Review Article

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Casting Technology: A Review

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ABSTRACT

Background: Casting technology has undergone developments at a very fast pace in the past two decades. Conventional casting is being replaced by newer fully computerized techniques. This article briefly reviews two such techniques i.e., Computer aided design/computer aided manufacturing (CAD/CAM) Milling and Direct metal laser sintering.

Keywords: CAD, CAM, Direct metal laser sintering.

INTRODUCTION

Casting process is used to fabricate several types of dental restorations to fulfill patients' demands and needs by offering dental prosthetic and restorative options such as inlays, onlays, crowns and bridges. Casting metals by using the "LOST WAX TECHNIQUE" is used in dentistry since the start of 20th century. Dr. Swasey (1890) was the first to introduce a technique of making solid gold inlay. Martin (1891) was the first to use wax for making gold inlays. Dr. Philbrook (1896) introduced pressure-casting method of producing gold inlays[1]. After 10 years in 1907 Dr. Taggart was the first to present a paper before the New York Odontological Group, in which he discussed his casting technique and machine[1]. Conventional casting or casting by the 'Lost wax technique,' is a process by which a wax pattern of a dental restoration is converted into an exact replicate in metal. It is one of the oldest existing technologies, and is still the preferred and most commonly used method for casting dental restorations it is one of the most convenient and inexpensive modes of casting.

Casting technology has evolved considerably over the past two decades; newer sophisticated processing technologies and systems have been introduced into dentistry. These systems include the 'Computer-aided design' and 'Computer-aided manufacturing' (CAD-CAM) technology. The application of CAD/CAM technology in dentistry provides an innovative, state-of-the-art dental service to patients and is also beneficial for general practitioners[4]. The digitalized CAD/CAM technology is broadly divided into CAM milling technology and Direct metal laser sintering. CAM milling technology is a subtractive process, which involves taking a block of material and cutting away that is not necessary until final restoration emerges. Whereas, direct metal laser sintering is an additive process, which involves adding of material layer by layer in a series of successively thin layer i.e., 0.02-0.06mm to build the final product[1].

Dr. Francois Duret, was the first in the field of dentistry to develop and introduce CAD/CAM technology. He began his work in the early 70's and conceptualized a series of system that started with an optical impression of the abutment tooth in mouth, followed by designing an optimal crown considering functional movement, and milling a crown using a numerically controlled milling

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machine[2]. He later developed the Sopha system. Dr. Moermann, later developed CEREC system (by Sirona dental), which is an in-office chair side CAD/CAM system. Dr. Andersson, used CAD/CAM in a specialized procedure. He attempted to fabricate titanium copings by spark erosion and also introduced CAD/CAM technology into process of composite veneered restorations. He later introduced the PROCERA system (Nobel Biocare) in the year 1991.

Dr. Carl Deckard and Dr. Joe Beaman, introduced Direct metal laser sintering in dentistry and designed and built the 'Selective laser sintering machine.'

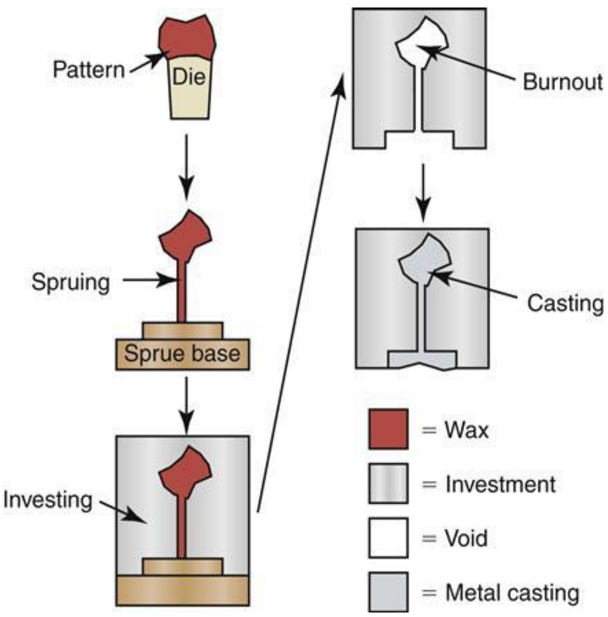

Fig 1: Outline of "Lost wax technique"

CAD/CAM MILLING

The CAD/CAM milling systems are divided into 3 different production concepts depending on the location of the components:

i. Chair side production
ii. Laboratory production
iii. Centralized fabrication in a production center

The system consists of 3 components:

i. A digitization scanner or tool i.e., an intraoral scanner
ii. A software that will process the data, and depending on the application will produce data sets for the product to be fabricated
iii. A production unit, that will transform the data set into the desired product

CHAIRSIDE PRODUCTION utilizes a digitization instrument i.e., an intraoral scanner, which replaces a conventional impression.

The introral scanner scans the prepared tooth and the restorations can be fabricated and cemented within a single appointment, example of this system includes the Cerec system (Sirona dental systems LLC, Charlotte, NC)

Fig 2: The Cerec chairside production unit.

LABORATORY PRODUCTION

This is an indirect system, which uses a stone model as their starting point. It scans a stone cast or a die. The scanned data is then processed by means of dental design software. After the CAD process the data is the sent to the milling unit that produces the restorations in the laboratory. The surface of the stone model is measured using various measuring tools to obtain the digital data that represents the morphology of the target tooth[2].

Different scanning methods include:

i. Contact probe (Fig 4)
ii. Laser displacement gauge (Fig 5)
iii. Line laser beam with CCD (Charged coupled device) camera (Fig 6)

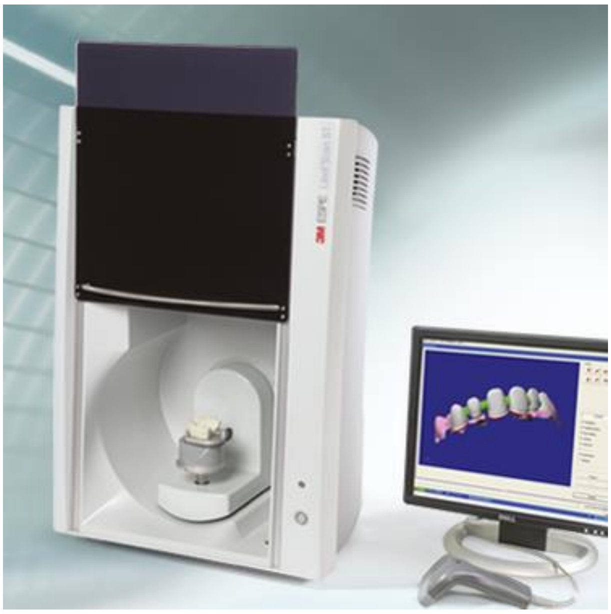

Fig 3: The Lava ZT scan design system

When a fine tip probe is used as the contact probe, even if it is very precise, it takes time to scan the entire model surface. A laser displacement gauge is relatively inexpensive and measurement takes less time than with a contact probe. However, because the reflected light of the projected laser beam is recognized by a PSD (Position Sensitive Device), the precision decreases with the effects of diffusion. When a line laser is used, the scanning time is greatly reduced, but the resolution of the CCD camera affects the precision[2].

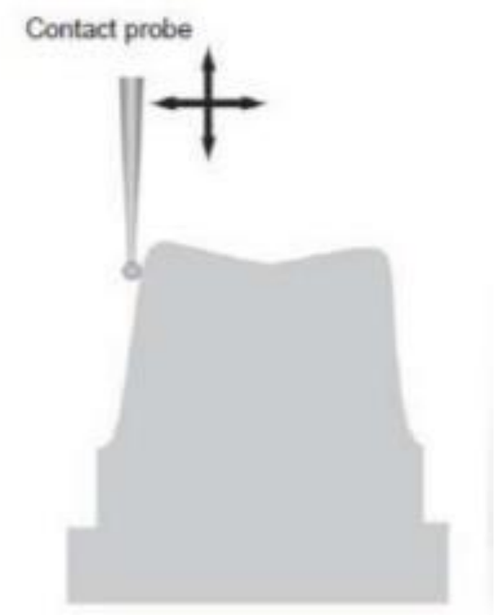

Fig 4: Contact Probe.

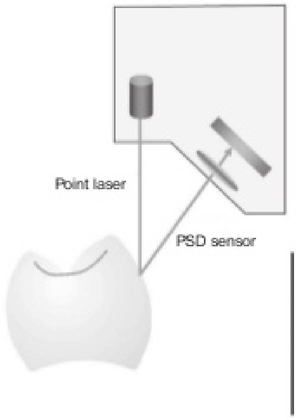

Fig 5: Laser displacement gauge

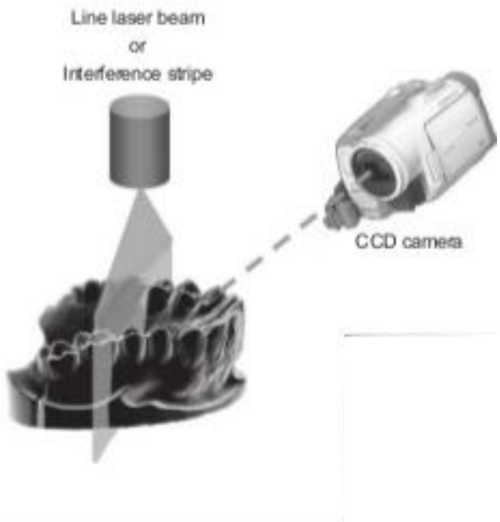

Fig 6: Line laser beam with CCD camera

Different systems available include:

i. Cerec In-lab
ii. Dux (Titan) system
iii. Denti CAD system
iv. Lava ZT scan system (3M™ ESPE) (Fig. 3)
v. Everest system

CENTALISED PRODUCTION IN A PRODUCTION CENTRE

This method utilizes chair side scanning and milling in the laboratory and both are connected via the Internet. Newly introduced intraoral scanners, scans the tooth introrally and the data sets are shared with the lab through the internet and the restoration is fabricated using a dental design software in the dental laboratory, and later the production center sends the prosthesis to the laboratory.

Example of this system include:

i. The 'Procera system,' (By Noble biocare) (Fig 7)
ii. The CS 3500 intraoral scanner (By Carestream dental) (Fig 8)

The CS 3500 intraoral scanner is one of the latest available powder-free intraoral scanners, that enable dental professionals to scan patients' teeth to create color 3D images. It has a click-and-point-system. The scanner can be used to design crown, bridges, inlays, onlays and veneers utilizing its CS Restore software, and milled with the optional dedicated Carestream milling machine (CS 3000), or the data can be sent to a laboratory for the design and milling of the restorations.

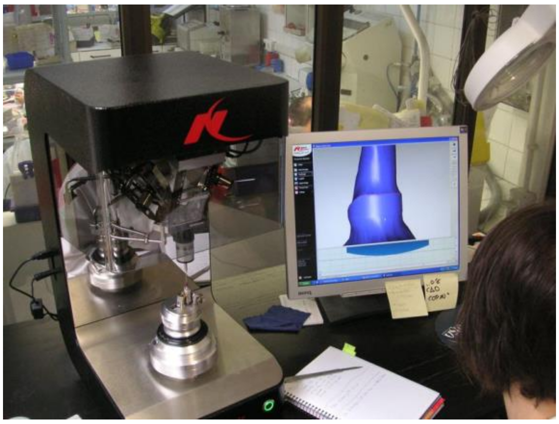

Fig 7: The 'Procera System'

Fig 8: The intraoral scanner CS 3500

ADVANTAGES OF THE CAD/CAM SYSTEM

i. Reduced time and labour
ii. Cost effectiveness
iii. Quality control

DIRECT METAL LASER SINTERING (DMLS)

Laser sintering also described as the '3D printing' is manufacturing of solid parts by solidifying powder like materials layer by layer by exposing the surface of a powder bed by laser. A high power laser is focused on a bed of powdered metal and these areas fuse into a thin solid layer.

It requires 3 inputs:

1. Material (Powdered metal)
2. Energy source (Laser beam)
3. CAD model

The material mainly used is cobalt-chromium alloys in powdered form. The particles are usually in the size of 3-14µm. The energy used is usually from a high powered (200W) Ytterbium fiber optic laser. CAD model is made from a CAD drawing which is read by the machine, and then lays down successive layers of alloy powder in a series of thin layers (0.02-0.06mm). The data interface between CAD software and the sintering machine is in the format of STL (Standard Tessellation language) file. The STL file creation converts the continuous geometry in the CAD file into a header, small triangles, or coordinates triplet list of x, y, and z coordinates and the normal vector to the triangles. The smaller the triangles the closer they are to reality[3].

There are two methods to perform the DMLS process, the powder deposition method and powder bed method. The two methods differ from each other in the way each layer of powder is applied. The most commonly used method is the powder bed method, it consists of a chamber area with 2 platforms, material dispensing platform and build platform. The material dispensing platform along with a recoater blade is used to move new powder over the build platform and the metal is fused into a solid part by melting it using the focused laser beam.

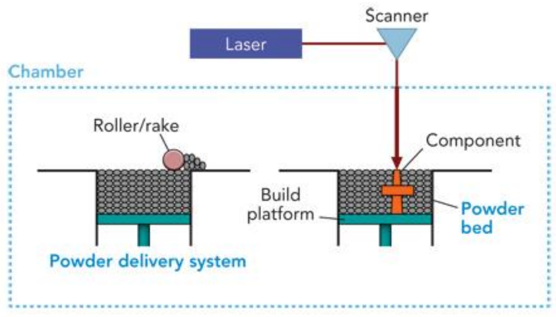

Fig 9: Schematic representation of laser sintering process.

Fig 10: The Direct metal Laser Sintering Unit.

Fig 11: Laser sintered copings.

ADVANTAGES

1. Densely (99.9%) sintered crowns with practically no voids.
2. Highly accurate.
3. The fully automated scanning and CAD software results in crowns with lesser discrepancies and lesser possibilities of inclusions of defects than manual casting.
4. Upto 90-120 units of crowns/bridge can be obtained per run of the machine.
5. Consistent work quality
6. Time effective and cost effective in the long run

CONCLUSION

CAD/CAM Milling and Direct Metal Laser Sintering, these techniques though relatively new than the 'Lost wax technique', but are still rapidly developing and promise more accurately manufactured restorations, with lesser defects and simplified post processing procedures. The accuracy of the computerized techniques rely on the scanners used and software that transforms the scanning data in to 3D model and also on the accuracy of the machine that uses CAM to produce objects from the CAD data. Conventional laboratory technology and dental technician skills still remain important and both conventional and new technology must be combined to meet the patient demands.

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