,Antibacterial Activity For Orange peel and Grape peel Formulation Mediated Silver Nanoparticles Based on Mouthwash rinse against Enterococcus Faecalis and Lactobacillus Species-Tooth Sample

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**Abstract :**Microbial infections like those caused by Enterococcus faecalis and Lactobacillus species pose serious problems for oral health, which is why it is so important. Because synthetic antimicrobial agents are frequently found in conventional oral care products, long-term use and possible side effects are concerns. Aim of the study is to provide scientific evidence regarding the antibacterial efficacy and safety of orange and grape peel mouth rinse with silver nanoparticles as a natural and potentially alternative oral hygiene productColony-forming units in orange and grape peel (AgNPs) mouthwash were analyzed by performing the antibacterial activity of green-synthesized silver nanoparticles using the agar well diffusion technique. Mueller Hinton agar plates were sterilized and poured onto sterile Petri plates. Bacterial suspensions of both *Enterococcus faecalis and Lactobacillus* species were spread, wells of 9mm diameter were created, and filled with different Ag NPs concentrations. The plates were incubated, and antibacterial activity was assessed by measuring the inhibition zone diameter. While the control group's colony forming units were counted by exposed tooth samples in sterile water. Tooth samples exposed to bacteria were counted, and the zone of inhibition was measured in millimeters.Bacterial growth colonies of *E.faecalis* is 56\*10[⁵](https://www.hotsymbol.com/symbol/superscript-five) CFU/mL while *Lactobacillus* showed growth less than *E.faecalis* with 40\*10[⁵](https://www.hotsymbol.com/symbol/superscript-five) CFU/mL with significant antibacterial activity against both *E*.*faecalis* and *Lactobacillus* but the activity shown against growth *Lactobacillus* is more than that against *E.faecalis.* Agar diffusion assays demonstrated a zone of inhibition for the mouthwash formulation containing AgNPs, which demonstrated strong antibacterial activity against *Lactobacillus* species and *Enterococcus faecalis.*The silver nanoparticles synthesized with orange peel and grape peel extracts demonstrated potent antibacterial activity against *E.faecalis and Lactobacillus* sp. isolated from tooth samples. The incorporation of these nanoparticles into a mouthwash rinse formulation presents a promising approach for developing effective oral hygiene products with potential applications in preventing and treating oral infections.

**Keywords**: Antibacterial activity, silver nanoparticles, orange peel extract, grape peel extract, mouthwash rinse, *Enterococcus faecalis, Lactobacillus* species, oral hygiene, tooth samples.

# Introduction

Orange and grape peels, which are abundant and widely available waste materials, have gained considerable attention due to their rich composition of bioactive compounds [(Capasso & Di Cesare Mannelli, 2021)](https://paperpile.com/c/bqsYIJ/J6vq). Fruit consumption plays a vital role in our daily diet, providing essential nutrients and antioxidants. However, the peel and other residues generated during fruit processing often end up as waste, resulting in environmental concerns and economic losses. Orange and grape peels, in particular, are significant by-products of the citrus and grape industries, respectively [(Saleem et al., 2023)](https://paperpile.com/c/bqsYIJ/j1Fw). Orange and grape peels exhibit remarkable chemical compositions, consisting of diverse bioactive compounds such as phenolic compounds, flavonoids, carotenoids, dietary fibre, and essential oils [(Aparna et al., 2021; Talon et al., 2020)](https://paperpile.com/c/bqsYIJ/gybK+fCO0). These constituents contribute to the unique sensory attributes, as well as the health-promoting properties of the peels

The scientific hallmarks of orange and grape peel underscore their potential as sources of bioactive compounds with diverse health benefits. Silver nanoparticles and phenolic compounds have the capability to generate reactive oxygen species for bacteria [(Rodríguez & Ruiz, 2016; Verma & Muthuswamy Pandian, 2021)](https://paperpile.com/c/bqsYIJ/Cpcd+cpNi). This can create a more oxidative environment within bacterial cells, contributing to increased antibacterial effects. The combination may target bacterial membranes, cell walls, and interfere with cellular processes, leading to increased efficacy against a broad spectrum of Enterococcus faecalis and Lactobacillus [(Rodríguez & Ruiz, 2016; Rumbaugh & Ahmad, 2014)](https://paperpile.com/c/bqsYIJ/Cpcd+BrIZ). Silver nanoparticles have been studied for their potential antibacterial properties due to their small size and high surface area [(Nazemi Salman et al., 2022; Poornima et al., 2021)](https://paperpile.com/c/bqsYIJ/6Dm6+XZu9). Several mechanisms are involved in the interaction between orange and grape peel extracts and silver nanoparticles (AgNPs), antibacterial actions of AgNPs against Enterococcus and Lactobacillus species [(Nazemi Salman et al., 2022; Zheng et al., 2018)](https://paperpile.com/c/bqsYIJ/6Dm6+uJL8). AgNPs can have increased antibacterial activity when combined with the bioactive substances found in grape and orange peel extracts. AgNPs are known to interact with bacterial cell membranes, causing structural damage and increased permeability. This can lead to leakage of intracellular components and eventual cell death.[(Ganapathy 2021; Pandiyan et al., 2022)](https://paperpile.com/c/bqsYIJ/DX7a+uQyk)

Antibacterial Activity in a mouthwash formulation of silver nanoparticles derived from orange and grape peel extracts was assessed. Strong inhibitory effects were demonstrated by these nanoparticles against pathogenic bacteria, such as Enterococcus faecalis and Lactobacillus species, which are frequently linked to oral health problems.[(Chokkattu et al., 2022; Merchant et al., 2022)](https://paperpile.com/c/bqsYIJ/0lWh+Q35f) The growth of these bacteria was found to be greatly inhibited by the presence of silver nanoparticles in the mouthwash, suggesting that this could be a natural and efficient method of preserving dental hygiene. Addressing these challenges would enhance the reliability and applicability of research on the antibacterial activity of orange and grape peel extracts. Further studies should focus on standardising new methodologies, investigating mechanistic aspects, conducting clinical trials, ensuring stability, and navigating regulatory requirements to facilitate their potential use as natural antibacterial agents. [(Jain & Verma, 2022; Marya et al., 2022; Ramamurthy et al., 2022)](https://paperpile.com/c/bqsYIJ/u5vk+qHj7+WUyo) The antibacterial activity of orange and grape peel has been the subject of numerous research studies. However, these studies have encountered several challenges, which have impacted the overall understanding and consistency of the findings. Most research on the antibacterial activity of orange peel and grape peel extracts has been conducted in vitro or in different method of analysis.[(Sreevarun et al., 2023; Wadhwani et al., 2022)](https://paperpile.com/c/bqsYIJ/HiwP+bQWz)

The aim of this study is to provide scientific evidence regarding the antibacterial efficacy and safety of orange and grape peel mouth rinse with silver nanoparticles as a natural and potentially alternative oral hygiene product. The findings could contribute to the development of novel, effective, and environmentally friendly mouth rinses with potential applications in dental care.

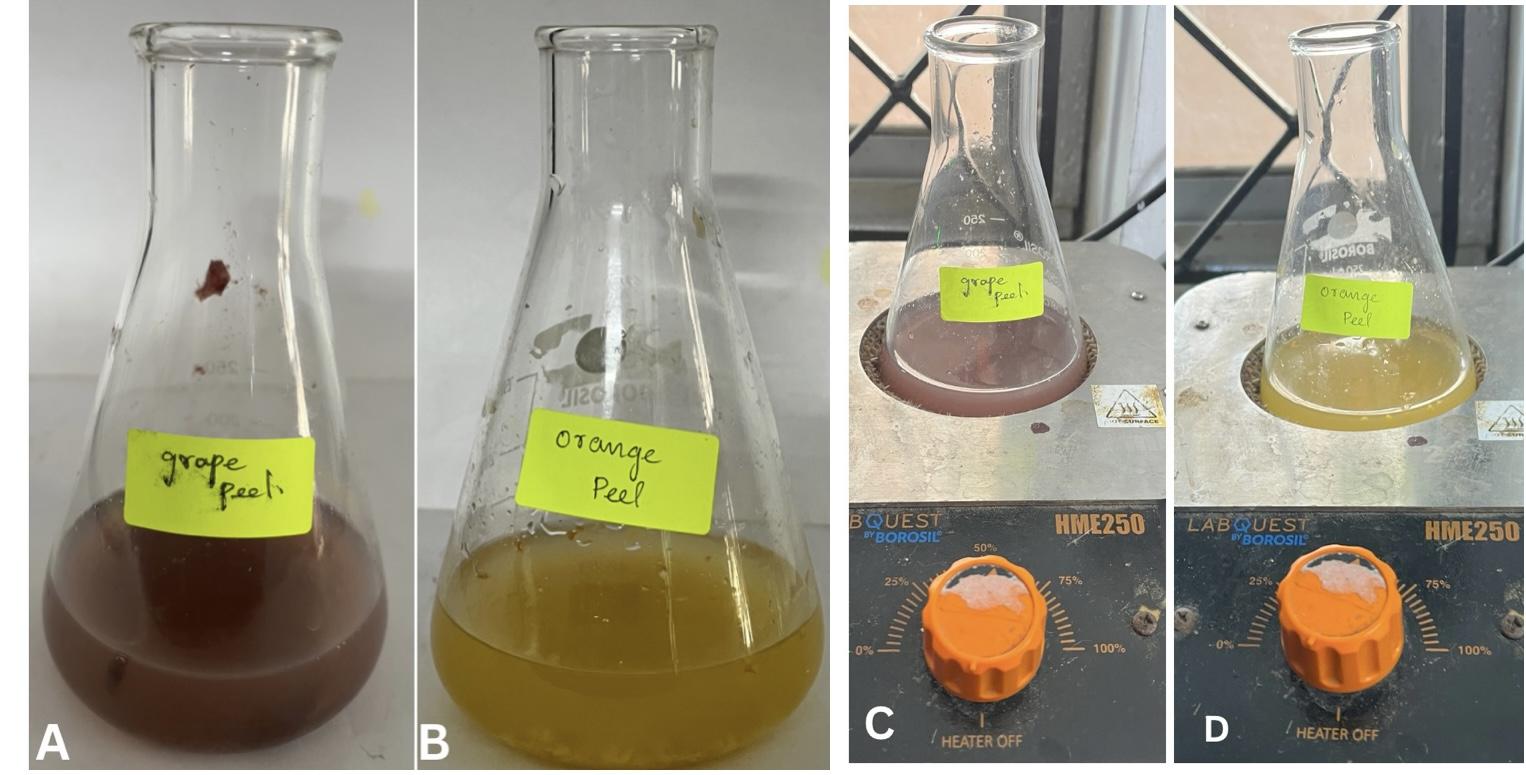
# Materials & methods

## Extract preparation



**Figure 1.** (A)Grape peel and (B).orange peel

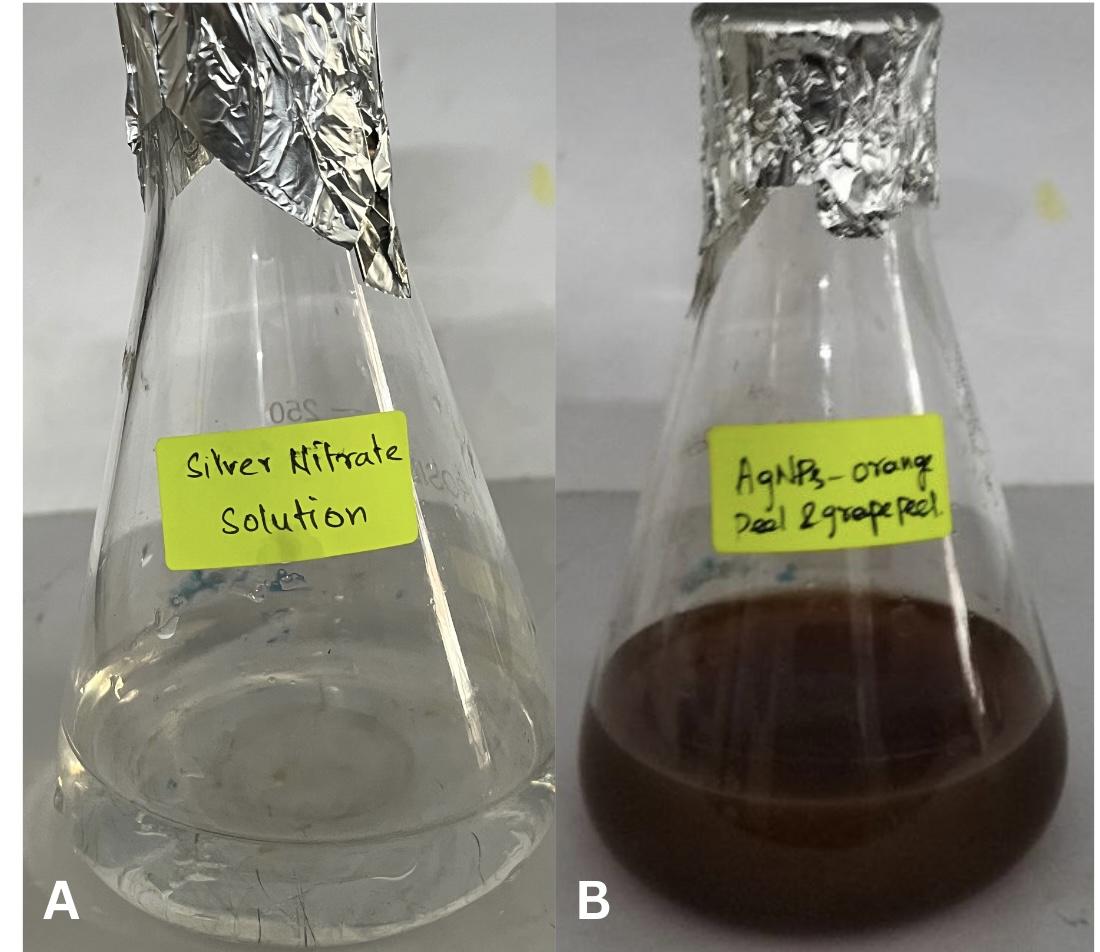
Orange and grape peels were dehydrated for 24 hours in a hot air oven. The next day, 2g of grape and orange peel were each taken and crushed with a mortar and pestle. A sterile cotton cloth was then used to filter the mixture after 100 millilitres of distilled water had been added. After that, the filtered liquid was put in a heating mantle and kept at 50 to 60 degrees until it condensed to a volume of 10 millilitres(figure 2).



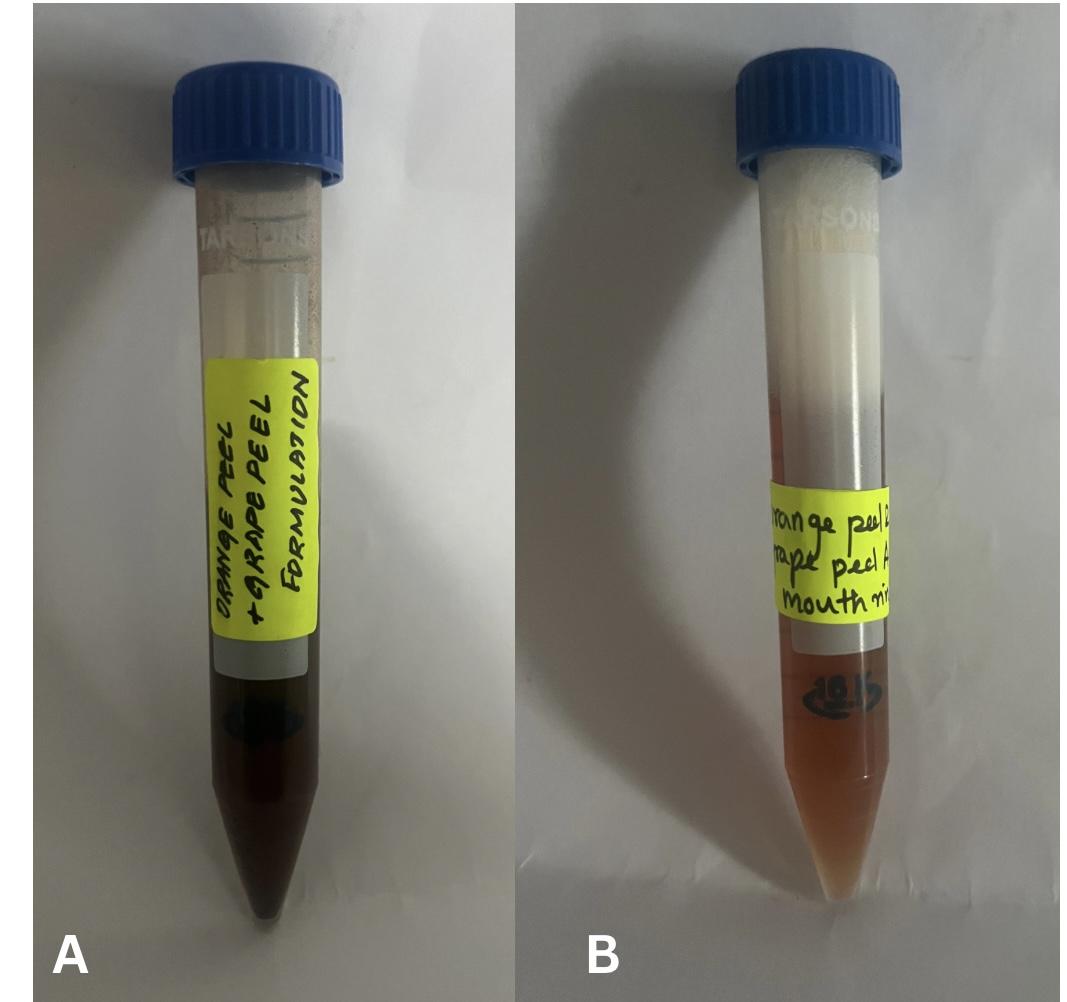
**Figure 2:** A.Grape peel extract B.Orange Peel extracts C&D.Grape and orange peel extract kept in heat mantle

# Silver nitrate solution preparation

One millimole of silver nitrate solution was taken with a micropipette and mixed with 10 ml of orange and grape peel extract in the proportions of 80:10:10 ratio and the entire solution is kept in the heating mantle and is condensed to 10 ml(figure 3).

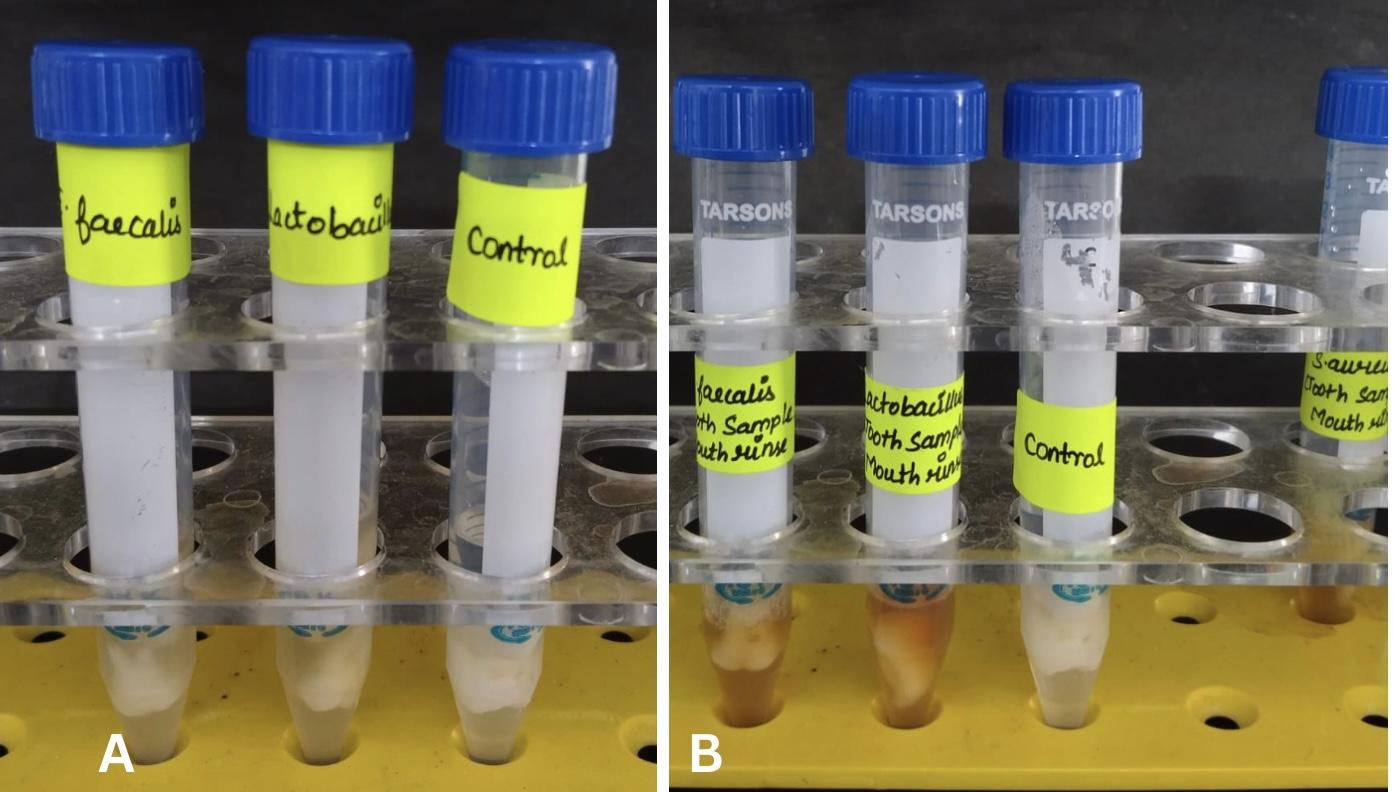


**Figure 3.** A.Silver nitrate solution B.Silver nitrate solution mixed with grape and orange peel extract



**Figure 4.** A&B.Orange and grape peel extract and mouth rinse

To eradicate any remaining microbes from the extracted teeth, the tooth samples were submerged in hydrogen peroxide for a duration of 24 hours. Once in sterile water, the tooth samples were taken out. To evaluate the antibacterial activity, grouping was done. Group 1, was selected to receive media contaminated with *Enterococcus faecalis*. The tooth sample from Group 2 was selected, and it was placed in media contaminated with *Lactobacillus*. A sample of teeth was submerged in tap water as the control group(figure 5).



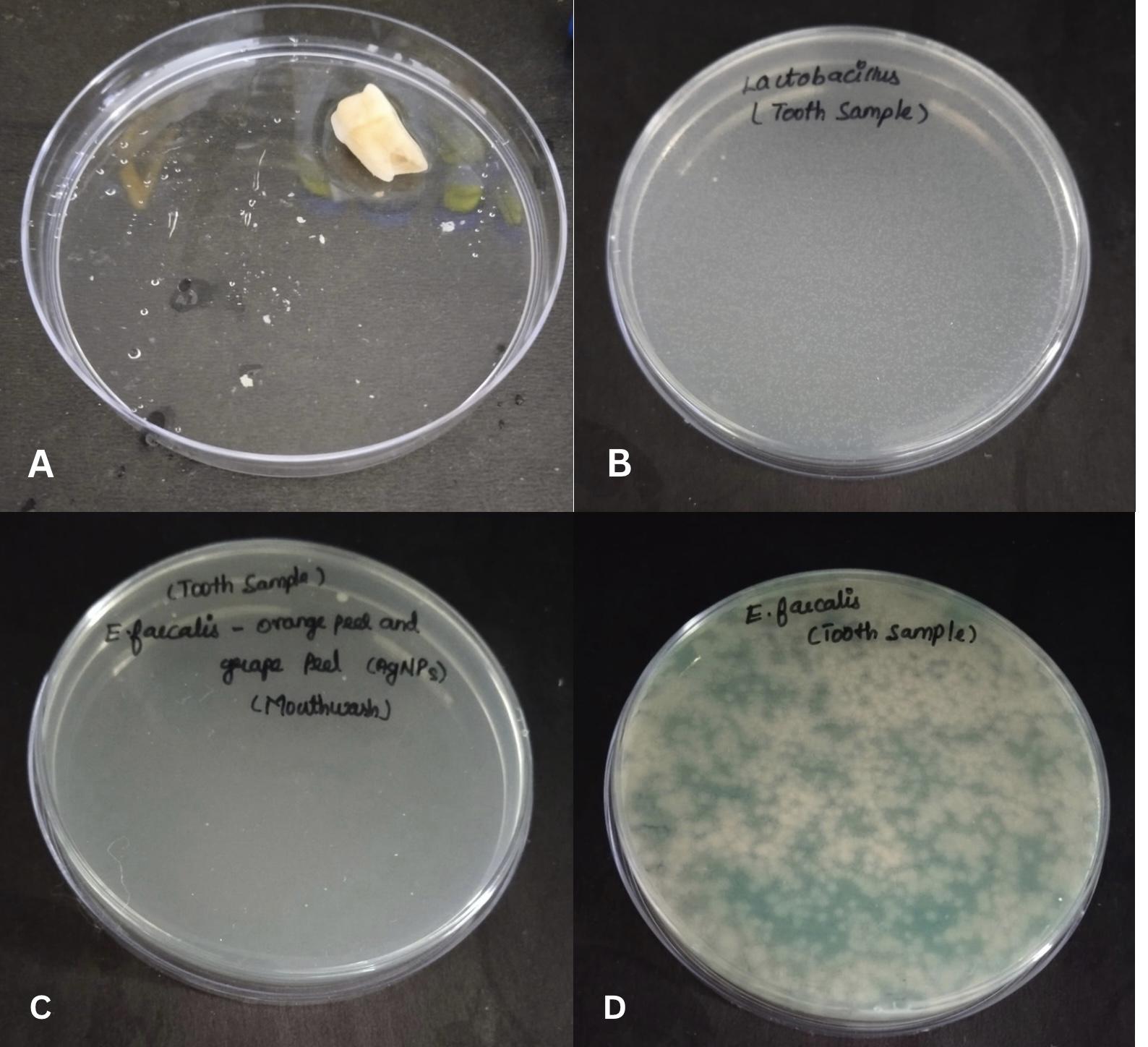
**Figure 5.** A&B.*Lactobacillus and E.faecalis* with tooth sample

## Antibacterial activity

The antibacterial activity of the green synthesized silver nanoparticles was evaluated using the agar well diffusion technique. Mueller Hinton agar plates were prepared and sterilized using an autoclave at 121oC for 15- 20 minutes. After sterilization, the medium was poured onto the surface of sterile Petri plates and allowed to cool to room temperature. The bacterial suspension (Enterococcus faecalis, Lactobacillus sp) was spread evenly onto the agar plates using sterile cotton swabs. Wells of 9mm diameter were created in the agar plates using a sterile polystyrene tip. The wells were then filled with different concentrations (25 µg, 50 µg, 100 µg) of Ag NPs. An antibiotic (e.g., Bacteria-Amoxyrite) was used as a standard. The plates were incubated at 37°C for 24 hours and 48 hours for bacterial cultures. The antibacterial activity was evaluated by measuring the diameter of the inhibition zone surrounding the wells.

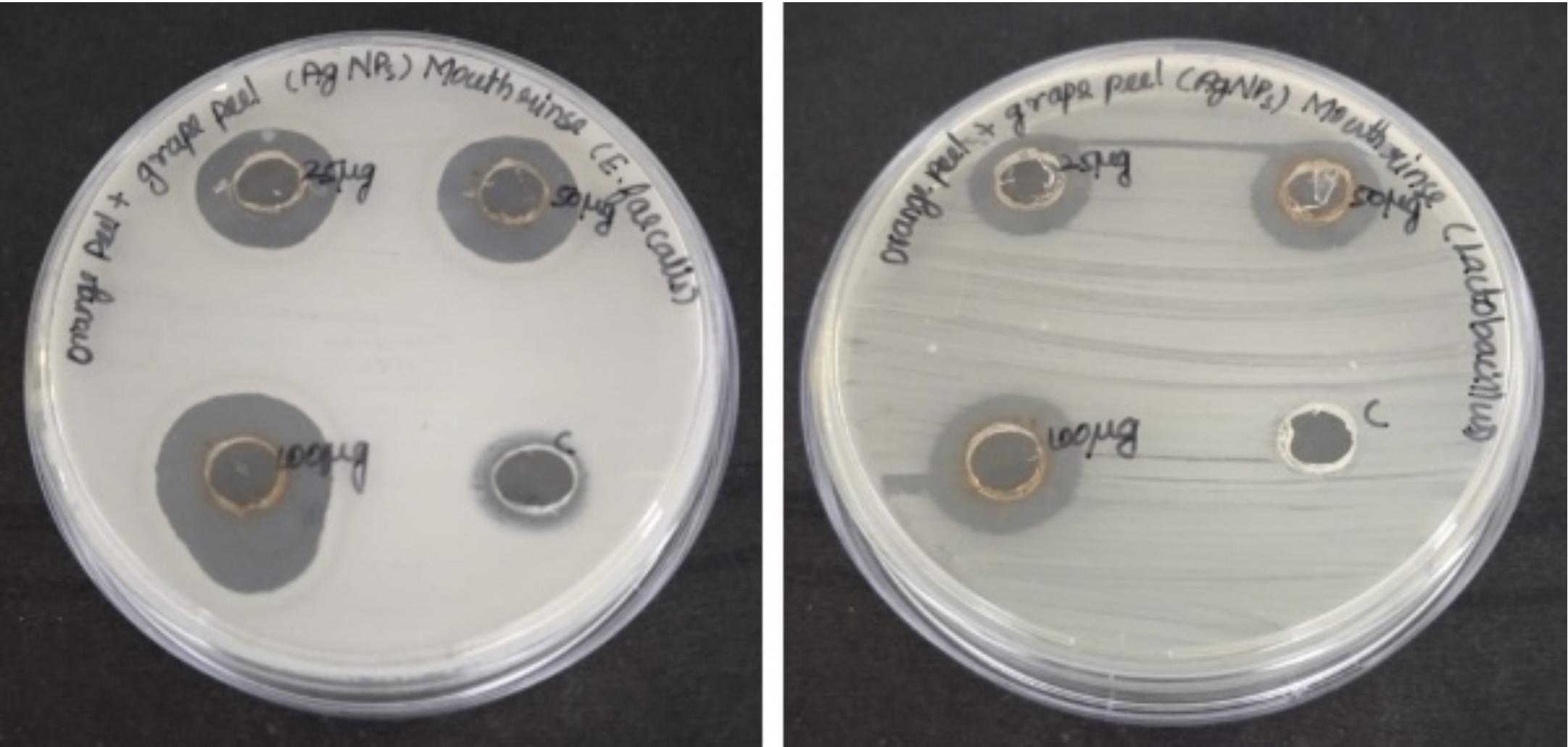
The number of colony forming unit in Orange and grape peel (AgNPs) Mouthwash were analyzed calculated with the below formula, while the number of colony forming units in control by the exposed tooth sample (only sterile water) was counted

Bacterial growth =Number of colonies of bacteria \*10[⁵](https://www.hotsymbol.com/symbol/superscript-five) CFU/mL



**Figure 6.** A. Tooth sample B. *lactobacillus* with tooth sample C. Tooth sample with orange and grape peel silver nanoparticles mouthwash D. The bacterial growth of *Enterococcus faecalis*

The tooth samples were exposed to *Enterococcus faecalis and Lactobacillus* petri plates. Tap water was taken as control media. Tooth samples were then kept in orange and grape peel extract. Number of colonies was counted (figure 6). Another set of tooth samples were placed in just tap water and the growth of microbes of the control group was observed by placing it on the petri plate. And the zone of inhibition was calculated in millimetres (mm) for tooth samples placed in both *Enterococcus faecalis and lactobacillus*. The diameter of the zone of inhibition was measured using a ruler and recorded in mm and the zone of inhibition was calculated.

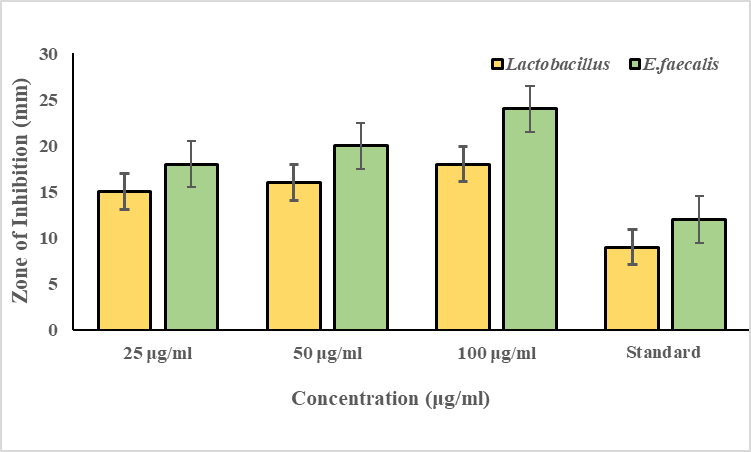


**Figure 7.** Zone of inhibition of *E.faecalis* and *Lactobacillus*

# Results

## Antibacterial activity

The control group included tooth samples immersed in tap water. Group 1 consisted of tooth samples placed in a culture medium affected by E.faecalis, while Group 2 involved tooth samples in a culture medium affected by Lactobacillus. The measurement of the zone of inhibition, determined by bacterial growth on a petri plate, was conducted for each group. In the control group, the calculated zone of inhibition was 11mm for E.faecalis and 12mm for Lactobacillus. For Group 1 (E.faecalis), the zone of inhibition was 25mm at 25µg/ml, 20mm at 50µg/ml, and 24mm at 100µg/ml. In Group 2 (Lactobacillus), the zone of inhibition was 15mm at 25µg/ml, 16mm at 50µg/ml, and 18mm at 100µg/ml.A graph was plotted for the data obtained above and the sample of orange and grape peel extract was found to have significant antibacterial activity against the pathogens E.faecalis and lactobacillus . It's activity was found to be much better than that of normal tap water hence it would be very effective as a mouthwash. When the antibacterial activity against E.faecalis and lactobacillus are compared with each other, the sample was found to work better against E.faecalis than Lactobacillus .



**Figure 8:** Antibacterial activity of orange and grape peel extract + Ag NPs against *E.faecalis and Lactobacillus*

Bacterial growth colonies of *E.faecalis* is 56\*10[⁵](https://www.hotsymbol.com/symbol/superscript-five) CFU/mL while *Lactobacillus* showed growth less than *E.faecalis* with 40\*10[⁵](https://www.hotsymbol.com/symbol/superscript-five) CFU/mL. Hence we can say that the plant extract does show significant antibacterial activity against both *E*.*faecalis* and *Lactobacillus* but the activity shown against growth *Lactobacillus* is more than that against *E.faecalis.*

# Discussion

The study results may indicate that the mouthwash rinse formulated with silver nanoparticles synthesised using orange and grape peel extracts exhibited significant antibacterial activity against E(Rafi et al., 2024). faecalis and Lactobacillus species isolated from tooth samples [(Rams et al., 2022)](https://paperpile.com/c/bqsYIJ/2ZHg). The antibacterial activity could be attributed to the silver nanoparticles' ability to release silver ions that can interact with the bacterial cells, leading to cell membrane damage and inhibition of bacterial growth [(Mostafa et al., 2021)](https://paperpile.com/c/bqsYIJ/2CVs). The effectiveness of the mouthwash rinse may have been assessed by measuring the inhibition zones or determining the minimum inhibitory concentration (MIC) values [(Adel et al., 2023; Joshi, 2018)](https://paperpile.com/c/bqsYIJ/5VHf+tUR5).

E. faecalis and Lactobacillus are bacteria commonly associated with oral infections [(Niluxsshun et al., 2021; Solanki et al., 2023; Subramanian & Harikrishnan, 2023)](https://paperpile.com/c/bqsYIJ/9D8v+eqi0+VRdw). E. faecalis, in particular, is known for its resistance to traditional antimicrobial agents, making it a challenging target. Lactobacillus, while often considered beneficial, can contribute to oral health issues under certain conditions [(Saratale et al., 2018)](https://paperpile.com/c/bqsYIJ/Uw68). Because of its antibacterial qualities, silver nanoparticles have drawn interest. They have a broad-spectrum antibacterial activity, which makes them appropriate for a number of uses, including dental care. An environmentally beneficial aspect to the research is the manufacture of silver nanoparticles from natural sources, like orange and grape peels [(Chokkattu et al., 2023; Christina et al., 2023; Muthuswamy Pandian et al., 2022)](https://paperpile.com/c/bqsYIJ/kX9V+BDmd+o1ZT). Bioactive substances such as flavonoids and polyphenols are abundant in both orange and grape peels. The production and stability of silver nanoparticles may be assisted by these substances. Furthermore, the application of fruit peel extracts is consistent with the notion of putting agricultural waste to good use. The incorporation of silver nanoparticles into a mouthwash formulation suggests a simple and practical oral hygiene application [(Anupong et al., 2023)](https://paperpile.com/c/bqsYIJ/1XUF). Mouthwashes are widely used because they can effectively clean areas that toothbrushes cannot, making them an ideal vehicle for delivering antibacterial agents.The study's practical component is enhanced by the use of tooth samples, which replicate actual oral conditions. Evaluating the formulation's potential efficacy requires an understanding of how it interacts with tooth surfaces and influences bacterial populations[(Anti-Inflammatory Potential of a Mouthwash Formulated Using Clove and Ginger Mediated by Zinc Oxide Nanoparticles: An In Vitro Study, n.d.; Laghari et al., 2023; Prasher & Sharma, 2022)](https://paperpile.com/c/bqsYIJ/99MT+MTFo+cK8l).Our study on the antibacterial activity of orange and grape peel extract presents compelling evidence supporting its potential as an effective alternative for oral hygiene, particularly in comparison to tap water. The control group, immersed in tap water, exhibited a baseline zone of inhibition of 11mm for E.faecalis and 12mm for Lactobacillus. In contrast, the tooth samples treated with orange and grape peel extract (Group 1 and Group 2) displayed significantly enhanced antibacterial activity. Group 1, affected by E.faecalis, showed remarkable zones of inhibition, measuring 25mm at 25µg/ml, 20mm at 50µg/ml, and 24mm at 100µg/ml. Similarly, Group 2, affected by Lactobacillus, demonstrated significant inhibitory effects with measurements of 15mm, 16mm, and 18mm at corresponding concentrations. The graphical representation of these data highlighted the substantial antibacterial activity of the plant extract compared to tap water. The observed superiority of the plant extract over tap water suggests its potential as an effective mouthwash (16,17). Notably, the extract's effectiveness against E.faecalis was found to be greater than that against Lactobacillus. This specificity in antibacterial activity could be attributed to the unique bioactive compounds present in the orange and grape peel extract, which may have a targeted impact on certain bacterial strains (Tuluwengjiang et al., 2024). The comparison of bacterial growth colonies further supported our findings, with E.faecalis displaying a higher growth of 56\*10⁵ CFU/mL compared to Lactobacillus, which showed growth at 40\*10⁵ CFU/mL. The higher inhibition of E.faecalis growth, despite its higher baseline growth, indicates the efficacy of the plant extract against this pathogen.The presented study provides valuable insights into the antibacterial effects of Orange and grape peel extract in combination with silver nanoparticles as a mouthwash against E. faecalis and Lactobacillus. However, it is crucial to recognize certain limitations that could impact the generalization and interpretation of the findings. Variables like pH variations, salivary components, and the presence of other microorganisms may influence the efficacy of the tested antibacterial agents differently in vivo. Although the focus on E. faecalis and Lactobacillus is significant for oral health, it may not fully represent the entire oral microbiota. Further investigations, encompassing a broader range of concentrations, are necessary to establish optimal and safe levels for practical application. Extended studies over prolonged durations could provide insights into the sustained effectiveness of the antibacterial agents and the potential development of resistance by microbial strains. In future research endeavors, consideration of potential interactions with human cells is essential to ensure that the proposed agents do not inadvertently harm host tissues.

# Conclusion

In conclusion, our study adds valuable insights to the existing literature on antibacterial activity by plant extracts. The orange and grape peel extract exhibits significant and specific antibacterial activity against both E.faecalis and Lactobacillus, showcasing its potential as a natural and potent antimicrobial agent for oral health applications. Future research can build upon these findings and explore additional optimization and clinical evaluation to establish the effectiveness and practicality of the silver nanoparticle-based mouthwash rinse.

# References

1. [Adel, S. M., El-Harouni, N., & Vaid, N. R. (2023). White Spot lesions: State of the art biomaterials and workflows used in prevention, progression and treatment. Seminars in Orthodontics. https://doi.org/](http://paperpile.com/b/bqsYIJ/tUR5)[10.1053/j.sodo.2023.01.002](http://dx.doi.org/10.1053/j.sodo.2023.01.002)
2. [Anti-inflammatory Potential of a Mouthwash Formulated Using Clove and Ginger Mediated by Zinc Oxide Nanoparticles: An In Vitro Study. (n.d.).](http://paperpile.com/b/bqsYIJ/MTFo)
3. [Anupong, W., On-Uma, R., Jutamas, K., Joshi, D., Salmen, S. H., Alahmadi, T. A., & Jhanani, G. K. (2023). Cobalt nanoparticles synthesizing potential of orange peel aqueous extract and their antimicrobial and antioxidant activity. Environmental Research, 216(Pt 2), 114594. https://doi.org/](http://paperpile.com/b/bqsYIJ/1XUF)[10.1016/j.envres.2022.114594](http://dx.doi.org/10.1016/j.envres.2022.114594)
4. [Aparna, J., Maiti, S., & Jessy, P. (2021). Polyether ether ketone - As an alternative biomaterial for Metal Richmond crown-3-dimensional finite element analysis. Journal of Conservative Dentistry: JCD, 24(6), 553–557. https://doi.org/](http://paperpile.com/b/bqsYIJ/fCO0)[10.4103/jcd.jcd\_638\_20](http://dx.doi.org/10.4103/jcd.jcd_638_20)
5. [Capasso, R., & Di Cesare Mannelli, L. (2021). Plant Extracts: Biological and Pharmacological Activity. MDPI.](http://paperpile.com/b/bqsYIJ/J6vq) <https://books.google.com/books/about/Plant_Extracts.html?hl=&id=xOArEAAAQBAJ>
6. [Chokkattu, J. J., Mary, D. J., Shanmugam, R., & Neeharika, S. (2022). Embryonic toxicology evaluation of ginger- and clove-mediated titanium oxide nanoparticles-based dental varnish with zebrafish. The Journal of Contemporary Dental Practice, 23(11), 1157–1162. https://doi.org/](http://paperpile.com/b/bqsYIJ/Q35f)[10.5005/jp-journals-10024-3436](http://dx.doi.org/10.5005/jp-journals-10024-3436)
7. [Chokkattu, J. J., Neeharika, S., & Rameshkrishnan, M. (2023). Applications of nanomaterials in dentistry: A review. Journal of International Society of Preventive & Community Dentistry, 13(1), 32–41. https://doi.org/](http://paperpile.com/b/bqsYIJ/BDmd)[10.4103/jispcd.JISPCD\_175\_22](http://dx.doi.org/10.4103/jispcd.JISPCD_175_22)
8. [Christina, B., ThanigaiMani, K., Sudhakaran, R., Mohan, S., Arumugam, N., Almansour, A. I., & Mahalingam, S. M. (2023). Pyto-Architechture of Ag, Au and Ag-Au bi-metallic nanoparticles using waste orange peel extract for enable carcinogenic Congo red dye degradation. Environmental Research, 117625. https://doi.org/](http://paperpile.com/b/bqsYIJ/kX9V)[10.1016/j.envres.2023.117625](http://dx.doi.org/10.1016/j.envres.2023.117625)
9. [Ganapathy, D.. (2021). Awareness of hazards caused by long-term usage of polyethylene terephthalate (PET) bottles. International Journal of Dentistry and Oral Science, 2976–2980. https://doi.org/](http://paperpile.com/b/bqsYIJ/DX7a)[10.19070/2377-8075-21000605](http://dx.doi.org/10.19070/2377-8075-21000605)
10. [Jain, R. K., & Verma, P. (2022). Visual assessment of extent of White Spot lesions in subjects treated with fixed orthodontic appliances: A retrospective study. World Journal of Dentistry, 13(3), 245–249. https://doi.org/](http://paperpile.com/b/bqsYIJ/WUyo)[10.5005/jp-journals-10015-2042](http://dx.doi.org/10.5005/jp-journals-10015-2042)
11. [Joshi, L. (2018). Green Synthesis/biosynthesis of Silver Nanoparticles by Using Orange Peel Extract.](http://paperpile.com/b/bqsYIJ/5VHf) <https://books.google.com/books/about/Green_Synthesis_biosynthesis_of_Silver_N.html?hl=&id=nAa5zQEACAAJ>
12. [Laghari, I. A., Pandey, A. K., Samykano, M., Aljafari, B., Kadirgama, K., Sharma, K., & Tyagi, V. V. (2023). Thermal energy harvesting of highly conductive graphene-enhanced paraffin phase change material. Journal of Thermal Analysis and Calorimetry, 148(18), 9391–9402. https://doi.org/](http://paperpile.com/b/bqsYIJ/cK8l)[10.1007/s10973-023-12336-5](http://dx.doi.org/10.1007/s10973-023-12336-5)
13. Maheshwaran, B., Priyadharshini, R., Kumar, S. R. and Sinduja, P. (2021) “Antimicrobial Activity and Cytotoxicity of Mouthwash Prepared from Azadirachta indica and Stevia rebaudiana Extract– An In vitro Study”, Journal of Pharmaceutical Research International, 33(59B), pp. 96–107.
14. [Marya, A., Venugopal, A., Karobari, M. I., & Rokaya, D. (2022). White Spot lesions: A serious but often ignored complication of orthodontic treatment. The Open Dentistry Journal, 16(1). https://doi.org/](http://paperpile.com/b/bqsYIJ/qHj7)[10.2174/18742106-v16-e2202230](http://dx.doi.org/10.2174/18742106-v16-e2202230)
15. [Merchant, A., Ganapathy, D. M., & Maiti, S. (2022). Effectiveness of local and topical anesthesia during gingival retraction. Brazilian Dental Science, 25(1), e2591. https://doi.org/](http://paperpile.com/b/bqsYIJ/0lWh)[10.4322/bds.2022.e2591](http://dx.doi.org/10.4322/bds.2022.e2591)
16. [Mostafa, Y. S., Alamri, S. A., Alrumman, S. A., Hashem, M., & Baka, Z. A. (2021). Green Synthesis of Silver Nanoparticles Using Pomegranate and Orange Peel Extracts and Their Antifungal Activity against , the Causal Agent of Early Blight Disease of Tomato. Plants, 10(11). https://doi.org/](http://paperpile.com/b/bqsYIJ/2CVs)[10.3390/plants10112363](http://dx.doi.org/10.3390/plants10112363)
17. [Muthuswamy Pandian, S., Subramanian, A. K., Ravikumar, P. A., & Adel, S. M. (2022). Biomaterial testing in contemporary orthodontics: Scope, protocol and testing apparatus. Seminars in Orthodontics. https://doi.org/](http://paperpile.com/b/bqsYIJ/o1ZT)[10.1053/j.sodo.2022.12.011](http://dx.doi.org/10.1053/j.sodo.2022.12.011)
18. [Nazemi Salman, B., Mohammadi Gheidari, M., Yazdi Nejad, A., Zeighami, H., Mohammadi, A., & Basir Shabestari, S. (2022). Antimicrobial Activity of Silver Nanoparticles Synthesized by the Green Method Using . Extract Against Oral Pathogenic Microorganisms. Medical Journal of the Islamic Republic of Iran, 36, 154. https://doi.org/](http://paperpile.com/b/bqsYIJ/6Dm6)[10.47176/mjiri.36.154](http://dx.doi.org/10.47176/mjiri.36.154)
19. [Niluxsshun, M. C. D., Masilamani, K., & Mathiventhan, U. (2021). Green Synthesis of Silver Nanoparticles from the Extracts of Fruit Peel of , , and for Antibacterial Activities. Bioinorganic Chemistry and Applications, 2021, 6695734. https://doi.org/](http://paperpile.com/b/bqsYIJ/9D8v)[10.1155/2021/6695734](http://dx.doi.org/10.1155/2021/6695734)
20. [Pandiyan, I., Sri, S. D., Indiran, M. A., Rathinavelu, P. K., Prabakar, J., & Rajeshkumar, S. (2022). Antioxidant, anti-inflammatory activity of Thymus vulgaris-mediated selenium nanoparticles: An in vitro study. Journal of Conservative Dentistry: JCD, 25(3), 241–245. https://doi.org/](http://paperpile.com/b/bqsYIJ/uQyk)[10.4103/JCD.JCD\_369\_21](http://dx.doi.org/10.4103/JCD.JCD_369_21)
21. [Poornima, P., Krithikadatta, J., Ponraj, R. R., Velmurugan, N., & Kishen, A. (2021). Biofilm formation following chitosan-based varnish or chlorhexidine-fluoride varnish application in patients undergoing fixed orthodontic treatment: a double blinded randomised controlled trial. BMC Oral Health, 21(1), 465. https://doi.org/](http://paperpile.com/b/bqsYIJ/XZu9)[10.1186/s12903-021-01805-8](http://dx.doi.org/10.1186/s12903-021-01805-8)
22. [Prasher, P., & Sharma, M. (2022). Silver Nanoparticles: Synthesis, Functionalization and Applications. Bentham Science Publishers.](http://paperpile.com/b/bqsYIJ/99MT) <https://books.google.com/books/about/Silver_Nanoparticles_Synthesis_Functiona.html?hl=&id=gYhsEAAAQBAJ>
23. Rafi, D. M., Lakshmi, T. V., Shirley, C. P., Ravivarman, G., & Senthilkumar, G. (2024, April). Improving Prostate Cancer Diagnosis with Weakly Supervised Learning and Radiology-Confirmed Negative MRI Data. In 2024 International Conference on Inventive Computation Technologies (ICICT) (pp. 1183-1188). IEEE.
24. [Ramamurthy, S., Thiagarajan, K., Varghese, S., Kumar, R., Karthick, B. P., Varadarajan, S., & Balaji, T. M. (2022). Assessing the in vitro antioxidant and anti-inflammatory activity of Moringa oleifera crude extract. The Journal of Contemporary Dental Practice, 23(4), 437–442. https://doi.org/](http://paperpile.com/b/bqsYIJ/u5vk)[10.5005/jp-journals-10024-3323](http://dx.doi.org/10.5005/jp-journals-10024-3323)
25. [Rams, T. E., Sautter, J. D., & Shin, S. S. (2022). Molecular Iodine Mouthrinse Antimicrobial Activity Against Periodontopathic Bacteria. The Journal of Contemporary Dental Practice, 23(12), 1183–1189. https://doi.org/](http://paperpile.com/b/bqsYIJ/2ZHg)[10.5005/jp-journals-10024-3447](http://dx.doi.org/10.5005/jp-journals-10024-3447)
26. Roshan, A., Priyadharshini, R., Rajeshkumar, S. and Sinduja, P. (2021) “Preparation of Mouth Wash Using Musa sapientum Mediated Silver Nanoparticles and Its Antimicrobial Activity”, Journal of Pharmaceutical Research International, 33(64A), pp. 177–185.
27. [Rodríguez, J. M. L., & Ruiz, D. F. (2016). Grape Seeds: Nutrient Content, Antioxidant Properties and Health Benefits. Nova Science Publishers.](http://paperpile.com/b/bqsYIJ/Cpcd) <https://books.google.com/books/about/Grape_Seeds.html?hl=&id=GHNAjwEACAAJ>
28. [Rumbaugh, K. P., & Ahmad, I. (2014). Antibiofilm Agents: From Diagnosis to Treatment and Prevention. Springer Science & Business Media.](http://paperpile.com/b/bqsYIJ/BrIZ) <https://play.google.com/store/books/details?id=mZqKAwAAQBAJ>
29. [Saleem, M., Durani, A. I., Asari, A., Ahmed, M., Ahmad, M., Yousaf, N., & Muddassar, M. (2023). Investigation of antioxidant and antibacterial effects of citrus fruits peels extracts using different extracting agents: Phytochemical analysis with in silico studies. Heliyon, 9(4), e15433. https://doi.org/](http://paperpile.com/b/bqsYIJ/j1Fw)[10.1016/j.heliyon.2023.e15433](http://dx.doi.org/10.1016/j.heliyon.2023.e15433)
30. [Saratale, R. G., Shin, H.-S., Kumar, G., Benelli, G., Ghodake, G. S., Jiang, Y. Y., Kim, D. S., & Saratale, G. D. (2018). Exploiting fruit byproducts for eco-friendly nanosynthesis: Citrus × clementina peel extract mediated fabrication of silver nanoparticles with high efficacy against microbial pathogens and rat glial tumor C6 cells. Environmental Science and Pollution Research International, 25(11), 10250–10263. https://doi.org/](http://paperpile.com/b/bqsYIJ/Uw68)[10.1007/s11356-017-8724-z](http://dx.doi.org/10.1007/s11356-017-8724-z)
31. [Solanki, L. A., Dinesh, S. P. S., Jain, R. K., & Balasubramaniam, A. (2023). Effects of titanium oxide coating on the antimicrobial properties, surface characteristics, and cytotoxicity of orthodontic brackets - A systematic review and meta analysis of in-vitro studies. Journal of Oral Biology and Craniofacial Research, 13(5), 553–562. https://doi.org/](http://paperpile.com/b/bqsYIJ/VRdw)[10.1016/j.jobcr.2023.05.014](http://dx.doi.org/10.1016/j.jobcr.2023.05.014)
32. [Sreevarun, M., Ajay, R., Suganya, G., Rakshagan, V., Bhanuchander, V., & Suma, K. (2023). Formulation, configuration, and physical properties of dental composite resin containing a novel 2π + 2π photodimerized crosslinker - cinnamyl methacrylate: An in vitro research. The Journal of Contemporary Dental Practice, 24(6), 364–371. https://doi.org/](http://paperpile.com/b/bqsYIJ/bQWz)[10.5005/jp-journals-10024-3480](http://dx.doi.org/10.5005/jp-journals-10024-3480)
33. [Subramanian, A., & Harikrishnan, S. (2023). 3D printing in orthodontics: A narrative review. Journal of International Oral Health: JIOH, 15(1), 15. https://doi.org/](http://paperpile.com/b/bqsYIJ/eqi0)[10.4103/jioh.jioh\_83\_22](http://dx.doi.org/10.4103/jioh.jioh_83_22)
34. [Talon, M., Caruso, M., & Gmitter, F. G., jr. (2020). The Genus Citrus. Woodhead Publishing.](http://paperpile.com/b/bqsYIJ/gybK) <https://play.google.com/store/books/details?id=dslaDwAAQBAJ>
35. Tuluwengjiang, G., Rasulova, I., Ahmed, S., Kiasari, B. A., Sârbu, I., Ciongradi, C. I., & Samaniego, S. S. C. (2024). Dendritic cell-derived exosomes (Dex): Underlying the role of exosomes derived from diverse DC subtypes in cancer pathogenesis. Pathology-Research and Practice, 254, 155097.
36. [Verma, P., & Muthuswamy Pandian, S. (2021). Bionic effects of nano hydroxyapatite dentifrice on demineralised surface of enamel post orthodontic debonding: in-vivo split mouth study. Progress in Orthodontics, 22(1), 39. https://doi.org/](http://paperpile.com/b/bqsYIJ/cpNi)[10.1186/s40510-021-00381-5](http://dx.doi.org/10.1186/s40510-021-00381-5)
37. [Wadhwani, V., Sivaswamy, V., & Rajaraman, V. (2022). Surface roughness and marginal adaptation of stereolithography versus digital light processing three-dimensional printed resins: An in-vitro study. Journal of Indian Prosthodontic Society, 22(4), 377–381. https://doi.org/](http://paperpile.com/b/bqsYIJ/HiwP)[10.4103/jips.jips\_8\_22](http://dx.doi.org/10.4103/jips.jips_8_22)
38. [Zheng, T., Huang, X., Chen, J., Feng, D., Mei, L., Huang, Y., Quan, G., Zhu, C., Singh, V., Ran, H., Pan, X., Wu, C.-Y., & Wu, C. (2018). A liquid crystalline precursor incorporating chlorhexidine acetate and silver nanoparticles for root canal disinfection. Biomaterials Science, 6(3), 596–603. https://doi.org/](http://paperpile.com/b/bqsYIJ/uJL8)[10.1039/c7bm00764g](http://dx.doi.org/10.1039/c7bm00764g)