CAD/CAM CERAMICS- THE PARADIGM SHIFT IN FIXED PROSTHODONTICS

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ABSTRACT

Ceramics are broadly utilized as circuitous helpful materials in dentistry because of their extensive biocompatibility and satisfying aesthetics. The objective is to review the different CAD/CAM all-ceramic biomaterials. CAD/CAM all-ceramic biomaterials are highlighted and a subsequent literature search was conducted for the relevant subjects utilizing PubMed followed by manual search. Advancements in CAD/CAM innovation have catalyzed inquiry in all-ceramic biomaterials and their applications. Feldspathic glass ceramic and glass penetrated ceramic can be manufactured by conventional research facility strategies or CAD/CAM. The appearance of polycrystalline ceramics may be a coordinate result of CAD/CAM innovation without which the manufacture would not have been conceivable. The clinical employments of these ceramics have met with variable clinical victory. Numerous choices are presently accessible to the clinicians for the creation of aesthetic all ceramic restorations.

Keywords : CAD/CAM; ceramics; dentistry; technology

INTRODUCTION

Previously our team had conducted numerous researches on dental ceramics to analyse marginal discrepancies in various settings (Ganapathy *et al.*, 2016; Ranganathan, Ganapathy and Jain, 2017), conducted many surveys to understand the dental knowledge of rural population (Ashok and Suvitha, 2016), carried out extensive studies on dental implants (Ajay *et al.*, 2017; Kannan and Others, 2017; Duraisamy *et al.*, 2019), analysed the effect of various biological agents and its prosthodontic application (Selvan and Ganapathy, 2016; Subasree, Murthykumar and Others, 2016), threw some critical light on health status of different demography (Jyothi *et al.*, 2017; Basha, Ganapathy and Venugopalan, 2018), investigated clinical scenarios (Ashok *et al.*, 2014; Venugopalan, Ariga and Aggarwal, 2014; Vijayalakshmi and Ganapathy, 2016) and conducted innumerable systematic reviews (Jain *et al.*, 2018; Kannan and Venugopalan, 2018). Now we are focussing on relevant reviews to gain comprehensive knowledge on recent developments in the field of prosthodontics.

CAD/CAM dentistry is a field of dentistry and prosthodontics using CAD/CAM (computer-aided design and computer-aided manufacturing) to improve the design and creation of dental restorations, especially dental prostheses, including crowns, crown lays, veneers, inlays and onlays, fixed dental prostheses bridges, dental implant supported restorations, dentures (removable or fixed), and orthodontic appliances. CAD/CAM technology allows the delivery of a well-fitting, aesthetic, and durable prostheses for the patient. (Li, Chow and Matinlinna, 2014) CAD/CAM complements earlier technologies used for these purposes by any combination of increasing the speed of design and creation; increasing the convenience or simplicity of the design, creation, and insertion processes; and making possible restorations and appliances that otherwise would have been infeasible. Other goals include reducing unit cost and making affordable restorations and appliances that otherwise would have been prohibitively expensive. However, to date, chairside CAD/CAM often involves extra time on the part of the dentist, and the fee is often at least two times higher than for conventional restorative treatments using lab services. CAD/CAM is one of the highly competent dental lab technologies. (McMahon and Browne, 1999)

Like other CAD/CAM fields, CAD/CAM dentistry uses subtractive processes (such as CNC milling) and additive processes (such as 3D printing) to produce physical instances from 3D models.(Fasbinder, 2010) In some cases, "CAD/CAM" in dental technology is used to describe prostheses made by milling technology but this is not fully correct as the term "CAD/CAM" does not relate to the method of production. Although CAD/CAM dentistry was used in the mid-1980s, early efforts were considered a cumbersome novelty, requiring an inordinate amount of time to produce a viable product.(Tinschert *et al.*, 2004) This inefficiency prevented its use within dental offices and limited it to labside use (that is, used within dental laboratories). As adjunctive techniques, software, and materials improved, the chairside use of CAD/CAM (use within dental offices/surgeries) increased. For example, the commercialization of Cerec by Sirona made CAD/CAM available to dentists who formerly would not have had avenues for using it.(McMahon and Browne, 1993)

DIFFERENCE FROM CONVENTIONAL RESTORATION

Chairside CAD/CAM restoration typically creates and lutes(bonds) the prosthesis the same day. Conventional prostheses, such as crowns, have temporaries placed for one to several weeks while a dental laboratory or in-house dental lab produces the restoration. The patient returns later to have the temporaries removed and the laboratory-made crown cemented or bonded in place. An in-house CAD/CAM system enables the dentist to create a finished inlay in as little as one hour. CAD/CAM systems use an optical camera to take a virtual impression by creating a 3D image which is imported into a software program and results in a computer-generated cast on which the restoration is designed. (McMahon and Browne, 1999)

Bonded veneer CAD/CAM restorations are more conservative in their preparation of the tooth. As bonding is more effective on tooth enamel than the underlying dentin, care is taken not to remove the enamel layer. Though one-day service is a benefit that is typically claimed by dentists offering chairside CAD/CAM services, the dentist's time is commonly doubled and the fee is therefore doubled. (Rajurkar and Yu, 2000)

PROCESS INVOLVED IN CAD/CAM TECHNOLOGY

All CAD/CAM systems contain:

1. An optical scanner that captures the intraoral or extraoral condition
2. Software that can turn the captured images into a digital model to produce and design the prosthesis (Beuer, Schweiger and Edelhoff, 2008)
3. Technology that changes the data into a product. As in other fields, additive manufacturing (3D printing) first entered CAD/CAM dentistry in the form of laboratory experiments, but its use has since expanded; and chairside use, although not yet widespread, is advancing. (Li, Chow and Matinlinna, 2014)
4. Typically CAD/CAM dental restorations are milled from solid blocks of ceramic or composite resin that closely match the basic shade of the restored tooth. Metal alloys, including zirconia, can also be milled. Several of these materials require processing such as baking or sintering following their milling. The system can be used chair-side, in a laboratory setting, or in a production centre.(Fuster-Torres and Albalat-Estela, 2009)

For a single unit prosthesis, after decayed or broken areas of the tooth are corrected by the dentist, an optical impression is made of the prepared tooth and the surrounding teeth. These images are then turned into a digital model by proprietary software within which the prosthesis is created virtually. The software sends this data to a milling machine where the prosthesis is milled. Stains and glazes can be added to the surfaces of the milled ceramic crown or bridge to correct the otherwise monochromatic appearance of the restoration. The restoration is then adjusted in the patient's mouth and luted or bonded in place. (Jain *et al.*, 2018)

Integrating optical scan data with cone beam computed tomography datasets within implantology software also enables surgical teams to digitally plan implant placement and fabricate a surgical guide for precise implementation of that plan. Combining CAD/CAM software with 3D images from 3D imaging systems means greater safety and security from any kind of intraoperative mistakes.(Liu, 2005)

ADVANTAGES AND DRAWBACKS

CAD/CAM has improved the quality of prostheses in dentistry and standardised the production process. It has increased productivity and the opportunity to work with new materials with a high level of accuracy. It has decreased chair time for the patient by the use of intra-oral scanning systems which allow the dentist to send electronic impressions to the lab. The restorations are milled from a block of ceramic which has fewer flaws.(British Standards Institute Staff, 1918)

However, CAD/CAM requires a large initial investment. Occlusal detail isn't always the best and has to be amended by hand. Most doctors that use chair side technology find the level of detail to be more than adequate in a clinical setting.(Santos, Boksman and Santos, 2013)

Though CAD/CAM is a major technological advancement, it is important that the dentists' technique is suited to CAD/CAM milling. This includes: correct tooth preparation with a continuous preparation margin (which is recognisable to the scanner e.g. in the form of a chamfer); avoiding the use of shoulderless preparations and parallel walls and the use of rounded incisal and occlusal edges to prevent the concentration of tension. (Davidowitz and Kotick, 2011)

Depending on the material, CAD/CAM treatments may have aesthetic drawbacks, whether they are created at the dental practice or outsourced to a dental laboratory. Depending on the dentist or technician, CAD/CAM restorations can be layered to give a deeper more natural look. Just like traditional restorations, CAD/CAM restorations also vary in aesthetic value. Many are monochrome.(Duret and Preston, 1991) In some hand-layered crowns and bridges, feldspathic porcelain is fused to glass-infiltrated aluminum oxide (alumina) or zirconium-oxide (zirconia) creating a high-strength, highly aesthetic, metal-free crown or bridge. In other traditional restorations, the porcelain is layered onto a metal substructure and often displays colour brightness, an opaque "headlight", and dark oxide lines (a "black line" in the vicinity of the gum line). As these dark metal substructures are not conducive to a natural appearance, metal-free restorations are typically more aesthetically pleasing to the patient. (Li, Chow and Matinlinna, 2014)

There are also different medical repercussions for each restorative technique. If the CAD/CAM restorative material is zirconia, the restoration becomes "radio-opaque", just as metal restorations are, blocking x-rays. Only alumina, lithium disilicate materials are "radio-lucent", allowing dentists to track potential decay. Zirconia, conventional porcelain-to-metal, and traditional gold and other all-metal crowns block x-ray radiation, disallowing evaluation over time. Therefore, doctors have to examine restorations visually and with a dental explorer to diagnose decay. (British Standards Institute Staff, 1918)

Crowns and bridges require a precise fit on tooth abutments or stumps. Fit accuracy varies according to the CAD/CAD system utilized and from user to user. Some systems are designed to attain higher standards of accuracy than others and some users are more skilled than others. It is estimated that 20 new systems are expected to become available by 2020.(Rajurkar and Yu, 2000)

Further research is needed to evaluate CAD/CAM technology compared to the other attachment systems (such as ball, magnetic and telescopic systems), as an option for attaching overdentures to implants. (Pollard, 1985)

COMMON CAD/CAM SYSTEMS

1. Cerec

Cerec : An acronym for chair side economic reconstruction of esthetic ceramic Cerec introduced in 1980s, improved cerec 2 introduced in 1996 and the advanced 3-D Cerec 3 in 2000. With Cerec 1 and Cerec 2, an optical scanner is used to scan the prepared tooth or impression and a 3-D image is generated on the monitor. A milling unit is used to prepare the restoration. With newer Cerec 3-D, the operator records multiple images within seconds, enabling the clinician to prepare multiple teeth in the same quadrant and create a virtual cast for the entire quadrant. Designed restoration is transmitted to a remote milling unit for fabrication. Cerec in-lab is a lab system in which they are laser scanned and images are displayed on screen. After designing VITA In-cream blocks are used for milling.(Li, Chow and Matinlinna, 2014) The coping is glass infiltrated and veneer porcelain added . In vitro evaluation of marginal adaptation of crown of cerec 3-D (47.5 µm+-19.5 µm) was better compared with cerec 2 (97.0 +- 33.8 µm).(Ellingsen et al,2002) (left) Simulated digitized image, (right) partially milled feldspathic ceramic (VITABLOCS Triluxe Forte) processed by the Sirona inLab CAD-CAM system. (Left) CAD-CAM ceramic block before milling. (Center) An intermediate stage of milling. (Right) After removal of the inlay from the mounting stub. (Li, Chow and Matinlinna, 2014)

2. DCS President

Comprises of a Preciscan laser Scanner and Precimill CAM multitool milling center. The DCS software automatically suggests connector sizes and pontic forms for bridges. It can scan 14 dies simultaneously and mill up to 30 frameworks units in one fully automated operation. It is one of the few systems that can mill titanium and fully dense sintered zirconia. An in vitro study showed that marginal discrepancies of alumina and zirconia based posterior fixed partial denture machined by the DCS system was between 60 µm to 70µm. (McMahon and Browne, 1993)

3. Cercon

Commonly referred to as a CAM system, it does not have a CAD component. The system scans the wax pattern and mills a zirconia bridge coping from pre sintered zirconia blanks, which is sintered at 1350 C for 6-8 hrs. Veneering is done with a low fusing, leucite free cercon Ceram to provide esthetic contour. Marginal adaptation for cercon all ceramic crowns and fixed partial dentures was reported 31.3 µm and 29.3 µm respectively. (Millet *et al.*, 2014)

4. Procera all cream system

Introduced in 1994, it is the first system which provided outsourced fabrication using a network connection. Once the master die is scanned the 3-D images are transferred through an internet link to the processing center where an enlarged die is milled by a computer controlled milling machine. This enlargement compensates for sintering shrinkage. Aluminum oxide powder is compacted on the die and coping is milled before sintering at a very high temp (>1550°C). The coping is sent back to the lab for porcelain veneering. According to research data, the average marginal gap for Procera all Ceram restoration ranges from 54 µm to 64 µm. (Chelule, Coole and Cheshire, 2001)

5. CICERO - Computer Integrated Crown Reconstruction System

Introduced by Denison et al in 1999, it includes optical scanning, metal and Ceramic sintering and computer assisted milling to obtain restoration. Basic reconstruction includes layered life like ceramic for natural esthetics, a precision milled occlusal surface and a machined high strength ceramic core. The aim of CICERO is to mass produce ceramic restoration at one integrated site. It includes rapid custom fabrication of high strength alumina coping and semi finished crowns to be delivered to dental laboratories for porcelain layering / finishing. (McMahon and Browne, 1999; Li, Chow and Matinlinna, 2014)

6. Lava CAD/CAM system

Introduced in 2002, used for fabrication of zirconia framework for all ceramic restorations. This system uses yttria stabilized tetragonal zirconia polycrystals (Y-TZP) which have greater fracture resistance than conventional ceramics. Lava system uses a laser optical system to digitize information. The Lava CAD software automatically finds the margin and suggests a pontic. CAM produces an enlarged framework to compensate shrinkage. (Kannan and Others, 2017)

RESTORATIVE MATERIALS FOR CAD/CAM CAD/CAM

Systems based on machining of pre sintered alumina or zirconia blocks in combination with specially designed veneer ceramics satisfy the demand for all-ceramic posterior crowns ,inlays and onlays . Many ceramic materials are available for use as CAD/CAM restorations. Common ceramic materials used in earlier dental CAD/CAM restorations have been machinable glass ceramics such as Dicor-k or Vita Mark II. (British Standards Institute Staff, 1918)

Although mono-chromatic, these ceramic materials offer excellent esthetics, biocompatibility, great color stability, low thermal conductivity, and excellent wear resistance. They have been successfully used as inlays, onlays ,veneers , and crowns. However, Dicor and Vita Mark II are not strong enough to sustain occlusal loading when used for posterior crowns. For this reason, alumina and zirconia materials are now being widely used as dental restorative materials. (Santos, Boksman and Santos, 2013)

These ceramic agents may not be cost- effective without the aid of CAD/CAM technology. In-Ceram l, first described by Degrange and Sadoun, has been shown to have good flexural strength and good clinical performance. However, the manufacture of conventional In-Ceram restoration takes up to 14 hours. By milling copings from pre sintered alumina or zirconia blocks within a 20 minute period and reducing the glass infiltration time from 4 hours to 40 minutes, CEREC in Lab decreases fabrication time by 90%.

Zirconia is strong and has high biocompatibility. Fully sintered zirconia materials can be difficult to mill, taking 3 hours for a single unit. Compared with fully sintered zirconia, milling restorations from pre sintered or partially sintered solid blocks is easier and less time-consuming, creates less tool loading and wear, and provides higher precision. After milling, In-Ceram spinell, alumina, and zirconia blocks are glass infiltrated to fill fine porosities. Other machinable pre sintered ceramic materials are sintered to full density, eliminating the need for extensive use of diamond tools.
Under stress the stable tetragonal phase may be transformed to the monoclinic phase with a 3% to 4% volume increase. This dimensional change creates compressive stresses that inhibit crack propagation. This phenomenon, called “transformation toughening,” actively opposes cracking and gives zirconia its reputation as the “smart ceramic.” The quality of transformation toughness and its effect on other properties is unknown. (Millet *et al.*, 2014)

Zirconia copings are laminated with low fusing porcelain to provide esthetics and to reduce wear of the opposing dentition. If the abutment lacks adequate reduction the restoration may look opaque. Because they normally are not etchable or bondable, abutments require good retention and resistance form. Alumina and zirconia restorations may be cemented with either conventional methods or adhesive bonding techniques. Conventional conditioning required by leucite ceramics (eg, hydrofluoric acid etch) is not needed.

Microetching with Al2O3 particles on cementation surfaces removes contamination and promotes retention for pure aluminum oxide ceramic. A resin composite containing an adhesive phosphate monomer in combination with a silane coupling/bonding agent can achieve superior long- term shear bond strength to the intaglio surface of Procera AllCeram and Procera AllZirkon restorations. (Chelule, Coole and Cheshire, 2001)

CAD/CAM systems also can be applied to restorations requiring metal and are used to fabricate implant abutments and implant-retained overdenture bars. The DCS system can fabricate crown copings from titanium alloy with excellent precision .

MARGINAL INTEGRITY OF CAD/CAM RESTORATIONS

One of the most important criteria in evaluating fixed restorations is marginal integrity. Evaluating inlay restorations, Leinfelder and colleagues (1993) reported that marginal discrepancies larger than 100 µm resulted in extensive loss of the luting agent. O'Neal and colleagues (1993)reported the possibility of wear resulting from contact of food particles with cement when the gap dimension exceeded 100 µm.(Mehl *et al.*, 2004)

Essig and colleagues (1999) conducted a 5-year evaluation of margin gap wear and reported that vertical wear is half of the horizontal gap. The wear of the gap increased dramatically in the first year, becoming stable after the second year. McLean and Von Fraunhofer (1971) proposed that an acceptable marginal discrepancy for full coverage restorations should be less than 120 µm. (Peumans *et al.*, 2007)

Christensen (1966) suggested a clinical goal of 25 µm to 40 µm for the marginal adaptation of cemented restorations. However, most clinicians agree that the marginal gap should be no greater than 50 µm to 100 µm. Current research data indicate that most dental CAD/CAM systems are now able to produce restorations with acceptable marginal adaptation of less than 100 µm. Perng-Ru Liu. A Panorama of Dental CAD/CAM Restorative Systems.(Peumans *et al.*, 2007)

TECHNICAL INNOVATIONS

The Cerec 2 camera: Optical impression The Cerec 2 camera has been given a new design and is easy to handle. To maintain good accessibility to the oral cavity, the size of the intraoral frontal part of the camera has not been modified. An important hygienic feature is the detachable cover, which can be sterilized by dry heat in case of exposure to a higher risk of infection.(Krejci, Lutz and Reimer, 1994)

Usually, the cover is removed, a plug is inserted in its opening, and it is then washed in a thermal disinfector. The camera can also be wiped clean with a dispensable cloth moistened with a liquid disinfectant.(El Zohairy *et al.*, 2003)

The further development of the intraoral three dimensional camera has been carried out in accordance with the original Cerec process. Pixel size(picture element) has been reduced from 54x54um to 25 X 29 um. Thus, in the pixel image system, the voxel (volume element) pattern has come to 25 X 25 X 29 um in the pixel image system. Because of the optimization of the optical beam path by means of symmetric beam geometry, major measurement errors in the measuring volume of a typical inlay have been brought down to less than +- 25 um.(Hannig *et al.*, 2005)

A more accurate control of the projected measuring pattern and the particularly low-noise level processing of the video signal has resulted in a distinct reduction of the spurious components in the measuring data. Because of the smaller pixel size and the higher accuracy in the depth measuring, the resolution of the optical impression has been doubled compared to that of the Cerec 1 unit.(Kassem, Atta and El-Mowafy, 2012)

CONCLUSION

Systems offer automation of fabrication procedures with standardized quality in a shorter period of time. They have the potential to minimize inaccuracies in technique and reduce hazards of infectious cross contamination. It allows application of newer high strength materials with outstanding biocompatibility combined with adequate mechanical strength, provisions for esthetic designs, excellent precision of fit and longevity. However, these advantages must be balanced against the high initial cost of CAD/CAM systems and the need for additional training. Patient's expectations, financial constraints, operator's preference, as well as availability of CAD/CAM systems will dictate the suitability of this type of restorations on an individual basis in the future. Innovations will continue to affect and challenge dentistry.

ACKNOWLEDGEMENT

The authors are grateful to Saveetha Dental College for providing a platform to express our knowledge.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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