



## NANOZIRCONIA AND RESTORATIVE MATERIALS

## Dentistry

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## ABSTRACT

Nanozirconia is a versatile material with numerous applications including dental restorative materials. This review explores the science of nanozirconia (NZ), their significance and applications in restorative materials. NZ has proven to be a material of interest due to their excellent physical, optical and mechanical properties and their introduction in restorative material is expected to enhance their properties. As evident from multiple studies focusing on various mechanical properties, such as compressive strength, flexural strength, hardness, elastic modulus, film thickness, tensile strength and so on, have shown promising results. In GIC NZ along with other metal oxides have shown improved properties whereas in PMMA denture base resins compressive strength increase at lower weight% but as the percentage was increased to 10wt% and above compressive strength (CS) declined, this is perhaps due to NZ settling down in polymethyl metacrylate (PMMA). Similar results were found for young's modulus, microhardness and surface roughness. Studies show the effect of NZ on self-adhesive resin cement wherein significant improvement was noted in mechanical properties of resin cement and maximum improvement was noted at 3wt%. While water sorption remains unaffected, film thickness at lower wt% was unaffected but at 5wt% film thickness increased but was within permissible limit of 50µm. Flexural strength (FS) did not show any significant improvement. Dental ceramics showed positive results when FS was compared, and FS increased with increase in NZ percentage.

## KEYWORDS

Nanozirconia, Nanoparticles, Nanotechnology, Nanofiller

## INTRODUCTION

Dental restorations are broadly classified as provisional and permanent. Provisional restorations include zinc phosphate, polycarboxylate cement, zinc oxide and non-eugenol cement etc. and permanent restorations most used include amalgam restoration, glass ionomer cement (GIC), resin modified glass ionomer (RMGIC) and resin cements. While amalgam has excellent mechanical properties it is aesthetically unacceptable therefore GIC and its modifications and resin cements are preferred by the patients and clinicians. Though these restorative materials are aesthetically acceptable, their strength is a matter of concern as good physical and mechanical properties are mandatory to withstand occlusal loads. To overcome this, filler particles such as silver, zinc oxide, graphene, calcium phosphate, calcium fluoride, hydroxyapatite, Zirconia, silica, titania (TiO<sub>2</sub>), iron oxide, diamond etc. were introduced and the results were promising [1][2][3]. In this review we shall focus on zirconia nanoparticles.

Zirconium dioxide (ZrO<sub>2</sub>) is often called zirconia and it has long been used in biomedical applications. It is similar to titanium and has strong anti-corrosion resistance. Zirconium is a strong transition metal and available in amorphous and crystalline form. It is stabilized by combining metal oxides like MgO, CaO, and Y<sub>2</sub>O<sub>3</sub> [4]. Y<sub>2</sub>O<sub>3</sub> stabilized zirconia is most commonly used in dentistry as it has better mechanical properties and tear resistance than the one mixed with other metal oxides [5]. It is often referred to as ceramic steel due to excellent mechanical properties which is due to the fact that zirconia is 96-99% crystalline with no glassy phase. With the introduction of nanotechnology, zirconia nanoparticles have been extensively studied and are preferred nanoparticles. A nanomaterial measures between 1-100nm. NZ can be used as nano powder filling, nano-coatings and for sintering raw materials. Based on their crystal structure they have been classified as monoclinic, tetragonal and cubic [6]. Of these, monoclinic is the most stable form. Zirconia can transform from one phase to another at high temperatures which improves its mechanical properties but in due process its translucency and aging resistance is compromised [10][11]. Yttrium-stabilized tetragonal zirconia polycrystal-stabilized material is the most used form of zirconia for dental applications. A balance should be maintained between toughness and translucency which is done by adjusting phase ratios, surface treatment and so on and the resulting zirconia will have excellent strength and aesthetics [12]. There are various methods of manufacturing NZ such as sol-gel method, precipitation method, hydrothermal method, flame spray pyrolysis method, template-assisted synthesis [7]. Sol-gel, hydrothermal and flame spray pyrolysis method is the most common used for NZ synthesis. Some of the properties of NZ are mentioned table 1 [4].

**Table 1: Mechanical Properties of NZ**

Mechanical properties	Value
Density	6.05g/cm <sup>2</sup>
Hardness	1200HV
Bend strength	900-1200MPa
Compressive strength	2000MPa
Fracture toughness	7-10MPa <sup>1/2</sup>
Young's modulus	210GPa
Thermal expansion co-efficient	11*10 <sup>-6</sup> /K

Apart from these properties, NZ also have good natural colour, high chemical stability, excellent corrosion resistance, chemical and microbial resistance, low thermal and ionic conductivity [8][9][13].

## Methods

This study is a literature review about nanozirconia and use in dental restorative materials. Data is collected from articles published on pub med, science direct, Google scholar, MDPI journals and research gate, searching for nanozirconia, nanomaterial, nanofiller, ceramics. The data applicable to dentistry was included whereas that unrelated was excluded.

## DISCUSSION

Zirconia has attracted the attention of researchers and clinicians in the field of science and medicine and in the last decade it has been extensively studied for its synthesis to its applications and tremendous advancements have been achieved so far. Its uniqueness is its physical and mechanical properties along with its translucency thus facilitating its use in aesthetic restorations, particularly the anterior teeth. In dentistry zirconia is used in dental abutments, dental implants, crown and bridges and restorative cements. Zirconia has been incorporated in various dental restorative materials and the outcome has been very promising in terms of enhancing the mechanical properties of the materials.

Y.W.Gu et al conducted a study wherein GIC was modified with hydroxyapatite-zirconium (HA-ZrO<sub>2</sub>) NPs with different volumes (4, 12, 28 and 40 Vol%) [14]. The effect of different volume percentage of HA-ZrO<sub>2</sub> NPs on compressive strength (CS), microhardness (MH), dimetral tensile strength (TS) of GIC was investigated. All the properties of modified GIC were found to be improved. GIC with 4 and 12 vol% HA-ZrO<sub>2</sub> showed superior qualities than original GIC. Also the properties of HA-ZrO<sub>2</sub> modified GIC were better than HA-GIC due to the properties of zirconia. Similarly, Gjorgievska et al. investigated impact of Al<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub> and TiO<sub>2</sub> NPs at 2, 5 and 10 wt%, respectively on conventional GIC [15]. The results showed an increase in CS with ZrO<sub>2</sub> and TiO<sub>2</sub> NPs whereas the cement became weak with Al<sub>2</sub>O<sub>3</sub> From

these studies it appears that the effect of ZrO<sub>2</sub> on GIC has been studied combined with other metal oxides and such a combination has positive effect on mechanical properties of GIC.

Savita kumari et al. studied the effects of various weight% (1.5,10,15 wt%) of zirconia on heat cured PMMA denture base resin on its compressive strength, young's modulus, fracture toughness and crack length [16]. There was an increase in the compressive strength (60.4, 69MPa and 76.6 MPa) when the wt% of zirconia was increased from 1wt% to 5wt% but on further increasing the concentration to 10wt% and 15wt% a decline in CS (68.5MPa and 47.3MPa) was noted. This decline might be due to dense NZ particles settling down in PMMA. Similarly, young's modulus also increased by  $0.59 \pm 0.006$  GPa on addition of 5wt% NZ to PMMA but a further increase in NZ reduced the young's modulus. In another study conducted by Mahmut Sertac ozdogan and Ramazan karlioglu, the effect of different concentrations (0.0 to 70 wt%) of yttria-stabilized zirconia (YSZ) on microstructure and mechanical properties of PMMA was investigated [17]. It was found that microhardness and density of PMMA increased to 60 wt% YSZ and surface roughness was not affected but beyond 60 wt% the mechanical properties reduced and surface roughness increased due to agglomeration of NPs.

The effects of NZ on resin cements were evaluated by Baraa M. El-Kemary et al [18]. Different weight percentage (1,2,3 and 5 wt%) was added to commercially available RelyX Unicem self-adhesive universal resin cement and the mechanical properties like fracture resistance, compressive strength, diametral tensile, and microhardness were studied. The result showed a significant increase in all the mechanical properties of the resin cement. Maximum improvement was noted with 3wt% NZ. Anastasia Beketova et al, in their study evaluated the impact of NZ at varying weight percentage (1,2.5 and 5 wt%) on film thickness, flexural strength, water sorption and shear bond strength of RMGIC and two self-adhesive resin cements [19]. Water sorption was unaffected by NZ addition in all three cements. The film thickness was within the permitted limit of 50µm. Though 1wt% and 2.5wt% did not cause any significant change in film thickness but the addition of 5wt% increased the film thickness. Flexural strength results were different for different cements and at different percentages. Overall, there was no significant improvement in the cements.

Zirconia based ceramics possess the best mechanical among all other ceramic materials due to high flexural strength (FS) of zirconia (900-1200MPa) and fracture toughness of 7 to 10 MPa·m<sup>1/2</sup> [20][21][22]. Rajdeep Tah et al. studied effect of zirconia-silica nanofibres on flexural strength of ceramic [23]. Different percentages (0, 2.5, 5, 7.5 wt%) of Zr-Si nanofibre were used. The FS of ceramic modified with nanofibres (2.5, 5, 7.5 wt%) was higher ( $176.70 \pm 5.51$ ,  $189.07 \pm 5.52$ , and  $196.71 \pm 5.25$  MPa, respectively) than unmodified ceramic ( $141.08 \pm 31.27$ ) and FS increased with increase in the nanofibre percentage. In yet another study done by Sasikala. C and Chander. NG, FS of feldspathic and lithium-Disilicate ceramics was compared after addition of NZ at different weight percentage (5, 10, 15, 20 wt%). The results showed an increase in the FS of feldspathic ceramic with the increase in percentage of NZ whereas for lithium disilicate FS increased (93.8, 97.1, 100.6, and 100.8 MPa) with increase in percentage (5, 10, 15, 20 wt%) of NZ however the values were far below the unmodified control group whose FS was 221.7 MPa.

## CONCLUSION

Nanozirconia and restorative materials are very interesting materials due to their properties and applications, and tremendous success has been achieved so far in exploring their potential and combining them to obtain reliable and durable restorative materials. As evident from multiple studies introductions of NZ has enhanced overall properties of restorative materials. There is still need for research in developing a stable zirconia and overcome its shortcoming, particularly its bonding resin cements with the substrate to achieve successful and long lasting restorations.

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