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Reinforcement of All Ceramic Dental Materials

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ABSTRACT

A prosthetic dentistry is a branch of dentistry that replaces missing teeth with artificial components made of various materials. Almost universally, unexpected dental structure loss, particularly anterior teeth, results in physical and functional difficulties and frequently psychological and social disorders. Ceramics were initially used as material for restoration in dentistry during the late 1700's; owing to their ability to imitate the appearance of the normal teeth, since alexis duchateau's initial use of porcelain to create a complete denture in 1774, various dental porcelain compositions have been produced.

Key words: Prosthetic dentistry, Teeth, Artificial components, Porcelain, Restoration

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INTRODUCTION

Ceramic crowns have historically been constructed on a platinum matrix and were known as porcelain jacket crowns, while Porcelain Fused to Metal (PFM) restorations comprise a metal coping that supports the ceramic on top [1]. One drawback of PFM Fixed Partial Denture (FPD) is that it cannot transmit light, which has a detrimental influence as darkening the restoration's aesthetic result [2]. The primary drawback of early all ceramic restorations was their weakness, which limited their use to low stress conditions such as those faced by anterior teeth; this prompted the creation of materials with increased strength. These advances have taken two distinct courses, the first method of fabricating the repair is to employ two high strength materials, but the unattractive ceramic core is veneered with lower strength but more attractive porcelain. The alternative strategy is to produce a ceramic that is both aesthetically pleasing and extremely strong; this has the advantage of eliminating the requirement for additional material thickness to conceal a high strength core [3].

MATERIALS AND METHODS

Ceramic prostheses' fracture resistance can be enhanced by one or more of the following methods:

- Choose ceramics that are stronger and more durable.
- Create residual compressive stresses within the material's surface through thermal tempering and ion exchange.
- Produce residual compressive stress within interfacial regions of weaker, less robust ceramic layers by suitably matching thermal expansion and contraction coefficients.
- Reduce the tensile stress in the ceramic through using stiffer supporting materials (greater elastic moduli).
- Design the ceramic prosthesis with greater bulk and broader radii of curvature for connectors in areas of potential tensile stress [4].

Ceramics fundamentals

Ceramics are a family of hard materials; have lower toughness than metals; are stiff; and are poor thermal and electrical conductors. They may be cast or machined to create dental restorations. A dental ceramic's translucency and opacity can be customized. When compared to metals or polymers, ceramics usually exhibit minimal plastic activity and are hence termed brittle. Their stress strain curves are typically linear and do not exhibit plastics strain [5].

Restorations made entirely from ceramic

The ceramic material used in an all ceramic repair might be monolithic (one layer) or bi-layered; the bi-layered ceramic restoration's ceramic core gives structural support and strength, while the veneer provides final shape, shade and beauty. In contrast, the core may contribute to the final repair's shadow development; delamination and breaking of the veneer core connection are restorations' weakest areas [6]. On the other side, monolithic restorations are more durable than bi-layered restorations since they are composed of a single ceramic material [7].

Composition based classification: Ceramics are divided into three groups based on their composition these are mainly formed from glass, particle filled glass and polycrystalline ceramics [8].

Classification according to the technique of processing: Includes; powder/liquid construction, slip casting, hot ceramic pressing and CAD/CAM.

Classification by microstructure: Involved; leucite based ceramics, alumina based ceramics, lithium disilicate based ceramics and zirconia ceramics.

RESULTS AND DISCUSSION

A recent method of classification for all ceramic and ceramic like materials depending on the chemical phase (s) they contain; glass matrix ceramics have a glass phase, polycrystalline ceramics contain just a crystalline phase and "resin matrix ceramics" encompasses materials with a polymer matrix and a high concentration of inorganic refractory substances (Table 10) [10].

Table 1: Comparisons of the different all ceramic systems available.

Crystalline phase	Leucite	Leucite	Lithium di silicate	Zirconia
Strength	Medium/low	Medium/low	High	Very high
Recommended usage	Inlay, on lay, crown, veneers	Inlay, on lay, crown, veneers	Anterior three unit FPDs, crowns	Posterior crowns and FPDs
Translucency	Medium	Medium	Medium	Low
Manufacture	Dent mat	Ivoclar viva dent	Ivoclar viva dent	Glide well laboratories

Techniques for reinforcing dental ceramics

Micro cracks and porosity caused by manufacturing errors and inadequate thermal dilatation parameters lead to mechanical failure in porcelain repair [11]. This needs a way to prevent these micro cracks from developing and propagating in dental ceramics to enhance their mechanical strength. Ceramic structures should be supported by metal or more robust substructures that mitigate the impacts of tension strength on the surface; alternatively, they should be strengthened structurally directly [12].

Thermal strengthening

When glasses are gently cooled below their melting point, the tension strengths created in the glasses dissipate. However, if it is abruptly cooled, the interior structure in its soft state transforms into a rigid surface layer. Tensions created inside the structure are captured. For instance, if cold air is repelled from a melted surface, the entire structure shrivels equivalently; the tensions generated by this shriveling act as a barrier to external pressures. Thermal reinforcement is predicated on this idea [13].

Strengthen through the method of controlled crystallization

When glass is heated to a specific temperature and then cooled to room temperature, it does not crystallize under normal conditions. This process involves heating the ceramic structure to the softening temperature. Internal crystals are formed and grow in size during this treatment. Then, as a result of nucleation, little crystals spread uniformly. Crystallization occurs more readily as the temperature rises. The quantity and size o f crystals formed depend on the temperature and duration of application. Due to the aesthetic drawbacks, this is not a favored approach [14].

To reduce tension stress through the use of an optimal restorative design by avoiding restorations with sharp edges and visible thicknesses, the most effective method of reducing bridge tensile strength is to create connection zones that are subjected to severe stress and have a suitable thickness and form [15].

Exchange of ions

The ion exchange process aims to build a compressive layer on the ceramic's surface at a low temperature. This compressive layer is produced by exchanging specific ions with larger ions in the glass matrix. Dental ceramic material is immersed in a melted potassium nitrate salt tank at a lower temperature than the glass transition, The Na^+ ions on the surface of the dental ceramic exchange place with the K^+ ions in the salt tank. Potassium ions, larger than sodium ions, create compression power when they compress on a silicate system, on the other side, a surface that has been reinforced *via* the ion exchange approach is not sufficiently deep and 100 μm depth erosion allows it to regain its previous strength level [16].

Distribution of crystals inside the glass phase

Glass dental ceramics can be reinforced by increasing their crystal content, such as leucite, lithium disilicate, alumina, magnesia alumina, spinel and zirconia [17]. In summary, crystal particles prevent micro fractures from propagating and create a more robust structure. This degree of endurance is dependent on the kind, size, spacing between particles and perimeter of heat expansion.

Transformation saturation

The "saturation" refers to the quantity of energy absorbed during a micro fracture push [18]. Change saturation is a physical phenomenon that occurs due to a phase transformation induced by tension strength. It reduces the pushing force exerted by micro fractures in all materials, to reinforce the ceramic using the transformation saturation technique; we mainly employ leucite and zirconium. Temperature variations in the ceramic material are critical in this technique. Thermal changes increase leucite and zirconium in the glassy phase, which causes pressure strains inside the structure. Pressures prevent micro fractures from propagating and reduce tension strains at the micro fracture's peak [19]. Crack shielding occurs due to the regulated transition of the metastable tetragonal phase to the stable monoclinic phase.

Reinforced ceramic substructures

These ceramics are utilized for substructures and coated with ceramics for aesthetic purposes:

- **Aluminosis sub structured ceramics:** This ceramic is composed of feld spathic glass that contains between 40% and 50% alumina [20]. Hi-Ceram is an excellent illustration of this category.
- **Glass in filtered aluminos is sub structured ceramics:** Slip casting alumina powder over a heat resistant stump is used to create the substructure ceramic. After the plaster stump absorbs the water, we sinter it for 10 hours at 1120°C to create a porous structure and then we infiltrate lanthanum oxide glass into this porous structure and repeat the sinterization process for 4-6 hours at 1100°C. Glassy porous material fills in the cracks in the alumina framework, increasing flexion resistance [21]. This group is represented by In-Ceram.
- **Substructures of pure alumina:** This system is based on CAD/CAM technology. A computer aided analysis is used to evaluate the models and then metal stumps are created taken account for alumina's sinterization shrinkage. Then, high purity aluminum oxide powder is crushed onto metal stumps. The resulting substructures are sinterized for 1 hour at 1550°C [22]. PrSocera serves as an excellent example of this category.

Glass ceramics

- **Leucite strengthened feld spathic glass ceramics:** The amount of leucite in porcelain is related to the fracture propagation strength. Increased leucite concentration results in a higher reduction in fracture propagation [23]. The leucite crystals function as barriers, reducing the tensile stresses that might result in micro cracks development. This ceramic may be pressed directly onto a metal coping or utilized as an all ceramic crown [24]. IPS empress serves as an excellent example of this category.
- **Lithium disilicate glass ceramics:** This ceramic material includes 70% lithium disilicate crystals, it has an enhanced flexural strength of about 360 MPa (milled version) to 400 MPa (hot pressed version) and the strength enhancement is due to the lithium disilicate's unusual microstructure, which consisting of tiny randomly arranged platform crystals [25]. Cracks deflect, branch or blunt due to the lithium disilicate crystals, which halts fracture growth [26]. Empress 2 is an excellent example of a glassy matrix.
- **Apatite based glass:** Synthetic hydroxyapatite is the most accurate substance for replicating the natural tooth structure. Also refers to it as molding apatite. A perfect example is hydroxyapatite cerapearl.

Fluoromica glass ceramics

The composition of fluoromica glass ceramics is 45% glass and 55% tetracyclic mica crystals. Mica crystals produce a flexible substance and have more penetration of the surface. Additionally, they build resistance to breakage incidents [27]. Dicor is an excellent illustration of this concept.

Zirconium oxide substructure system

A distinctive property of zirconia is its ability to halt the propagation of cracks, a process known as "transformation toughening". Subsequent fracture creates tensile stresses, which result in a transition from a tetragonal to a monoclinic structure and a localized volume increase of 3% to 5%. This volume increase leads to a shift in the stresses created around the fracture tip from tensile to compressive. Compressive forces balance the external tensile pressures and prevent the fracture from progressing further [28]. Cerconve zirkonzahn is excellent example.

Nano ceramics

Nanotechnology enables the modification of the particle size and chemical characteristics of materials. When the particle size is lowered to nano scale levels, its chemical reactivity rises [29]. Nano ceramics are made up of nano sized ceramic particles and a resin matrix comprising bisphenol A-Glycidyl Methacrylate (Bis-GMA), Urethane Dimethacrylate (UDMA), Bis-EMA and Triethylene Glycol Dimethacrylate (TEGDMA). The matrix comprises silica nanoparticles with a diameter of 20 nm and zirconia nanoparticles with a diameter of 4-11 nm. The silane molecule is incorporated into the structure during the block manufacturing process and forms chemical bonds between the resin matrix and the nanostructure [30].

Nano ceramics are made up of 80% ceramic and 20% resin components. According to the manufacturer, a large concentration of nanoparticles incorporated in the resin matrix makes the material resistant to wear and fracture. Additionally, the nanoscale structure of the ceramics reinforces chemical connections created between the inorganic ceramics and the organic resin matrix [31].

Recent advancements in dental technology allow for the treatment of edentulous areas with dental implants [32]. It is critical to select force absorbing restorative materials when fabricating implant prostheses [33]. It was reported that nanoceramics absorbed more force than conventional ceramics utilized in the production of implant prostheses. Lava ultimate (3M ESPE, USA) is a nanoceramic used in CAD/CAM systems [34]. The material's force-absorbing capability is high enough to fabricate posterior nanoceramic restorations.

Polymer infiltrated glass ceramics or hybrid ceramics

Two penetrating phase materials have stronger flexural strength than single phase materials [35]. This idea led to hybrid ceramics. Inorganic (ceramic) and organic (polymers) components combine to produce hybrid ceramics. Inorganic filler particles with an organic matrix are used to create composite materials. Unlike composites, hybrid ceramics allowed inorganic filler particles and organic matrix to interact. As a result, the material's mechanical properties improved. The chemical structure of hybrid ceramics allows occlusal pressures to spread widely and minimize stress. Hybrid ceramics can compensate for more occlusal loads than conventional ceramics [36]. Hybrid ceramics have a lesser hardness than silica based ceramics; thus, they are causing wear less than conventional ceramics. Due to their poor hardness, hybrid ceramics lose more material than conventional ceramics over time [37].

Lithium disilicate ceramics with zirconia reinforcement

The extensive usage of CAD/CAM technologies now leads to enhanced mechanical and aesthetic qualities. CAD/CAM systems started with lithium disilicate reinforced glass ceramic blocks, then utilized to produce zirconia infiltrated lithium disilicate ceramic blocks. Ceramics include this ceramic may be used to make inlays, on lays, partial crowns and laminate veneers. In 2013, the introduction of zirconia reinforced lithium disilicate glass ceramic blocks was developed by vita and dentsply. Vita suprinity is the brand name of zirconia reinforced lithium disilicate glass ceramic block [38,39].

CONCLUSION

This review study revealed the development of all ceramic restorative materials and their applications, current limitations and the challenges which still need to be tackled. As seen, there is no single material and/or system that possess all the characteristics of ceramic existing in clinical situations. The following most relevant

Conclusions can be drawn:

- Ceramics offer reliable esthetic alternative to restore the missed or esthetically compromised teeth.
- Feld spathic glass ceramic have high esthetic and low mechanical properties.
- Increasing crystalline phase increases the mechanical properties of the dental ceramics but on the expense of esthetics.
- Creation of materials with increased strength by two methods which might be monolithic (one layer) or bi layered techniques.
- A surface reinforcement *via* ion exchange approach was not sufficiently deep.
- Thermal strengthening reach deeper in ceramic materials. But the difficulty in cooling rate control is one of disadvantages of this method.
- Strengthen through the method of controlled crystallization, due to the aesthetic drawbacks was not a favored approach.
- Mechanical properties of leucite reinforced glass ceramics were higher than feld spathic porcelains, used in veneers over crystalline ceramic substructure, inlays and on lays, anterior crowns.
- Nanoceramic restorations have higher force absorbing capability than conventional ceramics.
- Hybrid ceramics lose more material than conventional ceramics over time.
- Lithium disilicate reinforced glass ceramics can be employed as a monolithic or substructure.
- The mechanical properties of zirconia reinforce lithium disilicate glass ceramic higher than lithium disilicate ceramics.
- Reinforced ceramic substructures are stronger than conventional ceramic; these ceramics are utilized for substructures and coated with ceramics for aesthetic purposes.
- Zirconia ceramics can be employed as a monolithic or substructure due to transformation saturation properties.

REFERENCES

1. Denry I, Holloway JA. Ceramics for dental applications: A review. Materials 2010; 3:351-368.
2. Sharkey S. Metal ceramic versus all ceramic restorations: Part III. J Ir Dent Assoc 2011; 57:110-113.
3. Mehra M, Vahidi F. Complete mouth implant rehabilitation with a zirconia ceramic system: A clinical report. J Prosthet Dent 2014; 112:1-4.
4. Anusavice KJ, Shen C, Rawls HR. Phillips' science of dental materials. Elsevier Saunders Co, 12th edition, St. Louis, United State, 2013; 418-473.
5. Sakaguchi R, Powers J, Ferracane J. Craig's restorative dental materials. Elsevier, United State, 14th edition, United State, 2018.
6. Rekow ED, Silva NRFA, Coelho PG, et al. Performance of dental ceramics: Challenges for improvements. J Dent Res 2011; 90:937–952.
7. Holden JE, Goldstein GR, Hittelman EL, et al. Comparison of the marginal fit of pressable ceramic to metal ceramic restorations. J Prosthodont 2009; 18:645-648.
8. Mclaren EA, Cao PT. Ceramics in dentistry part I: Classes of materials. Inside Dentistry 2009; 5:94-105.
9. Rosenstiel SF, Land MF, Junhei Fujimoto J. Contemporary fixed prosthodontics. Elsevier Inc, 4th Edition, St. Louis, 2016; 674-692.

10. Gracis S, Thompson VP, Ferencz JL, et al. A new classification system for all ceramic and ceramic like restorative materials. Int J Prosthodont 2015; 28:227-235.
11. Aksoy G. The importance of dental ceramics in glazer layer. J Ege University Faculty Dent 2003; 24:103-111.
12. Atala MH, Gul E. How to strengthen dental ceramics. Int J Dental Sci Res 2015; 3:24-27.
13. Anusavice KJ, Shen C, Lee RB. Strengthening of feld spathic porcelain by ion exchange and tempering. J Dent Res 1992; 71:1134-1138.
14. Yavuz O. Seramometal restoration of the fracture resistance of all ceramic crowns and fracture resistance of comparative investigation. Doctorate Thesis, Ege University, Izmir. 1996.
15. Anusavice KJ, Philips RW, Rawls HR. Phillips' science of dental materials. Elsevier Health Science, 11th edition, Saunders St Louis, United State, 2012.
16. Zaimoglu A, Can G. Dental ceramics: Part I an overview of composition, structure and properties. Fixed prosthodontics. Ankara: Ankara University Publishing, Turkey, 2011; 139-159.
17. Crispin BJ. Contemporary esthetic dentistry. Practice fundamentals. Implant Dentistry 1995; 4:67-68.
18. Gogotsi GA. Criteria of ceramics fracture (edge chipping and fracture toughness tests). Ceram Int 2013; 39:3293-3300.
19. Eroglu Z. *In vitro* comparison of fracture strength of galvano ceramic, metal ceramic and all ceramic 3 unit bridge. Doctorate Thesis, Erciyes University, Kayseri. 2010.
20. Claus H. Vita in-ceram, a new system for producing aluminum oxide crown and bridge substructures. Quintessenz Zahntech 1990; 16:35-46.
21. Conrad HJ, Seong WJ, Pesun IJ. Current ceramic materials and systems with clinical recommendations: A systematic review. J Prosthet Dent 2007; 98:389-404.
22. O'Brian WJ. Dental materials and their selection. Quintessence Publishing, 4th edition, Canada, 2002.
23. Cesar PF, Gonzaga CC, Miranda JWG, et al. Correlation between fracture toughness and leucite content in dental porcelains. J Dent 2005; 33:721-729.
24. Ohyama T, Yoshinari M, Oda Y. Effects of cyclic loading on the strength of all ceramic materials. Int J Prosthodont 1999; 12:28-37.
25. Chen YM, Smales RJ, Yip KH, et al. Translucency and biaxial flexural strength of four ceramic core materials. Dent Mater 2008; 24:1506-1511.
26. Shenoy A, Shenoy N. Dental ceramics: An update. J Conserv Dent 2010; 13:195-203.
27. Yavuzyılmaz H, Turhan B, Bavbek B, et al. All porcelain systems I. J Gazi Univ Fac Dent 2005; 22:41-48.
28. Helvey GA. Zirconia and Computer Aided Design/ Computer Aided Manufacturing (CAD/CAM) dentistry. Inside Dent 2008; 4:72-79.
29. Melo MAS, Guedes SFF, Xu HHK, et al. Nanotechnology based restorative materials for dental caries management. Trends Biotechnol 2013; 31:459-467.
30. Guth JF, Zuch T, Zwinge S, et al. Optical properties of manually and CAD/CAM fabricated polymers. Dental Mater J 2013; 32:865-871.
31. Patterson Dental. Lava ultimate restorative brochure. 2011.
32. Yoshida N, Koga Y, Peng CL, et al. *In vivo* measurement of elasticlic modulus of the human periodontal ligament. Med Eng Phys 2001; 23:567-572.
33. Mihali S, Bortun C, Bratu E. Nano ceramic particle reinforced composite-lava ultimate CAD/CAM restorative. Rev Chim 2013; 64:435-437.
34. Lauvahutanon S, Takahashi H, Shiozawa M, et al. Mechanical properties of composite resin blocks for CAD/CAM. Dent Mater J 2014; 33:705-710.
35. Wegner LD, Gibson LJ. The fracture toughness behavior of interpenetrating phase composites. Int J Mech Sci 2001; 43:1771–1791.
36. Coldea A, Swain MV, Thie N. Mechanical properties of polymer infiltrated ceramic network materials. Dent Mater 2013; 29:419-426.
37. Nguyen JF, Ruse D, Phan AC, et al. High temperature pressure polymerized resin infiltrated ceramic networks. J Dent Res 2014; 93:62-67.
38. Vita suprinity. Technical and scientific documentation. 2013.
39. Zimmermann M, Mehl A, Reich S. New CAD/CAM materials and blocks for chair side procedures. Int J Comput Dent 2013; 16:173-181.