorations. It includes a laser scanner, a design center and a milling unit, which scans the target tooth at 2 rubber feet distance. The software gradually creates a 3D image after each picture is taken.The system automatically detects the margins and marks them on the screen. After restoration is approval, the data are transmitted to either the in-house milling machine or a dental laboratory. From the chosen blocks of ceramic or composite the office milling machine will then manufacture the restoration.

4D imaging for dynamic CAD:- [12]

It captures the jaw motions with high resolution 3D surface, for which fluorescent polystyrene microspheres beads of 20 micrometers are brushed on target area by producing high contrast random optical pattern. After this totally 8-bit monochrome camera images are transmitted to the laboratory for processing. Photomodeler software is used from EOS system. For each clinical motion sequence, a set of 3D files of fluorescent area is produced with point to point accuracy with 10 micro meters. 4D model with 6° of expressions are produced to derive animations with accurate registrations. Dynamic CAD, develops true virtual articular for producing occlusion within physiological parameters. Development of 4D imaging camera helps in integrating patient specific motion into CAD/CAM technology.

Restorative materials used:-

Divided based on fabrication into Pre sintered, densely sintered, glass infiltrated.

Pre sintered:-

Materials like Cercon, DC-Zirokon DCS, Everest ZS-Blanks, IPS e.max ZirCAD, LAVA Frame, procera all zircon, vita YZ composed of Partially stabilized zirconia. Where as Procera all cerem composed of alumina.[7]

Densely sintered:-

Denzir, Digizon, Everest ZH- Blanks, Zirkon composed of Partially stabilized zirconia. Degicerem L, Everest G- Blanks, Pro CAD, Vita blocs Mark II, Vita blocs triluxe composed of leucite glass. IPS Emax CAD composed of lithium disilicate glass.[7]

Glass infiltrated:-

In cerem Alumina – composed of galss alumina with 500Mpa

In cerem spineli – composed of glass alumina spinal with 350 Mpa

In cerem zirconia – composed of glass alumina PS zirconia with 750 Mpa.[5]

Fabrication of prosthesis using CAD/CAM technology:-
Computer surface digitization, Computer-aided designing, Computer assisted manufacturing, Computer-aided esthetics and Computer-aided finishing. The last two steps are more difficult and are still being developed for inclusion in different commercial systems.[5]

Computer digitization- Scanning can be done by LED based or by laser based scanning.

LED based:- Video camera (hand held) with a 1cm wide lens (scanner) placed over the occlusal surface of the prepared tooth, emits infrared light which passes through an internal grid having a series of parallel lines. The light and dark stripes which falls on the prepared tooth surface is reflected back to the scanning head and onto a photoreceptor, where its intensity is recorded (V)and transmitted as digital data to the CAD unit.

LASER based:- A high speed laser helps to create an interactive 3D image. It allows automatic capture of digital images at the operator's speed that allows to scan both intra orally and extra-orally on conventional impressions or models, without the application of powder by rapid scaning. Subgingival level based optical coherence tomography (OCT) is scanned using newer laser based scanners. Minimum 9 scans are required to produce the 3D image. Stabilizers in scanning help to differentiate scanned image. If image is correct it will appear green in color, if it is near correct it appears yellow in color but if scanned image does not meet the requirements, it appears red in color. Photogrammetry, computed tomography (CT-Scan), magnetic resonance imaging (MRI), 3-D ultrasonography etc. are some of the technologies used for digitization.

Computer-aided designing (CAD):-
The obtained 3D image of the die can be rotated for observation from any angle on screen. Once the 3-D image is captured using any of the computer surface, digitization techniques, 3-D image processing is done and the data is entered in the computer. Lastly , curve smoothening data reduction and blocking of undercuts can be done at this stage. Designing is done using CAD software, which in turn sends data signals to the CAM unit, for fabricating the restoration.

Computer assisted manufacturing (CAM):- [11]
Third and final step in fabrication which is divided into three groups:-

Subtractive technique using Solid Block: Milling is done with computerized electrically driven diamond disks or burs which cut the restoration from ingots or blocks and the size is limited to size of FPDs.

Additive technique:- This is done by applying materials on die . Here Alumina or Zirconia is dry pressed on the die and the temperature is raised to the presintering state where its stable. Later it is milled to the desired shape and coping, removed from die, and sintered into the furnace for firing for full sintering.

Solid free form fabrication: Includes new technologies originating from the area of Rapid Prototyping (RP), for the needs of dental technology.

Rapid Prototyping Techniques:- [11,12]
This includes Stereolithography, Selective Laser Sintering (SLS) , 3-D Printing, Fused Deposition Modeling (FDM), Solid Ground Curing , Laminated Object Manufacturing (LOM) .

Stereolithography :
This technique helps in creating 3 dimensional objects in which a computer controlled moving laser beam is used to build up the required structure using layer by layer technique. Occlusal splints/stents and diagnostic templates for oral implantology can be produced using this technique.

Selective Laser Sintering:
Firstly converts the CAD data in series of layer and transfers to the additive SLS machine which begins to lay the first layer of powder . The material is heated and subsequently fuses together as the laser scans the surface. Layer by layer formation of object takes place. Once the single layer formation is completed, the powder bed is lowered and the next layer of powder is rolled out smooth and subjected to laser.

3-D Printing:
After computer-aided designing is done, the machine is used to print a wax pattern of the restoration. Later this wax pattern is cast similar to coventional lost-wax technique. Advances replacing wax with resin-type material is being used to fabricate patterns of restorations .

Advantages of CAD/CAM technology include:- [8,9]
Newer materials like high strength ceramics for fpds frameworks are used which had been difficult to process using conventional methods. Time effectiveness, decreased labour work, quality control, a digital impression helps dentist not to use impression material and trays on patients thereby saving them from discomfort. Latest innovation allows occlusion to be viewed and developed in dynamic state.

Disadvantages of CAD-CAM technology include:- [11]
Higher learning curve is required, expensive and demands rapid large scale production of good quality restoration. Necessity to achieve financial viability, fewer CAD/CAM system that depends on margin capture for digitization, thus making subgingival margin capture challenging. Matching tooth shade with CAD/CAM blocks can be challenging to dentist initially.

CONCLUSION:-
Application of CAD/CAM technology in dentistry provides innovative state of art dental service. CAD/CAM systems now provides automatic fabrication of frameworks with higher accuracy and decreased time span, uses high strength biocompatible materials, good esthetics which is flexible for both dentist and laboratory technician along with minimizing cross infections . The systems and materials available to us will continue to evolve, improve, and enhance dentistry significantly. Ever advancing technology, dentist need to be upgraded of updates oftenly, we dentists must not procrastinate in executing new trends for the benefit of our patients which contributes to quality of life and health .

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