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Synthesis, characterization and biological significance of ZnO, CuO and NiO metal oxides nanoparticles: A review

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Abstract
In the present study different metal oxide nanoparticles (Copper, Zinc and Nickel) were synthesized using wet chemical method. These nanoparticles were characterized using FTIR, SEM, TEM and XRD to investigate their structural and morphological properties. XRD data was used to calculate the particle size using Debye Scherrer method and it was found to be in the nano-range. SEM analysis also supported that metal oxide particles are in the nano range with varying morphology. Metal oxide nanoparticles exhibit various biological activities, including antibacterial, pro-regenerative, and antitumor potentials, due to their size and unique properties. These activities stem from mechanisms like generating reactive oxygen species, disrupting cell membranes, and interacting with cellular components like DNA. The specific biological effects of MONPs depend on their physicochemical properties, such as size, shape, and surface charge, and can vary depending on the type of metal oxide and the biological target. The use of these nanoparticles made of synthetic and natural materials in dentistry is developing quickly, has been included in a variety of dental materials and has assisted in the treatment of oral disorders as well as the removal of biofilms and smear layers. The reader will gain up-to-date knowledge on MONPs, their modes of action, and their significance in Endodontics.

Keywords: Metal oxide, nanoparticles, synthesis, characterization, biological activity

Introduction

Nanomaterials (NMs) are materials that are generally on the nanoscale, defined as having dimensions less than 100 nm. With the potential to revolutionize biology, medicine, and other health-related professions, nanotechnology offers an exceptional opportunity to study and control a wide range of biological processes at the nanoscale [1]. It is important to develop methods for nanoparticle synthesis that allow for control of nanoparticle characteristics, including size distribution, morphology, crystallinity, purity, and composition. Several methods for the synthesis of nanoparticles and their composite materials have been reported previously, including liquid-phase-, solid-phase- and gas-phase-processes [2]. However, to be feasible for use in industry, a process needs to be simple, inexpensive, and able to operate continuously with a high production rate. Thus, this review focuses on aerosol spray methods, such as flame-assisted methods, spray pyrolysis, and spray drying, because these methods are simple, and inexpensive, and operate continuously to produce high-purity nanoparticle materials at a rapid rate [3]. Metal and oxide nanoparticles (NPs) are the most researched material groups. Several studies have demonstrated the significant therapeutic benefits of metal nanoparticles (NPs) (Cu, Ag, Pt, Au, Pt, Mg, Zn, etc.) and metal oxides (ZnO, TiO2, CuO, Ag2O, etc.). Because of these advantages, they are being used in many different domains, including biosensors, drug delivery systems, tissue engineering scaffolds, and diagnostic imaging applications [4]. Chemical and physical techniques represent the main routes for the synthesis of metal and metal oxide nanoparticles (NPs). Precipitation, the sol-gel method, chemical reduction, and polyol synthesis are the most studied chemical synthesis routes; on the other hand, evidence of microwave-assisted combustion, laser evaporation, and pulsed laser deposition was found for physical synthesis routes [5-6].

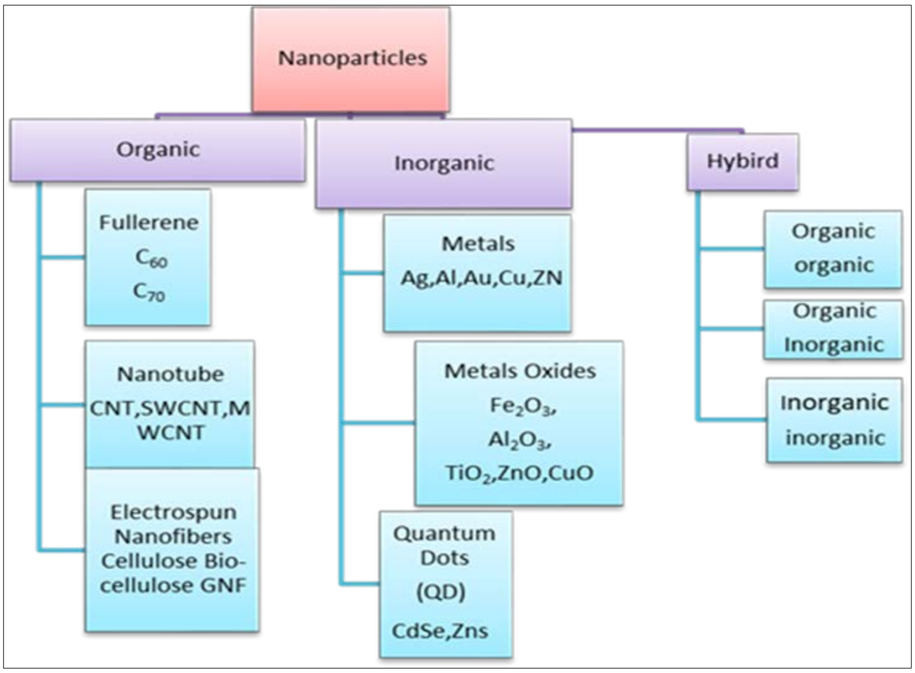

Fig 1: Classification of nanoparticles

These techniques do have several drawbacks, though, including the use of hazardous materials, inefficiency in terms of cost, the use of risky processes, and the creation of hazardous byproducts that are bad for the environment. The intricate processes and disadvantages associated with the aforementioned synthesis routes compromise the biocompatibility of nanoparticles. Therefore, the development of an economical, one-step, dependable, biocompatible, and non-toxic method for the synthesis of environmentally friendly nanoparticles is urgently needed. One line of inquiry employs biological techniques involving the use of microorganisms, plant extracts, and enzymes [7-8]. By substituting eco-friendly metabolites and biomolecules inspired by synthesis routes like biomimetic or biological synthesis, the steps taken in green synthesis methods for metallic NPs aim to reduce or eliminate the use of toxic substances and solvents [9]. The use of metallic and metal oxide nanoparticles (NPs) in tissue engineering has increased, particularly because of their antibacterial qualities [10-11]. NPs have been applied in this direction to support various functions in tissue engineering, including DNA transfection, gene delivery, cell patterning, and viral transduction, in addition to improving mechanical, electrical, and biological properties. NPs' primary functions are to support the development of various tissue types or to aid in molecular detection or biosensing. Additionally, depending on the intended application, the use of NPs in tissue engineering can both improve and add properties to the scaffolds. Due to their small size and correlation with a high surface-to- volume ratio, the extra properties are provided. As a result, the NPs can readily diffuse across membranes, which promotes cell uptake. Furthermore, NPs can replicate the dimensions of extracellular matrix elements in native tissues [12-15]. High control over the properties of the resulting scaffolds, such as maximising their mechanical strength and providing the potential for controlled release of bioactive agents, is another crucial feature of metal nanoparticle [16]. Despite the fact that numerous studies found that metal nanoparticles (NPs) were more toxic, more recent studies have shown that the right dosage, size, and distribution of the materials can actually lower their toxicity. The primary characteristics of these materials could be enhanced to produce a more effective therapeutic effect because of their nature and ease of functionalisation [17-18]. Their optimization's primary objective was to create specific conditions in order to pursue the mechanical and biological properties that would make them perfect materials for the intended use. In order to overcome the primary obstacles in tissue engineering, the developed NPs offer high surface area and adjustable surface properties, enhancing the scaffolds' mechanical strength, antiseptic properties, and antibacterial activity. Numerous metal/metal oxide nanoparticles have been used up to this point to alter and enhance the functionality of scaffolds. In many cases, the scaffolds incorporate polymers along with ceramic, polymeric, and other NPs [19].

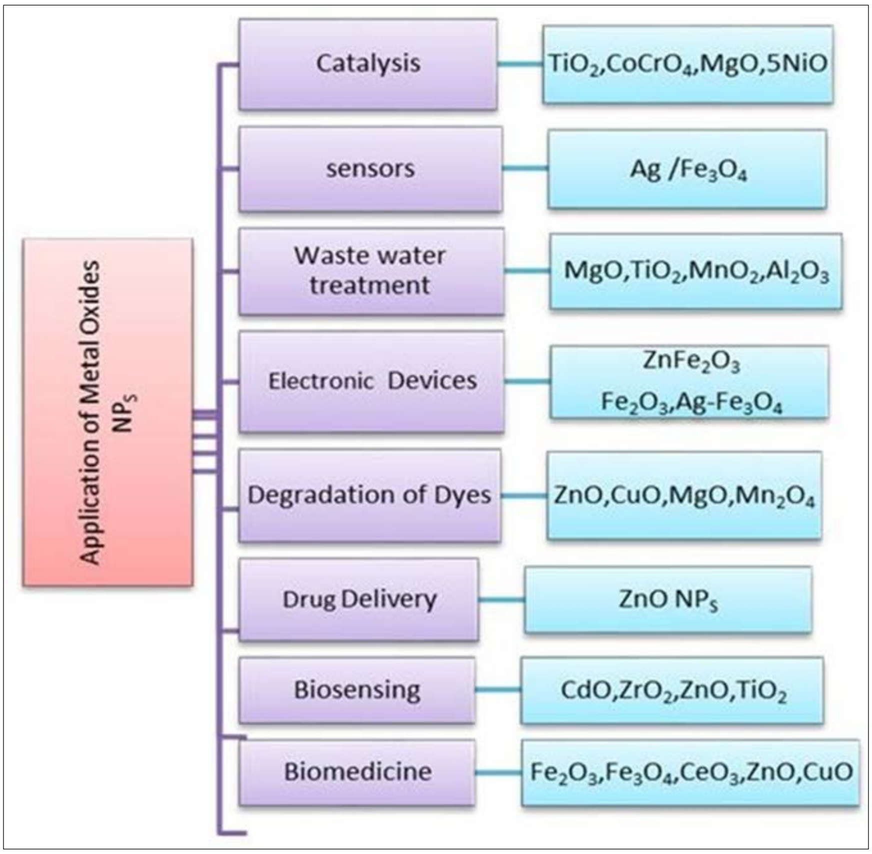

Fig 2: Applications of metal oxides NPS

The development of employing inorganic nanoparticles for biomedical requests is particularly noteworthy. For instance, zinc oxide nanoparticles (ZnO NPs) have been extensively studied for their antimicrobial properties, making them suitable for coating medical devices and implants to prevent infections [19]. Silver nanoparticles (Ag-NPs) are widely recognized for their potent antibacterial and antifungal activities and are used in wound dressings, antibacterial coatings, and water purification systems [20]. Moreover, metal/metal oxide nanoparticles have applications beyond the biomedical field. In environmental science, these nanoparticles are used in water treatment processes due to their ability to degrade pollutants and contaminants [21]. In the agricultural sector, they are used to develop nanopesticides and nano-fertilizers, which enhance crop yield and protect against pests more efficiently than traditional methods [22]. In the energy sector, metal oxide nanoparticles are integral components of solar cells and batteries, improving energy conversion and storage capacities [23]. Numerous researchers have recommended that plants appear to be the chief candidate and are suitable for a great level of biosynthesis of metal nanoparticles with various nanoparticles' shapes comprising increased rates than the other bio-sources [24-25]. The imperative chemical constituents of the plant extract such as phenols, flavonoids, alkaloids, lipids, and enzymes, participate in the bioproduction process and hence stabilize the formed nanoparticles [26-28]. Metal oxide nanoparticles demonstrated remarkable features such as band gap, great binding energy, and extraordinary piezoelectric properties [29]. The green protocols for the biosynthesis of metal/metal oxide nanoparticles delivered safe, economical, biocompatible, and nontoxic nanomaterials, which these nanomaterials can be applied in different fields of industry, medicine, and nanotechnology [30-31].

Experimental procedure, method and material

All the chemicals used for precursors and maintaining reaction conditions were of reagent grade. They were used without further purification. The distilled water was used as a solvent in the entire solution. The preparation was followed as per the reported method.

Synthesis of CuO nanoparticle

The CuO nanoparticles were prepared by a low temperature hydrothermal route. To prepare CuO, 0.5 M of copper sulphate was dissolved in 50 ml deionized water and kept in vigorous mixing for 30 min. An appropriate amount of sodium hydroxide solution (NaoH) was added drop by drop to the prepared mixture to attain the 8.5 pH value of the mixture solution and again stirred for 3 hrs. to form homogeneous solution. The prepared solution was transformed in Teflon lined stainless steel autoclave and kept in heating furnace which is upheld at 180 °C for 12 hrs., then the mixer was allowed to cool, the dark brown precipitate was extracted. The harvested precipitate was splashed multiple times with distilled water and ethanol to remove contaminants and finally dried in hot air oven at 80 °C for 12 h to gain CuO nanoparticles.

Synthesis of ZnO nanoparticle

0.8g of sodium hydroxide (NaOH) was added to the beaker containing 200 ml of distilled water to make 0.1M NaOH solution. The solution was then stirred at magnetic stirrer for 30 minutes at 600 RPM, maintaining the temperature of the solution at 500C. At separate flask 5.950g of Zn $(NO_3)_2$. $6H_2O$ was added to the beaker containing 200 ml of distilled water to make it 0.1M Zn $(NO_3)_2.6H_2O$ solution. Then it was stirred at the magnetic stirrer for 2 hours at 600 RPM maintaining the temperature of the solution at 600C. Four drops of 3% ammonia solution was added to the solution to make the pH of the solution to 12. Now, already prepared 0.1M NaOH solution was added to it drop wise lowering its temperature gradually to the room temperature. The solution was further stirred for 2 hours at 600 RPM at room temperature. The final product of the solution with whitish ppt. was filtered, washed with ethanol, dried and grinded.

Synthesis of NiO nanoparticle

0.1M Ni $(NO_3)2.6H_2O$ solution was prepared by using double distilled water under constant stirring. While at room temperature, 0.8M NaOH solution was added drop by drop. This solution was stirred constantly at a temperature of 80±5 ° C for 4 hours. After completion of the reaction, the green coloured precipitate was obtained and it was thoroughly washed with double distilled water to remove all the other ions and then centrifuged. The final precipitate was dried in a hot air oven at 80 °C for 2 hours. The above resulting dried precursors was crushed into powder and calcined at 600 °C for 5 hours. The final product (NiO) was stored in air tight container for further analysis.

Results and discussion

Characterizations of Metal Oxide Nanoparticles

X-ray diffraction (XRD) has been used to examine the phases purity of the synthesized to determine the crystalline part of the materials. (XRD, Bruker D8 Advance, Germany) by a Cu-Ka radioactive source of 0.15405 nm in the 2 range of 20° to 80°. The XRD results were obtained with diffraction intensity versus 2ɵ. Scanning electron microscopy was employed to determine the surface topography of the samples (JEOL, JSM-7600F, Japan). The material was FTIR spectroscopically examined in the 400-4000 cm^{-1} range (with Per-kin Elmer 1650, USA) using a Thermo-Nicolet Avatar 370 model FTIR to better comprehend the structural and chemical characteristics of nanoparticles.

X-ray analysis of CuO, NiO and ZnO nanoparticles

The powder XRD pattern was used to describe the acquired materials, which were acquired using a XRD, Bruker D8 Advance, Germany with CuKa radiation (k = 1.5417 Å). The crystallographic planes validated the material’s crystalline phase and are very well aligned to specifications (JCPDS - card # 05 - 0661). The grain size of the crystallites of as synthesized product was calculated using Debye-Scherrer formula.

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

Where the wavelength of X-ray is used (0.15418nm in the present case), is the full width in radiation at half-maximum of the peak, and is the Bragg angle of X-ray diffraction peak.

Fig. 3a depicts the characterization of X-ray diffraction peaks of CuO nanoparticles observed in the range of 2 between 20° and 80°. The result shows the characteristics diffraction peaks located at 2h = 22.75°, 28.31°, 35.65°, 38.59°, 41.14°, 46.32°, 52.55°, 61.49°, 66.37°, and 72.17°. There really is no discernible shift in peak location, and the spikes are observed to be extremely acute and powerful. The Debye Scherrer equation was used to compute the regular crystalline sizes of CuO.

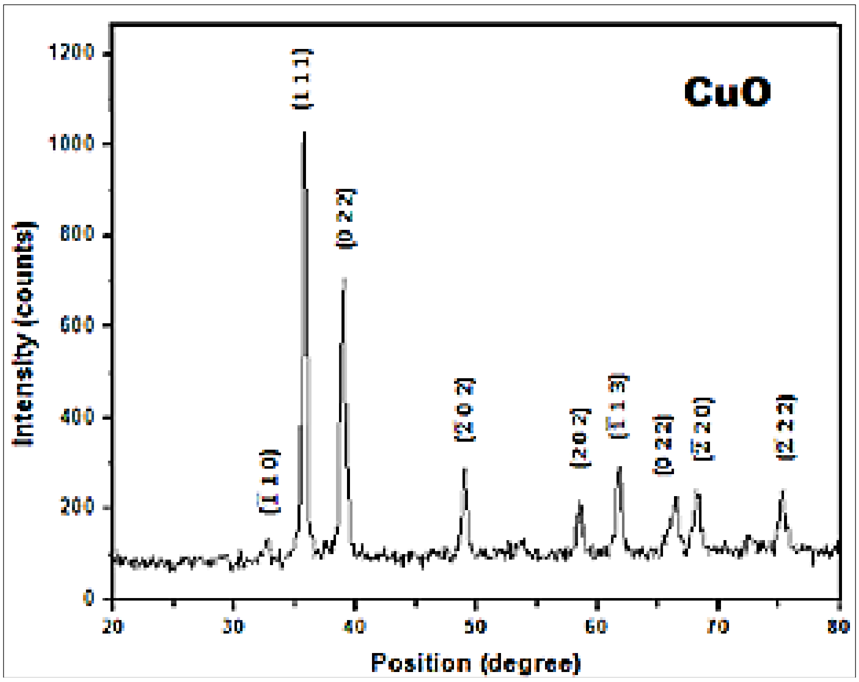

Fig 3a: XRD pattern of prepared CuO nanoparticles.

Fig. 3b depicts the XRD pattern of the as synthesized NiO nanoparticles.

The XRD peaks are appeared at angles (2θ) of 37.26˚, 43.50˚, 63.08˚, 75.39˚ and 79.50˚ corresponding to (111), (200), (220), (311), and (222) planes, and very good accordance with a cubic NiO crystal structure (JCPDS Card No: 78- 0643: space group = Fm3/m). The average crystallite size of the as synthesized nanoparticles was 21.49 nm.

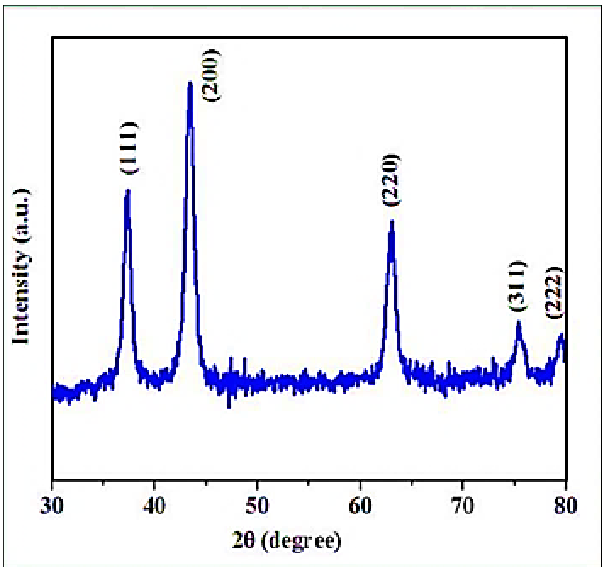

Fig 3b: XRD pattern of prepared NiO nanoparticles.

ZnO powder sample were studied with XRD using Cu K alpha radiation (k = 1.5406 angstrom). The XRD pattern is shown in the Fig. 3c. The prominent peaks are obtained at 31.57º, 34.16º, 36.56º, 47.75º, 56.44º, 60.53º, 62.83º, 66.33º, 68.13º, 69.12º corresponding to the planes (100), (002), (101), (102), (110), (103), (200), (112), (201), (004) respectively which corresponds to the hexagonal wurtzite structure of ZnO.

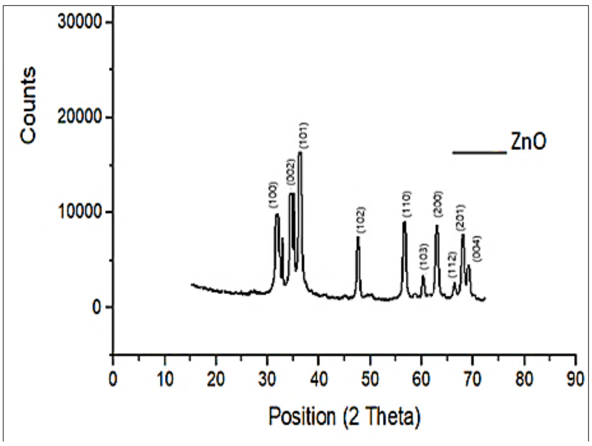

Fig 3c: XRD pattern of prepared ZnO nanoparticles.

Scanning electron microscopic (SEM) studies

Fig. 4a depicts the SEM image of CuO looks flower like morphology nanostructure. The morphology of prepared nanoparticles was studied using scanning electron microscopy. The nanoflower-like shape used in this study enables for more results from a combination of reactant molecules to much more active areas, improve the effectiveness of photocatalysis.

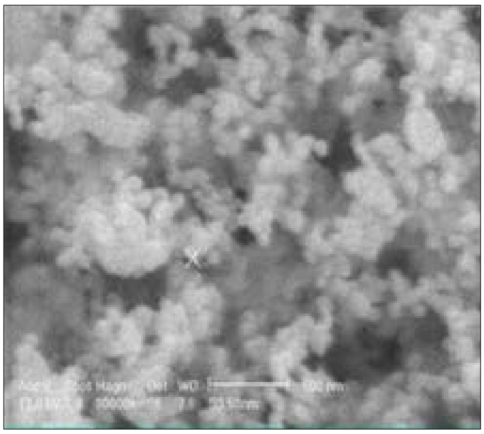

Fig 4a: SEM image of ZnO nanoparticles.

Fig. 4b shows the SEM image of synthesized NiO nanoparticles. From the figure, the surface is observed to be smooth and covered with uniform spherically shaped grains and also we observed the agglomerated particles due to surfactant free synthesis of NiO nanoparticles.
The morphology of the prepared pure ZnO was obtained using SEM. Using the SEM image, we can observe the surface of the sample. Fig. 4c gives us the SEM image of the prepared pure zinc oxide nanoparticle at a magnification of 100,000. From the SEM image, we can see that the nanoparticles are in the form of flocks. Also as a result of this, the nanoparticles have different shapes.

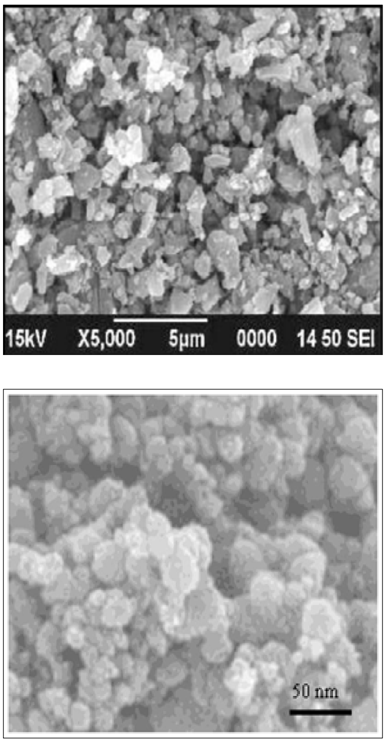

Fig 4: SEM image of the **4b**: NiO and **4c:** ZnO nanoparticles

Fourier Transformation Infra-Red (FTIR) analysis

The Fig. 5 shows the FTIR spectra of CuO, NiO and ZnO nanoparticles. From the spectrum of 5a the peaks 3000 cm^{-1} to 3500 cm^{-1} are due to bending oscillations of -OH groups which generally semi conducted nanostructure material absorbed in the surface owing to its mesoporous arrangement (Kana *et al*., 2019; Zheng and Liu, 2007). In the spectrum of CuO dual frequency crests at 596 and 521 cm^{-1} relates to M-O band vibration frequency supports that the presence of monoclinic phases (Lim *et al*., 2012; Mehedi Hassan *et al*., 2015). The vibrational characteristics of CuO nanostructures were allocated to the low frequency range 400-700 cm^{-1} in the current study. Due to the sheer oxygen stretching vibration frequencies, there really is no peaks between 1500 and 3300 cm^{-1}. Peaks at 525 and 580 cm^{-1} in the FTIR spectra of CuO-NPs have been observed and are very well aligned with findings (Rathnakumar *et al*., 2019; Chandrasekar *et al*., 2021). As a result, the metal-oxygen occurrences measured for pure and doped CuO-NPs are quite identical to those described in the literature.

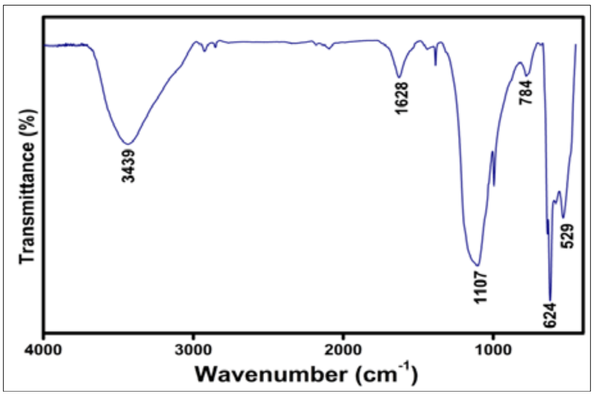

Fig 5a: FTIR spectra of the CuO nanoparticle

Fig. 5b displays the FTIR spectrum of NiO nanoparticles. The broad absorption band at 3425cm^{-1} and the weak peak at 1627cm^{-1} are assigned to -OH stretching and bending modes of water, respectively. The wide absorption band around 1381cm^{-1} can be ascribed to CO_3^{2-} ions. The peak at 1033 cm^{-1} corresponds to stretching and bending vibrations of the intercalated C-O species and the bands at 2924 cm^{-1} and 2854 cm^{-1} can be assigned to -CH_2 vibrations. The peak observed at 416 cm^{-1} which correspond to Ni-O nanoparticles stretching mode.

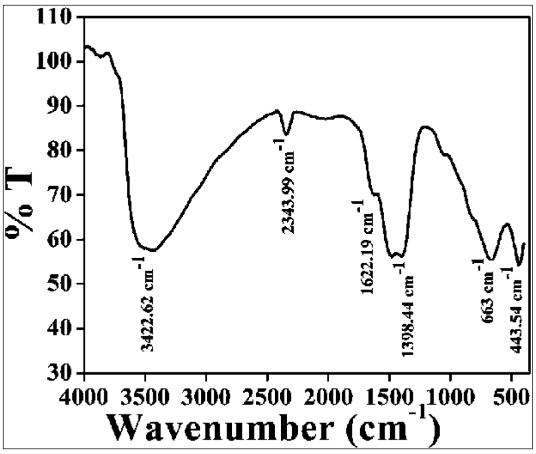

Fig 5b: FTIR spectra of the NiO nanoparticle

The UV-visible absorption spectra of ZnO nanoparticles are shown in Figure 7c. Although the wavelength of our spectrometer is limited by the light source, the absorption band of the ZnO nanoparticles shows a blue shift due to the quantum confinement of the excitations present in the sample as compared with the bulk ZnO particles. This optical phenomenon indicates that these nanoparticles have a quantum size effect.

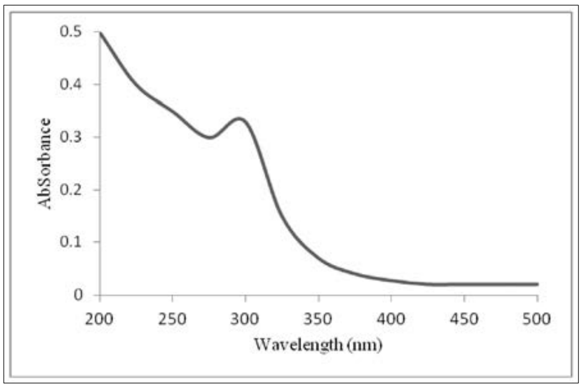

Fig 5b: UV-Visible spectra of the ZnO nanoparticle

Microbiology of Root canal Infections

Mechanism of Action of Metal Oxide (MO) Nanoparticles Breakdown of the cell membrane caused by electrostatic interaction The negatively charged surfaces of bacteria interact with positively charged nanoparticles through the law of attraction between negative and positive charges, causing NPs to accumulate on the surface of bacterial cells. Because of the efficient bonding between these positively charged NPs and the cell membrane, the structure of the cell wall is disrupted, which makes the cell more permeable and makes it easier for NPs to enter the bacteria and cause cellular content escape. Those nanoparticles impact DNA replication, division, and respiration by attaching to mesosomes [32-33].

Generation of Reactive Oxygen Species (ROS)

When nanoparticles penetrate a microorganism's cell membrane, they release ROS, which puts the cell under stress due to oxidation and initiates the bacterium's attack. The attack results in reduced respiration and ATP synthesis, which damages the cell membrane. Active redox reactions and the pro-oxidant functional group on the metal oxide nanoparticles interface allow a metal oxide to produce ROS [34]. Enzyme and protein malfunction By initiating the oxidative process of the amino acid chain, NPs promote the creation of carbonyls, which are naturally protein bound and result in protein breakdown, the deactivation of numerous enzymes, and disruption of catalytic activity [35-36].

Effective Physiochemical Properties of MONPs on Antimicrobial Activity Chemical composition of MONPs

The antibacterial ability of metal oxides is impacted by the kind of metal ion particles and the composition of their molecules. Metal ions including Ca^{2+}, Mg^{2+}, Cu^{2+}, Zn^{2+}, Co^{2+}, Fe^{2+} and Ni^{2+} are required for various metabolic processes in the majority of surviving bacterial strains, but at larger quantities, they may be toxic. Ag^{+} and Hg^{2+} two unnecessary metal ions, demonstrated a significantly higher antibacterial action at remarkably low quantities [37].

The ability of metal ions to bind selectively to ligand atoms found in biomolecules and cellular constituents may contribute to their antibacterial action. Hard soft acid base theory is the foundation for the interaction between ligand atoms and metal ions (HSAB principle). According to the HSAB principle, hard acids join with hard bases, while soft acids join with soft bases [38]. An excellent affinity of divalent copper for biological molecules is shown by the Irving Williams series of ligand affinity for the essential first-row transition divalent metal ions. This shows that at higher concentrations, divalent copper may be most dangerous [39].

MONPs Size and Surface Properties

Particle size has a major impact on how MONPs interact with bacterial cells and other biological systems. Because of their increased surface to volume ratios and noticeably higher particle numbers per mass, nanoparticles demonstrated stronger antibacterial activity than microscaled (bulk) particles. Numerous reports have documented the size-dependent interaction between bacteria and MO nanostructures. Under normal lighting conditions, the Zinc Oxide Nanoparticles (ZnONPs) considerably inhibit gram-positive as well as gram-negative bacteria in comparison to the bulk particles [40-42]. The zeta potential of MONPs describes their surface charge characteristics. The Point of Zero Charge (PZC) is the pH at which the surface charge is neutral. MONPs can exhibit positive, negative, or neutral charges. NPs with the highest positive charge show the greatest antibacterial activity, followed by those with neutral, then negative charges. When the pH is below the PZC, the oxide surface is positively charged; when above, it is negatively charged.

Concentration of MONPs

With increasing concentration in the media, MONPs exhibit increased antibacterial activity [43]. Greater MONP concentrations may be associated with a greater surface area, this eventually promotes stronger contact with bacterial cells and increased antibacterial activity. The Minimum Inhibitory Concentration (MIC) is the most often used metric in microbiology to quantify the in vitro antibacterial activity assessment of MONP [44]. The MIC of an antimicrobial drug is the concentration at which, following overnight incubation, bacteria cannot grow visibly [45].

The shape dependent antibacterial characteristics of MONPs

Each form of nanoparticle has unique physicochemical properties, such as surface characteristics, solubility, and the potential to produce ROS in certain metal oxides, which influence their antibacterial activity. Studies show that different forms of MO-NPs exhibit varying antibacterial properties. For instance, ZnO nanopyramids have significantly greater antibacterial activity against Methicillin-Resistant Staphylococcus aureus (MRSA) compared to nanoplates and nanospheres40. Another study found that spherical ZnO NPs possess higher antibacterial power than rod-shaped ZnO NPs [40].

Various MONPs in Endodontics

Copper oxide

Copper is a cheap, readily available metal that can be affordably manufactured into nanoparticles. Either copper metal ions or oxidized cupric ions produced from copper nanoparticles (sizes ranging from 1 to 100 nm) have antimicrobial action. It is simple to mix and link copper nanoparticles with polymers, ceramics and other metals. In certain combinations, they exhibit physiochemical stability as well [46]. Copper is a common metal in dental and medical research because of its low toxicity and antibacterial properties [47]. According to reports, Copper Oxide Nanoparticles (CuO NPs) exhibit antibacterial properties and prevent the formation of biofilms [48]. Copper nanoparticles' high surface area to volume ratio amplifies their antibacterial activity [49]. Furthermore, dose dependence is shown in the antibacterial activity of copper oxide nanoparticles [50]. The antibacterial properties of these nanoparticles have been well studied, yet it is unclear how precisely copper nanoparticles work against microorganisms [51-53]. These nanoparticles are effective against both gram positive and gram negative bacteria because they have the ability to enter bacterial cell membranes and damage the organism's vital enzymes. They possess some antifungal properties as well [54]. In caries prevention, copper nanoparticles have the ability to inhibit S. mutans from growing and colonizing on the surface of tooth roots, hence preventing root caries [55]. Composites with distinct physio chemical properties can be created by simply incorporating copper oxide nanoparticles into polymers. Copper oxide nanoparticles can be used to dental adhesive to prevent early or carious white spot lesions because they are antibacterial without compromising shear bond strength [55-56]. In soft denture liners CuO NPs were added, and this resulted in a considerable reduction in oral pathogen colonization and plaque development, particularly C. albicans accumulation.

Zinc oxide

Zinc oxide Although most living things require zinc as a trace metal for numerous metabolic functions, excessive amounts of zinc can be toxic. Because ZnO NPs are less harmful to humans than CuO NPs and AgO NPs and can be synthesized at a cheap cost, they are frequently utilized in cosmetic items, medicine and wound healing to treat fungal infections and acne. They also display a broad spectrum of antibacterial activity [57]. It has been discovered that ZnO NPs possess antibacterial qualities. Modest amounts of ZnO NPs had no effect on the mechanical properties of dental resin composites, but they did prevent *S. mutans* from growing and adhering to the material [58]. When ZnO NPs were added into Glass Ionomer Cement, it considerably increases antibacterial activities against *S. mutans* without affecting mechanical properties [59]. According to the study, ZnO NP doped with magnesium and silver has a stronger antibacterial effect than ZnO NP against *S. mutans*.

Synthesized NP exhibits antibacterial activity against bacteria when its cell walls are compromised. These results in the distortion of constructional proteins, inactivation of enzymes, disruption of electron transport chains, deformation of nucleic acids, and facilitation of oxidative stress caused by reactive oxygen species. According to a number of studies, adding ZnO NPs to dental adhesive systems greatly enhanced their antimicrobial capabilities without having a negative impact on the bond strength [60-62].

One method that is most frequently utilized to treat endodontic infections is endodontic treatment. Complete eradication of dental infections is not possible because to the polymicrobial character of endodontic infections, which involve a variety of bacteria and germs such as *E. faecalis, S. mutans and S. anginosus, F. nucleatum,* and *S. aureus* [63-64]. An excellent filling material for root canals should not shrink, f ill the channels easily, stick to the walls easily, or harm the periapical tissue or permanent tooth germ.

Additionally, two important considerations while selecting the best among them are their antibacterial and biocompatible qualities [65-68]. The micro leakage and antibacterial properties of zinc oxide eugenol (ZOE), epoxy resin sealer (AH26), silver ZnO nano powders, and ZnO nanopowders were investigated. Shayani Rad reports that the nano ZnO sealer demonstrated better antibacterial properties against *E. faecalis, E. coli, C. albicans, S. mutans* and *S. aureus* than two widely used endodontic sealers, AH26 (resin-based) and Pulpdent (ZnO based) [69-70]. These nanoparticles enhance alkalinization and antibacterial activity against Escherichia faecalis when coupled with calcium hydroxide nanoparticles and chlorhexidine as an intracanal medication. After being coated with ZnO NPs and pre-treated with argon plasma, f lawless gutta percha cones displayed antibacterial action against *S. aureus* and *E. faecalis*. As a result, there is less chance of reinfection and endodontic failure and an effective hermetic seal is created [71].

Conclusion

In this work, we have synthesized metal oxide nanoparticles by employing a simple and cost effective, wet chemical precipitation method.

The XRD spectra revealed the hexagonal wurtzite structure in the prepared ZnO nanoparticles. The optical characterization has been performed using the UV-Vis spectroscopy. The blue shift in the absorbance spectrum of as - prepared ZnO sample with respect to the bulk counterpart has been identified. The absorption peak of as prepared ZnO sample was centered at 301.2 nm. The widening of band gap has been observed for the prepared ZnO sample. The optical band gap of as prepared ZnO nanoparticle was found to be 3.7943 eV. The transmittance spectra analysis revealed very high transmittance of a prepared ZnO sample to the visible region. The particle size of the synthesized ZnO nanoparticle was estimated using effective mass model and was found to be 4.38 nm.

Due to their excellent mechanical, chemical, biological, and physical properties, nanomaterials (NMs) have recently become more and more prominent in technological advancements. These qualities have allowed performance to rise above that of its conventional counterparts. Nanomaterials can be used to fight endodontic and caries-related bacteria, lessen the formation of biofilms, and prevent the demineralization of the tooth structure. These results have been positive enough to open the door for more clinical studies that will confirm the usefulness of nanotechnology based materials for therapeutic purposes. Thus, by promoting better oral health and lowering healthcare costs, the use of metal oxide nanoparticles in dentistry can ultimately benefit both individual patients and society at large. It can also increase the antibacterial efficacy, lengthen the duration of dental treatments and significantly reduce the incidence of dental diseases.

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