REVIEW

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NANOCERAMICS AND HYBRID MATERIALS USED IN CAD/CAM SYSTEMS

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ABSTRACT

CAD/CAM systems are widely popular in contemporary procedures. There are many products and materials to use with different cases and indications in the market. In the current study, most current materials, mainly nanoceramics and hybrid ceramics are investigated, their advantages and disadvantages are evaluated, and the current products in the market are listed.

Keywords: CAD/CAM, nanoceramics, hybrid.
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ÖZET

CAD/CAM sistemleri günümüzde yaygın olarak kullanılmaktadır. Farklı endikasyonlara uygun restoratif çözümler için birçok malzeme bu sistemlerle kullanılmak üzere piyasada mevcuttur. Bu derlemede, en güncel malzemeler olan nanoseramikler ve hibrid malzemeler incelenmekte, mekanik özellikleri, avantajları ve dezavantajları değerlendirilmekte ve piyasada mevcut ürünler belirtilmektedir.

Anahtar kelimeler: CAD/CAM, nanoseramik, hibrid

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INTRODUCTION

Currently, various restorative materials are used with CAD/CAM systems. Glass ceramics are often preferred especially in anterior restorations according to their high aesthetic characteristics.[2, 11-14, 19] The mechanical properties of glass-ceramics can be improved using different methods.[27, 33-35] Furthermore, alternative materials that have proper characteristics of ceramics are also improved. Nanoceramics and hybrid ceramics were developed to combine the favorable properties of ceramics and composites. The aim of this review is to give information about newly developed nanoceramic and ceramic hybrid materials used with CAD/CAM systems.

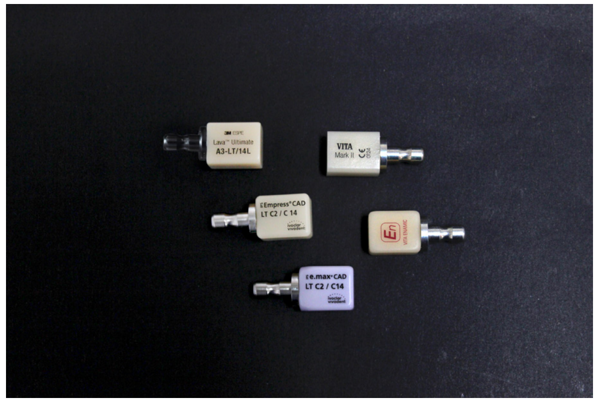

Figure 1: CAD/CAM block samples: LAVA Ultimate (Nanoseramic), Vita Mark II (Feldspathic ceramic), IPS Empress CAD(leucite reinforced), Vita Enamic (ceramic-composite hybrid) ve IPS e.max CAD(lithium disilicate).

Nanoceramics (Resin nanoceramics)

Recently, silica based ceramics are frequently used with CAD/CAM systems in consequence of their unique aesthetic properties. Feldspathic ceramics and leucite reinforced glass ceramics has not only high esthetical properties but also low fatigue resistance.[4, 22] Due to the poor mechanical characteristics of glass ceramics, composite-based restorative materials are preferred instead.[15, 17] Composite-based restorative materials' elastic modulus value is close to tooth and they both have similar occlusal force absorption capacity. However, composite material undergoes more surface wear due to the inadequate hardness, for this reason the surface polish has not last longer.[12, 16] Therefore, favorable properties of composites and ceramics were integrated using nanotechnology and developments in the production of new dental restorative materials shows remarkable progress (Figure 1).

The science of controlling matter on the atomic and molecular level is named as nanotechnology. Particle size of the materials and chemical properties can be changed by nanotechnology.[28] The chemical reactivity of the material increases whenever the particle size of materials reduced to nanoscale dimensions.[7]

Nanoceramics are comprised of nano-sized ceramic particles, Bis-GMA, UDMA, Bis-EMA and TEGDMA containing resin matrix. The structure of the matrix consists of 20 nm in diameter silica nanomers and 4-11nm in diameter zirconia nanomers. Silane molecule joined in the structure during production of the blocks and provides the formation of chemical bonds between the resin matrix and the nano-structure.[15]

Silane is a bifunctional molecule and capable of forming chemical bonds between the organic (resin based materials) and inorganic (ceramic and oxidized metal alloys) materials.[25, 26] Constituent particle of the silane molecule is 3-methacryloxy propyl-trimetoksisilan. Silane molecule contains two different chemical structures including methacrylate and methoxy groups. While methacrylate group is connecting organic matrix of the resin structure, methoxy group forms a chemical bond with the ceramic structure.[1]

Nanoceramics are composed of 80% ceramics and 20% resin materials. It is stated that, a high proportion of nanoparticles embedded in resin matrix enables the material abrasion and fracture resistant. Nano-sized structure of the ceramics also strengthens chemical bonds formed between inorganic ceramics and organic resin matrix. The dimensions of nanoparticles are ranged between 0.6-1 micrometers.[24]

The modulus of elasticity is defined as the measure of elastic deformation of the material under stress. The elastic moduli of restorative materials used in dentistry have to be compatible with elastic modulus of tooth. This compatibility has a positive impact on the long-term success of the restorations.[3, 21]

It is stated that, concordant elastic modulus value of tissues and nanoceramics prevents material from fractures and provides long-term of success in high rates. The minimum thickness of the nanoceramic restorations has to be at least 1mm in order to exhibit sufficient fracture resistance against occlusal forces.[6, 15] However, hardness value of nanoceramics is compatible with tooth, for this reason, the amount of wear on the opposing teeth formed quite low. Additionally, ceramic material in the structure provides high color stability when compared to the composite materials. Simple surface finishing process and long-term survive of polished surfaces were reported as a major advantage of nanoceramic materials.[5, 30]

Recent developments in the field of dental technology enable treatment of edentulous regions with dental implants. Dental implants have proper features like, giving any damage to adjacent tissues, increasing the chewing efficiency, fulfilling the esthetic and phonation. However, one of the most important disadvantages of the implants is inability to form periodontal ligament.[18] Periodontal ligaments are located between the root surface and alveolar bone; and ligaments absorb chewing forces, and distribute them to the alveolar bone.[42] Therefore, choosing force-absorbing featured restorative materials in the production of implant prosthesis is very important.[29] It was stated that the force-absorption capacity of the nanoceramics was higher than traditional ceramics used in the fabrication of implant prosthesis.[24]

Lava Ultimate (3M ESPE, USA) is in the group of nanoceramics and used in conjunction with CAD/CAM systems. As a reason of the strong chemical bonds formed between nanoceramic structure and resin, the material has high fracture strength. Besides, flexural strength of the material is 200 MPa. Lauvahutanon and et al. reported the elastic moduli of Lava Ultimate as 29.8 GPa and stated that this value is very close to the dentin.[23] For this reason, it was thought that force-absorbing property of the material is high enough and this allows fabrication of posterior nanoceramic restorations.[24, 29]

Inlay, onlay, laminate veneers and crown restorations can be manufactured with Lava Ultimate blocks. Adhesive bonding systems are recommended in the cementation of restorations that fabricated with this system. In contrast to conventional adhesive cementation technique the inner surface of the restoration that fabricated with this system does not require hydrochloric acid etching. Sand blasting technique is more proper to roughen the inner surface of the restorations.[6, 24]

Lava Ultimate has high translucent (HT) and low translucent (LT) blocks, and each block has 8 different shades (A1, A2, A3, A3.5, B1, C2, D2 and Bleach). In order to produce larger restorations in 14 L-size blocks are also available.[24]

Hybrid ceramics (Polymer infiltrated glass-ceramics)

Materials consisting of two penetrated phases have higher flexural strength when compared to the single-phase materials.[32, 37, 39] Hybrid ceramics was developed according to this this idea. Hybrid ceramics are formed by a combination of inorganic and organic components. Inorganic and organic structures were consisting of ceramics and polymers, respectively.

Composite materials contain inorganic filler particles and organic matrix. However, unlike composites, inorganic filler particles and organic matrix penetrated to each other in hybrid ceramics. For this reason, the mechanical property of the material was improved. A crack occurred in the ceramic phase could be prevented by the polymer structure of the material. Chemical structures of the hybrid ceramics provide occlusal forces to spread from contact points to a wide area and reduce the stress. The occlusal load-compensation capacity of hybrid ceramic is higher than traditional ceramics.[8, 9, 10]

Hybrid ceramics contains 86% of ceramics and 14% of polymer. Ceramic structure includes, 58-63% SiO_2, 20-23% Al_2O_3, 9-11% Na_2O, 4-6% K_2O, 0.5-2% B_2O_3 and less than 1% ZrO2 and CaO. Resin structure was composed of urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (EGDMA).[40]

Primarily, the pre-sintered porous structured feldspathic ceramics are produced. Changing size of the ceramic particles and firing temperature affects the porosity of the ceramic structure. In the second stage, porous ceramic structure is filled with resin. Prior to the infiltration of the resin structure into the ceramic structure silane is added as a bonding agent. The chemical bond between polymer structure and ceramic structure is occurred due to the silane.

Vita Enamic (VITA Zahnfabrik, Germany) is placed in the hybrid ceramics group and flexural strength, elastic modulus and stiffness (hardness) of the material is, 150-160 MPa, 30 GPa and 2.5 GPa, respectively.[40] Elastic modulus value of Vita Enamic is 30 GPa and material exhibits similar elastic properties like teeth.[9, 40]

Hardness value of hybrid ceramics were lower than silica-based ceramics, therefore hybrid ceramics cause less wear than traditional ceramics. Moreover, due to the low hardness of the hybrid ceramics, the amount of material lost by wear over time is more than traditional ceramics.[8, 30, 31]

Vita Enamic allows producing inlays, onlays, laminate veneers, crowns and anterior-posterior restorations. The material has high translucent (HT) and low translucent (T) blocks and for all groups totally 10 shade (OM1, 1M1, 1M2, 2M2 and 3M2) options are available. In the production of laminate veneers and anterior restorations HT blocks are recommended, however, in the restorations of discolored teeth T blocks are recommended. Additionally, 14L sized blocks are also available for larger restorations.

The restorations obtained from Vita Enamic block must be cemented with adhesive bonding systems. In contrary to nanoceramics, the inside of the hybrid ceramic restorations are etched with hydrofluoric acid in the concentration of 5% applied on the surface for 5 minutes.[38, 40]

Zirconia reinforced lithium disilicate ceramics

Currently, widespread use of the CAD/CAM systems leads up various materials with improved mechanical and aesthetic properties. Lithium disilicate reinforced glass ceramic blocks were the first blocks used in CAD/CAM systems and recently, lithium disilicate reinforced glass ceramics were used as a basis to develop zirconia infiltrated lithium disilicate ceramic blocks. Ceramic structure is composed of, 56-64% SiO_2, 15-21% Li_2O, 1-4% K_2O, 3-8% P_2O_5, 1-4% Al_2O_3, and 8-12% ZrO_2 materials.

Zirconia reinforced lithium disilicate ceramics allow the manufacture of inlays, onlays, crowns, partial crowns and laminate veneers. Additionally, more esthetic restorations can be obtained with cut back technique.

Vita and Dentsply, introduced zirconia reinforced lithium disilicate glass ceramic blocks in 2013. The brand name of zirconia reinforced lithium disilicate glass ceramic block of Vita is Vita Suprinity (Figure 2).

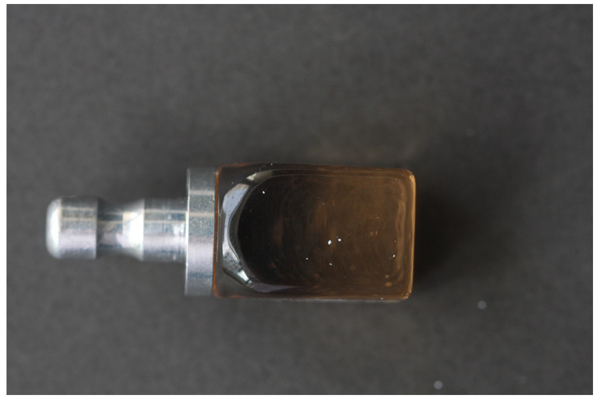

Figure 2: Vita Suprinity block.

The material has translucent (T) and high translucent (HT) blocks.[41, 43] The brand name of zirconia reinforced lithium disilicate glass ceramic block of Dentsply is Celtra CAD. The material has low translucent (LT) and high translucent (HT) blocks.

CONCLUSIONS

Nanoceramics and ceramic-composite hybrids are recently introduced in prosthetic and restorative dentistry, and these materials have a potential success in clinical use.

In-vivo and in-vitro studies evaluating clinical use of lithium disilicate ceramics and leucite-reinforced ceramics are in progress.

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