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Zirconia as A Core Material - A Literature Review

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Abstract: Teeth that have become severely compromised by decay, large failing restorations, or fracture most often require full-coverage crowns to restore them to their original form and function. A core buildup is a restoration placed in a badly broken down or grossly decayed tooth to restore the bulk of the coronal portion of the tooth. This facilitates the subsequent restoration by means of an indirect extra coronal restoration. The strength of the tooth can be enhanced with intracoronal support. It should have compressive strength to resist intraoral forces and flexural strength to prevent core dislodgement during function. It should also have sufficient flexural strength, biocompatibility, resistance to leakage of oral fluids at the core-tooth interface, ease of manipulation, and ability to bond to remaining tooth structure. The primary purpose of a core build- up is to replace enough missing tooth structure to permit the creation of ideal retention and resistance form in the crown preparation. Materials used for core restoration after endodontic treatment include amalgam, resin composites, zirconia to name a few. The aim of this review is to evaluate the use of zirconia as a core material by assessing the studies available in comparison to other core materials.

Keywords: core, material, literature

INTRODUCTION

Teeth that have become severely compromised by decay, large failing restorations, or fracture most often require full-coverage crowns to restore them to their original form and function(Gupta *et al.*, 2014; Suksaphar *et al.*, 2017). Clinicians must then evaluate whether there is enough structural integrity remaining to support a definitive crown by a core build-up alone, or use an endodontically retained post to secure the core foundation to the root('Indirect composite partial coverage crowns to restore anterior teeth', 2005; Owen and Barber, 2018).

A core buildup is a restoration placed in a badly broken down or grossly decayed tooth to restore the bulk of the coronal portion of the tooth(Yadav, Kumar and Gupta, 2012). This facilitates the subsequent restoration by means of an indirect extra coronal restoration(Mohapatra *et al.*, 2016). The strength of the tooth can be enhanced with intracoronal support(Bass, 2002). A core restoration provides satisfactory strength and resistance during crown preparation and impression procedures(Iftekhar, 2019). This contributes to the retention and support of the temporary crown and in long term the definitive restoration(Motlani, Jaiswal and Jain, 2016). The primary purpose of a core build- up is to replace enough missing tooth structure to permit the creation of ideal retention and resistance form in the crown preparation(Chandra, 2007).

The core material should have compressive strength to resist intraoral forces and flexural strength to prevent core dislodgement during function. It should also have sufficient flexural strength, biocompatibility, resistance to leakage of oral fluids at the core-tooth interface, ease of manipulation, and ability to bond to remaining tooth structure(Levartovsky *et al.*, 1994; Jayanthi and Vinod, 2013). Materials used for core restoration after endodontic treatment include amalgam, resin composites, zirconia to name a few.

In endodontically treated teeth, a core buildup is usually retained by a combination of posts, tooth preparation features or a bonding system(Kumar, Pal and Pujari, 2015). With the proliferation of high translucency ceramics for fixed prosthodontics clinicians have placed increasing importance on the esthetic qualities of post and core materials(Kosmač *et al.*, 2002). Many dentists have moved away from dark cast metal posts and cores in favor

of white or translucent fiber or ceramic posts. With esthetics as the primary goal, a wide variety of core materials with disparate properties are used by clinicians in the restoration of endodontically treated teeth(Nalliah, 2015).Our team has rich experience in research and we have collaborated with numerous authors over various topics in the past decade (Deogade, Gupta and Ariga, 2018; Ezhilarasan, 2018; Ezhilarasan, Sokal and Najimi, 2018; Jeevanandan and Govindaraju, 2018; J *et al.*, 2018; Menon *et al.*, 2018; Prabakar *et al.*, 2018; Rajeshkumar *et al.*, 2018, 2019; Vishnu Prasad *et al.*, 2018; Wahab *et al.*, 2018; Dua *et al.*, 2019; Duraisamy *et al.*, 2019; Ezhilarasan, Apoorva and Ashok Vardhan, 2019; Gheena and Ezhilarasan, 2019; Malli Sureshbabu *et al.*, 2019; Mehta *et al.*, 2019; Panchal, Jeevanandan and Subramanian, 2019; Rajendran *et al.*, 2019; Ramakrishnan, Dhanalakshmi and Subramanian, 2019; Sharma *et al.*, 2019; Varghese, Ramesh and Veeraiyan, 2019; Gomathi *et al.*, 2020; Samuel, Acharya and Rao, 2020)
The aim of this review is to compare zirconia as a core with other commonly used core materials .

Core Materials
Although a variety of core materials are available, the materials discussed here are amalgam, composite and zirconia.
Amalgam has been used successfully for many years, as it exhibits high strength and low solubility. Its coefficient of thermal expansion is similar to that of a tooth. Amalgam exhibits the great compressive strength (65,000 PSI), and has a safe, successful clinical history(Arcoria *et al.*, 1989). The marginal adaptation that occurs through condensation improves with the deposition of corrosive products. An added advantage is that these corrosive products are naturally bacteriostatic. Both mechanical tests and finite element analyses have indicated that amalgam cores have superior performances in comparison to resin composite cores(Kovarik, Breeding and Franklin Caughman, 1992; Huysmans, M.C.D.N.J.M. Huysmans and Van der Varst, 1993; Huysmans, Marie-Charlotte D N J and van der Varst, 1995).
The disadvantage of silver amalgam is that the dentist should wait 24 hours after restoring a tooth before preparing it for a cast restoration. Preparation of a tooth containing an amalgam buildup before complete set of the amalgam may result in a fracture or weakening of the core. It can be challenging in severely damaged teeth(Bowen, 1963, 1964). Retention is with slots, grooves, or undercuts that require more invasive preparations compared to adhesive alternatives(Saygılı and Şahmalı, 2002). When pins are used to retain amalgam cores they do not reinforce the amalgam in compression and they weaken it in tension. Aso these pins can lead to crack propagation and iatrogenic penetration into vital pulp spaces(Going *et al.*, 1968). It is also not esthetically pleasing, especially when compared with all-ceramic restorations(Frejlich and Goodacre, 1992).
Silver alloy powder is added to a type II restorative glass ionomer cement powder. When this is mixed, an admixture with polyacrylic acid liquid was intended to make this first metal- reinforced glass ionomer cement radiopaque and harder. This was called miracle mix(Simmons, 1990). According to Ali et al, Miracle Mix had more fracture resistance followed by Composite and reinforced GIC. However esthetics was poor and the strength was not comparable to that of amalgam(Ali *et al.*, 2015).
Composite resin has many desirable properties combined into one material. They have adequate strength, and are easy to handle. They can be bonded to the tooth structure. Hence, they are one of the commonly used materials for core build up(Yavirach *et al.*, 2009; Stewardson, Shortall and Marquis, 2012; Nagasawa *et al.*, 2017). Their compressive strength is comparable to amalgam cores, approximately 45,000 PSI(Jayanthi and Vinod, 2013; Mádi, Varga and Mikó, 2017). Fluoride releasing composites are also available. Apart from esthetics, resin composite cores have a number of advantages over amalgam(Garg and Garg, 2010). Due to the immediate polymerization, teeth can be prepared for a crown restoration at the same appointment. Resin composites can also be bonded to dowels and crowns whenever appropriate bonding techniques are used(Kupiec, 1999; Lin *et al.*, 2020).
They, however, have a tendency to absorb moisture(Hirasawa *et al.*, 1983). This, in the oral environment, is saliva along with its microbes(Hirasawa, 1965). A common finding is an odor that frequently occurs when a crown built over a composite resin core is accessed for endodontic treatment. This odor originates from salivary bacteria that have permeated the composite material(Misra and Bowen, 1977). Unlike amalgam, most composite resin cores are not condensable, and their interface with tooth structure is at its optimum level upon placement(Yüzügüllü *et al.*, 2008). They also have a higher coefficient of thermal expansion relative to that of enamel and an increased risk of possible contamination by eugenol containing provisional cements(Oliva and Lowe, 1986).
Both dual-cure and light-cure formulated composite resins are available. These are specifically designed for core build-ups. The flowable consistency of the dual-cure composite core systems allow for easy adaptation to irregular preparations and endodontic posts(Ritter, Ghaname and Pimenta, 2013).They, however, can be difficult to manipulate and contain when crown-forms or band retainers are not used. Other disadvantages of dual-cure core composite materials are the potential of trapping air while dispensing, and limited working time. The trapped air creates voids(Tay *et al.*, 2003).

Light-cure-only core materials, however, can be condensed and sculpted to the desired form. They have nearly unlimited working time. The primary concern with light-cure-only core materials is the depth of cure(Park, Chae and Rawls, 1999). Traditional composite formulations are not designed to be used in increments greater than 1 mm to 2 mm. They are also not ideal for bulk placement in large core preparations.To overcome this disadvantage, dedicated light-cure-only composite core materials specifically formulated for placement in large increments with sufficient depth of cure and ideal physical and handling properties have been created and marketed(Pedalino, 2012).

A study done by Hormetti et al states that composite resin cores have greater microleakage than amalgam under crowns(Hormati and Denehy, 1980). A study done to compare dimensional stability by Oliva et al stated that composite resin cores absorbed moisture up to one week before reaching an equilibrium while amalgam was stable in two hours(Oliva and Lowe, 1987). A study by Kovarik et al. compared amalgam and composite direct build up materials and they found that amalgam cores had the lowest failure rate, and that more than one million cycles were required to produce the median fatigue life of the amalgam cores. Composite resin cores experienced 83.3 % failure and required only 385,212 cycles to achieve their median fatigue life(Kovarik, Breeding and Franklin Caughman, 1992). Reddy et al concluded that the core buildup done with composite offered better occlusal fracture resistance strength compared to light curable GIC and miracle mix(Reddy *et al.*, 2016).

However, the introduction of nanocomposites made a change in the market. A study by Jayanti et al stated that flurocore and nanocomposite are stronger than amalgam(Jayanthi and Vinod, 2013).

Zirconia is a soft silver coloured material mined from deposits majorly present in Africa and Australia as zircon mineral. This mineral is then purified to produce zirconia powder with controlled composition and particle size. Other metal oxides like yttrium (stabilizer), magnesium (stabilizer), calcium (stabilizer), hafnium (reduces pore development) and aluminium (prevents water corrosion) are added to stabilize the material. Various tints are also added to get the desired shade(Sinha, 1992).

Various types of zirconia are available, each with different properties. In terms of flexural strength core material Finesse (Leucite reinforced glass ceramic, Dentsply) had the lowest mean strength value - 88.04±31.61 MPa, and Cercon Zirconia (Yttria stabilized zirconia, Dentsply) had the highest strength value - 1140.89±121.33 MPa. The other mean (SD) strength values in MPa were: 94.97±13.62 for Cergo (Pressable all ceramic, Dentsply), 101.18±13.49 for IPS Empress (Leucite reinforced glass ceramic, Ivoclar Vivadent), 341.80±61.13 for In-Ceram Alumina (Alumina based glass infiltrated ceramic, Vita), and 541.80±61.10 for In-ceram Zirconia (Zirconia based glass infiltrated ceramic, Vita)(Yilmaz, Aydin and Gul, 2007).

Fracture toughness is the ability of the material to resist crack propagation(Kanninen, 1974). Cracks generally originate from flaws in the material like porosity, or any damage during finishing(Kawaguchi, Yamade and Kishi, 1992). Tensile stress induces fracture of the brittle ceramic usually perpendicular to the applied force(Oh, Delong and Anusavice, 2002) . Thermal coefficient mismatches, processing (porosity, impurity inclusion) and inherent material defects (large grains, residual scratches) will increase the probability of crack propagation under loading(Denry, 2013).

Fracture toughness values for feldspathic porcelain range from 1 to 1.3, 5 Y-TZP are 2 to 4, and 3 Y-TZP vary from 3.5 to 4.5 MPa(Nathanson *et al.*, 2010; Denry and Kelly, 2014). Another study stated that Cergo (Pressable all ceramic, Dentsply) had the lowest mean toughness (SD) value at 1.73 MPa x m0.5±0.02, and Cercon Zirconia (Yttria stabilized zirconia, Dentsply) had the highest toughness value at 6.27 MPa x m0.5±0.05. The other mean toughness values (SD) in MPa x m0.5 were: 1.88±0.07 for Finesse (Leucite reinforced glass ceramic, Dentsply), 2.40±0.09 for IPS Empress (Leucite reinforced glass ceramic, Ivoclar Vivadent), 4.78±0.18 for In-Ceram Alumina (Alumina based glass infiltrated ceramic, Vita), and 5.56±0.18 for In-ceram Zirconia (Zirconia based glass infiltrated ceramic, Vita)(Yilmaz, Aydin and Gul, 2007). 3Y-TZP zirconia has the highest critical stress intensity factor between 6 $MPam^{1/2}$ to 11 $MPam^{1/2}$, which is more similar to that of metals than other materials.

The most important components of esthetic tooth appearance are: color, fluorescence, opalescence and translucency(Lee and Bin, 2016). Zirconia is an opaque ceramic, which limits its use(Jang *et al.*, 2011). Tooth enamel has 97% hydroxyapatite mineral and is very translucent(Jang *et al.*, 2011; Reyes-Gasga and Alcántara-Rodríguez, 2017). This can transmit up to 70% of light(Gardner *et al.*, 1992). Dentin is also able to transmit up to 30% of light(Fawzi *et al.*, 1977). In metal-ceramic restorations, opaque porcelain masks a metal substrate. It reflects light and decreases translucency. Consequently, they appear brighter intraorally. In-Ceram Spinnell had higher levels of translucency than In-Ceram Alumina, followed by In-Ceram Zirconia, when compared to a metal alloy(Ban, 2008).

When the properties of a material are the same in all directions, the material is isotropic. Cubic-containing zirconia is isotropic, which improves light transmission. In Y-TZP zirconia, the grains have irregular boundaries that limit light transmission (anisotropic)(Zhang, 2014). However, smaller grains improve light transmission(Lucas *et al.*, 2015). The different indexes of refraction of the materials compositing 3 Y-TZP

zirconia (alumina, yttria, colorants) increases light reflection, as incident light transmission is decreased(Kim *et al.*, 2013).
The translucency of zirconia is commonly lower than those of alumina, spinell, and feldspathic porcelains. However, it is better than metal, because zirconia has no metallic color and slight transmission(Ban, 2008).
A lot of studies state that zirconia exhibits very good long-term stability, functional and esthetic performance. They were also reliable. However, the zirconia-based FDPs frequently exhibited problems such as marginal deficiency or chipping of the veneering ceramics(Sax, Hämmerle and Sailer, 2011; Ohlmann, Eiffler and Rammelsberg, 2012; Peláez *et al.*, 2012; Sorrentino *et al.*, 2012).
Zirconia is generally covered by ceramic/porcelain to improve esthetics. However, under the scanning electron microscope, a reaction layer between the zirconia and the veneering porcelain was not present. It can be concluded that veneering porcelains are mainly bonded to zirconia with mechanical interlocking and compressive stress(Giordano, Campbell and Pober, 1994; Aboushelib, Kleverlaan and Feilzer, 2006; Sato *et al.*, 2008).
Cement bonds zirconia to the tooth. The clinical success of the restoration depends on how strong the cement bonds to the tooth. Some studies evaluated the effect of sandblasting on the bonding strength of dental ceramics to resin cements . The surfaces of Y-TZP and NANOZR were sandblasted by 70 mm alumina and 125 mm SiC powders. The shear bonding strength of of both the surfaces to a resin cement showed no significant difference. These results demonstrated that the surface roughness prepared by alumina is enough to produce the bonding of zirconia to resin cement. The shear bonding strengths of alumina-sandblasted zirconia to three resin cements varied with the cement and they decreased with the thermal-cycling in all the resin cements. There was no effect of silane coupling agent on bonding strength and durability between zirconia and resin cement(Kern and Wegner, 1998; Dérand and Dérand, 2000; Janda *et al.*, 2003; Blatz *et al.*, 2004).
However, a study done by Seung-Geun Ahn et al stated that amalgam had the highest flexural strength, followed by composite and then zirconia. The glass-ceramic core had a strength in the range of the lower strength composite resins yet it had an elastic modulus that was about five times greater than the two highest strength composite resins and nearly three times that of the highest elastic modulus composite resin (BisCore Dual). The modulus of elasticity of the glass ceramic was about 73% of amalgam, 49% of Type III gold, 45% of human enamel, 36% of Au-Pd alloy, and 24% of a Ni-Cr alloy(Ahn and Sorensen, 2003).Our institution is passionate about high quality evidence based research and has excelled in various fields ((Pc, Marimuthu and Devadoss, 2018; Ramesh *et al.*, 2018; Vijayashree Priyadharsini, Smiline Girija and Paramasivam, 2018; Ezhilarasan, Apoorva and Ashok Vardhan, 2019; Ramadurai *et al.*, 2019; Sridharan *et al.*, 2019; Vijayashree Priyadharsini, 2019; Chandrasekar *et al.*, 2020; Mathew *et al.*, 2020; R *et al.*, 2020; Samuel, 2021)

CONCLUSION

Within the limitations of this review, it can be concluded that amalgam is the material of choice in terms of mechanical properties. However, they give a dark metallic shade and are unaesthetic.Composite resins have adequate strength, but there is a high rate of debonding at the core-tooth interface.
Zirconia, is esthetic, but had less strength when compared with amalgam and composite and could be used in the anterior teeth as post and core where esthetics is of prime concern.

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