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Methods of Synthesis of Nanoparticles Used in Dentistry A Review Article

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Abstract:- The profession of dentistry has been transformed by nanotechnology. Nanomaterials are very sophisticated because of their distinctive and exceptional characteristics, like their large surface area. The most important element is that when nanoparticles are added, the performance of the material they are mixed into is improved. Advanced Nanomaterials have been developed and can now be used in dentistry thanks to a combination of impacts from other disciplines. There are many processes that can be used to create nanoparticles. Techniques for creating nanoparticles used in dentistry are described in this review.

Keywords:- *Nanotechnology, Synthesis, Nanoparticles, Dentistry*

I. INTRODUCTION

A Tokyo Science University student came up with the phrase “nanotechnology” in 1974(1). The manipulation of matter at the atomic and molecular levels, as well as matter that is smaller than a billionth of a metre or a nanometer, or around the size of two or three atoms, is the subject of this study. (2). Dentistry will enter a new age in the future when all procedures will be carried out with the aid of nanotechnology-based tools and equipment(3). Future oral health will depend heavily on high-tech and efficient administration of the tiny level, or nanotechnology, according to researchers. This article discusses the many physical, chemical, and biological processes utilised to create the nanoparticles used in dentistry(4). Three criteria for nanotechnology are set out by the US national nanotechnology programme:

- *The advancement of nanotechnology at the atomic, molecular, or macromolecular level, between one and one hundred nanometers(5).*
- *Creating and utilising compact or medium-sized systems, buildings, and equipment with unique features. (6)*
- *The capacity for atomic- and molecular-scale control or manipulation.(7)*

II. NANOPARTICLE CLASSIFICATION

According to their source, size, and composition, nanoparticles can be categorised;

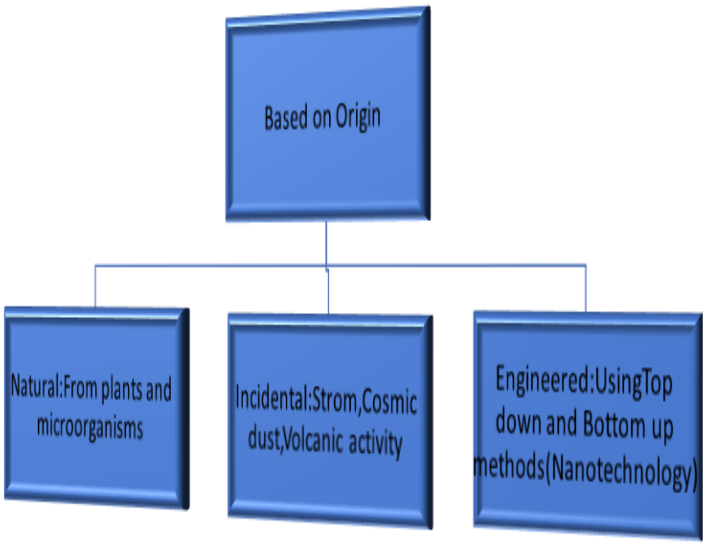

Fig. 1 Nanoparticle Classification Based on Origin

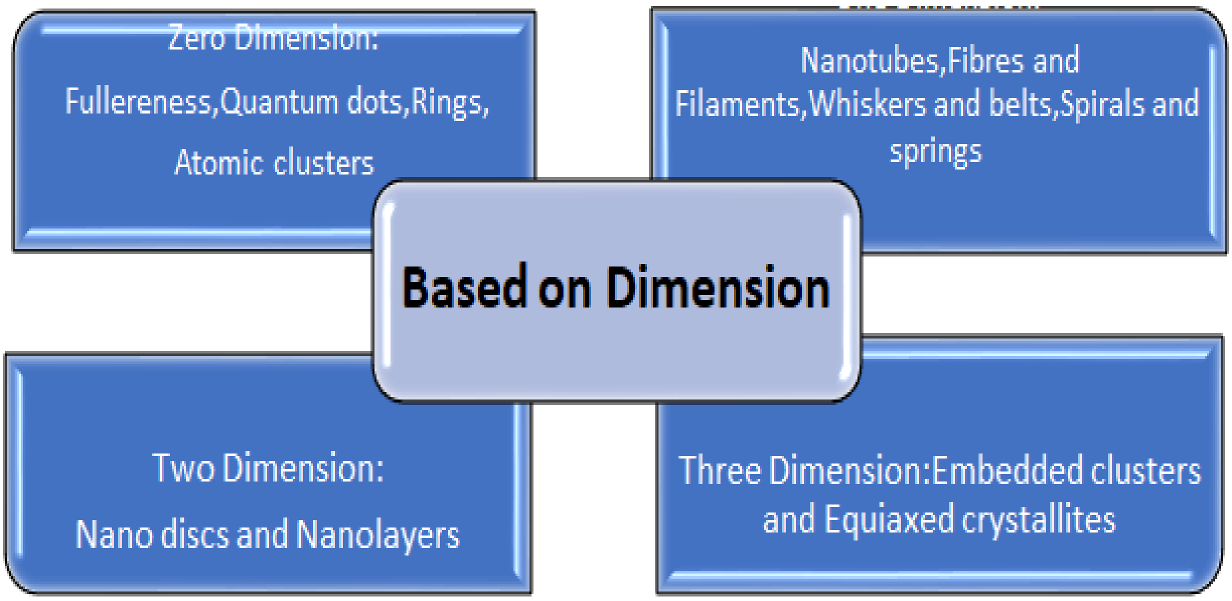

Fig. 2 Nanoparticle Classification Based on Dimension

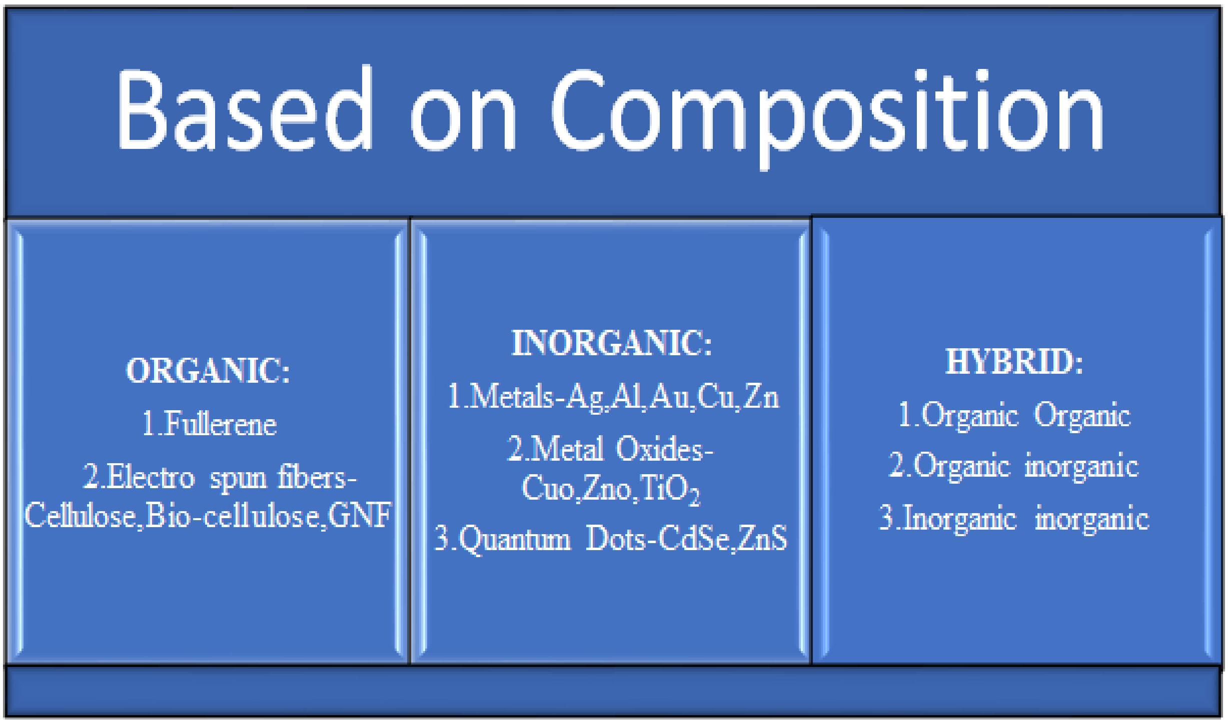

Fig. 3 Nanoparticle Classification Based on Composition

III. NANOPARTICLES USED IN DENTISTRY AND THEIR APPLICATIONS

Silver nanoparticles (AgNPs),Copper NPs(Cu NPs),Hydroxyapatite NPs(HA NPs), Aluminium oxide NPs(Al2O3 NPs),Zirconium dioxide NPs(ZrO2 NPs),Cobalt Chromium NPs(CoCr NPs),Gold nanoparticles (Au NPs),Calcium Phosphate NPs(CaP NPs),Zinc oxide NPs (ZnO NPs), Silicone dioxide NPs(SiO2 NPs),Quantam dots, Quaternary ammonium polyethylenimine NPs(QPEI NPs), Amorphous Calcium Phosphate NPs(ACP NPs),Triclosan and Tetracycline NPs, Titanium dioxide NPs (TiO2 NPs), Polyvinyl pyrolidone NPs(PVP) are the nanoparticles which plays the important role in Dentistry.

TABLE 1 Nanoparticles Used In Dentistry And Their Applications

Nanoparticles used in dentistry	Applications
Ag nanoparticles	Silver nanoparticles are utilised in composite materials such as Chitalac-Ag (12), AgNP-methyl polymethylmethacrylate amorphous calciumAgNP-phosphate (8), and fluorides (Nano Silver Fluoride). Silver plasma or silver nanoparticles can also be used by itself. (22).
Copper nanoparticles	It generates enough antibacterial action against Streptococcus mutans to protect dental adhesives against the bacteria and stops the adhesive contact from deteriorating. (11)
Hydroxyapatite nanoparticles	Used in nanofilled glass ionomer cements (17)
Aluminium oxide nanoparticles	Remineralisation of tooth surface (21)
Zirconium dioxide nanoparticles	Used as Nanoapatites for biofilm management on the tooth surfaces(9)
Cobalt Chromium nanoparticles	Surface covering made of nanocomposites to stop pathogenic microorganisms from adhering. (15)
Gold nanoparticles	Used as surface modifiers for implants,also used as optical probes which are used to detect early stages of oral cancer(18)
Calcium phosphate nanoparticles	These are deposited by discrete crystallisation on a surface that has been twice acid-etched (20)
Zinc oxide nanoparticles	used in root canal sealers as an antibacterial agent (28)
Silicone dioxide nanoparticles	Used as polishing agents and fillers(33)
Amorphous calcium phosphate nanoparticles	Used for irrigation in root canal treatments(40)
Quantam dots and Quaternary ammonium polyethylenimine nanoparticles	Used as alternate contrasting agents for the diagnosis of oral cancer, as a filler in commercially available endodontic sealers as Guttaflow because of its antibacterial qualities, and in root canal disinfectants (5,24)
Triclosan and Tetracycline nanoparticles	For treating deep periodontal pockets, commercially available as nanogen and arestin(39)
Titanium dioxide nanoparticles	High strength, corrosion resistance, and also biocompatible. Produced when it is incorporated into composite resins (40,41)
Polyvinyl pyrolidone nanoparticles	Remineralisation of demineralised dentin(42)

IV. NANOPARTICLES SYNTHESIS METHODS

There are two main methods utilised for the synthesis of nanomaterials, which are typically categorised as top-down and bottom-up methods.

A. Top-Down Approach

Large materials are reduced all the way to the nanoscale by top-down manufacturing. This method uses a lot of materials and, if extra material isn't disposed, could result in waste. The "top-down" manufacturing processes used to create nanoscale structures are mostly advancements of those currently utilised in micron-scale small-scale assembly. By reducing size even further, the nano dimension is reached (Lieber,2001)-(10).The methods employed-

- Mechanical milling
- Nanolithography
- Laser ablation
- Sputtering
- Thermal decomposition

B. Bottom-Up Approach

In bottom-up method of nanomanufacturing, items are assembled from smaller-scale atomic and molecular components, which might take a lot of time(11). Scientists are investigating the idea of combining specific molecular scale components that will naturally "self assemble" into organised structures(12).The methods employed in this approach-

- SolGel
- Spinning
- Chemical vapour deposition
- Pyrolysis
- Biosynthesis(Green Synthesis)

➢ *Top-Down Approaches*

- *Mechanical Milling*

One of the most well-liked top-down methods for creating different nanoparticles is mechanical milling. It is employed in the synthesis process, when various components are milled and to post-anneal the particles . Plastic deformation affects cold-welding, which increases particle size, fractures, which decreases particle size, which generates the nanoparticles. (13).

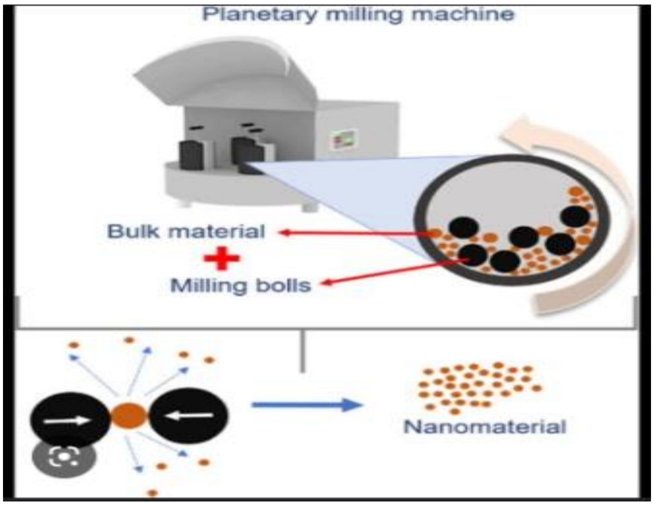

Fig. 4 courtesy-[43]

- *Nano-Lithography*

Nano-lithography, also termed as photonic, non - linear and non, scanning probe, and electron beam lithography(13), is the study of the construction of nano -scale nanostructures with dimension in range between 1 and 100 nm (14).

- *Laser Ablation*

It's a famous technique for making nanomaterials in a diverse range of solvents. (15), that requires exposing a metal (in solution medium) to light laser that consolidates to yield nanomaerials (16).

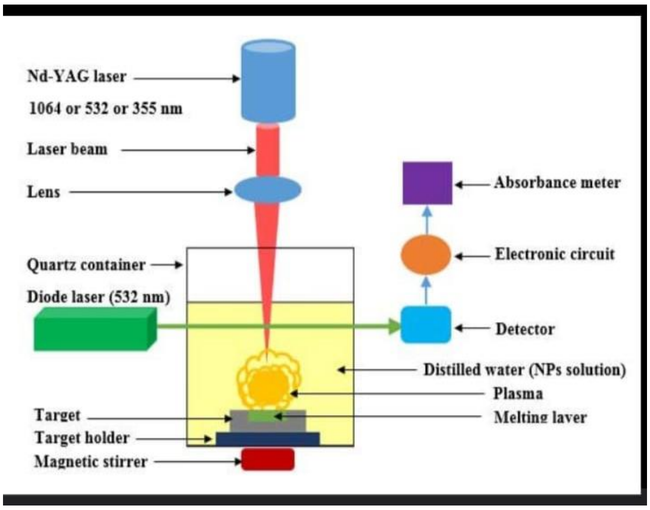

Fig. 5 courtesy-[44]

- *Sputtering*

Sputtering is the process of ejecting particles from an object when it collides with ions, depositing them on a surface as nanoparticles The usual procedure entails depositing a thin layer of NPs and annealing them. These variables control the substrate type, temperature, layer thickness, annealing time, and sizes and forms of the NPs(17).

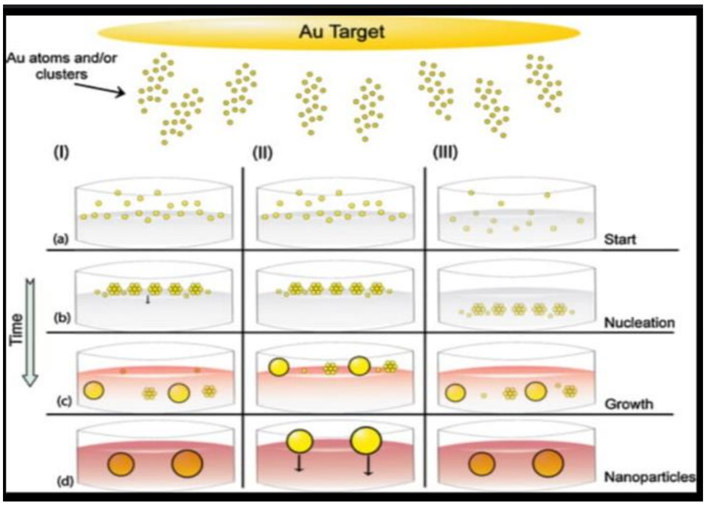

Fig. 6 courtesy-[45]

- *Thermal Decomposition*

The endothermic, chemically reactive heating process that dissolves chemical bonds in substances is referred to as the "thermal decomposition process." At certain temperatures, the breakdown of metal results in a chemical reaction and the creation of byproducts, which is how nanomaterials are created (18).

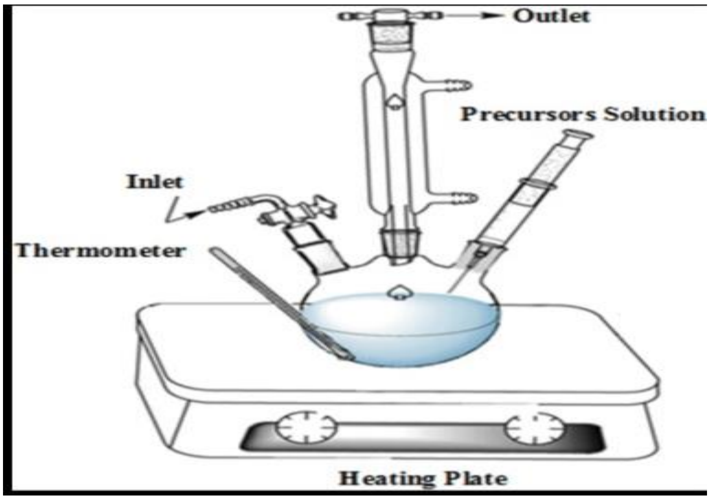

Fig. 7 courtesy-[46]

➢ *Bottom-Up Approaches*

- *Sol-Gel Process*

Due of its simplicity, the bottom-up sol-gel approach is widely used. The "sol-gel" wet-chemical technique produces discrete particles using a chemical solution (19). The mostly employed agents in this procedure are metal oxide and chloride. It's then stirred, shaken, or dispersed ultrasonically in a host liquid (20). A liquid phase and a solid phase are present in the finished system.The nanomaterials are recovered using a separated phase and a variety of processes, such as centrifugation, filtration, and sedimentation. Drying is frequently used in addition to removing moisture(21).

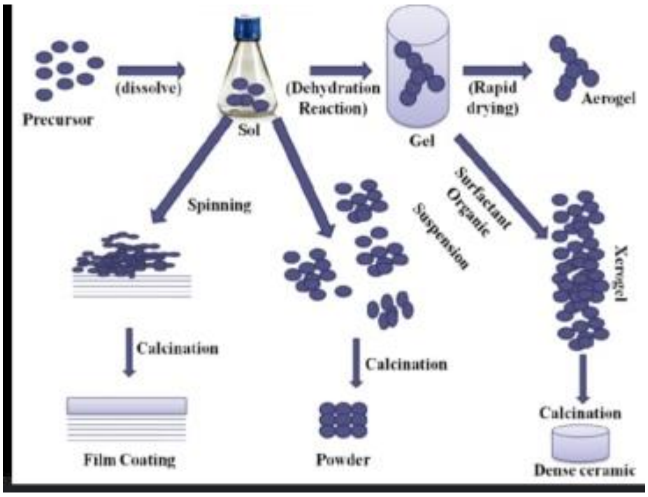

Fig. 8 courtesy-[47]

- *Spinning*

The reactor (SDR) spins nanomaterials inside a spinning disc where physical features can be seen (22). Some agents are introduced to remove undesirable reactants (23).Water and precursor solution are injected into the rotating disc at varied rates. Following the union of substances during the spinning process, precipitation, collection, and drying occur (24). A number of operational factors, affect the characteristics of nanomaterials generated by SDR (25).

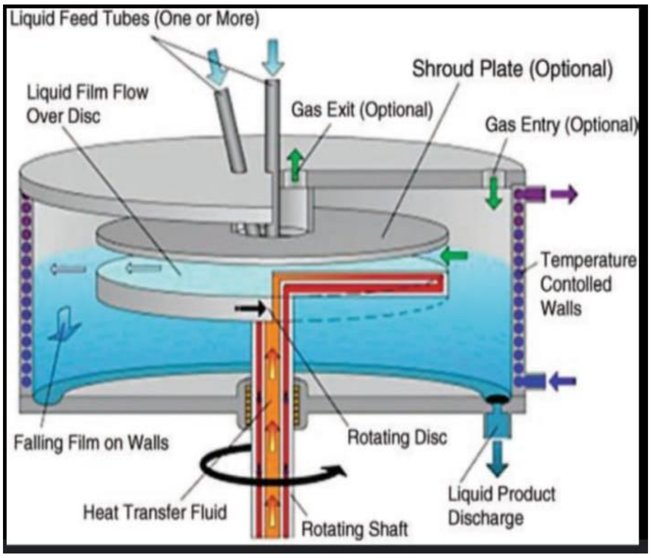

Fig. 9 courtesy-[48]

- *Chemical Vapour Deposition*

It is a method which works by depositing a thin layer on substrate (26). This reaction is carried out by mixing the substances in reaction chamber. When this heated underlayer interacts , a reaction takes place (27). Which leads to the formation of a layer of recyclable and reusable material on the substrate surface (28).One of the parameters impacting CVD is the substrate's temperature(29). Higher purity, homogeneity, and hardness are some of the advantages of CVD, but it has the drawback of requiring specialised equipment and producing gaseous by-products that are extremely hazardous(30).

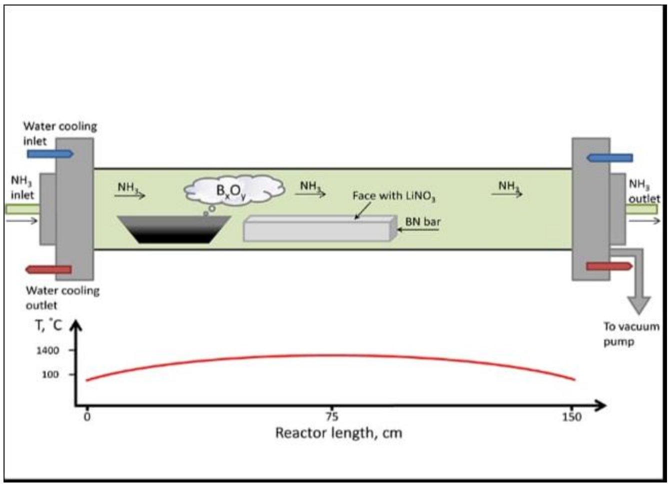

Fig. 10 courtesy-[49]

- *Pyrolysis*

Businesses that manufacture Nanoparticles on a large scale usually use the pyrolysis technique, which involves burning a precursor with a flame (31). To burn, it's pumped into furnace under very high pressure having a small opening (32). Then, in order to recover the nanomaterials, the by-product or combustion gases are divided into categories (33). Many furnaces create extreme raise in temperatures for straightforward evaporation using laser instead of using flame (34). Benefits include cost-effectiveness, continuous operation, and high yields (35).

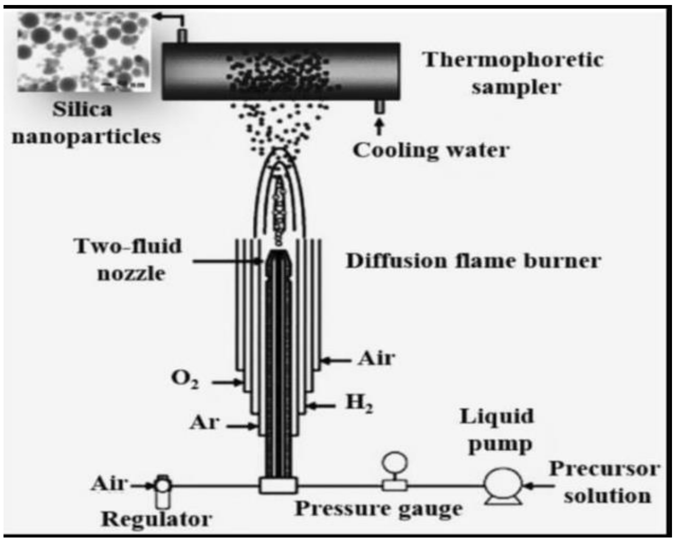

Fig. 11 courtesy-[50]

- *Biosynthesis*

The phrase "bio-synthesis" means safe and eco-friendly process- to produce nanomaterials that may be biodegradable and pose a much lower risk (36).Bio-Synthesis is otherwise called as green synthesis(using plants, algae, bacteria, fungi, yeast, actinomyces)(41).

Although conventional methods have long been used, studies have indicated that GS is the most effective technique for developing NPs because it has lower failure risks, is more affordable, and is simpler to characterise. GS particles differ from those made through physical and chemical processes. The chemical method, which replaces an expensive chemical RA with biological components like a plant extract, is analogous to GS, a bottom-up mechanism for developing MNPs. There is a lot of potential for NP production in biological entities. Green MP to NP conversion is cost-effective, scalable, chemical-free, sustainable, and environment-friendly(39).

Additionally, the GS of NPs results in the recycling of priceless metal salts like Au and Ag that are present in waste steams. Due to their better features, green coordinated NPs are currently favoured over NPs obtained through conventional means. Additional compounds that are harmful and dangerous to human health and the environment may increase particle reactivity and toxicity as well as have unintended negative effects on health because of their uncertainty and ambiguous composition(38).

Green synthesis techniques are intriguing because they can reduce the toxicity of nanoparticles. The use of plant extracts is growing in acceptance as a result (32, 33). The first stage in a typical plant-mediated metal nanoparticle manufacturing is to collect and purify the desired plant component. The herb is then dried and ground into powder. Depending on the concentration needed to produce plant extract, deionized distilled water is typically added to the plant powder.

After that, this solution is boiled before it is filtered. The proper amount of metal salt solution is added to a certain volume of the extract. The mixture is fully mixed as it is heated to the necessary temperature for the designated amount of time. When metal ions are transformed into metal nanoparticles, the solution takes on a different colour, which may be seen in the solution's UV-visible spectrum(40).

- *Benefits of Plant-Delivered Green Synthesis Over Microorganism-Delivered Methods:*

In plant extract-based synthesis techniques, the reaction rate is relatively high. This reaction can take anywhere between a few minutes and several hours, depending on the type and quantity of plants, while with microorganism-based techniques, microbe cultivation takes much longer (2 or more days). This demonstrates that this is a methodical approach. In addition to these bacteria, some of them are quite dangerous and a health risk to people. However, the majority of these, including Pseudomonas, Fusarium, and E. coli, are secure and safe to produce nanoparticles(41). In nature, there are several plants that are almost constantly present, especially evergreens. Plant extracts can primarily produce metal nanoparticles at room temperature, but when it comes to reactions, the reaction mixture and growth medium need to be heated. Plant extracts, rather than microbes, are better suitable for mass production(42).

So, these are all the some physical, chemical and biological methods used for nanoparticle synthesis by top-down and bottom-up approaches.

V. CONCLUSION

Integration of this technology and dentistry will improve the standard and present treatment strategies. It may offer a cutting-edge technique for the manufacture of dental materials that improves the effectiveness, precision, and speed of care while lowering costs. The treatments in dentistry may be improved by further investigation into nanotechnology and antibacterial materials. Its effectiveness in dentistry depends on substantial study into the creation of cutting-edge, restorative nanomaterials. This review article emphasises the need for further advancement in nanotechnology and clarifies the steps involved in creating the nanoparticles utilised in dentistry.

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