Silver Nanoparticles Based Nanocomposite for Dental Cements

D Manoj Aravindan1, Yagini Sri1,a)

1Manoj Medical Centre, Chennai, Tamilnadu, India.

Corresponding author: a) [yagnithasri@gmail.com](mailto:yagnithasri@gmail.com)

Abstract: Silver nanocomposites (AgNCs) have garnered significant attention due to their multifunctional properties, making them promising candidates for biomedical applications. This study investigates the structural, antimicrobial, and antioxidant properties of synthesized AgNCs, with a focus on their potential use in dental cements. SEM analysis revealed that the nanocomposites possess an irregular shape, rough surface texture, and exhibit aggregation, with dimensions ranging from the nanoscale to microscale. The antimicrobial activity of AgNCs was evaluated using the agar well diffusion method against *Staphylococcus aureus* (Gram-positive) and *Escherichia coli* (Gram-negative). A dose-dependent antibacterial effect was observed, with the 100 mg concentration exhibiting a significantly larger zone of inhibition compared to 50 mg, demonstrating AgNCs' strong efficacy in inhibiting bacterial growth. Additionally, the antioxidant potential of AgNCs was assessed using the DPPH radical scavenging assay, which revealed a concentration-dependent increase in scavenging activity, with the highest activity recorded at 30 mg/mL. These findings suggest that AgNCs possess significant antibacterial and antioxidant properties, alongside nanoscale structural features that could enhance the mechanical and functional properties of dental cements. By incorporating AgNCs, dental cements could potentially become more biocompatible, durable, and resistant to infections, addressing key challenges in restorative dentistry. Further studies are recommended to optimize AgNC-enhanced formulations and evaluate their clinical applicability.

Keywords: Silver nanocomposite, antimicrobial activity, antioxidant potential, dental cements, Staphylococcus aureus, Escherichia coli, restorative dentistry, biocompatibility

# INTRODUCTION

Silver nanoparticles (AgNPs) have emerged as promising candidates for enhancing the properties of dental composites[(Aparna et al., 2021)](https://paperpile.com/c/mjGEWF/cPMWo). The integration of these nanoparticles into dental materials opens up new avenues for improving both the mechanical and antimicrobial characteristics of dental restorations [(Poornima et al., 2021)](https://paperpile.com/c/mjGEWF/vn0wl). This innovation addresses the challenges associated with bacterial colonization and secondary caries, offering a multifaceted approach to enhancing the overall performance of dental composites [(Verma & Muthuswamy Pandian, 2021)](https://paperpile.com/c/mjGEWF/vySXu).

One key advantage of incorporating silver nanoparticles is their well-documented antimicrobial properties [(Merchant et al., 2022; Pandiyan et al., 2022)](https://paperpile.com/c/mjGEWF/7Kx02+FALxw). Silver has been known for its antibacterial effects for centuries, and in nanoparticle form, it exhibits enhanced efficacy [(Ganapathy 2021)](https://paperpile.com/c/mjGEWF/ZxPDK)). The small size of nanoparticles provides a larger surface area for interaction with bacteria, disrupting their cell membranes and interfering with vital cellular processes [(Chokkattu et al., 2022)](https://paperpile.com/c/mjGEWF/yFyTb). This antimicrobial action is particularly relevant in the oral environment, where bacterial colonization on dental surfaces can lead to the development of caries and other oral diseases4.

In the realm of dental composites, the incorporation of silver nanoparticles aims to create a nanocomposite material with inherent antimicrobial capabilities [(Ramamurthy et al., 2022)](https://paperpile.com/c/mjGEWF/n0cdi). This feature is especially valuable in dental restorations, where the prevention of bacterial growth is crucial for maintaining the integrity of the restoration and preventing secondary caries [(Jain & Verma, 2022; Marya et al., 2022)](https://paperpile.com/c/mjGEWF/tPGwa+Gc7Qp). The use of silver nanoparticles in dental composites has shown promising results in inhibiting the growth of common oral pathogens, contributing to improved oral health outcomes for patients5.

Beyond their antimicrobial properties, silver nanoparticles can positively influence the mechanical performance of dental composites5. The addition of nanoparticles can enhance the material's strength, hardness, and wear resistance6. This reinforcement is essential for dental restorations, as they are subjected to various mechanical stresses in the oral cavity, including chewing forces7. By improving the mechanical properties, silver nanoparticle-based nanocomposites contribute to the durability and longevity of dental restorations, reducing the likelihood of fractures or wear over time8.

Moreover, silver nanoparticles have demonstrated anti-inflammatory effects, which can be advantageous in the context of dental materials9. Inflammation is a common concern in dental procedures and restorations, and materials that exhibit anti-inflammatory properties can contribute to better biocompatibility [(Chokkattu et al., 2023)](https://paperpile.com/c/mjGEWF/jABD0). Reduced inflammation at the restoration site promotes faster healing and a more comfortable experience for the patient10.

Furthermore, the clinical applications of silver nanoparticles-based nanocomposites in dental cement extend beyond traditional restoration procedures [(Muthuswamy Pandian et al., 2022; Ramakrishnan et al., 2023)](https://paperpile.com/c/mjGEWF/jjMTC+3u3LW). These nanocomposites show promise in applications such as pulp capping and root canal sealants, where antimicrobial properties are particularly crucial11 12. The incorporation of AgNPs may contribute to improved clinical outcomes by preventing bacterial ingress and promoting asepsis in these critical dental procedures11.

The integration of silver nanoparticles into dental composites represents a significant advancement in dental materials science[(Laghari et al., 2023)](https://paperpile.com/c/mjGEWF/LVS2q) . The synergistic combination of antimicrobial efficacy and improved mechanical properties makes silver nanoparticle-based nanocomposites promising for enhancing the performance and longevity of dental restorations8. As research in nanotechnology continues to evolve, the development of innovative dental materials will likely play a crucial role in advancing the field of restorative dentistry, offering improved solutions for both clinicians and patients13.

# MATERIALS AND METHODS

## Preparation of Silver and zirconia

Following the dissolution of 1 mM silver nitrate in 100 mL of deionized water, 0.1 mM sodium citrate (a capping agent) was added. For an hour, the prepared silver nitrate solution was mixed quickly (Chehelgerdi et al., 2023). After adding 0.12 g of the reducing agent (NaBH4), the mixture was constantly stirred for half an hour. When silver nanoparticles effectively cover ZrO2, the white color of the zirconia nanoparticles changes to a light yellow tinge. The combination was then centrifuged, and the pellet was removed and cleaned with deionized water and ethanol. The pellet was employed for characterisation experiments after it had been completely dried in a vacuum oven at 80 °C14.

## Surface characterization

The morphological feature was studied using Field Emission Scanning Electron Microscope and a JEOL Energy Dispersive X-ray Spectrometer (EDS) model (JSM –IT800 NANO SEM).

## Antibacterial activity

The Gram negative and Gram positive bacterial strains used to assess the antibacterial activity of the synthesized silver nanoparticles were *Escherichia coli* (ATCC 25922) and *Staphylococcus aureus* (ATCC 25923). Trypcase Soy Agar (TSA) plates was used for the revival of bacterial strain from glycerol stock. The bacterial stock culture was streaked in TSA plated and incubated at 37 °C for 18 to 24 hours (Saadh et al., 2024). A single colony from the plate was inoculated in 50 mL of autoclaved Tryptic Soy Broth (TSB) medium and incubated at 37 °C, 80 rpm for eighteen to twenty-four hours. The bacterial strains were cultivated at a 1:50 ratio in fresh TSB and incubated for two hours at 80 rpm and 37 °C before being used for the assay. 20 µl sample of different concentration of 50 mg/ml and 100 mg/ml was loaded in sterile on both the sides of sterile Whatmann No. 1 filter paper (5 mm diameter). 10 µl of ampicillin (200 µg/ml) was added as control in a well. The plates were incubated at 37 °C for 18 hours. The plates were then checked for zone of inhibition15.

# Anti-oxidant activity

## DPPH Radical scavenging assay

For DPPH free radical scavenging activity, different concentrations (10, 20, 30 mg/mL) of AgNPs and Ascorbic acid as the standard reference compound were assayed while the reaction mixture comprising only methanol and DPPH was used as the negative control. The reaction mixture contained different concentrations of the DPPH reagent and silver nanocomposite both of which were cultured in a dark environment. The absorbance was measured at 517 nm using a UV-VIS spectrophotometer with an ELISA reader on a 96-well plate16.

# RESULT

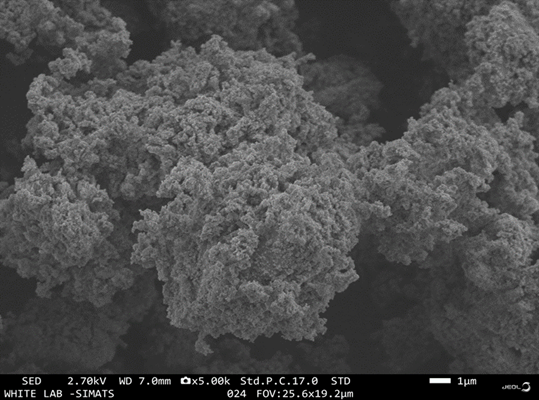


Figure 1: SEM analysis of silver nanocomposite

The SEM analysis provides valuable insights into the structural and morphological properties of the nanoparticles, which are critical for understanding their behavior in the intended functional context. At a magnification of 5000×, the nanoparticles appear to have an irregular shape with a rough surface texture. The estimated size of individual particles seems to fall within the microscale-to-nanoscale range, aligning with the expected dimensions for this synthesis process. For a more comprehensive understanding, further studies using complementary techniques, such as TEM (Transmission Electron Microscopy), could provide higher-resolution insights into the shape and size of individual nanoparticles.

## Antibacterial studies

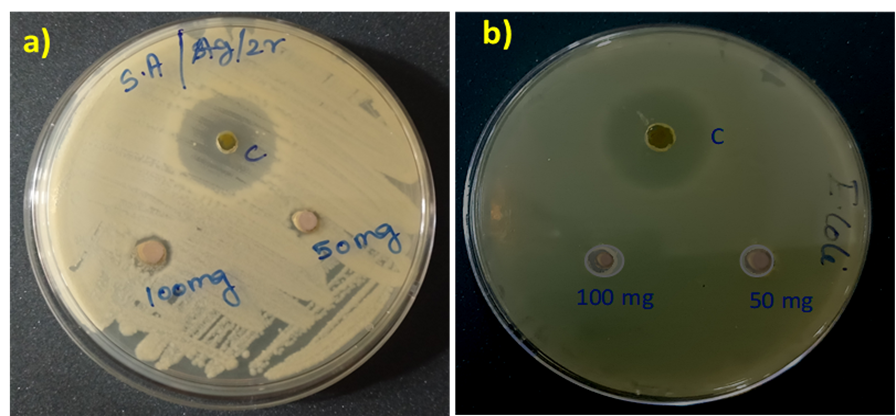


Figure 2: Antibacterial activity of silver nanocomposite against *Staphylococcus aureus* and *Escherichia coli* with ampicillin as control

The antimicrobial activity of silver nanocomposite was evaluated against **Staphylococcus aureus** (*S.A*) and **Escherichia coli** (*E. coli*), as depicted in Figure (a) and (b), respectively, using the agar well diffusion method. The zones of inhibition (ZOI) was observed for two concentrations of nanocomposite (50 mg and 100 mg), along with a control (C). In **Figure (a)**, the nanocomposite demonstrated significant antibacterial activity against *S. aureus*. A clear ZOI was observed, with the 100 mg concentration producing a larger inhibition zone compared to 50 mg. This indicates a dose-dependent antimicrobial effect, where higher concentrations of silver nanocomposite result in greater bacterial inhibition. Similarly, in **Figure (b)**, the nanocomposite showed effective antimicrobial activity against *E. coli*. The ZOI observed was slightly smaller than that for *S. aureus*, suggesting that *E. coli*, a Gram-negative bacterium, might be less sensitive to AgNPs compared to *S. aureus*, a Gram-positive bacterium. Despite this, the dose-dependent trend persisted, with the 100 mg concentration exhibiting a more pronounced inhibition zone than the 50 mg concentration.

## Anti-oxidant activity

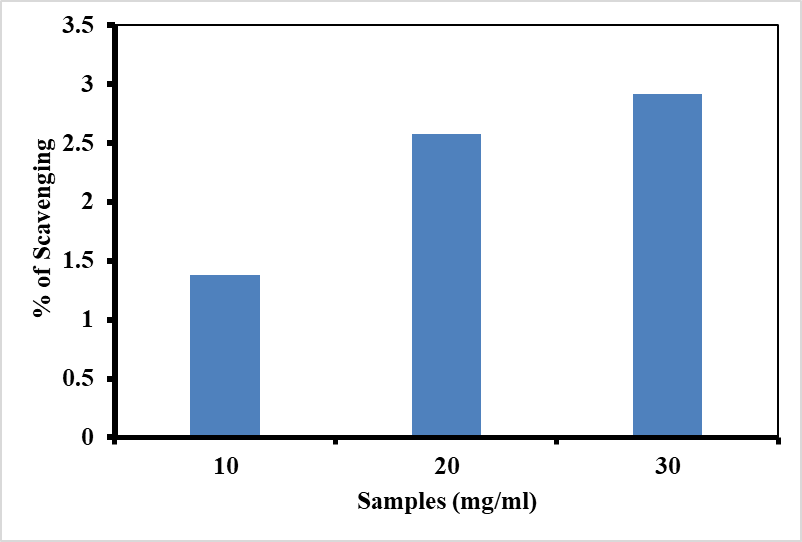


Figure 3: Antioxidant potential of synthesized silver nanoparticles at different concentrations

The antioxidant potential of synthesized silver nanocomposites (AgNCs) was assessed using the DPPH radical scavenging assay, and the results are presented in Figure 3. The scavenging activity was measured at three different concentrations of AgNCs: 10 mg/mL, 20 mg/mL, and 30 mg/mL. The results demonstrated a concentration-dependent increase in the scavenging activity of AgNPs. At 10 mg/mL, the % scavenging activity was relatively low, suggesting limited antioxidant potential at lower concentrations. However, a significant improvement in scavenging activity was observed at higher concentrations, with the highest activity recorded at 30 mg/mL. However, further studies are necessary to understand the mechanisms underlying their antioxidant activity and to evaluate their efficacy in biological systems.

# DISCUSSION

It is evident from the SEM image, the nanocomposite exhibit an aggregated structure, suggesting the formation of clusters. This aggregation is likely a result of interparticle interactions, such as van der Waals forces or hydrogen bonding, which are commonly observed in nanoparticulate systems[(Solanki et al., 2023)](https://paperpile.com/c/mjGEWF/yzRpo)[(Ganapathy 2021)](https://paperpile.com/c/mjGEWF/BQLce). The present study evaluated the antimicrobial activity of a silver nanocomposite against *Staphylococcus aureus* (S. aureus) and *Escherichia coli* (E. coli) using the agar well diffusion method, revealing a dose-dependent antibacterial effect [(Wadhwani et al., 2022)](https://paperpile.com/c/mjGEWF/Vnzvb)[(Sreevarun et al., 2023)](https://paperpile.com/c/mjGEWF/vrctk) . This aligns with findings from similar studies, such as Yamada et al.'s investigation of AgNP-coated yttria-stabilized zirconia (YSZ), which also demonstrated significant antimicrobial efficacy against *S. aureus* and *E. coli* 17. In this study, the scavenging activity of synthesized AgNCs showed a marked increase with concentration, achieving the highest activity at 30 mg/mL [(Adel et al., 2023)](https://paperpile.com/c/mjGEWF/QK0Z9). Similarly, the ZrO₂/Ag NCs reported by Muthuchamy18 exhibited strong DPPH radical scavenging activity, with an inhibition of 83.6% at a concentration of 1000 µg/mL. While the absolute concentrations used differ, both studies highlight a concentration-dependent trend, indicating that higher dosages amplify the antioxidant effects [(Subramanian & Harikrishnan, 2023)](https://paperpile.com/c/mjGEWF/mJ28b). The precise mechanism underlying the antioxidant activity of AgNCs in this study remains to be investigated

# CONCLUSION

The findings of this study underscore the potential of silver nanocomposites (AgNCs) as a multifunctional additive for dental cements, offering both biological and mechanical advantages. The pronounced antimicrobial activity of AgNCs against *Staphylococcus aureus* and *Escherichia coli* highlights their capability to inhibit bacterial growth and prevent biofilm formation, which are critical for reducing the risk of infections and secondary caries around dental restorations. Furthermore, the antioxidant properties of AgNCs, as demonstrated by their dose-dependent DPPH scavenging activity, suggest their ability to neutralize free radicals and mitigate oxidative stress, which can otherwise compromise oral tissues and accelerate the degradation of dental materials. Structurally, the nanoscale size and rough surface texture of AgNCs, along with their composite nature, could enhance the mechanical properties of dental cements by improving their adhesion to tooth surfaces and restorative materials, as well as increasing their compressive strength and durability. These findings highlight the potential of AgNC-incorporated dental cements to provide long-lasting, biocompatible, and infection-resistant solutions in restorative dentistry. However, further studies are essential to optimize their formulation, evaluate their long-term performance, and ensure their safety for clinical applications.

# REFERENCES

1. Lal HM. Polymer Nanocomposites Based on Silver Nanoparticles: Synthesis, Characterization and Applications. Springer International Publishing AG; 2021.
2. Nam KY. Characterization and antimicrobial efficacy of Portland cement impregnated with silver nanoparticles. J Adv Prosthodont. 2017;9(3):217. doi:10.4047/jap.2017.9.3.217
3. Andronescu E, Grumezescu AM. Nanostructures for Drug Delivery. Elsevier; 2017.
4. Iwuji C, Saha H, Ghann W, et al. Synthesis and characterization of silver nanoparticles and their promising antimicrobial effects. Chem Phys Impact. 2024;9:100758. doi:10.1016/j.chphi.2024.100758
5. Corrêa JM, Mori M, Sanches HL, Cruz ADD, Poiate E, Poiate IAVP. Silver Nanoparticles in Dental Biomaterials. Int J Biomater. 2015;2015:1-9. doi:10.1155/2015/485275
6. Zhao J, Xie D. Effect of Nanoparticles on Wear Resistance and Surface Hardness of a Dental Glass-ionomer Cement. J Compos Mater. 2009;43(23):2739-2752. doi:10.1177/0021998309345341
7. Alshamrani A, Alhotan A, Kelly E, Ellakwa A. Mechanical and Biocompatibility Properties of 3D-Printed Dental Resin Reinforced with Glass Silica and Zirconia Nanoparticles: In Vitro Study. Polymers. 2023;15(11):2523. doi:10.3390/polym15112523
8. Barot T, Rawtani D, Kulkarni P. Physicochemical and biological assessment of silver nanoparticles immobilized Halloysite nanotubes-based resin composite for dental applications. Heliyon. 2020;6(3):e03601. doi:10.1016/j.heliyon.2020.e03601
9. Fernandez CC, Sokolonski AR, Fonseca MS, et al. Applications of Silver Nanoparticles in Dentistry: Advances and Technological Innovation. Int J Mol Sci. 2021;22(5):2485. doi:10.3390/ijms22052485
10. Kanjevac T, Taso E, Stefanovic V, et al. Estimating the Effects of Dental Caries and Its Restorative Treatment on Periodontal Inflammatory and Oxidative Status: A Short Controlled Longitudinal Study. Front Immunol. 2021;12:716359. doi:10.3389/fimmu.2021.716359
11. Grumezescu AM. Antimicrobial Nanoarchitectonics: From Synthesis to Applications. William Andrew; 2017.
12. Kishen A, Shrestha A. Nanoparticles for Endodontic Disinfection. In: Kishen A, ed. Nanotechnology in Endodontics. Springer International Publishing; 2015:97-119. doi:10.1007/978-3-319-13575-5\_6
13. Dipalma G, Inchingolo AD, Guglielmo M, et al. Nanotechnology and Its Application in Dentistry: A Systematic Review of Recent Advances and Innovations. J Clin Med. 2024;13(17):5268. doi:10.3390/jcm13175268
14. Naeem Ashiq M, Aman A, Alshahrani T, et al. Enhanced electrochemical properties of silver-coated zirconia nanoparticles for supercapacitor application. J Taibah Univ Sci. 2021;15(1):10-16.
15. Razmavar S, Abdulla MA, Ismail SB, Hassandarvish P. Antibacterial Activity of Leaf Extracts of Baeckea frutescens against Methicillin-Resistant Staphylococcus aureus. BioMed Res Int. 2014;2014:1-5. doi:10.1155/2014/521287
16. Dauthal P, Mukhopadhyay M. In-vitro free radical scavenging activity of biosynthesized gold and silver nanoparticles using Prunus armeniaca (apricot) fruit extract. J Nanoparticle Res. 2013;15(1):1366. doi:10.1007/s11051-012-1366-7
17. Yamada R, Nozaki K, Horiuchi N, et al. Ag nanoparticle–coated zirconia for antibacterial prosthesis. Mater Sci Eng C. 2017;78:1054-1060. doi:10.1016/j.msec.2017.04.149
18. Muthuchamy M. Zirconium Oxide Supported Silver Nanocomposites: Synthesis, Characterization and in Vitro Evaluation of Anticancer, Antioxidant, Antibacterial Applications.
19. [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/mjGEWF/QK0Z9)[10.1053/j.sodo.2023.01.002](http://dx.doi.org/10.1053/j.sodo.2023.01.002)
20. [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.](http://paperpile.com/b/mjGEWF/cPMWo)
21. Chehelgerdi M., Chehelgerdi, M., Allela, O. Q. B., Pecho, R. D. C., Jayasankar, N., Rao, D. P. & Akhavan-Sigari, R. (2023). Progressing nanotechnology to improve targeted cancer treatment: overcoming hurdles in its clinical implementation. Molecular cancer, 22(1), 169.
22. [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.](http://paperpile.com/b/mjGEWF/yFyTb)
23. [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.](http://paperpile.com/b/mjGEWF/jABD0)
24. [Ganapathy, D (2021). Health benefits of Annona muricata - A review. International Journal of Dentistry and Oral Science, 2965–2967.](http://paperpile.com/b/mjGEWF/BQLce)
25. [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.](http://paperpile.com/b/mjGEWF/ZxPDK)
26. [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.](http://paperpile.com/b/mjGEWF/Gc7Qp)
27. [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.](http://paperpile.com/b/mjGEWF/LVS2q)
28. [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/mjGEWF/tPGwa)[10.2174/18742106-v16-e2202230](http://dx.doi.org/10.2174/18742106-v16-e2202230)
29. [Merchant, A., Ganapathy, D. M., & Maiti, S. (2022). Effectiveness of local and topical anesthesia during gingival retraction. Brazilian Dental Science, 25(1), e2591.](http://paperpile.com/b/mjGEWF/FALxw)
30. [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/mjGEWF/jjMTC)[10.1053/j.sodo.2022.12.011](http://dx.doi.org/10.1053/j.sodo.2022.12.011)
31. [Pandiyan, I., Sri, S. D., Indiran, M. A., Rathinavelu, P. K., Prabakar, J., & Rajeshkumar, S. (2022). Antioxidant, anti-inflammatory activity of -mediated selenium nanoparticles: An study. Journal of Conservative Dentistry : JCD, 25(3), 241–245.](http://paperpile.com/b/mjGEWF/7Kx02)
32. [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.](http://paperpile.com/b/mjGEWF/vn0wl)
33. [Ramakrishnan, M., Shanmugam, R., Neeharika, S., Selvaraj, S., Chokkattu, J. J., & Thangavelu, L. (2023). Anti-inflammatory potential of a mouthwash formulated using clove and ginger mediated by zinc oxide nanoparticles: An in vitro study. World Journal of Dentistry, 14(5), 394–401.](http://paperpile.com/b/mjGEWF/3u3LW)
34. [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.](http://paperpile.com/b/mjGEWF/n0cdi)
35. Saadh, M. J., Rasulova, I., Almoyad, M. A. A., Kiasari, B. A., Ali, R. T., Rasheed, T. & Ciongradi, C. I. (2024). Recent progress and the emerging role of lncRNAs in cancer drug resistance; focusing on signaling pathways. Pathology-Research and Practice, 253, 154999.
36. [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.](http://paperpile.com/b/mjGEWF/yzRpo)
37. [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 Research. The Journal of Contemporary Dental Practice, 24(6), 364–371.](http://paperpile.com/b/mjGEWF/vrctk)
38. [Subramanian, A., & Harikrishnan, S. (2023). 3D printing in orthodontics: A narrative review. Journal of International Oral Health: JIOH, 15(1), 15.](http://paperpile.com/b/mjGEWF/mJ28b)
39. [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.](http://paperpile.com/b/mjGEWF/vySXu)
40. [Wadhwani, V., Sivaswamy, V., & Rajaraman, V. (2022). Surface roughness and marginal adaptation of stereolithography versus digital light processing three-dimensional printed resins: An study. Journal of Indian Prosthodontic Society, 22(4), 377–381.](http://paperpile.com/b/mjGEWF/Vnzvb)