ORIGINAL RESEARCH PAPER
Volume - 14 | Issue - 06 | June - 2025 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

NANODIAMOND IN RESTORATIVE MATERIALS

Dentistry

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ABSTRACT

Introduction of nanotechnology has transformed the modern world, including dentistry. Nanoparticles (NPs) have revolutionized the world of medicine and dentistry. The latest among the NPs to be used are nanodiamond (NDs). NDs possess excellent mechanical properties and making them an excellent filler material in restorative materials. They have been used in Poly(methyl methacrylate) PMMA denture base resin, composite resin, resin luting cement and GIC and have had positive impact in improving their properties, though in GIC their influence was insignificant. Overall incorporation of NDs in restorative materials have improved their compressive strength, flexural strength, elastic modulus, wear resistance, antifungal and antibacterial property and so on. Though their effect is promising in restorative materials but their potential is fully not understood yet and hence there is a need to further explore and study in depth their role and effect and applications in restorative materials.

KEYWORDS

Nanodiamond (ND), Nanoparticles (NP), Dental materials, Restorative materials, Nanotechnology, Nanofiller

INTRODUCTION

Nanotechnology is one of the major breakthroughs in modern scientific era. It deals with materials at nanoparticle level and has changed the outlook of researchers across the scientific fields and dentistry is no alien to it. Nanoparticles have sizes between 1nm-100nm. They are used in dental restorative materials to enhance their properties such as hardness, strength, aesthetics, durability, long life, wear resistance, reduce shrinkage and so on [1]. Some of the nanoparticles used are silver, zinc oxide, grapheme, calcium phosphate, calcium fluoride, hydroxyapatite, Zirconia, silica, titania (TiO_2), iron oxide, diamond etc. [2][3][4].

Nanodiamond is an allotrope of carbon well known for its superior physical, mechanical, thermal and optical features [5]. There are various techniques of manufacturing NDs, such as detonation or shock wave synthesis, chemical vapor deposition (CVD), milling high-pressure, high-temperature (HPHT), plasma-assisted CVD, laser ablation, ball milling, irradiation methods [6]. Of all these methods detonation is the most commonly used commercial method and NDs were first synthesized using this technique in 1963. Based on their particle size they are categorized into three groups, first is Nano-crystalline particles where particle size is in tens of nanometres, second is ultra-crystalline particles where particle size is in several nanometres and third is diamondoids where particle size is 1-2nm. Diamondoids are the building blocks of nanotechnology and derived from petroleum and are not easy to manufacture. Of all the nanodiamond materials monocrytalline natural diamond powder is the purest form. It is their excellent physical and mechanical properties that has drawn attention of researchers and compelled their incorporation in dental restorative materials to enhance the materials mechanical properties. Some of the properties of nanodiamond is mentioned in table 1.

Table 1: Mechanical Properties of Nanodiamond

Property	Value	Reference
Hardness	56 GPA-257 GPA 10 (On Mohs scale)	[7] [8]
Compressive strength	54 GPa	[9]
Young's modulus	1050 GPa	[10][11]
Co-efficient of thermal expansion (CTE)	1.1 × 10−5 K−1	[12]

Apart from their use in restorative dentistry NDs have various other applications such as in drug delivery, bio imaging, guided tissue regeneration, reinforcement of polymers, dental implants coating with antibacterial etc. [13].

Other than their excellent mechanical properties NDs also have low toxicity [14], biocompatibility [15], stable fluorescence [16] and other properties of bulk diamond but superior to them [17][18]. In restorative dentistry NDs have been used in resin luting cements, composite resins, PMMA denture base resins and glass ionomer cement (GIC). Currently NDs are one of the important focuses of study and investigation and still there is need to explore the benefits of adding it to restorative materials.

Methods

This study is a literature review on nanodiamond and their importance and applications in restorative materials. A number of articles were referred to from pub med, science direct, Google scholar, MDPI journals and research gate, searching for nanotechnology, nanoparticles, nanodiamond in dentistry and nanodiamond in restorative materials. Data relevant to dentistry and the subject of this article was taken while data which broadly related to medical interests was excluded.

DISCUSSION

Healthy teeth is one of the most important and primary requisite of a good oral health. Maintaining healthy teeth often requires their restoration in cases where they undergo wear or are subjected to oral bacteria resulting in dental caries and loss of tooth structure, also there could be a tooth anomaly that requires correction and so on. Some of the permanent restorative methods include prosthesis, building up of tooth structure, restoration tooth with filling material, cementation of indirect restorations etc. over the period of time various permanent restorative materials have been introduced such as PMMA denture base resins, composite resins, luting resin cements and GIC. They have undergone transformation and have been improvised to match the ideal qualities of a restorative material to mimic the natural teeth. One of the crucial focus of the studies is their mechanical properties so as to obtain a material that is durable and last long and in order to do so various fillers have been tested successfully one such filler is diamond particles [17,18,19].

Nanodiamond has been found to enhance microhardness of composite resins. In the study conducted by Rocío Moriche et al in 2024 [19] wherein different percentages of ND (0.8, 1.6 and 3.2 wt.%) was added to the composite resins and the results were astonishing with an increase in MH of 95% for 0.8% of ND to up to 420% for 3.2% ND. It also highlights a key point that a very low percentage of ND is enough to cause considerable increase in MH of the resin cements.

Shaima M.F et. al found an increase in the flexural strength of PMMA denture base resin at low ND percentage and a decline in FS with an increase the ND percentage. ND was used at 0.1%, 0.25% and 0.5%. NDs at low concentration (0.1% and 0.25%) had higher FS (124.7 ± 9 MPa and 128.8 ± 18.4 MPa, respectively) compared to that of higher concentration of NDs 0.5% (113.5 ± 8.7 MPa). Similar results were obtained in another study conducted by Fahad A.A et al where NDs were tested at 0.5%, 1.0% and 1.5% and FS was found highest at 0.5% (96.95±3.54MPa)followed by 1.0% (83.76±1.66MPa) and 1.5% (73.62±3.67MPa).

Rian.M and Nadia.M investigated effect of NDs on physical properties

of restorative GIC. Surface roughness, microhardness and compressive strength and proportional limit were determined in GIC modified with 5 wt% and 10 wt% NDs. Overall the results showed no significant difference between modified and conventional GIC [22].

ND has antifungal and antibacterial effect. Utkarsh.M et.al concluded in his study that NDs (0.1%, 0.3% and 0.5%) addition to PMMA denture base resins significantly reduced candida albicans biofilm formation compared to nanozirconia [23]. In another study by Utkarsh.M et al antibacterial effect was noted against streptococcus mutans biofilms when 0.1 wt% ND was used [24].

Polyelectrolyte Composite Films are used in dental restorative materials to improve adhesion, durability and biomechanical properties [25, 26]. Tony Tiainen et al studied the elastic modulus of Polyelectrolyte Composite Films with addition of up to 2% NDs and young's modulus increased to 161% [25].

CONCLUSION

Over the last decade NDs have attracted the attention of researchers and extensive investigation and work is being done on use of NDs in medicine and dentistry. They present a positive outlook and have given promising results. It is due to their biocompatible and non-toxic inert nature along with excellent physical and mechanical properties that they are extensively used in various dental restorative materials. There is a need of further studies to better understand their nature and properties and usage to improve the existing restorative materials to as close to the ideal material as possible.

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