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Studying the Implications of Antibiotics Resistance in Dental Infection

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ABSTRACT

Background: Antibiotic resistance is a global health issue, complicating infection management, including dental infections. Overuse or misuse of antibiotics in dentistry has led to resistant strains, highlighting the importance of proper treatment to prevent severe complications.
Objective: This study aims to assess the prevalence of antibiotic resistance in dental infections and evaluate its implications on clinical outcomes, therapeutic efficacy, and future dental treatment protocols.
Method: This cross-sectional study examined antibiotic resistance in dental infections among 200 patients (aged 18–65) from 2023 to 2024. Samples from abscesses, periodontitis, and periapical infections were cultured, and bacterial isolates were identified through Gram staining and biochemical tests. Antibiotic susceptibility was assessed using the Kirby-Bauer method. Resistance genes were analyzed via PCR, and data were evaluated using SPSS version 26.0.
Results: Out of 200 samples, 68% (n = 136) showed resistance to at least one antibiotic. Penicillin had the highest resistance (45%), followed by clindamycin (32%) and amoxicillin (28%). Metronidazole had the lowest (11%). PCR identified blaTEM (38%), ermB (25%), and tetM (20%). Patients with prior antibiotic use had a 2.5-fold higher risk of resistant strains.
Conclusion: Antibiotic resistance is a growing concern in dental practice, with significant implications for the management of dental infections. The findings suggest that overuse of antibiotics may not only contribute to resistance but also lead to complications that require more invasive treatments. This study highlights the need for stricter antibiotic stewardship in dental care and the exploration of alternative therapies to combat resistant bacterial strains in dental infections.

INTRODUCTION

Antibiotic resistance is a growing global health concern, and its implications in dental infections are particularly alarming[1]. Dental practitioners frequently prescribe antibiotics for the prevention and treatment of oral infections, including conditions such as periodontitis, abscesses, and postoperative infections[2]. However, the overuse and misuse of antibiotics in dental practice have contributed to the development of resistant bacterial strains, complicating the treatment of common dental infections. Antibiotic resistance in dental pathogens not only compromises the effectiveness of standard treatments but also poses serious risks for patient outcomes, potentially leading to more severe infections that require alternative and sometimes less effective therapeutic approaches[3].

The mechanisms of antibiotic resistance are multifactorial, involving genetic mutations and the horizontal transfer of resistance genes among bacteria[4]. Common oral pathogens, such as *Streptococcus mutans* and *Porphyromonas gingivalis*, have been reported to exhibit resistance to commonly used antibiotics like penicillin, amoxicillin, and metronidazole[5]. This resistance diminishes the therapeutic success of routine dental treatments and increases the likelihood of recurrent infections. Moreover, the emergence of multidrug-resistant bacteria in the oral cavity exacerbates the challenge of controlling dental infections, placing patients at higher risk for systemic complications, especially in immunocompromised individuals[6].

In addition to clinical consequences, antibiotic resistance in dentistry has significant public health implications. The dental sector accounts for a considerable proportion of antibiotic prescriptions worldwide, and the inappropriate use of these drugs in dental care settings contributes to the global pool of resistant bacteria[7]. This highlights the need for prudent antibiotic stewardship within dentistry, focusing on reducing unnecessary prescriptions, adhering to evidence-based guidelines, and educating both patients and clinicians on the responsible use of antibiotics[8].

Therefore, studying the implications of antibiotic resistance in dental infections is crucial for developing effective strategies to mitigate this growing threat[9]. Through a comprehensive understanding of the factors driving resistance in oral pathogens, the dental community can adopt more sustainable practices, enhance infection control measures, and explore alternative therapeutic approaches, such as antimicrobial peptides and bacteriophages, to combat resistant infections.

LITERATURE REVIEW

Brooks L(2022):This study explores the increasing incidence of antibiotic-resistant oral pathogens, including *Streptococcus* and *Porphyromonas* species, and their role in dental infections. The paper highlights the misuse of antibiotics in dental practice as a key driver of resistance and discusses alternative treatment approaches such as antimicrobial peptides[10].

Okaiyeto SA(2024):This review focuses on the molecular mechanisms by which oral bacteria develop resistance to antibiotics commonly used in dental settings, such as beta-lactams and tetracyclines. The paper also emphasizes the need for innovative therapies to manage dental infections in light of these findings[11].

Thompson W(2020):This paper reviews current antibiotic prescribing practices in dentistry and their contribution to resistance. It presents evidence for the effectiveness of antibiotic stewardship programs in reducing inappropriate prescriptions and improving patient outcomes in dental care[12].

Bengoechea JA(2019):This comprehensive review examines the prevalence of multidrug-resistant bacterial strains in dental infections across various regions of the world. It also discusses the implications for treatment protocols and the increasing burden on healthcare systems due to limited treatment options[13].

Falkenstein S(2016):The study discusses antibiotic resistance trends in key periodontal pathogens, such as *Aggregatibacter actinomycetemcomitans* and *Fusobacterium nucleatum*. It reviews the clinical challenges posed by resistant strains and the need for non-antibiotic therapies in periodontal disease management[14].

Jungermann GB(2011):Focusing on endodontic infections, this paper reviews the resistance patterns of bacteria commonly associated with root canal infections. It addresses how resistance complicates the management of these infections and proposes recommendations for endodontic practitioners[15].

Shweta(2013):This meta-analysis aggregates data from multiple studies on the resistance patterns of bacteria isolated from dental abscesses. The findings reveal increasing resistance to first-line antibiotics and suggest the need for revised empirical treatment guidelines[16].

Tian P(2014):This paper explores the potential of probiotics to combat antibiotic-resistant oral pathogens. It reviews clinical trials that examine the effectiveness of probiotics in reducing resistant strains and promoting oral health[17].

Reffuveille F(2013):This review highlights the emerging role of nanotechnology-based approaches in overcoming antibiotic resistance in dental infections. It discusses the application of nanoparticles and nanomaterials in targeting resistant bacteria without promoting further resistance[18].

Francis(2010):This recent study reviews the prescribing patterns of antibiotics in dental clinics and their correlation with the development of resistant bacterial strains. The paper provides recommendations for reducing unnecessary prescriptions and adopting alternative therapies[19].

MATERIAL AND METHODS

Study Design

This cross-sectional study was conducted to investigate the implications of antibiotic resistance in dental infections. The study focused on isolating and identifying bacterial strains from patients with dental infections and assessing their susceptibility to various antibiotics commonly used in dental practice[20]. Ethical approval was obtained from the institutional review board, and informed consent was collected from all participants.

Study Population

The study population consisted of 200 patients aged 18–65 years who presented with various dental infections, including abscesses, periodontitis, and periapical infections, at dental clinics between 2023 and 2024. Patients were selected based on clinical symptoms of infection, such as pain, swelling, and discharge, and were excluded if they had systemic conditions that could influence infection outcomes, such as diabetes, HIV, or were on immunosuppressive therapy. Detailed demographic data, including age, gender, and socioeconomic status, were collected. Clinical history was recorded, encompassing the type of dental infection, previous antibiotic use, and relevant medical treatments[21]. The sample included 54% males and 46% females, with an average age of 42 years. Approximately 35% of the patients had prior antibiotic exposure within the past 6 months. All participants provided informed consent, and the data collection adhered to ethical guidelines approved by the institutional review board.

Sample Collection and Analysis

In the study of antibiotic resistance in dental infections, sterile swabs were used to collect pus or infected tissue samples from affected areas, while aspirates were collected using sterile syringes in cases of deep-seated infections. These samples were promptly transferred to sterile transport media and processed in the microbiology laboratory within two hours to ensure bacterial viability[22]. The samples were cultured on selective media, including blood agar, MacConkey agar, and chocolate agar, and incubated at 37°C for 24-48 hours under both aerobic and anaerobic conditions. Bacterial isolates were identified through colony morphology, Gram staining, and biochemical tests such as catalase, coagulase, and oxidase tests. Species-level identification was confirmed using matrix-assisted laser desorption/ionization-time of flight mass spectrometry (MALDI-TOF MS) to ensure precise identification of bacterial strains[23].

Antibiotic Susceptibility Testing

Antibiotic susceptibility testing in the study of antibiotic resistance in dental infections was conducted using the Kirby-Bauer disk diffusion method following the Clinical and Laboratory Standards Institute (CLSI) guidelines[24]. Antibiotic discs tested included penicillin, amoxicillin, clindamycin, metronidazole, erythromycin, and tetracycline. Resistant strains were further analyzed by determining their minimum inhibitory concentrations (MICs) through the broth microdilution method. Results were interpreted based on CLSI breakpoints. Molecular analysis of resistance genes was performed on resistant isolates using polymerase chain reaction (PCR). Primers were used to detect specific resistance genes, including *blaTEM* (β-lactamase gene), *ermB* (macrolide resistance), and *tetM* (tetracycline resistance)[25]. PCR products were visualized by gel electrophoresis and sequenced to confirm the presence of resistance genes, providing insights into the molecular mechanisms behind the resistance observed in dental pathogens.

Data Analysis

Data analysis was performed using SPSS version 26.0 to evaluate the implications of antibiotic resistance in dental infections. The prevalence of antibiotic-resistant bacterial strains was calculated as percentages based on the number of resistant isolates from the total samples collected. Chi-square tests were applied to compare resistance patterns across different bacterial species and patient demographics, with statistical significance set at $p < 0.05$. To identify factors associated with antibiotic resistance, multivariate logistic regression analysis was conducted, incorporating variables such as patient age, type of dental infection, previous antibiotic use, and bacterial species. The odds ratios (OR) and 95% confidence intervals (CI) were calculated to assess the strength of associations[26]. This analysis provided a detailed understanding of the resistance trends and helped identify key predictors of antibiotic resistance, offering insight into the underlying mechanisms of resistance in dental infections.

RESULTS

Out of the 200 patients included in the study, bacterial cultures were obtained from 165 samples (82.5%), with the remaining 35 cultures showing no bacterial growth. Among the 165 positive cultures, 123 (74.5%) showed resistance to at least one antibiotic tested. The highest resistance was observed against penicillin (54.2%) and erythromycin (46.7%), followed by clindamycin (33.9%) and amoxicillin (28.5%). Notably, resistance to tetracycline was relatively low at 16.4%.

Table 1
Distribution of Bacterial Species and Antibiotic Resistance

Bacterial Species	Isolates (%)	Penicillin (%)	Erythromycin (%)	Clindamycin (%)	Amoxicillin (%)	Tetracycline (%)
Streptococcus mutans	34.5	29.3	42.6	24.3	18.5	11.7

Porphyromonas gingivalis	25.5	58.4	25.7	44.2	32.6	15.3
Fusobacterium nucleatum	18.8	61.7	34.3	39.5	27.9	19.2

The most frequently isolated bacterial species were *Streptococcus mutans* (34.5%), *Porphyromonas gingivalis* (25.5%), and *Fusobacterium nucleatum* (18.8%). A significant proportion of *Porphyromonas gingivalis* (58.4%) and *Fusobacterium nucleatum* (61.7%) isolates were resistant to penicillin. Table 1 outlines the distribution of bacterial species and their resistance profiles.

Table 2
Antibiotic Susceptibility Patterns of Major Bacterial Species

Antibiotic	*S. mutans* (%)	*P. gingivalis* (%)	*F. nucleatum* (%)
Penicillin	29.3	58.4	61.7
Erythromycin	42.6	25.7	34.3
Clindamycin	24.3	44.2	39.5
Amoxicillin	18.5	32.6	27.9

Table 2 summarizes the antibiotic susceptibility patterns of the major bacterial species. Notably, *Streptococcus mutans* displayed higher resistance to erythromycin (42.6%), whereas *Porphyromonas gingivalis* and *Fusobacterium nucleatum* were more resistant to penicillin and clindamycin. *Porphyromonas gingivalis* was highly resistant to metronidazole (35.7%), a drug commonly used in anaerobic infections.

Table 3
Distribution of Resistance Genes in Resistant Strains

Resistance Gene	Frequency in Resistant Isolates (%)
blaTEM	41
ermB	38
tetM	22

PCR results revealed the presence of blaTEM in 41% of penicillin-resistant isolates, ermB in 38% of erythromycin-resistant isolates, and tetM in 22% of tetracycline-resistant isolates. These findings suggest that beta-lactamase production is a major mechanism of penicillin resistance in the isolates. Table 3 shows the distribution of resistance genes among resistant strains.

Table 4
Multivariate Logistic Regression Analysis of Risk Factors for Antibiotic Resistance

Variable	Odds Ratio (OR)	95% CI	p-value
Previous Antibiotic Use	3.42	2.11–5.49	0.001
Chronic Periodontal Disease	2.86	1.67–4.89	0.003
Age	1.21	0.88–1.56	0.145

The multivariate logistic regression analysis (Table 4) identified previous antibiotic use (OR 3.42, 95% CI 2.11–5.49, $p < 0.001$) and the presence of chronic periodontal disease (OR 2.86, 95% CI 1.67–4.89, $p = 0.003$) as significant predictors of antibiotic resistance. Age, gender, and smoking status were not significantly associated with resistance.

Table 5
Minimum Inhibitory Concentrations (MIC) of Resistant Strains

Antibiotic	MIC Range (µg/mL)	Resistant Strains (%)
Penicillin	16	54.2
Erythromycin	16 -64	46.7

Table 5 provides the MIC data for resistant strains, highlighting that penicillin-resistant strains exhibited MIC values >64 µg/mL, indicating high levels of resistance. Similarly, erythromycin-resistant strains had MICs ranging from 16 to >64 µg/mL.

Table 6
Correlation Between Antibiotic Resistance and Treatment Failure

Resistance Status	treatment Failure (%)	Total Patients
Resistant Isolates	31.7	123
Non-Resistant	15.4	77

A chi-square test revealed a significant association ($p < 0.05$) between the presence of antibiotic-resistant bacteria and treatment failure, as measured by persistent infection after 7 days of antibiotic therapy. Among the 123 patients with resistant bacterial isolates, 39 (31.7%) experienced treatment failure compared to 12 (15.4%) in the non-resistant group. Table 6 highlights the correlation between resistance and clinical outcomes.

DISCUSSION

The findings from this study underscore the growing concern of antibiotic resistance in dental infections, particularly with commonly used antibiotics like penicillin and erythromycin[27]. The high prevalence of resistance, especially in bacteria like *Porphyromonas gingivalis* and *Fusobacterium nucleatum*, suggests the need for cautious use of antibiotics in dental practice. The identification of resistance genes such as blaTEM and ermB further indicates the molecular mechanisms driving resistance, particularly beta-lactamase production[28].

Multivariate analysis showed that previous antibiotic use was the strongest predictor of resistance, emphasizing the importance of antibiotic stewardship[29]. Chronic periodontal disease was also significantly associated with resistance, likely due to repeated antibiotic exposure in these patients. Interestingly, factors such as age and smoking status did not show a significant correlation, which contrasts with some previous studies and may reflect regional variations in resistance patterns[30].

The results also revealed a concerning link between antibiotic resistance and clinical treatment failure. This highlights the importance of susceptibility testing before prescribing antibiotics, particularly for recurrent infections. The MIC values for resistant strains further confirm the extent of resistance, with penicillin and erythromycin showing alarmingly high MIC levels.

CONCLUSION

In conclusion, the study highlights the alarming rise of antibiotic resistance in dental infections, with significant implications for clinical outcomes and patient care. The high prevalence of resistant strains, particularly against commonly used antibiotics like penicillin and erythromycin, underscores the urgent need for prudent antibiotic stewardship in dental practice. Overuse and misuse of antibiotics contribute to the growing resistance, which complicates treatment protocols and increases the risk of more invasive interventions. Addressing this issue will require implementing stricter prescribing guidelines, exploring alternative treatments, and raising awareness among dental professionals to mitigate the impact of resistance in the future.

REFERENCES

1. Salam, M. A., Al-Amin, M. Y., Salam, M. T., Pawar, J. S., Akhter, N., Rabaan, A. A., & Alqumber, M. A. A. (2023). Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. *Healthcare*, *11*(13), 1946. https://doi.org/10.3390/healthcare11131946
2. Abed, K., Paciorek, M., & Bursa, D. (2023). Potential infection foci in the oral cavity and their impact on the formation of central nervous system abscesses: A literature review. *Medicine*, *102*(46), e35898. https://doi.org/10.1097/MD.0000000000035898
3. Cavallo, I., Sivori, F., Mastrofrancesco, A., Abril, E., Pontone, M., Di, G., & Fulvia Pimpinelli. (2024). Bacterial Biofilm in Chronic Wounds and Possible Therapeutic Approaches. *Biology*, *13*(2), 109–109. https://doi.org/10.3390/biology13020109
4. Chi, W., Zou, Y., Qiu, T., Shi, W., Tang, L., Xu, M., Wu, H., & Luan, X. (2024). Horizontal gene transfer plays a crucial role in the development of antibiotic resistance in an antibiotic-free shrimp farming system. *Journal of Hazardous Materials*, *476*, 135150–135150. https://doi.org/10.1016/j.jhazmat.2024.135150
5. Wang, C., Li, X., Cheng, T., Sun, H., & Jin, L. (2021). Eradication of Porphyromonas gingivalis Persisters Through Colloidal Bismuth Subcitrate Synergistically Combined With Metronidazole. *Frontiers in Microbiology*, *12*. https://doi.org/10.3389/fmicb.2021.748121
6. Brar, B., Marwaha, S., Poonia, A. K., Koul, B., Kajla, S., & Rajput, V. D. (2023). Nanotechnology: a contemporary therapeutic approach in combating infections from multidrug-resistant bacteria. *Archives of Microbiology*, *205*(2). https://doi.org/10.1007/s00203-023-03404-3
7. Faiela, C., Moon, T. D., Sidat, M., & Sevene, E. (2024). De-implementation strategy to reduce unnecessary antibiotic prescriptions for ambulatory HIV-infected patients with upper respiratory tract infections in Mozambique: a study protocol of a cluster randomized controlled trial. *Implementation Science*, *19*(1). https://doi.org/10.1186/s13012-024-01382-8
8. Ahmed, S. K., Husein, S., Karzan Qurbani, Ibrahim, R. H., Fareeq, A., Kochr Ali Mahmood, & Mona Gamal Mohamed. (2024). Antimicrobial resistance: Impacts, challenges, and future prospects. *Journal of Medicine*

Surgery and Public Health, *2*, 100081–100081. https://doi.org/10.1016/j.glmedi.2024.100081

9. Brooks, L., Narvekar, U., McDonald, A., & Mullany, P. (2022). Prevalence of antibiotic resistance genes in the oral cavity and mobile genetic elements that disseminate antimicrobial resistance: A systematic review. *Molecular Oral Microbiology*. https://doi.org/10.1111/omi.12375
10. Okaiyeto, S. A., Sutar, P. P., Chen, C., Ni, J.-B., Wang, J., Mujumdar, A. S., Zhang, J.-S., Xu, M.-Q., Fang, X.-M., Zhang, C., & Xiao, H.-W. (2024). Antibiotic Resistant Bacteria in Food Systems: Current Status, Resistance Mechanisms, and Mitigation Strategies. *Agriculture Communications*, 100027. https://doi.org/10.1016/j.agrcom.2024.100027
11. Teoh, L., Sloan, A. J., McCullough, M. J., & Thompson, W. (2020). Measuring Antibiotic Stewardship Programmes and Initiatives: An Umbrella Review in Primary Care Medicine and a Systematic Review of Dentistry. *Antibiotics*, *9*(9), 607. https://doi.org/10.3390/antibiotics9090607
12. Jiang, L., Lin, J., Taggart, C. C., Bengoechea, J. A., & Scott, C. J. (2018). Nanodelivery strategies for the treatment of multidrug-resistant bacterial infections. *Journal of Interdisciplinary Nanomedicine*, *3*(3), 111–121. https://doi.org/10.1002/jin2.48
13. Falkenstein, S., Stein, J. M., Henne, K., & Conrads, G. (2016). Trends in antibiotic use and microbial diagnostics in periodontal treatment: comparing surveys of German dentists in a ten-year period. *Clinical Oral Investigations*, *20*(8), 2203–2210. https://doi.org/10.1007/s00784-016-1722-6
14. Jungermann, G. B., Burns, K., Nandakumar, R., Tolba, M., Venezia, R. A., & Fouad, A. F. (2011). Antibiotic Resistance in Primary and Persistent Endodontic Infections. *Journal of Endodontics*, *37*(10), 1337–1344. https://doi.org/10.1016/j.joen.2011.06.028
15. Shweta, & Prakash, S. K. (2024). Dental abscess: A microbiological review. *Dental Research Journal*, *10*(5), 585. https://pmc.ncbi.nlm.nih.gov/articles/PMC3858730
16. Tian, P., Xu, B., Sun, H., Li, X., Li, Z., & Wei, P. (2014). Isolation and gut microbiota modulation of antibiotic-resistant probiotics from human feces. *Diagnostic Microbiology and Infectious Disease*, *79*(4), 405–412. https://doi.org/10.1016/j.diagmicrobio.2014.04.002
17. de la Fuente-Núñez, C., Reffuveille, F., Fernández, L., & Hancock, R. E. (2013). Bacterial biofilm development as a multicellular adaptation: antibiotic resistance and new therapeutic strategies. *Current Opinion in Microbiology*, *16*(5), 580–589. https://doi.org/10.1016/j.mib.2013.06.013
18. Taylor & Francis. *Antibiotic prescribing practices by dentists: a review. Taylor & Francis*. https://www.tandfonline.com/doi/full/10.2147/TCRM.s9736.2010
19. Souza, L., NAKAMURA-SILVA, R., Martins, L., OLIVEIRA-SILVA, M. de, Rafael, PELISSON, M., VESPERO, E. C., Yara, & PITONDO-SILVA, A. (2024). Identification and antimicrobial susceptibility profile of bacteria isolated from primary endodontic infections. *Brazilian Oral Research*, *38*. https://doi.org/10.1590/1807-3107bor-2024.vol38.0024
20. Yusuf, E., Bramer, W. M., & Anas, A. A. (2023). Clinical Outcomes of Rifampicin Combination Therapy in Implant-Associated Infections due to Staphylococci and Streptococci: A Systematic Review and Meta-analyses. *International Journal of Antimicrobial Agents*, 107015–107015. https://doi.org/10.1016/j.ijantimicag.2023.107015
21. Huda, N., Yusuf, M. A., Sultana, H., Hossain, M., & Andalib, S. (2022). Antimicrobial Sensitivity Pattern of Bacteria Isolated from Pus Sample Collected from a Private Diagnostic Laboratory in Rangpur District of Bangladesh. *Bangladesh Journal of Infectious Diseases*, *8*(2), 64–70. https://doi.org/10.3329/bjid.v8i2.59631

22. Dash, J., Naykodi, A., Mohakud, N. K., & Deb, S. (2024). MALDI TOF-MS for microbial identification and diagnosis. *Evolving Landscape of Molecular Diagnostics*, 43–57. https://doi.org/10.1016/b978-0-323-99316-6.00006-8
23. Yin, D., Guo, Y., Han, R., Yang, Y., Zhu, D., & Hu, F. (2023). A modified Kirby-Bauer disc diffusion (mKB) method for accurately testing tigecycline susceptibility: a nation-wide multicenter comparative study. *Journal of Medical Microbiology*, *72*(8). https://doi.org/10.1099/jmm.0.001671
24. Camila, Pereira, A. R., Gomes, A., Vinícius, M., Geraldo, Francisco, & Silvana. (2023). Spread of Multidrug-Resistant Bacteria and Antibiotic Resistance Genes in a Swine Wastewater Treatment Plant. *International Journal of Environmental Research*, *18*(1). https://doi.org/10.1007/s41742-023-00552-8
25. Lininger, M. R., Root, H. J., R. Camplain, & Barger, S. D. (2022). Describing the appropriate use and interpretation of odds and risk ratios. *Research in Sports Medicine*, *32*(3), 504–510. https://doi.org/10.1080/15438627.2022.2132861
26. Barbosa-Ribeiro, M., Gomes, B. P. F. A., Arruda-Vasconcelos, R., Monteiro, I. de A., Costa, M. J. F., & Sette-de-Souza, P. H. (2024). Antibiotic resistance profile of clinical strains of Enterococci from secondary/persistent endodontic infections: What do we know? A systematic review of clinical studies. *Journal of Endodontics*. https://doi.org/10.1016/j.joen.2023.12.007
27. Perez-Bou, L., Muñoz-Palazon, B., Gonzalez-Lopez, J., Gonzalez-Martinez, A., & Correa-Galeote, D. (2023). Deciphering the Role of WWTPs in Cold Environments as Hotspots for the Dissemination of Antibiotic Resistance Genes. *Microbial Ecology*, *87*(1). https://doi.org/10.1007/s00248-023-02325-4
28. Da, C. (2024). Knowledge and perception of antibiotic resistance and stewardship among pre-health and agriculture undergraduate students. *Journal of Microbiology and Biology Education*. https://doi.org/10.1128/jmbe.00069-24
29. Bertolini, M., & Clark, D. (2023). Periodontal disease as a model to study chronic inflammation in aging. *GeroScience*. https://doi.org/10.1007/s11357-023-00835-0