Sophorin Mediated Gold Nanoparticles Synthesis and Assessment of its Antifungal Activity Against Dandruff Causing Malassezia Furfur

Sai Sanjana Ganji1 , S.Dyanesh1,a)

1Sanjana Derma Care, Hyderabad, Telangana, India

Corresponding Author: a)[dyaneshhsdc@gmail.com](mailto:dyaneshhsdc@gmail.com)

**Abstract:** Malassezia has been connected to a variety of skin conditions, from mild dandruff to severe atopic dermatitis and seborrhea. It affects the quality of life of the individuals. Antifungal drugs provide relief in many cases. However, there is an urgent need for new therapeutic options due to the problems of disease recurrence and the development of resistance to the antifungal medications. Herein, flavonoid sophorin mediated gold nanoparticles (Sop-AuNPs) were synthesized and determined its antifungal activity against dandruff causing *Malassezia furfur*. The synthesized Sop-AuNPs were characterized using UV-vis spectrophotometer (UV-vis), Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray (EDX), and Fourier Transform Infrared Spectroscopy (FTIR). Antifungal efficacy of Sop-AuNPs was assessed against *M. furfur* through Zone of Inhibition (ZOI), Minimum Inhibitory Concentration (MIC) and Minimum Fungicidal Concentration (MFC) studies. The size of the synthesized Sop-AuNPs was found between 9 and 32 nm with spherical shape. FTIR results confirmed that hydroxyl groups of sophorin were coated on the AgNPs. ZOI, MIC and MFC of Sop-AuNPs values were found to be 31.3±0.5 mm in diameter, 5 to 10 µg/mL, and 10 µg/mL, respectively. Overall, this study concludes that sophorin mediated AuNPs might be a potential drug to treat dandruff to severe atopic dermatitis causing *M. furfur.*

**Keywords:** Gold nanoparticles; dandruff, flavonoids, sophorin, *Malassezia furfur*

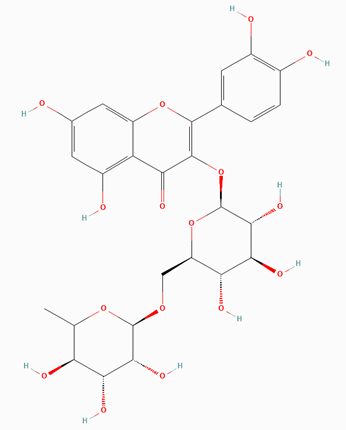
# Introduction

*Malassezia furfu*r is a yeast that lives on human skin and is associated with a variety of skin diseases [(Pedrosa et al., 2014)](https://paperpile.com/c/HTeMvP/TnaC). It is specifically connected to seborrheic dermatitis and tinea versicolor [(Ramsundar et al., 2023; Rieshy et al., 2023; Singh et al., 2023)](https://paperpile.com/c/HTeMvP/kiAjE+bB0Ek+qljFF). Additionally, it has been connected to pityriasis versicolor, malassezia folliculitis, dandruff, and malassezia intertrigo since it is an opportunistic pathogen [(Janniger et al., 2005)](https://paperpile.com/c/HTeMvP/Sr86). Furthermore, it can cause catheter-related fungemia and pneumonia in hematopoietic transplant patients. This opportunistic pathogen affects children more frequently than adults [(Prohic et al., 2015)](https://paperpile.com/c/HTeMvP/CpxT).Dandruff is a severe condition that affects people all over the world. It is characterized as scaling of the scalp [(Al-Waili, 2001)](https://paperpile.com/c/HTeMvP/VxAk). The association between yeast *M. furfur* and dandruff, as well as their pathogenic effects in humans, is extensively explored and well-documented [(Pavithra et al., 2023; Shenoy et al., 2023; Thomas & Jain, 2023)](https://paperpile.com/c/HTeMvP/mC005+YqxBp+xNJ1q). Dandruff recurrence is more common despite the number of commercially available shampoos that contain ketoconazole[(Doshi et al., 2023; Lampl et al., 2023; Pandiyan et al., 2023)](https://paperpile.com/c/HTeMvP/Hd4gD+KkFOp+DFaZa). The development of resistant strains of dandruff makes its resistance to antifungal agents even more intriguing [(Sathishkumar et al., 2016)](https://paperpile.com/c/HTeMvP/IZtY). In order to stop recurrence, an effective anti-dandruff product must be developed [(Rajeshkumar & Lakshmi, 2021; Sivakumar et al., 2021)](https://paperpile.com/c/HTeMvP/dLZpO+dd9dW). Several approaches like herbal products and nanoformulated herbal-metal nanoparticles have been reported to treat microbial infections causing opportunistic human pathogens [(Venkatesan & Sathishkumar, 2024)](https://paperpile.com/c/HTeMvP/zgdd),[(Khan et al., 2025; Murugapandi et al., 2023; Sowmya et al., 2025)](https://paperpile.com/c/HTeMvP/dvUX+Rukj+HYgn). In particular, biosynthesized metallic nanoparticles (MNPs) showed high efficiency in the treatment of different kinds of bacterial and fungal infections [(Selvaraj et al., 2024)](https://paperpile.com/c/HTeMvP/yTkw),[(Sathishkumar & Khan, 2024)](https://paperpile.com/c/HTeMvP/QHZW),[(Kannan et al., 2024)](https://paperpile.com/c/HTeMvP/MzuA). Among the biosynthesized MNPs, flavonoid mediated MNPs are highly attracted in the medical field to treat various diseased conditions, including microbial pathogens[(Janani et al., 2021; Kachhara et al., 2021; Subramanian et al., 2023)](https://paperpile.com/c/HTeMvP/dTSa+8Xfp+EUs0) . In the present study, sophorin mediated gold nanoparticles (Sop-AuNPs) were synthesized by simple approach and assessed their antifungal efficacy against dandruff causing opportunistic pathogen *M. furfur.*

# Materials and methods

## Chemicals and microorganisms

Gold precursor chloroauric acid (HAuCl4) obtained from Sigma Adrich (USA). Reducing agent flavonoid sophorin **(Fig. 1)** was obtained from Aladdin (China). Dimethyl sulfoxide (DMSO) and other solvents were purchased from Merck, India. Microbiological media Sabouraud Dextrose Agar (SDA) and Sabouraud Dextrose Broth (SDB) were procured from HiMedia (India). Yeast strain *M. furfur* MTCC 1374 was obtained from the Microbial Type Culture Centre (India).



**Figure 1.** Chemical structure of sophorin (flavonoid)

## Synthesis of Sop-AuNPs

A preliminary experiment was conducted using the procedure outlined in the previous work [(Selvaraj et al., 2024)](https://paperpile.com/c/HTeMvP/yTkw) in order to determine the optimum level of parameters for the Sop-AuNPs synthesis. According to our preliminary finding, a 1:2.5 M ratio (300:750 μM L−1) of sophorine and HAuCl4 was mixed in 130 mL of deionized water at pH 8 under 40 °C. The change of red wine from yellow colour in the reaction solution has confirmed the formation of Sop-AuNPs. Further, the surface plasmon resonance (SPR) of Sop-AuNPs was monitored using a UV–visible spectrophotometer.

## Nanomaterial characterization

The synthesized Sop-AuNPs were characterized using standard techniques such as UV-vis spectrophotometer (UV-vis; Jasco V-730, Japan) scanning electron microscope (SEM; JEOL, JSM-IT-800, Japan), energy-dispersive X-ray (EDX), and Fourier transform infrared spectroscopy (FTIR; Bruker Alpha II, Germany).

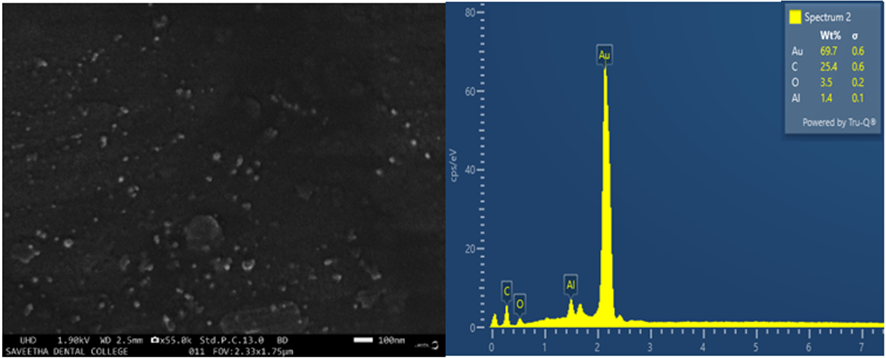
## Anti-dandruff efficacy assessment

Yeast *M. furfur* was maintained on SDA supplemented with 1% ghee and periodically sub-cultured. The antifungal properties of the synthesized Sop-AuNPs were analysed by measuring (ZOI), minimum inhibitory concentration (MIC), and minimum fungicidal concentration (MFC). For ZOI determination, the synthesized Sop-AuNPs was assessed against *M. furfu*r on the SDA supplemented with 1% ghee at 35 °C. In brief, the *M. furfur* inoculum (one optical density absorbance at 600 nm) was spread onto SDA plate supplemented with 1% ghee using cotton swab. Three wells were punched onto the yeast *M. furfur* inoculated SDA agar plates (1% ghee supplemented) with the help of a well-cutter (9 mm size in diameter). Then, 1000 µg of sophorin suspended in DMSO, 100 μg of Sop-AuNPs dispersed in DMSO, and 25 μg of standard antibiotic fluconazole dissolved in ethanol was loaded separately in the wells. The cultured SDA plates were kept at room temperature for 2 hours to diffuse the loaded drugs and further incubated at 35 °C overnight. After incubation, the ZOI was measured using the HiAntibiotic Zone Scale. The MIC of Sop-AuNPs for *M. furfur* was studied by micro-dilution methods with SDB (supplemented with 1% ghee) in a 96-well plate. The absorbance of the samples was recorded at 595 nm wavelength. SDB was maintained as a blank and *M. furfur* inoculated SDB without drug was maintained as a control. Both dilution methods can be used to determine whether a substance is active or not. However, it is impossible to predict whether the compound will kill the fungus or just stop its growth(Rafi et al., 2024). Therefore, MFC assay was performed to confirm the *M. furfur* inhibition. To determine the MFC, 100 µL of aliquots of different dilution from 10-1 to 10-4 were spread onto a petri plate containing SDA (supplemented with 1% ghee) and incubated at 35 °C for 48 hours of incubation. MFC was assessed following incubation by comparing its growth to that of the controls(Tuluwengjiang et al., 2024). The MFC was defined as the lowest drug concentration required to inhibit (99.9%) the growth of M. furfur or allowed less than three CFUs to form.

# Statistical analysis

All the experiments were performed in triplicate, and the results were expressed as mean with standard deviation values. Origin software was used for data analysis and graphical representation.

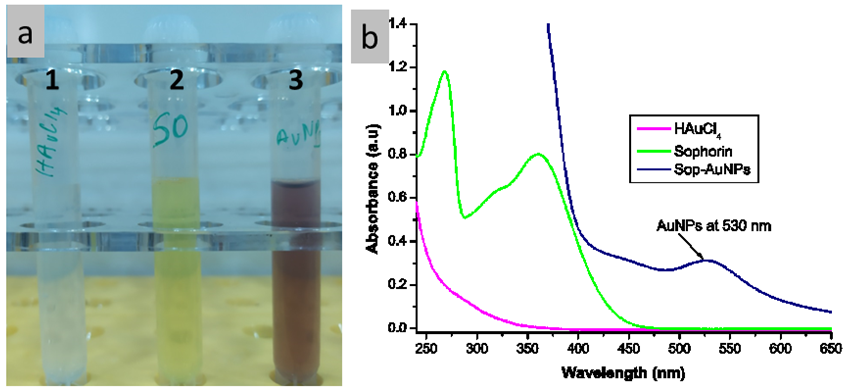
# Results and discussions



**Figure 2.** (a) Synthesis and (b) UV-vis spectra of Sop-AuNPs. a1 - HAuCl4 solution, a2 – Sophorin solution, and 3 – synthesized Sop-AuNPs.

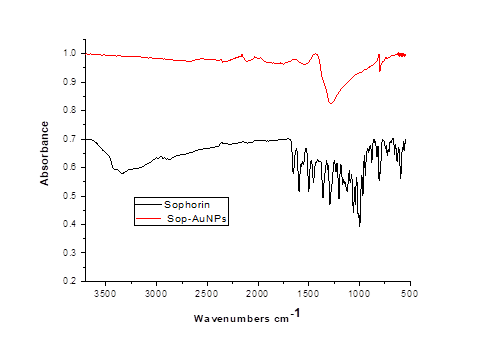
## Sop-AuNPs characterization

In this study, flavonoid sophorin was used as a reducing agent for the successful synthesis of AuNPs. As evident in **Fig. 2a**, the reaction solution color was turned into red wine color within two minutes, which was due to AuNPs formation (Au3+ ions to Au0). The UV-vis spectrum indicates that the SRP of the synthesized Sop-AuNPs was found around 530 nm, which confirms the successful synthesis of AuNPs (Fig. 2b). Several studies reported that the SRP of biosynthesized AuNPs ranged from 520 nm to 560 nm [(Mandhata et al., 2023)](https://paperpile.com/c/HTeMvP/hDT3);[(Olvera-Aripez et al., 2024)](https://paperpile.com/c/HTeMvP/pC3k). It could be due to differences in reaction conditions such as pH, temperature, and the molar ratios of reducing agent and precursor [(Selvaraj et al., 2024)](https://paperpile.com/c/HTeMvP/yTkw).**Fig. 3** shows the SEM and EDX images of the synthesized Sop-AuNPs. The SEM image reveals that the synthesized Sop-AuNPs appeared as spherical in shape within the range of 9 to 32 nm in diameter **(Fig. 3a)**, which is similar to the previous reports ([(Zhao et al., 2024)](https://paperpile.com/c/HTeMvP/i1Ds)). As illustrated in **Fig. 3b**, the EDX micrograph of the synthesized Sop-AuNPs indicates peaks around 0.28 keV, 0.53 keV, and 2.2 keV atoms for the elemental compositions such as carbon, oxygen, and gold, respectively. The peaks appearing for the carbon and oxygen might be due to the attachment of flavonoid sophorin during the metal ions reduction process [(Jabeen et al., 2025)](https://paperpile.com/c/HTeMvP/G9ei); [(Ramya et al., 2024)](https://paperpile.com/c/HTeMvP/EoH1).



**Figure 3**. (a) SEM image and (b) EDX micrograph of the synthesized Sop-AuNPs.

FTIR analysis was performed to investigate the functional groups attachment onto the synthesized Sop-AuNPs. FTIR analysis was performed for both flavonoid sophorin and Sop-AuNPs **(Fig. 4)**. The IR spectrum of sophorin showed important peaks at 3408 cm−1 and 3321 cm−1 for O-H stretching vibration, 2924 cm-1 and 2843 cm-1 for CH2-stretching vibrations, 1462 cm-1 for C=O groups, 1326 cm−1 for O-H in-plane bending vibrations, and 1383 cm-1 for C-OH vibrations [(Karakurt, 2016; Poonkuzhali et al., 2014)](https://paperpile.com/c/HTeMvP/L3Fg+nsTD). In the IR spectrum of Sop-AuNPs, a strong and broad peak appeared at 1330 cm−1 due to the O-H in-plane bending vibrations of flavonoid sophorin, which indicates that functional groups especially, O-H group of tannic acid play a crucial in the reduction **(Fig. 4).** Furthermore, the characteristic peaks of sophorin were slightly shifted and also the intensity of the peak has decreased. It confirms that sophorin molecules coated on the AuNPs, which prevent the particle's aggregation [(Selvaraj et al., 2024)](https://paperpile.com/c/HTeMvP/yTkw)



**Figure 4.** FTIR spectrum of sophorin and Sop-AuNPs.

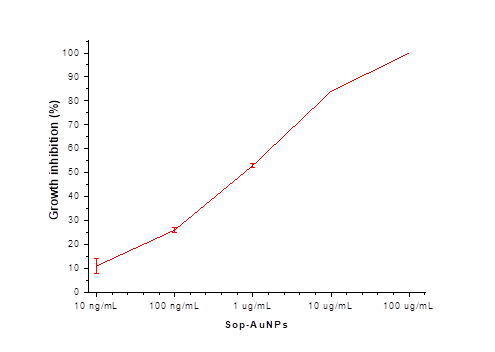
## Antifungal efficacy of Sop-AuNPs against *M. furfur*

The antifungal efficacy of the synthesized Sop-AuNPs was assessed against dandruff causing *M. furfur* via ZOI, MIC, and MFC assessment. **Fig. 5** illustrates the ZOI measurement of standard antibiotic fluconazole, sophorin, and Sop-AuNPs against *M. furfur* on SDA plate supplemented with 1% ghee by well diffusion method, after 48-hour incubation at 35 °C. The ZOI was observed as 40±1.0 mm, 13.6±0.5 mm and 31.3±0.5 mm in diameter for fluconazole, sophorin, and Sop-AuNPs, respectively.

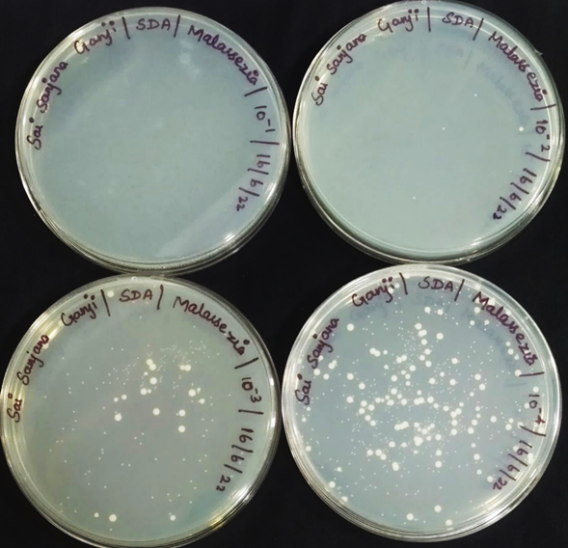


**Figure 5**. Antifungal activity of sophorin (S) and Sop-AuNPs. ZOI measurement on SDA supplemented with 1% ghee.

As represented in **Fig. 6**, the MIC level of the synthesized Sop-AgNPs was found between 5 and 10 μg mL-1 against M. furfur. The lowest concentration of Sop-AuNPs that efficiently inhibits above or around 99.5% of a fungus or its initial inoculum is called minimum fungicidal concentration (MFC). This study only enumerates live cells only. Thus, in this study, MFC was determined on an SDA plate amended with 1% ghee. MFC results also prove that complete inhibition was noted in 10 μg mL-1; whereas, three colony forming units (CFU) were recorded in 1 μg mL-1 (**Fig. 7**).



**Figure 6**. Minimal inhibitory concentration (MIC) assessment.



**Figure 7.** Minimal fungicidal concentration (MFC) assessment.

Previously, few researchers explored the antifungal efficacy of different biosynthesized MNPs against dandruff causing *M. furfur* [*(Gandhi et al., 2021; Katyal et al., 2023; Priyadharshini et al., 2023)*](https://paperpile.com/c/HTeMvP/uFHH5+709gV+me10s). For example, Macrophomina phaseolina mediated AgNPs exhibited high antifungal activity towards *M. furfur* [*(Joshi et al., 2013)*](https://paperpile.com/c/HTeMvP/2Xxl). However, there is only a limited report on anti-dandruff activity of biosynthesized metallic nanoparticles [(Chokkattu et al., 2023; Dharman et al., 2023; Govindaraj & Shanmugam, 2023)](https://paperpile.com/c/HTeMvP/C7cbO+t5yqR+uxbkj). The current finding suggests that biosynthesized Sop-AuNPs could be a more effective nanomedicine for treating *M. furfur* dandruff.

# Conclusion

In this study, gold nanoparticles were successfully biosynthesized using flavonoid sophorin. The sophorin-mediated gold nanoparticles exhibit excellent antifungal properties against dandruff causing opportunistic pathogen *M. furfur*. However, further investigation on animal modeling and clinical trial will bring this drug into real-world usage to overcome dandruff issues.

# ReferenceS

1. [Al-Waili, N. S. (2001). Therapeutic and prophylactic effects of crude honey on chronic seborrheic dermatitis and dandruff. European Journal of Medical Research, 6(7), 306–308.](http://paperpile.com/b/HTeMvP/VxAk) <https://www.ncbi.nlm.nih.gov/pubmed/11485891>
2. [Chokkattu, J. J., Neeharika, S., Brahmajosyula, I. P., & Thangavelu, L. (2023). Comparative Evaluation Cellular Toxicity Three Heat Polymerized Acrylic Resins: Vitro Study. World, 14(6).](http://paperpile.com/b/HTeMvP/t5yqR)
3. [Dharman, S., Maragathavalli, G., Shanmugam, R., & Shanmugasundaram, K. (2023). Biosynthesis Turmeric Silver Nanoparticles: Its Characterization Evaluation Antioxidant, Anti inflammatory, Antimicrobial Potential Against Oral Pathogens vitro Study. Journal Indian Academy Oral Medicine Radiology, 35(3), 299–305.](http://paperpile.com/b/HTeMvP/C7cbO)
4. [Doshi, K., Nivedhitha, M. S., Solete, P., Dp, S., Jacob, B., & Siddique, R. (2023). Effect adhesive strategy universal adhesives noncarious cervical lesions-an updated systematic review meta-analysis. BDJ open. 9.](http://paperpile.com/b/HTeMvP/Hd4gD)
5. [Gandhi, J. M., Gurunathan, D., Doraikannan, S., & Balasubramaniam, A. (2021). Oral health status for primary dentition - A pilot study. Journal of the Indian Society of Pedodontics and Preventive Dentistry, 39(4), 369–372. https://doi.org/](http://paperpile.com/b/HTeMvP/uFHH5)[10.4103/jisppd.jisppd\_155\_21](http://dx.doi.org/10.4103/jisppd.jisppd_155_21)
6. [Govindaraj, P., & Shanmugam, R. (2023). Effect chlorhexidine fluoride varnish incidence white spot lesion orthodontic patients. Annals Dental Specialty, 11(1-2023), 35–39.](http://paperpile.com/b/HTeMvP/uxbkj)
7. [Jabeen, N., Prabhalakshmi, K., Dhanraj, G., & Ramasubburayan, R. (2025). Biosynthesis of titanium dioxide nanoparticles using Sargassum tenerrimum as reductant and deciphering its antibiofilm role against cariogenic Candida albicans. Microbial Pathogenesis, 202, 107452. https://doi.org/](http://paperpile.com/b/HTeMvP/G9ei)[10.1016/j.micpath.2025.107452](http://dx.doi.org/10.1016/j.micpath.2025.107452)
8. [Janani, K., Teja, K. V., & Ajitha, P. (2021). Cytotoxicity of oregano essential oil and calcium hydroxide on L929 fibroblast cell: A molecular level study. Journal of Conservative Dentistry: JCD, 24(5), 457–463. https://doi.org/](http://paperpile.com/b/HTeMvP/EUs0)[10.4103/JCD.JCD\_560\_20](http://dx.doi.org/10.4103/JCD.JCD_560_20)
9. [Janniger, C. K., Schwartz, R. A., Szepietowski, J. C., & Reich, A. (2005). Intertrigo and common secondary skin infections. American Family Physician, 72(5), 833–838.](http://paperpile.com/b/HTeMvP/Sr86) <https://www.ncbi.nlm.nih.gov/pubmed/16156342>
10. [Joshi, P. A., Bonde, S. R., Gaikwad, S. C., Gade, A. K., Abd-Elsalam, K., & Rai, M. K. (2013). Comparative Studies on Synthesis of Silver Nanoparticles by Fusarium oxysporum and Macrophomina phaseolina and It’s Efficacy Against Bacteria and Malassezia furfur. Journal of Bionanoscience, 7(4), 378–385. https://doi.org/](http://paperpile.com/b/HTeMvP/2Xxl)[10.1166/jbns.2013.1148](http://dx.doi.org/10.1166/jbns.2013.1148)
11. [Kachhara, S., Nallaswamy, D., Ganapathy, D., & Ariga, P. (2021). Comparison of the CBCT, CT, 3D printing, and CAD-CAM milling options for the most accurate root form duplication required for the root analogue implant (RAI) protocol. Journal of Indian Academy of Oral Medicine and Radiology, 33(2), 141–145. https://doi.org/](http://paperpile.com/b/HTeMvP/8Xfp)[10.4103/jiaomr.jiaomr\_244\_20](http://dx.doi.org/10.4103/jiaomr.jiaomr_244_20)
12. [Kannan, K. P., Gunasekaran, V., Sreenivasan, P., & Sathishkumar, P. (2024). Recent updates and feasibility of nanodrugs in the prevention and eradication of dental biofilm and its associated pathogens-A review. Journal of Dentistry, 143, 104888. https://doi.org/](http://paperpile.com/b/HTeMvP/MzuA)[10.1016/j.jdent.2024.104888](http://dx.doi.org/10.1016/j.jdent.2024.104888)
13. [Karakurt, S. (2016). Modulatory effects of rutin on the expression of cytochrome P450s and antioxidant enzymes in human hepatoma cells. Acta Pharmaceutica (Zagreb, Croatia), 66(4), 491–502. https://doi.org/](http://paperpile.com/b/HTeMvP/nsTD)[10.1515/acph-2016-0046](http://dx.doi.org/10.1515/acph-2016-0046)
14. [Katyal, D., Jain, R. K., Sankar, G. P., & Prasad, S. (2023). Antibacterial, Cytotoxic, Mechanical Characteristics Novel Chitosan-Modified Orthodontic Primer: : In-Vitro: Study. Journal International Oral Health, 15(3), 284–289.](http://paperpile.com/b/HTeMvP/me10s)
15. [Khan, T., Raza, S., Hashmi, K., & Khan, A. R. (2025). Recent advancements in the plant-based synthesis and mechanistic insights of noble metal nanoparticles and their therapeutic applications. Inorganic Chemistry Communications, 171(113594), 113594. https://doi.org/](http://paperpile.com/b/HTeMvP/Rukj)[10.1016/j.inoche.2024.113594](http://dx.doi.org/10.1016/j.inoche.2024.113594)
16. [Lampl, S., Gurunathan, D., Krithikadatta, J., Mehta, D., & Moodley, D. (2023). Reasons for Failure of CAD/CAM Restorations in Clinical Studies: A Systematic Review and Meta-analysis. The Journal of Contemporary Dental Practice, 24(2), 129–136. https://doi.org/](http://paperpile.com/b/HTeMvP/DFaZa)[10.5005/jp-journals-10024-3472](http://dx.doi.org/10.5005/jp-journals-10024-3472)
17. [Mandhata, C. P., Bishoyi, A. K., Sahoo, C. R., Swain, S., Bej, S., Jali, B. R., Meher, R. K., Dubey, D., & Padhy, R. N. (2023). Investigation of in vitro antimicrobial, antioxidant and antiproliferative activities of Nostoc calcicola biosynthesized gold nanoparticles. Bioprocess and Biosystems Engineering, 46(9), 1341–1350. https://doi.org/](http://paperpile.com/b/HTeMvP/hDT3)[10.1007/s00449-023-02905-1](http://dx.doi.org/10.1007/s00449-023-02905-1)
18. [Murugapandi, M., Elanchezhiyan, S. S. D., Oh, T. H., Ramasundaram, S., & Muniyappan, N. (2023). Pharmacological applications of metal nanoparticles derived from Caralluma sarkariae species. Process Biochemistry (Barking, London, England), 132, 166–179. https://doi.org/](http://paperpile.com/b/HTeMvP/HYgn)[10.1016/j.procbio.2023.06.020](http://dx.doi.org/10.1016/j.procbio.2023.06.020)
19. [Olvera-Aripez, J., Camacho-López, S., Flores-Castañeda, M., Belman-Rodríguez, C., Vilchis-Nestor, A. R., & Castro-Longoria, E. (2024). Biosynthesis of gold nanoparticles by fungi and its potential in SERS. Bioprocess and Biosystems Engineering, 47(9), 1585–1593. https://doi.org/](http://paperpile.com/b/HTeMvP/pC3k)[10.1007/s00449-024-03053-w](http://dx.doi.org/10.1007/s00449-024-03053-w)
20. [Pandiyan, I., Arumugham, M. I., Doraikannan, S. S., Rathinavelu, P. K., Prabakar, J., & Rajeshkumar, S. (2023). Antimicrobial and Cytotoxic Activity of Ocimum tenuiflorum and Stevia rebaudiana-Mediated Silver Nanoparticles - An In vitro Study. Contemporary Clinical Dentistry, 14(2), 109–114. https://doi.org/](http://paperpile.com/b/HTeMvP/KkFOp)[10.4103/ccd.ccd\_369\_21](http://dx.doi.org/10.4103/ccd.ccd_369_21)
21. [Pavithra, S., Paulraj, J., Rajeshkumar, S., & Maiti, S. (2023). Comparative evaluation antimicrobial activity compressive strength conventional thyme-modified glass ionomer cement. Annals Dental Specialty, 11(1-2023), 70–77.](http://paperpile.com/b/HTeMvP/xNJ1q)
22. [Pedrosa, A. F., Lisboa, C., & Gonçalves Rodrigues, A. (2014). Malassezia infections: a medical conundrum. Journal of the American Academy of Dermatology, 71(1), 170–176. https://doi.org/](http://paperpile.com/b/HTeMvP/TnaC)[10.1016/j.jaad.2013.12.022](http://dx.doi.org/10.1016/j.jaad.2013.12.022)
23. [Poonkuzhali, K., Rajeswari, V., Saravanakumar, T., Viswanathamurthi, P., Park, S.-M., Govarthanan, M., Sathishkumar, P., & Palvannan, T. (2014). Reduction of hexavalent chromium using Aerva lanata L.: elucidation of reduction mechanism and identification of active principles. Journal of Hazardous Materials, 272, 89–95. https://doi.org/](http://paperpile.com/b/HTeMvP/L3Fg)[10.1016/j.jhazmat.2014.03.001](http://dx.doi.org/10.1016/j.jhazmat.2014.03.001)
24. [Priyadharshini, G., Gheena, S., Ramani, P., Rajeshkumar, S., & Ramalingam, K. (2023). Assessment antimicrobial efficacy cytotoxicity Cocos nucifera Triticum aestivum combination gel formulation therapeutic use. World Journal Dentistry, 14(5), 414–418.](http://paperpile.com/b/HTeMvP/709gV)
25. [Prohic, Sadikovic, T., Jovovic, Krupalija-Fazlic, M., & Kuskunovic-Vlahovljak, S. (2015). Malasseziaspecies healthy skin dermatological conditions. International Journal Dermatology, 55(5), 494–504. https://doi.org/](http://paperpile.com/b/HTeMvP/CpxT)[10.1111/ijd.13116](http://dx.doi.org/10.1111/ijd.13116)
26. 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.
27. [Rajeshkumar, S., & Lakshmi, T. (2021). Green synthesis gold nanoparticles using kalanchoe pinnata its free radical scavenging activity. Int J Dentistry Oral Sci, 8(7), 2981–2984.](http://paperpile.com/b/HTeMvP/dd9dW)
28. [Ramsundar, K., Jain, R. K., Balakrishnan, N., & Vikramsimha, B. (2023). Comparative evaluation bracket bond failure rates novel non-primer adhesive conventional primer-based orthodontic adhesive-a pilot study. Journal Dental Research, 17(1).](http://paperpile.com/b/HTeMvP/kiAjE)
29. [Ramya, J. R., Ali, S., K, T. A., Vijayalakshmi, R., Gajendiran, J., Gnanam, S., & Ramachandran, K. (2024). Antimicrobial efficiency against fish pathogens on the green synthesized silver nanoparticles. Microbial Pathogenesis, 193, 106725. https://doi.org/](http://paperpile.com/b/HTeMvP/EoH1)[10.1016/j.micpath.2024.106725](http://dx.doi.org/10.1016/j.micpath.2024.106725)
30. [Rieshy, V., Chokkattu, J. J., Rajeshkumar, S., & Neeharika, S. (2023). Mechanism action clove ginger herbal formulation-mediated TiO2 nanoparticles against lactobacillus species: vitro study. Journal Advanced Oral Research, 14(1), 61–66.](http://paperpile.com/b/HTeMvP/qljFF)
31. [Sathishkumar, P., & Khan, F. (2024). Leveraging bacteria-inspired nanomaterials for targeted controlling biofilm and virulence properties of Pseudomonas aeruginosa. Microbial Pathogenesis, 197, 107103. https://doi.org/](http://paperpile.com/b/HTeMvP/QHZW)[10.1016/j.micpath.2024.107103](http://dx.doi.org/10.1016/j.micpath.2024.107103)
32. [Sathishkumar, P., Preethi, J., Vijayan, R., Mohd Yusoff, A. R., Ameen, F., Suresh, S., Balagurunathan, R., & Palvannan, T. (2016). Anti-acne, anti-dandruff and anti-breast cancer efficacy of green synthesised silver nanoparticles using Coriandrum sativum leaf extract. Journal of Photochemistry and Photobiology. B, Biology, 163, 69–76. https://doi.org/](http://paperpile.com/b/HTeMvP/IZtY)[10.1016/j.jphotobiol.2016.08.005](http://dx.doi.org/10.1016/j.jphotobiol.2016.08.005)
33. [Selvaraj, K., Venkatesan, L. S., Ganapathy, D., & Sathishkumar, P. (2024). Treatment of dental biofilm-forming bacterium Streptococcus mutans using tannic acid-mediated gold nanoparticles. Microbial Pathogenesis, 189(106568), 106568. https://doi.org/](http://paperpile.com/b/HTeMvP/yTkw)[10.1016/j.micpath.2024.106568](http://dx.doi.org/10.1016/j.micpath.2024.106568)
34. [Shenoy, A., Maiti, S., Nallaswamy, D., & Keskar, V. (2023). An in vitro comparison of the marginal fit of provisional crowns using the virtual tooth preparation workflow against the traditional technique. Journal of Indian Prosthodontic Society, 23(4), 391–397. https://doi.org/](http://paperpile.com/b/HTeMvP/YqxBp)[10.4103/jips.jips\_273\_23](http://dx.doi.org/10.4103/jips.jips_273_23)
35. [Singh, S., Prasad, A. S., & Rajeshkumar, S. (2023). Cytotoxicity, antimicrobial, anti-inflammatory and antioxidant activity of camellia sinensis and citrus mediated copper oxide nanoparticle-an in vitro study. Journal of International Society of Preventive & Community Dentistry, 13(6), 450–457. https://doi.org/](http://paperpile.com/b/HTeMvP/bB0Ek)[10.4103/jispcd.JISPCD\_76\_23](http://dx.doi.org/10.4103/jispcd.JISPCD_76_23)
36. [Sivakumar, N., Geetha, R. V., Priya, V., Gayathri, R., & Ganapathy, D. (2021). Targeted phytotherapy forreactive oxygen species linked oral cancer. Int J Dent Oral Sci, 8.](http://paperpile.com/b/HTeMvP/dLZpO)
37. [Sowmya, K. P., Surenthar, M., & Lekha Sree, V. (2025). Effective treatment of oral microbial infections and biofilm using flavonoid rutin - An in vitro study. Journal of Oral Biology and Craniofacial Research, 15(3), 541–547. https://doi.org/](http://paperpile.com/b/HTeMvP/dvUX)[10.1016/j.jobcr.2025.03.007](http://dx.doi.org/10.1016/j.jobcr.2025.03.007)
38. [Subramanian, A. K., Lalit, H., & Sivashanmugam, P. (2023). Preparation, characterization, and evaluation of cytotoxic activity of a novel titanium dioxide nanoparticle-infiltrated orthodontic adhesive: An in vitro study. World Journal of Dentistry, 14(10), 882–887. https://doi.org/](http://paperpile.com/b/HTeMvP/dTSa)[10.5005/jp-journals-10015-2319](http://dx.doi.org/10.5005/jp-journals-10015-2319)
39. [Thomas, & Jain, R. K. (2023). Influence operator experience scanning time accuracy two different intraoral scanners-a prospective clinical trial. Turkish Journal Orthodontics, 36(1).](http://paperpile.com/b/HTeMvP/mC005)
40. 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.
41. [Venkatesan, L. S., & Sathishkumar, P. (2024). Combination therapy of natural products for the treatment of ESKAPE pathogens. Natural Product Research, 1–2. https://doi.org/](http://paperpile.com/b/HTeMvP/zgdd)[10.1080/14786419.2024.2425050](http://dx.doi.org/10.1080/14786419.2024.2425050)
42. [Zhao, Q., Chen, Z., Shan, C.-W., Zhan, T., Han, C.-Y., Han, G.-C., Feng, X.-Z., & Kraatz, H.-B. (2024). Construction and evaluation of AuNPs enhanced electrochemical immunosensors with [Fe(CN)6]3-/4- and PPy probe for highly sensitive detection of human chorionic gonadotropin. International Journal of Biological Macromolecules, 273(Pt 1), 132963. https://doi.org/](http://paperpile.com/b/HTeMvP/i1Ds)[10.1016/j.ijbiomac.2024.132963](http://dx.doi.org/10.1016/j.ijbiomac.2024.132963)