

## Original Research

# Knowledge and attitude towards application of nanotechnology in dentistry among post graduate dental students of Bhopal city: A cross-sectional study

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### ABSTRACT

Nano-dentistry utilizes nanoparticles and nano-materials to revolutionize dental treatments, offering enhanced precision, durability and effectiveness in oral health care solutions. A survey of 200 postgraduate dental students in Bhopal revealed that 65% were knowledgeable about nano-dentistry, with over 60% expressing positive views on the applications of nanomaterials in improving diagnosis and treatment of conditions like cancer, cardiovascular and neurological conditions, diabetes etc. More than 84% students wanted more information on nanodentistry in dental curriculum with 65% wanting it to be included as a separate subject. These findings indicate a strong awareness and positive perception towards nanotechnology in dental care. The study highlights the growing interest and underscores the need to integrate nanotechnology into dental curriculum to maximize its benefits for oral health care.

### Introduction

Nanoparticles are particles that are from 1 to 100 nanometres in size; they have large surface area to volume and size-related characteristics which make them suitable for use in various fields.<sup>1</sup>

This study looks at the clinical applications of nanotechnology in dentistry, with an emphasis on implantology, preventive care, orthodontics, restorative dentistry, and endodontics. Nanotechnology, the manipulation of matter on an atomic, molecular, and supramolecular scale, has revolutionized various scientific fields, including medicine and dentistry.<sup>2</sup>

Nanomaterials as raw materials manufactured robots are called "nanorobots". Due to the advancement of science and technology, nanomaterials have gained potential in

the field of medicines and pharmaceuticals. Nanorobots are mainly utilized for the treatment and diagnosis of cancer and are found also effective in other medical purposes like DNA probes, cell imaging materials, and cell-specific delivery vehicles.<sup>3</sup>

Nanotechnology offers innovative solutions in preventive, diagnostic, and therapeutic dental care. Applications include nanomaterials in restorative dentistry, endodontics, periodontics, oral surgery, and implantology.

The study was needed to assess dental students' knowledge and attitudes towards nanotechnology, as they are future practitioners who will drive its clinical integration. Identifying educational gaps will help improve dental curriculum ensuring students are well-

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prepared for modern, technology-driven practices.

### Material and methods

This was a cross sectional study for which structured questionnaire comprising of 14 questions was validated by subject experts in the field of dentistry. The postgraduate dental students were provided with online consent form and participant's information sheet. After gaining participant's consent, he/she was provided with online questionnaire through Google Form portal, which was shared with participants via email and WhatsApp and printed surveys were distributed in colleges for offline method.

The total number of students participated in the survey was 200. Exclusion criteria were students from other medical or non-medical fields, students who submitted incomplete or invalid responses to the questionnaire and those who did not provide informed consent to participate in the study. Collection period was 2-4 weeks with reminders. In the prevalidated questionnaire, first section consisted of demographic data and the second section consisted of 14 questions related to awareness, knowledge, attitude and perception about nanotechnology in dentistry. The data of participant's answers were entered into Excel sheet for further, descriptive and inferential statistical analysis.

### Statistical analysis

Statistical analysis of data was processed using Microsoft excel 2016 and statistical package for the social sciences (SPSS) software (version 30, SPSS Inc., Chicago, IL, USA). The results on continuous measurements were presented on mean  $\pm$  standard deviation and the results on categorical measurements were presented in number (%). One way ANOVA test and t- test were performed.  $p \leq 0.05$  was considered as a

significant result. Statistical Analysis will be done using SPSS Software version 30 (IBM Corp). The level of significance was fixed at  $p = 0.05$  and any value less than or equal to 0.05 was considered statistically significant.

### Observations and Results

From 248 postgraduate dental students, 200 participated in the study. Forty-eight postgraduate dental students were excluded from the study as they had not given consent to fill the forms and incomplete forms submitted. Out of the 200 participants, 136 were females and 64 were males (**Table 1**) with 92 participants in the age range of 24-25 years, 38 participants were within 25-26 years of age and 70 were above the age of 27 years. (**Table 2**)

**Table 3** indicates the distribution of postgraduate dental students according to the year of the study. Out of 200 postgraduate dental students, I MDS, II MDS, and III MDS were 95, 69, and 36, respectively. Only 133 (65.20%) students out of the total 200, have studied about nanomaterials in their dental course (**Figure 1**). About 100 students (49%) responded that only moderate information has been received through lectures regarding nanotechnology (**Figure 2**). Majority (75 students) responded correctly about the year in which government of India has launched a 5-year program called "NANO MISSION" with wider objectives and larger funding of USD 250 million (**Figure 3**). About 51 students responded that nano particles are being used in resin composites only whereas 80 students have answered that nanoparticles are used in toothpastes, resin composites, impression and endodontic materials (**Figure 4**). One twenty-three students responded that nano materials enable improved diagnosis, treatment and

monitoring of many serious illnesses including cancers, cardiovascular, neurological diseases and diabetes (**Figure 5**). According to **Figure 6**, majority of students (60%) responded that silver, carbon, gold and zinc oxide can be used as nanoparticle. Out of the total 200 participants, 135 of them were familiar with the term nano robots (**Figure 7**) but majority of them (44%) didn't know about its applications (**Figure 8**).

Most of them (172 students) want to get more information about the application of nanotechnology in dentistry in the dental curriculum (**Figure 9**). Seventy six students responded that nanotechnology could pose risks and limits in the area of economy, information loss and nanoparticle toxicity whereas fifty six of them were confused about the same (**Figure 10**). About the scope of nanotechnology improving the oral health and quality of life for countless people and communities in the future, on a scale of one to hundred, about 67 students have rated fifty (**Figure 11**). One hundred and fifteen students have agreed about the support/encourage for using nanomaterials in their future dental practice (**Figure 12**). Ninety students have responded that it will be easy to apply nanomaterials in their future dental practice and eighty-two of them have responded for the same that it will be difficult (**Figure 13**). Major number (134) consider the inclusion of "nanodentistry" as a subject. (**Figure 14**).

The **Figure 15** representing the association between age of the students and awareness about the application of nanotechnology in dentistry.  $p$ -value was 0.006 ( $<0.05$ ), and it was statistically significant.

The **Figure 16** represents the association between gender and awareness about the application of nanotechnology in dentistry.  $p$ -value was 0.001 ( $<0.05$ ). The X-axis represents gender, and the Y-axis represents the mean values

The **Figure 17** represents the association between year in which the student is studying and awareness about the application of nanotechnology in dentistry. X-axis represents MDS year, and Y-axis represents the mean values.  $p$ -value was 0.001 ( $<0.05$ ) and it was statistically significant.

## Discussion

Dentistry has transitioned through several years. It is experiencing yet another transformation in terms of assisting humanity, this time using nanotechnology in conjunction with nano-materials, biotechnology, and nano robotics.<sup>4</sup>

Nanomaterials research takes a materials science-based approach to nanotechnology, leveraging advances in materials metrology and synthesis which have been developed in support of microfabrication research.<sup>5</sup> Present survey showed 133 students have studied about nanomaterials in their dental course.

Nanotechnology is a novel arena that has aided in the development of new therapeutic and diagnostic agents, with the added benefit of improving drug accretion when minimizing the negative effects that small-molecule medications have. The enclosed molecules' tiny size, increased chemical stability, and apparent solubility, along with the multifunctionality of nanoparticles, are features that open up new perspectives for biological research.<sup>6</sup> This concept has been in use since decades but still the awareness regarding the same through lectures in the dental course remains moderate according to forty nine percent of the participants and more than forty one percent answered that they have received only little information.

**In 2007, the Government of India launched a 5-year**

**program called Nano Mission**, it was allocated a budget of Rs 1,000 crores. It had a wider scope of objectives and much larger funding. Fields involved in the mission were: **basic research in nanotechnology, infrastructure development, human resources development, and global collaboration.** Many institutions and departments were roped in for the work such as the Department of IT, DRDO, Department of Biotechnology, Council of Scientific and Industrial Research (CSIR), etc. In both IIT Bombay and IISc Bangalore, National Centers for Nanofabrication and Nanoelectronics were established. **Results of these initiatives include** India alone publishing over 23,000 papers in nanoscience and ranked 3rd in papers published in 2018 behind only the USA and China. There have been many patent applications in this field.<sup>7</sup> Here only 75 students out of 200 answered correctly that mission was launched in 2007.

Since their particle sizes are lesser than those of other materials, nanoparticles find application in dental products, topical agents, and device coverings.<sup>8,9</sup> For instance, composite materials use silver nanoparticles' antibacterial qualities, while toothpaste and mouthwashes use silver zeolite.<sup>10</sup> Since the nanoparticles possess antibacterial characteristics, they are utilized in restorative dentistry, cements, fiber posts, cavity liners, pit and fissure sealants, and cements to remineralize the tooth and improve treatment efficacy.<sup>11</sup> Alginate impression powders combined with water containing silver hydrosol may generate an impression medium with antimicrobial qualities that minimize microbial cross-contamination to the poured stone model from the sick impression. Nanoparticles are introduced to the imprint substance due to their hydrophilic properties and ability to enhance the flow of the material. Similarly, to enhance

tooth detailing, nano-fillers are applied to polyvinyl siloxane polymers.<sup>11</sup> Only 80 students answered correctly that nanoparticles are used in toothpastes, composite resins, impression materials and endodontic materials.

In today's fight against cancer, nanotechnology is regarded as one of the most promising breakthroughs in medication supply. With nanoparticles permitted chemotherapeutic administration, more cytotoxic medicine may be delivered at the targeted location, and the toxicity and efficiency are decreased off-target. In the medical field, nanomedicine uses nanotechnological expertise to prevent and treat severe conditions, including diabetes, cardiovascular disease and neurological diseases. Nanoscale materials, including biocompatible nanoparticles and medical nanobots, have helped doctors in recent advancements in nanotechnology to understand the objectives of action of a living creature.<sup>13</sup> Majority of the participants (123 out of 200) answered this correctly that nano materials enables improved diagnosis, treatment and monitoring of many serious illnesses.

Silver nanoparticles (AgNPs) are used in many commercial applications to prevent microbiological growth. Green produced AgNPs are being used more and more to treat and prevent dental conditions. Because of their nanosize, gold nanoparticles (GNPs) have a greater surface area and can interact with both organic and inorganic molecules more. As a result, GNPs are one of the possible anti-caries agents.<sup>14</sup> Zinc (Zn) and its oxide (ZnO) are among the most intriguing and promising metallic nanomaterials. In addition to being a vigorous reducing agent and a reasonably active element, zinc has the ability to readily oxidize and create zinc oxide, which is useful for the creation of zinc oxide nanoparticles

(ZnO NPs). Zinc at nanoscale, is antibacterial. Composite resins used in dentistry with ZnO NPs along with AgNPs have demonstrated notable antimicrobial effect against *Lactobacillus* and *S. mutans*.<sup>15</sup>

The carbon-based nanomaterials (CNT) can be bonded with a single strand of DNA, and can then be successfully inserted into a cell. The application as drug delivery is very common in carbon-based nanoparticles, especially the graphene-based nanoparticles.<sup>16</sup> One twenty three students responded correctly that silver, carbon, gold and zinc oxide all of them are used a nanoparticles.

Nanorobots are specialized tools to carry out programmed penetrations, clean the decayed tissue, and place composites to the required site using 3D filling technology. Dasgupta et al. published the use of magnetic nanobots incorporated in root canal operations. These nanobots could go deeper into the dentin, which is difficult using conventional methods. The special retrieval process of nanobots also made a better choice.<sup>17</sup> These nanobots work using a special algorithm or software. In 2015, Razavi et al. demonstrated simulation for dental restoration. The inclusion of robotics increases the speed by eight times.<sup>18</sup> 135 out of total 200 students were familiar with term nanorobots.

Orthodontic nanorobots can be injected directly to the site of tooth movement or through optiflex impregnated with nanocomposite materials which releases nanorobots in oral environment where they will manipulate cellular structures in periodontal tissue and alveolar bone, they can also remove the necrotic or degenerative tissues to enhance faster tooth movement.<sup>19</sup> When nanotechnology or nanorobots are used to induce anesthesia, the gingiva of the patient is instilled with a colloidal suspension containing millions of active, analgesic, micron-sized dental robots that respond to input supplied by the

dentist. Nanorobots in contact with the surface of the crown or mucosa can reach the pulp via the gingival sulcus, lamina propria, or dentinal tubules. Once in the pulp, they shut down all sensations by establishing control over nerve-impulse traffic in any tooth that requires treatment. After completion of treatment, they restore this sensation, thereby providing the patient with anxiety-free and needleless comfort. The anesthesia is fast-acting and reversible, with no side effects or complications associated with its use.<sup>20</sup> Nanorobotic dentifrices, when delivered either by mouthwash or tooth paste, can cover all subgingival surfaces, thereby metabolizing trapped organic matter into harmless and odorless vapors. Properly configured dentifrobots can identify and destroy pathogenic bacteria that exist in the plaque and elsewhere. These invisibly small dentifrobots are purely mechanical devices that safely deactivate themselves when swallowed.<sup>21</sup> The dentinal tubules of a hypertensive tooth have twice the diameter and eight times the surface density of those in nonsensitive teeth. These characteristics have led to the use of nanorobots that selectively and precisely occlude tubules in minutes, by using local, native materials, thus offering patients a quick and permanent cure.<sup>22</sup> Thus we see that nanorobots can be applied for inducing anesthesia, managing halitosis and oral prophylaxis, treating hypersensitivity and for accelerating orthodontic corrections. But only 22 students responded with the correct option whereas 88 of them were completely unaware of the same.

More than 84 percent of the students want to get more information about the application of nanotechnology in dentistry in the dental curriculum which shows the positive inclination and interest of the students towards learning newer and futuristic applications of nanorobots, nanoparticles and its technology.

Despite its benefits, nanotechnology also poses challenges and concerns, especially in relation to **toxicity and biocompatibility, for example** the interaction of nanoparticles with the body can cause lung inflammation, heart problems or adverse effects on drugs. Ethical considerations are paramount in nanotechnology. Issues such as privacy, equity, and security come into play, especially with applications like nanosensors and nanomedicine. Ensuring public awareness and involvement in policy-making can help address these ethical and social concerns. The rapid pace of nanotechnology development often outstrips existing regulatory frameworks.<sup>23</sup> There is a need for updated regulations that specifically address the unique characteristics of nanomaterials. International collaboration is also essential to create standardized guidelines and protocols. Wide-ranging socio-economic effects of nanotechnology include job creation and displacement, economic inequality, and access to goods and services made possible by nanotechnology. The advancement and application of nanotechnology ought to be directed toward encouraging inclusive growth, closing the digital divide, and resolving any potential socio-economic inequalities. Programs for education and training should be put in place to give people the knowledge and abilities they need to work in the nanotechnology industry. Additionally, efforts should be taken to guarantee that the benefits of nanotechnology are accessible, affordable, and properly disseminated, especially in developing nations.<sup>24</sup> According to Kumar and Vijayalakshmi, significant environmental, health, and safety issues might arise with development in nanotechnology since some negative effects of nanoparticles in our environment might be overlooked.<sup>25</sup> Seventy six students responded correctly that nanotechnology could

pose risks and limits in the form of nanoparticle toxicity, information loss and economy whereas a big number of fifty six students were not sure about the same.

Tooth-colored aesthetic shape-memory polymers that move teeth efficiently would be a game changer in the field of orthodontics, whereas in cosmetic dentistry, nanoscale diamond and sapphires used to replace enamel would be more durable and fracture resistant.<sup>26</sup> When asked to rate on the scale of 1 to 100 about the scope of nanotechnology in improving the oral health and quality of life for countless people and communities in the future, highest number of sixty seven students rated the future scope as 50.

More than 56 percent students agree for support or encourage to use nanomaterials in their future dental practice which shows an affirmative response towards maintaining near- perfect oral health through the use of nanomaterials such as tissue engineering and nanorobotics. This technology has aided drastically the advances made in the field of biomaterials and has broadened its holistic usage in dentistry.<sup>27</sup>

As discussed, there are several pieces of research in Nano dentistry but challenges inevitably arise when it comes to clinical practice. The aim of future studies should be to improve the available technology and enable easier production and implementation.<sup>28</sup> Ninety students responded that it will be easy for them to apply nanomaterials in their future dental practice whereas eighty four of them replied that it will be difficult for them.

More than 65 percent students want inclusion of "nanodentistry" as a subject. Other ways to increase knowledge of nanotechnology in dentistry are journals, conferences and CDE programs, advertisements, and public notice.

**Table 1: Comparison of mean knowledge of study subjects according to age**

Age Groups	N	Mean	Std. Deviation	95% Confidence Interval for Mean		F value	P (sig) value*
				Lower Bound	Upper Bound		
24-25 YEARS	92	5.6304	2.30488	5.1531	6.1078	5.317	0.006*
25-26 YEARS	38	6.3684	2.32984	5.6026	7.1342		
≥27 YEARS	70	6.8571	2.54971	6.2492	7.4651		
Total	200	6.2000	2.44949	5.8584	6.5416		

**Table 2: Comparison of mean knowledge of study subjects according to gender**

Gender	N	Mean	Std. Deviation	95% Confidence Interval for Mean		t- value	P value
				Lower Bound	Upper Bound		
MALES	64	6.1875	2.08452	-.75245	.71568	-.049	0.961
FEMALES	136	6.2059	2.61085	-.69711	.66035		

**Table 3: Comparison of mean knowledge of study subjects according to year of study**

YEAR OF STUDY	N	Mean	Std. Deviation	95% Confidence Interval for Mean		F value	P (sig) value
				Lower Bound	Upper Bound		
I MDS	95	5.9368	2.51722	5.4241	6.4496	1.541	.217
II MDS	69	6.6087	2.12974	6.0971	7.1203		
III MDS	36	6.1111	2.78545	5.1687	7.0536		
Total	200	6.2000	2.44949	5.8584	6.5416		

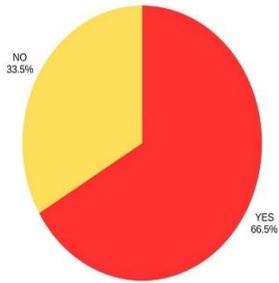


Fig 1: Studied about nanoparticles in dental course

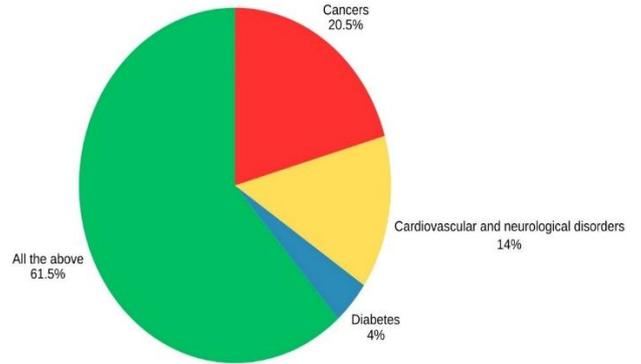


Fig 5: Nano materials enables improved diagnosis, treatment and monitoring of these serious illnesses

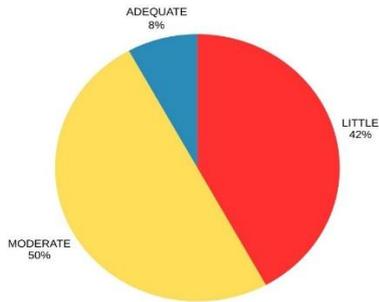


Fig 2: Information received from lectures regarding nanotechnology

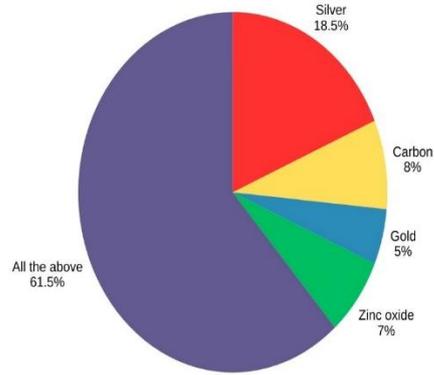


Fig 6: Materials that can be used as nanoparticles

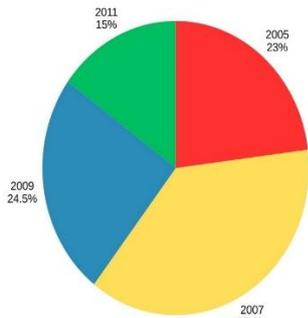


Fig 3: Year in which, the government launched a 5 year program called "NANO MISSION"

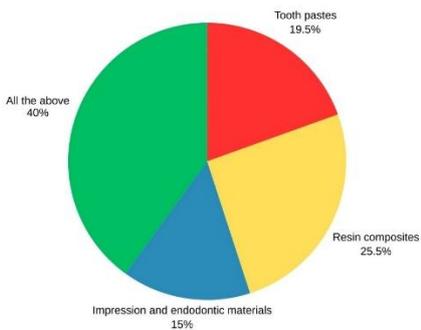


Fig 4: Usage of Nanoparticles in dental materials

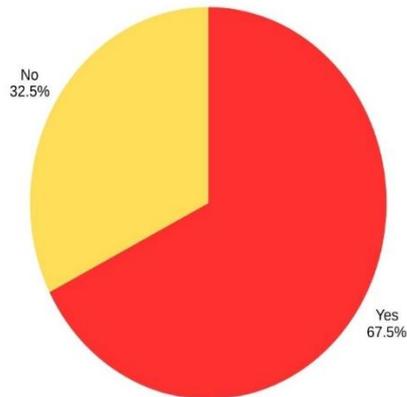


Fig 7: familiarity with the term "nanorobots"

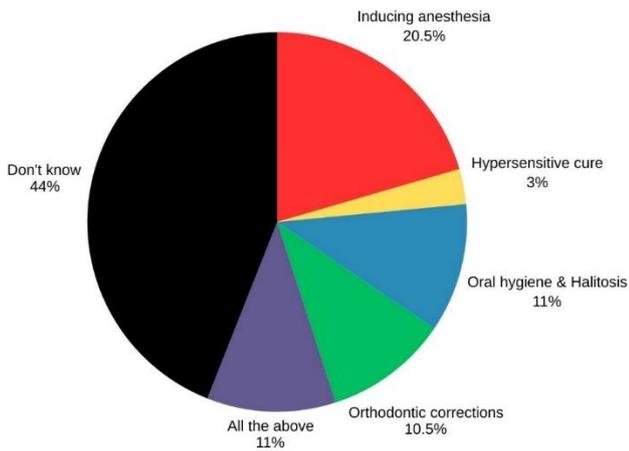


Fig 8: Applications of nanorobots

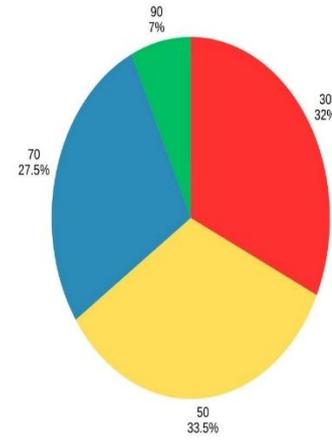


Fig 11: Rating of scope of nanotechnology in improving the oral health and quality of life for countless people and communities in the future

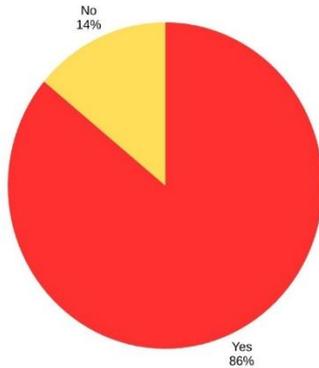


Fig 9: Students interested in getting more information about the application of nanotechnology in dentistry in the dental curriculum

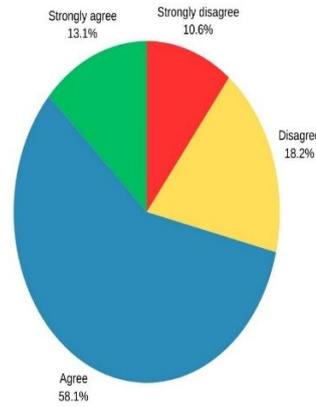


Fig 12: Support/encouragement to use nanomaterials in their future dental practice

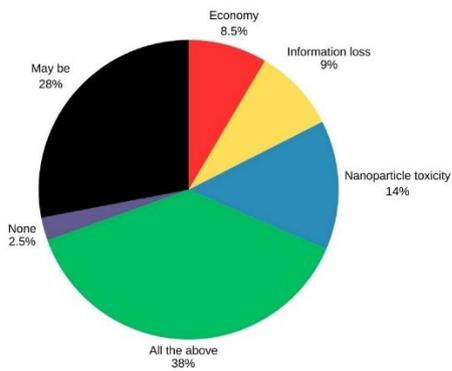


Fig 10: Ways in which nanotechnology could pose risks and limits

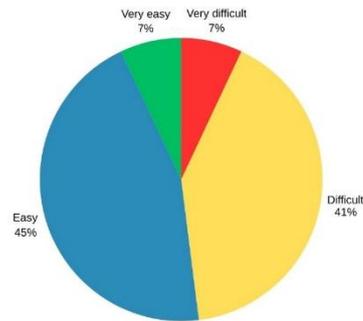


Fig 13: ease/ difficulty in applying nanomaterials in future dental practice

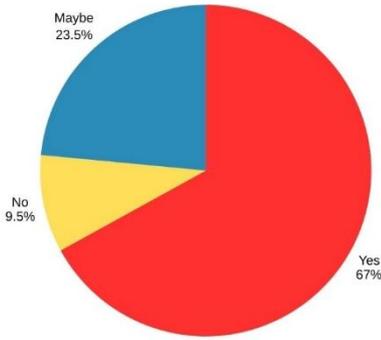
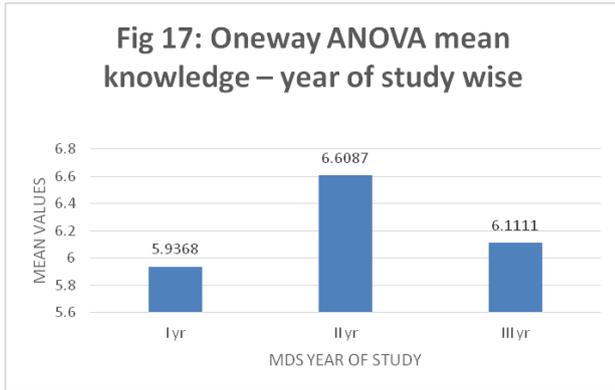
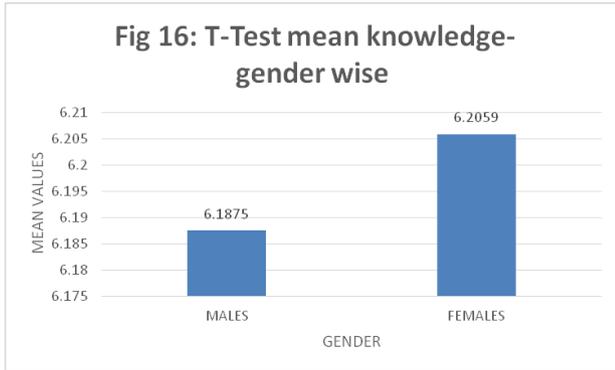
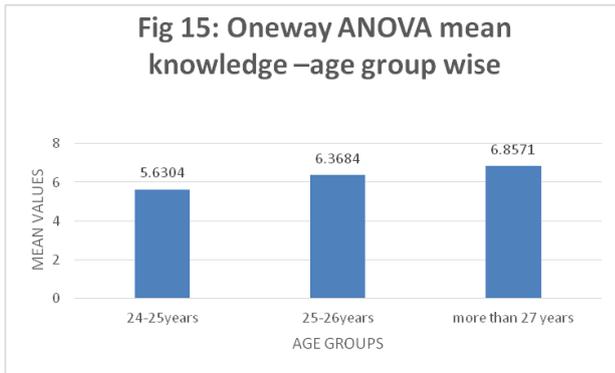


Fig 14: Views on inclusion of "nanodentistry" as a subject



**Conclusion**

More awareness regarding the dental applications of nanotechnology amongst students is required for further growth and usage of the same. Nanotechnology advancements should be evaluated in the perspective of other oral health-related discoveries projected in the next decades. Dental care will continue to improve as traditional treatments are refined, sophisticated restorative materials are developed, and novel drugs and pharmacological approaches are developed. The dentist’s function will continue to evolve in line with current trends.

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