Application of nanoparticles in biomedical science

4.1 Nanoparticles in dentistry

The poor oral hygiene, food habits, and intake of sugary materials may result in dental problems such as tooth decay, infection and maybe the formation of large cavities. When a patient visits a dental hospital or a dental surgeon, they are often advised to undergo root canal treatment or dental filling. The dental filling which is used for filling the dental cavity is mainly based on resin and other material, but it was noticed that they are not long-lasting and may leave the cavity in 2–3 years. Now, this resin-based composite is replaced by the nanoparticle-based nanocomposite which has additional properties of silver, i.e., antimicrobial which prevent infection due to dental pathogens. The nanomaterials are also used in decreasing biofilm accumulation. Nanomaterials help in the demineralization process and also remineralize the structure of the tooth apart from antibacterial activity against caries-related bacteria. This strong and effective antimicrobial activity is due to the nanoparticles of silver and ammonium compounds. The remineralization of the dental structure is achieved by the nanoparticles of calcium phosphate and calcium fluoride (Iftekhar, 2019).

The nanobiomaterials exploit the properties of chitosan, and modified chitosan is readily used in many biomedical applications. Chitosan has multiple properties as it is polyfunctional and with properties of biocompatibility and biodegradability, in addition to antibacterial activity

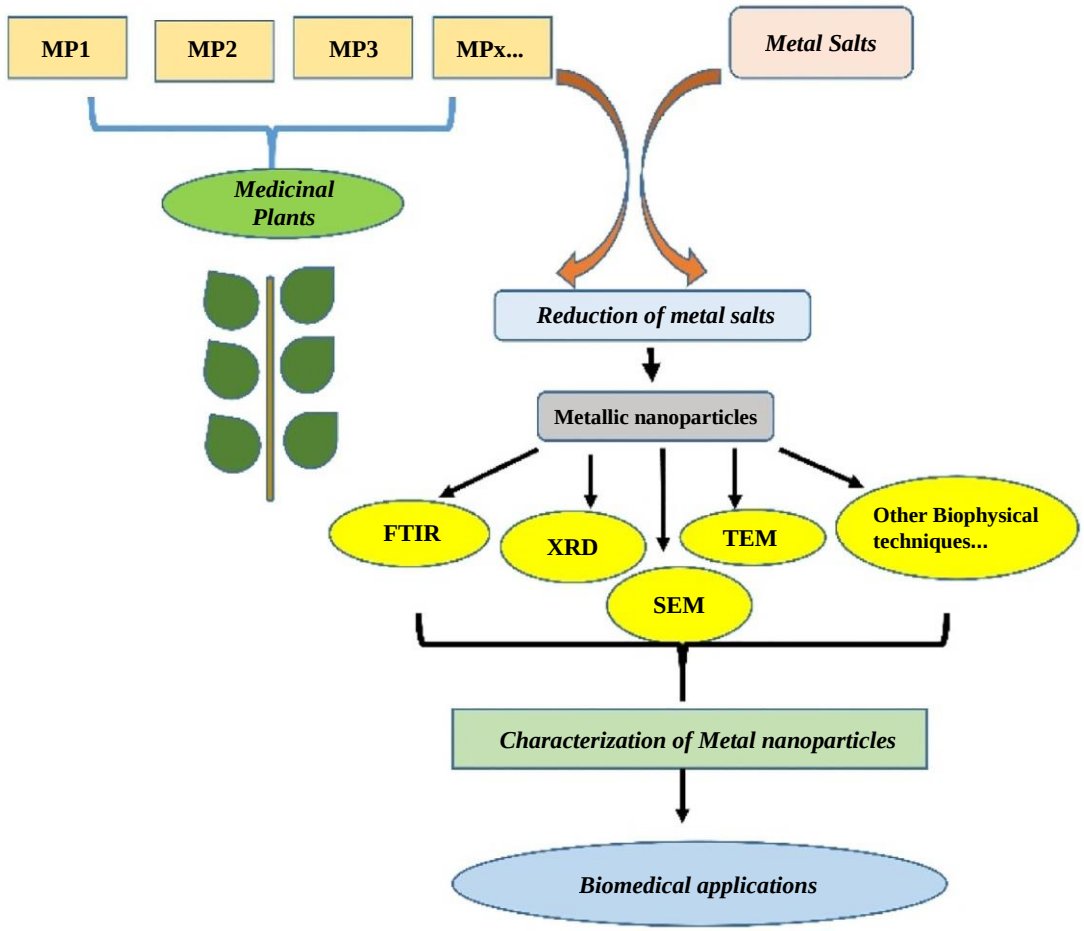

Fig. 3
Plant-assisted nanoparticle synthesis using the green approach.

and low immunogenicity. Chitosan can be chemically modified and the fabricated bionanomaterials find uses in biomedical applications. There is so much of advancement of nanobiomaterials, so chitosan has been chemically modified to form nanocomposites, and they are used in many medical applications (Ahmad et al., 2019).

Tooth decay is one of the common problems in dental science. If the decay is inevitable, then whole tooth has to be removed and in place of the uprooted tooth, there is a process of tooth implant in which a prosthetic tooth of metals like titanium, zirconia, etc. is used. However, the cost of implanting a prosthetic tooth of these materials is expensive. The carbon nanotube (CNT)-based implant is an interest of area because of its unique properties like simple structure, durability, and cost-effectiveness (Teh et al., 2019).

In restorative dentistry, there is use of restorative materials which are required for adhesion of filling material. The most common restoration materials used in restoration dentistry is Glass ionomers (GI) containing calcium, strontium aluminosilicate glass powder (base) combined with some copolymers.

The prepared silver nanoparticles were reinforced with glass ionomer cement to meet the said two limitations simultaneously. The reinforcement of AgNPs in GIC provides the enhancement in the hardness of conventional GIC. Silver nanoparticles were prepared by a novel green synthesis technique using Mangifera indica (Mango leaves) and found to be successfully used in dental applications (Sundeep et al., 2017).

4.2 Nanoparticles in cancer

In the past few decades, there is a burgeoning incidence of cancer patients in India and other countries. The possible reason for the increasing incidence might be the use of smoking, chewing Tobacco, packed foods, preservatives, sedentary lifestyle, inherited genetic defects, mutations due to radiation exposure, some viral or bacterial infections. The reasons for the cause are many, but in modern science treatment is complicated and painful. The patient who is suffering from cancer may be likely to have undergone one of the following methods, i.e., surgical removal of the affected part, use of chemotherapy, radiations, etc. The cure available to cancer is dependent on surgery, radiotherapy, and chemotherapy and there is a high risk of damage to tissues which are normal and healthy. Nanotechnology has provided immense opportunities in the cure of cancer cells and inhibition of neoplasms, thereby reducing painful treatments presently available. Due to these costly procedures, the patient may or may not recover from cancer because in most of the cases it was observed that due to chemotherapy patients encountered severe side effects such as loss of hair, hematogical imbalance, behavioral changes, nausea, vomiting, loss of appetite, constipation, etc. In ancient Indian literature, there are some examples of plants that are used for the treatment of certain cancers (Singhal, 1983). The literature survey suggests that some medicinal plants described in the ancient literature can be exploited to develop nanoparticles which have better action and produce significant results. Al-Sheddi et al. (2018) synthesized silver nanoparticles (av. size 33 nm) from *Nepeta deflersiana*, which showed anticancer potential by causing cell death HeLA and these anticancerous properties can be utilized for the treatment of cervical cancer cells. The black peel pomegranate was used to synthesize silver nanoparticles and evaluated against breast cancer cell lines, i.e., BT-20 and MCF-7. The synthesized AgNPs cause 81%–89% cell death of the tumor cell line and it does not have much toxicity against normal cells (Khorramia et al., 2019).

.3 Nanoparticles in theranostics

The major problem in medical science is the detection of cause of disease. The patient who is suffering from any disease comes very late to the doctors. In India, people are avoiding going to the specialized doctor due to many reasons such as economic condition and lack of time. So

they prefer to consult a pharmacist or drug seller for their ailment and take drugs prescribed by them, but the latter may not know what drug he is prescribing and how it acts. In case of cancer, the major problem associated with the condition is that cancer cells are detected very late and that is the main cause of mortality in India. Very few people in India are aware of screening and testing of cancer. Theranostics is a combination of diagnostics and therapeutics for cancer. It is the most advanced method for the treatment of several biomedical complications such as cancer, pulmonary disorder, cardiovascular diseases, kidney disorder, and neurodegenerative diseases. The nanotheranostic field is now having tremendous prospects in the diagnosis and treatment of different types of cancer (Rajasekharreddy et al., 2019).

4.4 Nanoparticles as antimicrobial agents

The first antibiotic penicillin was discovered in 1928. Since then, many antibiotics or antibiosis phenomena have been reported by several authors from microbial sources. The antibiotic penicillin was a miracle drug after its discovery, particularly for soldiers who encountered wound infection during the world war. Nowadays many antibiotics are present and saving the lives of many patients suffering from acute and chronic diseases. The importance of antibiotics in India and abroad is well established and it was irrationally prescribed for the treatment of common cold to many other diseases. The irrational use of antibiotics or antimicrobial agents on an empirical basis is mainly responsible for the wide spread of antibiotic resistance (Chandra et al., 2017; Srivastava et al., 2014). Rather than visit the doctor, people prefer to get the medicine from a pharmacist in India and get treated without knowing the exact dose and course of that antibiotic. Nowadays most of the bacteria becomes resistant to first- and second-generation antibiotics to date and no new antibiotic has been discovered. The problem of antibiotic resistance is not a problem of a single country; rather, it is a global problem. The emergence of MDR, XDR makes the life very difficult if we encounter diseases from these orthodox strains (WHO, 2000). The Indian subcontinent has a very rich diversity and traditional knowledge of medicinal plants which were used from ancient times to treat different ailments. The green synthesis of metal nanoparticles using medicinal herbs can be beneficial as antimicrobial therapeutic agents. Chandra et al. (2019) reported the antimicrobial potential of the medicinal plant Berberis aristata against urinary tract infection causing bacteria and the synthesized zinc oxide nanoparticle also possesses significant antioxidant properties.

The actinomycetes isolated from marine sponges was used to synthesize silver nanoparticles when tested against pathogenic bacterial species. The synthesiszed nanoparticles showed significant antimicrobial activity against *P. aeruginosa* and *Enterobacter cloacae* (Hamed et al., 2020). The green synthesized silver nanoparticles from *Nyctanthes arbortristis* were shown to have good antimicrobial activity against *E. coli* MTCC 443 (Gogoi et al., 2015). The cosmopolitan nature of microorganisms makes them very difficult to control; the presence of pathogenic bacteria is the leading cause of food poisoning and foodborne pathogen. The use of a preservative and physical process can reduce the burden of bacterial load. However, the use of

a preservative and other chemical can lead to some health issues, particularly in children. The possible way to tackle this problem is with a phytoassisted (medicinal) nanoparticle, which is safe and effective and can be used in small amounts as compared to a chemical preservative. Pu-erh tea leaves were used to synthesized silver nanoparticles, and they inhibited the growth of all tested foodborne pathogen *E. coli*, *Klebsiella pneumoniae*, *Salmonella* Typhimurium, and *Salmonella* Enteritidis (Loo et al., 2018). *Lysiloma acapulcensis* mediated synthesis of silver nanoparticles having an average size of 5nm showed significant antimicrobial activity against tested bacterial strains, maximum activity was shown against *E. coli* followed by *S. aureus*, *P. aeruginosa*, and *C. albicans*. As compared to chemical synthesized nanoparticles, green synthesized (biogenic) AgNPs possess higher antimicrobial activity (Garibo et al., 2020).

The extremophile *Bacillus pumilus* was isolated from the Wadi El-Natrun Lake, Egypt and was exploited for the production of AgNPs and evaluated for antimicrobial and nematicidal activity. The synthesized AgNPs also exhibited potent antimicrobial properties against *S. aureus*, *Staphylococcus epidermidis*, *Streptococcus bovis*, *E. coli*, *P. aeruginosa*, *Shigella sonnei*, *K. pneumoniae*, and *Salmonella* Typhimurium.

5 Drug delivery

The most important aspect of pharmaceutical research or other research organization is that they should develop a kind of drug that specifically act on targeted cell or tissue. This strategy becomes very crucial in case of cancerous cells where targeted treatment is highly required. In recent days, the burgeoning cases of cancer are reported to be frequently affecting all ages of human beings. It is the main cause of mortality in human beings. Modern sciences or modern therapy include chemotherapy, surgical removal, and Radiotherapy to treat localized cancerous cell, but the main problem with this treatment is side effects such as anemia, fatigue, nausea, weakness, loss of hair, reduction in WBC count, etc. Targeted drug delivery systems (TDDS) represent the most promising drug delivery strategy for drug accumulation in the tissues of interest in vivo. A targeted drug delivery system typically consists of a nanocarrier and a targeting moiety.

6 Nanocarriers as drug delivery systems

The green synthesized metal nanoparticles can be important bioengineered nanocarriers used for the diagnosis of cancer and drug delivery in cancerous cells (Karmous et al., 2020). The ideal properties of a nanocarrier as a drug delivery system are that the carrier molecule should have the capability to increase drug absorption through the mucosal membrane and be acid tolerant so that there should be no degradation of active molecules. These nanocarriers must be able (1) to be stable in blood till it reaches the targeted tumorous cell, (2) to evade the mononuclear phagocytic activity, (3) to accumulate in TME through irregular tumor

vasculature, (4) to penetrate into the tumor interstitial fluid of TME with high pressure, and (5) to reach the active site and interact with the targeted cells exclusively (Barar and Omidi, 2013). In recent days, the Nanoparticle base drug delivery system is classified into three categories (Attia et al., 2019):

1. Inorganic-based nanoparticle (ceramic, gold, carbon nanotubes, etc.)
2. Organic-based nanoparticles (Micelles, liposome, etc.)
3. Hybrid nanoparticles

The major disadvantage with chemotherapy is the associated side effects such as nausea, gastrointestinal disturbance, anemia, loss of hair, reduction in WBC and it also affects the normal cells. To keep in mind the associated side effects, modern drugs (nanocarrier based) should be formulated in such a way that it should reach the target site without losing the activity as well as specific action against tumor cells.

The nanoparticle synthesized from the biodegradable polymer such as chitosan can be one of the best ways for the development of the drug delivery systems. The advantage of using chitosan for a drug delivery system is because it acts as an adjuvant and is capable of interacting and facilitating permeation across the plasma membrane. Another property which makes chitosan more useful as a nanocarrier is its low toxicity and high biocompatibility. The presence of a stabilizer such as chitosan in the synthesis of metallic nanoparticles can facilitate modification of the surface physical absorption, specific recognition, and electrostatic interaction and thus improve stability, which is important for determining the potential use of metallic nanoparticles as therapeutic agents (DeLong et al., 2010; Corbierre et al., 2004).

Conclusion

The burgeoning incidence of antibiotic resistance and emergence of new viral diseases such as COVID-19, SARS, Zika virus, Dengue viruses, Hanta virus, and many others has cost the lives of many human beings. The increasing incidence of mortality due to these diseases puts immense pressure on the scientific community to develop effective and cost-effective diagnostic and treatment technologies. More researches should be focused on the nano-based molecule, which can target the affected cells or tissues with minimal effect or no effect on adjacent cells. Nanotechnology has proven in the recent past years that this technology has immense potential in biomedical field as well as in therapeutics.