Review Article

Cad Cam All Ceramic Biomaterials…. A Supporlative Innovation

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Abstract

AIM: Ceramics used as indirect restorative materials in dentistry are known for their high biocompatibility and pleasing aesthetics. The aim is to review the state of the arts of CAD/CAM all-ceramic biomaterials. Scope: CAD/CAM all-ceramic biomaterials are highlighted and a subsequent literature search was conducted for the relevant subjects using PubMed followed by manual search.

Results: Developments in CAD/CAM technology have catalyzed researches in all-ceramic biomaterials and their applications. Feldspathic glass ceramic and glass infiltrated ceramic can be fabricated by traditional laboratory methods or CAD/CAM. The advent of polycrystalline ceramics is a direct result of CAD/CAM technology without which the fabrication would not have been possible.

Conclusions: The clinical uses of these ceramics have met with variable clinical success. Multiple options are now available to the clinicians for the fabrication of aesthetic all ceramic restorations.

Keywords: Calcium, Bone, Periodontitis, Osteoporosis, Atherosclerosis

Introuction

The utilization of all ceramic prosthesis in restorative treatments has become prevalant and many of these restorations can be fabricated by both time honoured laboratory methods and CAD/CAM machination1-4. The conventional methods of ceramic fabrication have been described to be protracted, technique sensitive and unpredictable due to the many variables and CAD/CAM may be a good alternative for both the dentists and laboratories3. the advances in CAD/CAM technology are instrumental in the research and development of high strength polycrystalline ceramics such as stabilized zirconium dioxide5-6 which could not have been practically processed by custo marylaboratory methods7-8. These materials have made feasible the use of all ceramic crowns and short span bridges in posterior load bearing regions3. In this review, we construct an overview on materials used in dental CAD/CAM technology.

CAD/CAM glass ceramics

CAD/CAM-compatible feldspathic ceramics

The premier CAD/CAM produced inlay was fabricated in 1985. The clinical performance of these CAD/CAM inlays and onlays fabricated using a ceramic block comprising fine grain feldspathic ceramic (VitaTM Mark I, Vita Zahnfabrik, Bad Sackingen, Germany) was evaluated in a 10-year prospective study and a success rate of 90.4% was achieved9-10. However, a much higher breakage rate of up to 36% after 2 years was also reported1. In 1991, it exhibited better mechanical properties2 with a reported flexural strength from about 100 MPa to 160 MPa when glazed11-12. VitaTM Mark II is monochromatic but available in multiple shades. The newer VitablocsTM TriLuxeTM, TriluxeTM Forte and RealLifeTM blocks (Vita Zahnfabrik, Bad Sackingen, Germany) contain multi-shade layers and offer a gradient of colour and translucency. CerecTM Blocs (Sirona Dental Systems, Ben-sheim, Germany) are similar in structure to VitaTM Mark II but use a different shading system. They are also available in aesthetically pleasing multi-shade blocks. This material have excellent aesthetic properties12 and have been recommended for use in fabricating veneers, inlays/onlays14,19,20 and single anterior and posterior13 crowns. However, the material is not considered to be strong enough for posterior load bearing areas although, when used in premolar region, the fracture load was found to be similar to natural teeth15,16. In addition, a cumulative survival rate of 94.6% after 55 months was reported when VitaTM Mark II molar crowns were examined17.

CAD/CAM and mica-based ceramics

The mica based glass ceramic marketed for both laboratory ceramming and machining. It has 70% crystalline phase, as compared to DicorTM which may explain the reported increasedflexural strength to about 229 MPa18. It has been shown that DicorTMMGC and VitaTM Blocs were very similar in clinical performance14 but its cumulative breakage at 2 years was found to be higher than for VitaTM Mark II1 Although both DicorTM and DicorTM MGC were very well studied, the materials are no longer in the market.

CAD/CAM with leucite-reinforced ceramics

ProCADTM (Ivoclar-Vivadent, Schaan, Liechtenstein) introduced in 1998 is a leucite reinforced ceramic, similar in structure to the heat pressed ceramic EmpressTM (Ivoclar-Vivadent). The marginal gap, internal fit and fracture load also compared favourably with EmpressTM in an in vitro study19. In a clinical study of partial crowns observed for 1–4 years, no fracture was reported with a survival rate of 100% after 2 years20. A mid-term evaluation of a 5-year clinical split-mouth investigation of all-ceramic partial coverage on molars reported a survival rate of 97% after 3 years21. EmpressTM CAD (Ivoclar-Vivadent), introduced in 2006, was the successor to EmpressTM ProCAD. Its main difference is in the optimizing manufacturing procedure and it has about 45% leucite with a finer particle size of about 1–5 mm that helps resist machining damages22. It was developed for chair-side single unit restora-tions and has a flexural strength of about 160 MPa. Clinically it is recommended for single tooth restorations and is available in High Translucency (EmpressTM CAD HT), Low Translucency (EmpressTM CAD LT) and polychromatic (EmpressTM CAD Multi) blocks.

CAD/CAM milling lithium disilicate reinforced ceramics

Lithium disilicate, Li_2SiO_5, glasses have their flexure strength between 350 MPa and 450 Mpa. A lithium disilicate CAD/CAM ceramic IPSTM e.max CAD (Ivoclar-Vivadent) was introduced in 2006 and is a chair-side monolithic restorative material. They are available in A–D and Bleach shades as well as in 3 translucencies (one of which is of medium opacity) and are supplied in a pre-crystallized so-called blue state. The ceramic contains 70 vol% of crystals of approximately 1.5 mm in size and the strength increases dramatically to 360 Mpa23. Laboratory studies have shown that fully anatomical e.maxTM CAD crowns may be resistant to fatigue in cyclic loading [40] and that its fracture load is significantly higher than the one for ProCADTM and EmpressTM CAD24. The material has been recommended for use in fabricating inlays, onlays, veneers, anterior and posterior crowns and implant supported crowns25 and clinical studie have shown trials on single crowns showed survival rates between 97.4%26 and 100%27, after two years.

CAD/CAM and glass infiltrated alumina and zirconia ceramics

The VitaTM InCeram Classic group of ceramics (InCeramTM Alumina, Spinell and Zirconia, Vita Zahnfabrik, Bad Sackin-gen, Germany) are slip cast, glass infiltrated ceramics that have at least two interpenetrating phases intertwined throughout the material. Alumina (Al_2O_3) and zirconia (ZrO_2) are discussed in more details below. CAD/ CAM InCeramTM Spinell has been reported to yield survival rates of 91.7% to 100% after 5 years15. It is the most translucent material of the group and is recommended especially for anterior crowns. CAD/CAM InCeramTM Alumina has been recommended for single anterior and posterior crowns. It was reported a survival rate of 92% after 5 years for premolar and molar crowns fabricated with a CERECTM 2 system (Sirona, Beinsheim, Germany)28. The manufacturer also recommends its use as anterior bridge substructures with no more than one pontic unit. CAD/CAM InCeramTM Zirconia is an example of glass infiltrated zirconia (ZrO_2) toughened alumina (ZTA) and has the highest strength of this group of materials30. However the opacity of zirconia has limited its use to the posterior region as substructures for crowns or bridges with one pontic. The flexural strength of CAD/CAM InCeramTM Zirconia was found to be favourable for fixed partial denture (FPD) frameworks28.

CAD/CAM compatible polycrystalline alumina and zirconia

Polycrystalline ceramic is relatively opaque by nature and is indicated for the fabrication of crown and bridge copings upon which a veneering ceramic is layered for the required aesthetic result8.The crystal lattice network is highly dense and it reduces crack propagation resulting in excellent mechanical properties. However, at the same time, the increase in strength means that well-fitting prosthesis could not be practically fabricated without CAD/ CAM systems.

Alumina based polycrystalline ceramics

This core material contains more than 99.9% alumina and has a flexural strength of about 600 Mpa31-32. The polycrystalline ceramic is relatively opaque, it was reported that when all ceramic materials at the respective clinically relevant thickness were compared, the translucency of ProceraTM AllCeram is between that of EmpressTM and EmpressTM 2 (Ivoclar-Vivadent, Schaan, Liechtenstein)33. It is used as laminates for patients with discoloured anterior34. The cumulative survival rates of ProceraTM AllCeram anterior and posterior crowns have been found to be about 97% after 5 years and 93.5% after 10 years35-36. Studies have reported a tendency for more failures in the posterior region and that crown failures were generally higher in molars than premolars35–38. ProceraTM AllCeram has been used in the fabrication of FPD's39. CAD/ CAM alumina based polycrystalline ceramics can also be used as metal free super-structures on implant abutments. Fully custom designed copings can now be fabricated and a procedure by which the all-ceramic coping is totally milled has been described40. The cumulative success rates of 98.3% after 4 years and 91% after 6 years have been reported41-42.However the crowns provided excellent aesthetics and colour stability in the observation period and that excessive parafunctional forces were considered a major reason for the ceramic fractures reported. A similar CAD/CAM ceramic is the VitaTM InCeram AL cubes (Vita Zahnfabrik, Bad Sackingen, Germany), introduced in 2005. The authors of this study conjectured that the high crystalline content and low porosity of the ceramic contributed to its superior mechanical properties43. InCer- amTM AL cube is indicated by the manufacturer for the fabrication of substructures for anterior single crowns and short span bridges and posterior single crowns.

Stabilized zirconia based polycrystalline ceramics

Zirconia is a polymorphic ceramic material in its unalloyed state and it has three crystallographic forms: monoclinic (M) from room temperature to 1170 8C, tetragonal (T) from 1170 8C to 2370 8C and cubic (C) from 2370 8C to the melting point2,3.

Transformation toughening of zirconia

The tetragonal phase is metastable and can transform to the monoclinic phase in response to mechanical stimuli such as a crack on the surface of the ceramic44. Stress is built up at the tip of the crack which will trigger the transformation. This T–M transformation at the fracture site is accompanied by an increase in volume of about 4% as monoclinic crystals are larger in size. Zirconia has high fracture toughness, 9–10 MPa m _1 and the flexural strength, 900–1200 MPa, is about twice that of alumina46,47. Given this, it should be noted that the propagation of a crack is not totally prevented, it is merely hindered, and the material would still fail under a sufficiently high stress.

Low temperature degradation of zirconia

Low temperature degradation of zirconia also known asceria-stabilized zirconia (12Ce-TZP) was resistant to simulated hydrothermal ageing and its flexural strength remained unaffected at a low level of 500 MPa 57. Although some concern was raised by the degradation of the femoral heads 20 years ago, no direct correlation has been established between LTD and clinical failure of zirconia in dentistry49,52.

Yttria partially stabilized tetragonal zirconia

polycrystals

Biomedical grade zirconia (3Y-TZP) contains 3 mol% yttria and since the 1990s it has been used in dentistry as orthodontic brackets53, endodontic posts54, crowns55,FDPs, implants56 and implant abutments 57. Natural zirconia is dull white, X-ray opaque and it has an obvious advantage over metal alloys as a substructure material. However, the translucency decreases with an increase in crystalline content and the opacity of zirconia is comparable to metal63. In this aspect it is useful in masking discoloured teeth or metal substructures such as metal posts and cores55 but its use in the aesthetic zone is limited to the fabrication of frameworks. Coloured zirconia frameworks are now available that may produce a more clinically acceptable colour match59. Long term clinical studies on zirconia-supported restorations were scarce and in the studies reviewed, the clinical survival rates were 92.7–100% after 3 years for single crowns and 94–96% for 3- to 4-unit FPDs after 4 years. Although some studies have shown that zirconia based FPDs can possibly withstand physiologic occlusal forces60, occlusal overloading caused by bruxism and insufficient framework thickness were cited as the major factors causing catastrophic fracture within the zirconia core, most commonly occurring in the connector areas of FPDs61.

Magnesium partially stabilized zirconia

This material has a higher wear rate due to residual porosities44. The material is stabilized by magnesia but the difficulties in obtaining Mg-PSZ precursors free of impurities result in a decrease in stability in the tetragonal phase in a wet environment and lower mechanical properties when com-pared to 3Y-TZP after veneering44.

Ceria stabilized zirconia/alumina nanocomposite (Ce-TZP/A)

Ce-TZP itself is resistant to LTD but has a low flexural strength51. Homogeneous dispersion of nanoscale alumina in thematrix increases the flexural strength without affecting the fracture toughness and preliminary results of a prospective case series have shown Ce-TZP/A (Nanozir, Hint-Els, Griesheim, Germany) to be a reliable framework material for posterior FDPs .

Precision of fit of stabilized zirconia based polycrystalline ceramics

The marginal fit of zirconia restorations is dependent on the configuration and design of the teeth preparations, the accuracy of the scanning system, the type of machining and the veneering procedures but ageing does not seem to influence the long term marginal integrity7. Depen ding on the study design and variables, the absolute marginal fit of zirconia FPDs have been reported to be between 9 mm and 206.3 mm and most of the available systems provide clinically acceptable marginal adaptation7.

Bonding to zirconia

Its superior biocompatibility and biomechanical properties7-8, but it has been concluded that conventional adhesive techniques do not yield a high enough bond strength to substrates. Researches are under way to establish a reliable, reproducible and commercially viable resin composite bonding protocol for zirconia and for porcelain zirconia bonding8. Grinding or air-abrasion to create a rough surface for micromechanical interlocking may intro- duce initial surface flaws that may compromise its strength and reliability.

Conclusion

Advances in CAD/CAM technology have catalyzed the devel- opments of aesthetic all ceramic restorations with superior biomechanical properties. Although none of these materials exhibit ideal clinical properties for universal applications, intense research efforts are under way to promote the strength, aesthetics, accuracy and an ability to reliably bond to dental substrates.

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