OHSU School of Dentistry
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Message from the School of Dentistry Anthology Team

Christina Truong, D.M.D., Samyia Chaudhry, D.M.D.

Welcome to the fifth issue of the OHSU School of Dentistry Anthology, or SODA. This issue showcases a diverse collection of research from dental students, residents and faculty members from the OHSU School of Dentistry.

The School of Dentistry held its annual Research Day on March 4, 2025, in the OHSU Robertson Life Sciences Building. This year, there was a record high of 84 poster presentations from dental students, postdoctoral scholars, faculty and staff. Attendees explored poster displays, discussed findings and engaged directly with presenters. As part of the event, presenters were entered into a poster competition. Dentists from the School of Dentistry judged the posters, as well as industry partners from Kaiser Permanente and Oregon Dental Association and faculty from the OHSU School of Medicine and Portland State University basic science department. Categories for the best poster competition include D.M.D. student, Ph.D. student, resident, postdoctoral scholar, staff, faculty, student choice and caseCAT.

In this issue are the abstracts from the two winners in the postdoctoral scholar category: one from the Fugolin Lab and the other from the Bertassoni Lab, along with the first, second and third place caseCAT poster winners.

The annual Oregon Dental Conference held in April at the Oregon Convention Center in Portland, is the location for another student poster competition. The multi-day event offers D.M.D. students two opportunities to showcase their caseCAT and research posters: one at the Convention Center and another at the OHSU Robertson Life Sciences Building during Alumni Day. This issue features the caseCAT and research categories winners from Alumni Day.

This issue also includes a manuscript from Jonathan Broadbent, Ph.D., a professor of dental epidemiology and public health at the University of Otago, in Dunedin, New Zealand. Discussed in his article is New Zealand's perspective on community water fluoridation and oral health. He presented the topic at a School of Dentistry Dean's Seminar on Feb. 3, 2025.

Additionally, the spring edition of SODA highlights the challenges Indigenous communities face in accessing dental care and emphasizes the essential role of dental professionals in enhancing Indigenous oral health. The manuscript features insights from Rachel Meek, D.M.D. '22, a dentist serving the Confederated Tribes of the Siletz Indians in Siletz, Oregon.

Thank you to our SODA editorial team: senior editor Ron Sakaguchi, D.D.S., Ph.D., M.B.A., senior communicator Rhonda Morin, APR, M.L.S., and Pam Pierce, M.L.S., M.S., OHSU Library, for their tremendous contribution and support in publishing the anthology.

We also deeply appreciate your continuous support and participation in the School of Dentistry Anthology.

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Effects of non-surgical periodontal therapy on blood pressure of hypertensive patients

Daniel Kim '27, Graydon Gamache '28
Mentor: Harjit Singh Sehgal, B.D.S., M.S., F.A.G.E.

Background/case scenario

Periodontitis is a chronic inflammatory disease that affects the supporting structures of teeth, including the gingiva, periodontal ligament, cementum and alveolar bone. It develops through a complex interaction between the oral microbiota and the host immune response, where microbial dysbiosis drives inflammation and progressive tissue destruction. The gingival sulcus serves as a unique microenvironment, with its leaky sulcular epithelium promoting localized bacteremia. The presence of calculus exacerbates this process, perpetuating chronic inflammation and potentially contributing to systemic inflammatory responses.

Emerging evidence highlights a significant association between periodontitis and hypertension, with these conditions frequently presenting as comorbidities. This connection raises the critical question: can the treatment of periodontitis influence blood pressure levels? In this caseCAT we aim to investigate whether non-surgical periodontal therapy can result in a clinically significant reduction in blood pressure, or BP, among hypertensive patients, drawing insights from current research studies.

Clinical question

Can non-surgical periodontal therapy alleviate hypertension by significantly reducing arterial blood pressure?

CAT 1

Article. Periodontitis, blood pressure and the risk and control of arterial hypertension: Epidemiological, clinical and pathophysiological aspects—review of the literature and clinical trials[1]
Authors. Surma, S., et al.
Published. May 2021
PubMed ID. 33961166

Methods. A literature review examined the association between periodontitis and hypertension. Epidemiological, clinical and

POPULATION
Patients with periodontitis and hypertension comorbidity

INTERVENTION
Non-surgical periodontal therapy

COMPARISON
No treatment

OUTCOME
A clinically significant decrease in systolic and diastolic blood pressure

Conclusion/reflection. Arterial hypertension affects 45% of the U.S. population and is a major risk factor for cardiovascular disease, stroke and kidney failure. Emerging evidence links periodontitis to hypertension, with chronic inflammation and bacterial dysbiosis contributing to increased blood pressure. Non-surgical periodontal therapy is an effective treatment for periodontitis that reduces bacterial load and systemic inflammation.

Current literature shows that scaling and root planning can have limited benefits in reducing blood pressure in patients with severe periodontitis and hypertension. Recognizing this connection underscores the need for interdisciplinary collaboration between dental and medical professionals to enhance patient care.

Keywords. Periodontitis, hypertension, periodontal therapy

pathophysiological data from observational studies, meta-analyses and clinical trials were analyzed to assess the impact of periodontal disease on blood pressure and hypertension risk.

Results/conclusion. Periodontitis was associated with a higher risk of hypertension with moderate cases increasing the likelihood by 50% and severe cases by 64% (OR 1.64, 95% CI 1.23–2.19). Patients with periodontitis exhibited higher systolic (↑4.49 mmHg) and diastolic (↑2.03 mmHg) blood pressure compared to healthy individuals.

Mechanistically, oral dysbiosis and systemic inflammation (increased IL-6, TNF-α) were linked to endothelial dysfunction, reduced nitric oxide availability and arterial stiffness, contributing to hypertension development.

Validity/applicability. While strong observational and clinical evidence supports the association between periodontitis and hypertension, confounding factors such as age, smoking and obesity complicate causality. Larger, controlled trials are needed to clarify the direct impact of periodontal disease on blood pressure regulation.

Level of evidence. Level IA–Systematic review of observational and clinical studies

Evidence search strategy

MeSH Terms:

- Periodontitis
- Periodontitis/therapy
- Periodontitis/epidemiology
- Dental scaling
- Hypertension
- Hypertension/therapy
- Blood pressure
- Cardiovascular disease
- Arterial pressure
- Meta-analysis
- Systematic review
- Review
- Randomized controlled trial

CAT 2

Article. Periodontal therapy and treatment of hypertension-alternative to the pharmacological approach. A systematic review and meta-analysis[2]
Authors. Sharma, S., et al.
Published. April 2021
PubMed ID. 33617973

Methods. A systematic review and meta-analysis of eight randomized controlled trials, or RCTs, assessed the impact of intensive periodontal therapy, or IPT, versus conventional periodontal therapy, or CPT, on blood pressure, endothelial function and inflammatory markers. Primary outcomes included changes in systolic, or SBP, and diastolic blood pressure, or DBP, with subgroup analysis for hypertensive/prehypertensive and normotensive patients.

Results/conclusion. Overall, IPT did not significantly lower SBP (-4.3 mmHg, $p = 0.08$) or DBP (-3.16 mmHg, $p = 0.06$) in normotensive individuals. However, in hypertensive and prehypertensive patients, IPT significantly reduced SBP (-11.41 mmHg, $p < 0.001$) and DBP (-8.43 mmHg, $p < 0.001$).

IPT also improved endothelial function and reduced CRP levels, indicating potential cardiovascular benefits.

Validity/applicability. Moderate heterogeneity was present due to differences in study designs and follow-up periods. While findings support IPT's role in cardiovascular health for hypertensive individuals, further RCTs are needed to confirm long-term effects.

Level of evidence. Level IA–Systematic review and meta-analysis of RCTs

CAT 3

Article. Effect of periodontal treatments on blood pressure[3]
Authors. Luo, Y., et al.
Published. Dec. 2021
PubMed ID. 34897644

Methods. A systematic review and meta-analysis of eight randomized controlled trials, or RCTs, evaluated the effect of periodontal treatment on blood pressure, or BP, in individuals with chronic periodontitis, with or without hypertension. Primary outcomes included changes in systolic, or SBP, and diastolic blood pressure, or DBP, with secondary outcomes assessing inflammatory markers (IL-6, hs-CRP), endothelial function and periodontal parameters.

Results/conclusion. No significant changes in SBP or DBP were observed in individuals with chronic periodontitis alone. In hypertensive individuals, one study reported a significant short-term reduction in SBP (-11.2 mmHg, $p < 0.001$) and DBP (-8.4 mmHg, $p < 0.001$), but certainty of evidence was moderate. There were inconsistent reductions in inflammatory markers, but minimal adverse effects were reported.

Validity/applicability. The review included only RCTs, ensuring methodological rigor. However, variability in periodontal treatment protocols, small sample sizes and high or unclear risk of bias in some studies limited the strength of conclusions. Certainty of evidence ranged from very low to moderate.

Level of evidence. Level IA–Systematic review and meta-analysis of RCTs

Figure 1. A 62-year-old man with advanced periodontal disease. There is radiographic bone loss and clinically, tartar deposits above and below the gingiva are visible.[1]

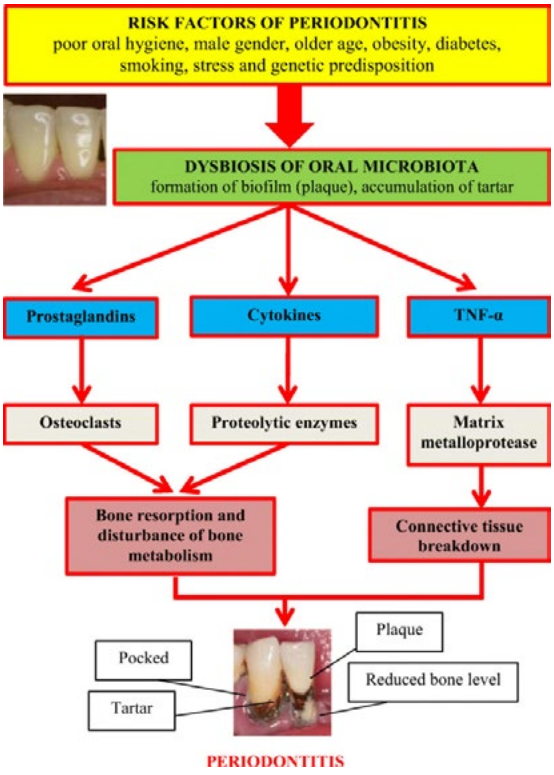

Figure 2. Etiopathogenesis of periodontitis. Tumor necrosis factor alpha (TNF-α) is a chemical messenger produced by the immune system that induces inflammation.[1]

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2. Sharma, S., Sridhar, S., McIntosh, A., Messow, C. M., Aguilera, E. M., Del Pinto, R., Pietropaoli, D., Gorska, R., Siedlinski, M., Maffia, P., Tomaszewski, M., Guzik, T. J., D'Aiuto, F., Czesnikiewicz-Guzik, M. (2021). Periodontal therapy and treatment of hypertension-alternative to the pharmacological approach. A systematic review and meta-analysis. *Pharmacological research*. 166, 105511. https://doi.org/10.1016/j.phrs.2021.105511

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The efficacy of zygomatic implants for the atrophic maxilla

Graham Kang '27, Dohyun Kim '27
Mentor: Christina Truong, D.M.D.

Background/case scenario

Rehabilitation of a severely resorbed, atrophic posterior maxilla presents a challenge for the surgeon due to inadequate bone for traditional implant placement. Consequently, zygomatic implants were proposed as an alternative procedure that does not involve significant bone grafting prior to implant placement.

Clinical question

For patients with severe atrophic and edentulous maxilla seeking prosthetic rehabilitation, do zygomatic implants provide a better rate of success than conventional implant placement?

CAT 1

Article. Autogenous bone grafting with conventional implants versus zygomatic implants for atrophic maxillae: A retrospective study of the oral health-related quality of life[1]
Authors. Laventure, A., et al.
Published. July 2022
PubMed ID. 35817319

Methods. Twenty-one patients who received autogenous bone grafting with conventional implants and 22 patients who received zygomatic implants were followed in a retrospective study regarding complications and quality of life.

Results/conclusion. There was no significant difference between the two intervention groups in survival rate and quality of life, but due to the decreased morbidity and treatment duration, zygomatic implants were found to be a more suitable procedure for most atrophic maxillae.

Validity/applicability. Though there was a small sample size, the selection criteria and follow-up durations were noted for each of the 43 patients. The procedures were completed at the same hospital.

Level of evidence. Level 3–Retrospective study

POPULATION
Patient with atrophic maxilla seeking prosthetic rehabilitation

INTERVENTION
Zygomatic implants

COMPARISON
Conventional implants

OUTCOME
Success rate of implants

Conclusion/reflection. Zygomatic implants are excellent alternatives for conventional implants that do not require invasive autogenous bone grafting or sinus augmentation procedures. Zygomatic implants can be immediately loaded and provide comparable survival rates of success and quality of life after placement when compared to conventional implants. Further research into the efficacy of zygomatic implants compared to other surgical interventions used for the atrophic maxilla, and the stability of prosthetics fabricated for zygomatic implants would provide more information in improving this treatment modality. The selected articles provide the most recent comparisons of zygomatic and conventional implants, which supports use of zygomatic implants due to their high success rates.

Keywords. Zygomatic implants, atrophic maxillae, implant survival

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CAT 2

Article. Survival rate and prosthetic and sinus complications of zygomatic dental implants for the rehabilitation of the atrophic edentulous maxilla: A systematic review and meta-analysis[2]
Authors. Gutiérrez Munoz, D., et al.
Published. June 2021
PubMed ID. 34209770

Methods. A systematic literature review and meta-analysis was conducted on clinical studies evaluating the survival rate of zygomatic implants for rehabilitation of the atrophic edentulous maxilla. Forty-six articles were selected for the qualitative analysis and 32 were selected for the quantitative analysis.

Results/conclusion. The failure rate of conventional dental implants was 2.89%. The failure rate of zygomatic implants was 0.69%. The follow-up times of the selected studies ranged from three to 163 months. The high survival rate paired with low rates of complications indicated zygomatic implants as a treatment option for the atrophic maxilla.

Validity/applicability. Results are well-supported by many quantitative and qualitative studies.

Level of evidence. Level 1–Systematic review with meta-analysis

CAT 3

Article. Success rates of zygomatic implants for the rehabilitation of severely atrophic maxilla: A systematic review[3]
Authors. Solà Pérez, A., et al.
Published. Aug. 2022
PubMed ID. 36005249

Methods. The systematic review was focused on cases involving severe maxillary atrophy and zygomatic implant placement. There were 196 publications included in this study.

Results/conclusion. The success rate of zygomatic implants was 98.5% in less than 1 year, 97.5% between 1 and 3 years, 96.8% between 3 and 5 years and 96.1% after more than 5 years. This minimal decrease in the success rate after the surgical intervention indicates that zygomatic

Evidence search strategy

Articles with the highest level of evidence that compared zygomatic implants with conventional implants were selected.

MeSH Terms

- Zygomatic implants
- Atrophic maxillae
- Implant survival

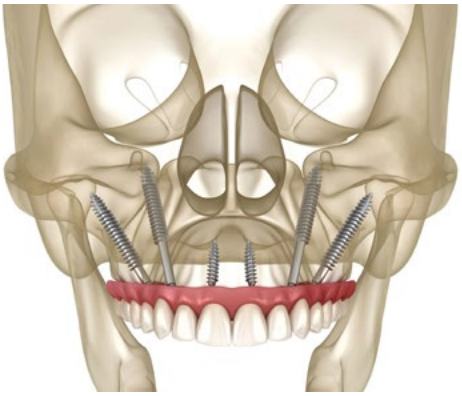

Figure 1. Zygomatic implants are an alternative to traditional dental implants where there is insufficient bone in the maxilla. They are inserted through the alveolar crest and maxillary sinus to involve the zygomatic bone for anchorage. *Image from* https://www.sfdentalgroup.com/dental-implants/zygomatic-implants. Accessed Apr. 14, 2025.

implants are a safe and reliable way to restore the atrophic maxilla. Although success rates were high, complications were not uncommon.

Validity/applicability. Many reviewed articles (196) suggest strong evidence of quality.

Level of evidence. Level 1–Systematic review with meta-analysis

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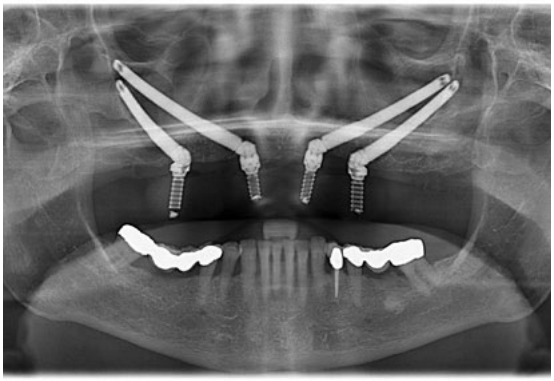

Figure 2. Panoramic image of zygomatic implants for the rehabilitation of the atrophic edentulous maxilla. *Image from* https://www.fastnewsmile.com/blog/zygomatic-implants. Published Sept. 22, 2016. Accessed Apr 14, 2025.

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Reduction of silver diamine fluoride staining in carious teeth using potassium iodide to form a silver-iodide precipitate

Peter Nguyen '27
Mentor: Carmem Pfeifer, D.D.S., Ph.D.

Background/case scenario

Silver diamine fluoride, or SDF, is a topical medication officially approved by the FDA to treat dentin hypersensitivity with an off-label use as an effective agent for arresting cavitated caries. Silver is antimicrobial while fluoride promotes remineralization.[1] Advantages include minimal invasiveness and non-aerosol-generating way of treating caries.[2] The major disadvantage is that silver particles react with the carious tissue and form a black stain. This can lead to decreased acceptance of SDF as a treatment option, especially in an aesthetic zone. Potassium iodide, or KI, is a proposed option to decrease the stain from the conjugate by forming a silver-iodide precipitate instead.[3] Staining can be measured using mean gray value, or MGV, or total color difference, or TCD.

Clinical question

In carious human teeth treated with SDF, does the application of KI at time of treatment result in less total color difference and mean gray value compared to SDF alone?

CAT 1

Article. Efficacy of glutathione biomolecule in reducing the tooth discoloration associated with silver diamine fluoride: A split-mouth in vivo study[1]
Authors. Karuna, Y.M., et al.
Published. Oct. 2023
PubMed ID. 38075536

Methods. Three primary teeth with natural caries in 20 children ages 3-8 years old were subjected to different treatments (n = 20; SDF, SDF + KI, SDF + Glutathione). Digital photographs were taken immediately and at six months of post-treatment (Figure 1). Mean grayscale value was analyzed using Image J software. Significance was calculated with a one-wayANOVA+Post-hoctestbetweengroups;apairedt-testwasusedwithin groups ($p < 0.05$).

POPULATION
Carious human teeth

INTERVENTION
Silver diamine fluoride and potassium iodine

COMPARISON
Silver diamine fluoride alone

OUTCOME
Less total color difference and mean gray value

Conclusion/reflection. Application of silver diamine fluoride and potassium iodide to carious lesions on human teeth significantly decreased the mean gray value and total color difference of stains. The effect may diminish with time.

Keywords. Silver diamine fluoride, potassium iodide, caries, staining

Evidence search strategy

Searched on PubMed, filtered by RCT and year range 2020-25, and chose articles that matched the PICO question.

MeSH Terms

- Silver diamine fluoride
- Potassium iodide

Results/conclusion. SDF + KI exhibited a statistically significant difference in mean gray value versus SDF immediately after treatment ($P < 0.001$) and after six months ($P = 0.003$). This suggests that the use of KI immediately after SDF in pediatric teeth reduces the darkness of the arrested carious lesion.

Validity/applicability. The study included and directly compared SDF and SDF + KI in carious human teeth. Examiner and clinical photographer were blinded. Large sample size.

Level of evidence. Level 1B–Clinical study, randomized controlled trial

CAT 2

Article. Laboratory evaluation of the potential masking of color changes produced by silver diamine fluoride in primary molars[2]
Authors. Hamdy, D., et al.
Published. July 2021
PubMed ID. 34243727

Methods. Fifty-two whole extracted human teeth with natural caries were divided into four groups and subjected to different treatments. After application of SDF, the masking effect was tested using KI, composite (CMP), and glass ionomer cement (GI) compared to just SDF alone (n = 13; SDF only, SDF + KI, SDF + CMP, SDF + GI). Spectrophotometric measurements were taken immediately posttreatment and after 24 hours of Suntest aging. L*, a*, b* ΔL, Δa, and ΔB was analyzed and calculated using CIELAB. Significance was calculated with a one-way ANOVA + Post-hoc test between groups.

Results/conclusion. SDF + KI exhibited a statistically significant difference in ΔL immediately after treatment ($0.001 > p > 0.008$) and after 24 hours of Suntest aging ($p = 0.04$). This suggests that the use of KI immediately after SDF reduces the darkness of the arrested carious lesion.

Validity/applicability. The study included and directly compared SDF and SDF + KI in carious human teeth. Blinding was deemed impossible due to SDF color change. Large sample size.

Level of evidence. Level 1A–Experimental study, randomized controlled trial

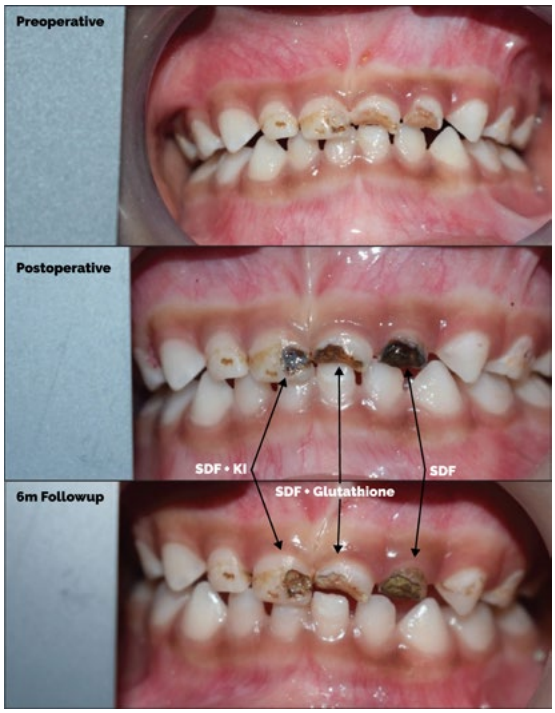

Figure 1. (a) Preoperative photo of a pediatric patient with carious teeth #E, #F and #G. (b) Immediate postoperative photo of tooth #E treated with SDF + KI, tooth #F treated with SDF + Glutathione and tooth #G treated with SDF. (c) At the six month follow-up, teeth treated with SDF and KI or SDF and glutathione had lighter stains compared to SDF alone.[1]

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CAT 3

Article. Optimal concentration of potassium iodide to reduce the black staining of silver diamine fluoride[3]
Authors. Detsomboonrat, P., et al.
Published. April 2022
PubMed ID. 35028051

Methods. Twenty-four whole extracted human teeth with natural caries were divided into six groups and subjected to different treatments (n = 4; SDF, SDF + 7.5% KI, SDF + 10% KI, SDF + 15% KI, SDF + 20% KI, SDF + saturated KI). Digital photographs were taken immediately, then one, three, seven and 14 days posttreatment (Figure 2). Mean grayscale value was analyzed using Image J software. Significance was calculated with a one-way ANOVA + Post-hoc test between groups; a paired t-test was used within groups ($p < 0.05$).

Results/conclusion. Immediately after treatment, all KI groups except the saturated KI exhibited statistically significant reduction in black staining ($p < 0.05$). Reduction for all KI groups diminished at all points that followed. This suggests that the use of KI immediately after SDF in carious teeth reduces the darkness of the arrested lesion, but the effect slightly diminishes over time.

Validity/applicability. The study included and directly compared SDF and SDF + KI in carious human teeth. No blinding, small individual sample size.

Level of evidence. Level 1B–Experimental study, randomized controlled trial

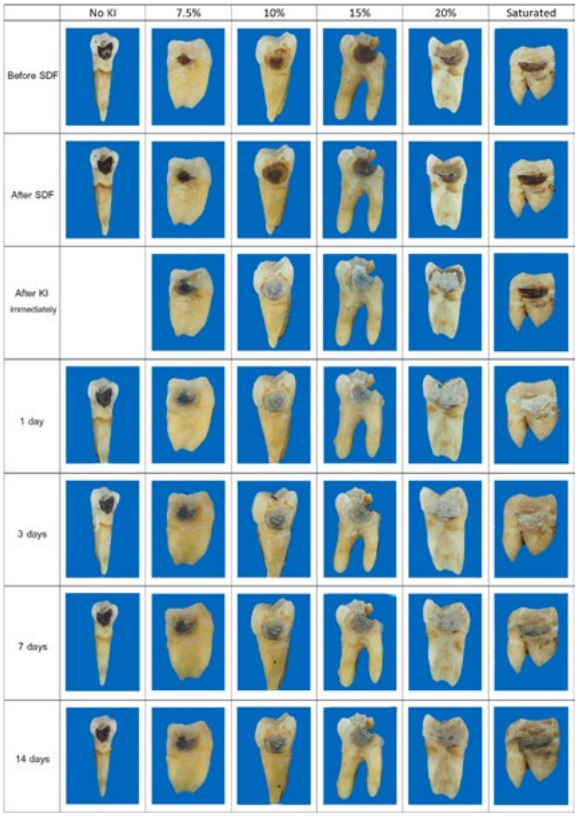

Figure 2. KI decreased the stain intensity of all concentrations of SDF applied to teeth with carious lesions. After 14 days, the stain reduction slightly decreased.[3]

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Advancing root canal treatment: Evaluating multisonic irrigation for enhanced disinfecting, debridement and patient outcomes

Hunter Rothfus '27
Mentor: Adam Lloyd, B.D.S., M.S.

Background/case scenario

Despite millions of successful root canals performed annually, treatment failures persist due to inadequate cleaning. Standard needle irrigation is unable to reach complex canal anatomy, whereas the GentleWave system, or GW, harnesses multisonic energy and advanced fluid dynamics to effectively debride and disinfect. This evaluation examines the effectiveness of the GW system in enhancing debridement, disinfection and decreasing post-operative pain.

Clinical question

Does multisonic irrigation using the GW system achieve better canal debridement and disinfection than standard needle irrigation, and does it decrease postoperative pain after root canal treatment?

CAT 1

Article. Comparative analysis of biofilm removal efficacy by multisonic ultracleaning system and passive ultrasonic activation[1]
Authors. Choi, H.W., et al.
Published. Oct. 2019
PubMed ID. 31731396

Methods. Biofilm removal efficacy was compared between GW and PUI in 47 extracted molars, infected with Enterococcus faecalis. Treatment groups were instrumented either minimally (GW group: 15/.04) or to a standard size (35/.04). The control group was un-instrumented. Histological sectioning of the roots at the apical and middle thirds, using modified Brown and Brenn staining or Hematoxylin and Eosin, were scored for biofilm presence.

Results/conclusion. GW showed superior biofilm removal (median score 0) compared to PUI and control ($p<0.001$), particularly in complex anatomical regions.

POPULATION
Patients requiring root canal treatment

INTERVENTION
Enhanced disinfection and debridement modality using the GentleWave system

COMPARISON
Standard needle irrigation, or SNI, with addition of passive ultrasonic irrigation, or PUI

OUTCOME
Removal of biofilm and debris, and decreased post-operative pain

Conclusion. The GentleWave system demonstrates superior debridement and disinfection in complex root canal systems compared to standard needle irrigation methods. This enhanced cleaning efficacy is achieved in minimally prepared canals, preserving pericervical dentin, offering dual benefits of improved cleaning and structural preservation.

Post-treatment pain assessments show comparable results between GentleWave and traditional methods, likely because conventional techniques already provide effective pain management. However, pain reduction represents only one aspect of treatment success. Current research lacks comprehensive evaluation of critical

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Validity/applicability. Strong validity due to controlled conditions and standardized histological scoring, however clinical applicability is limited by its in vitro design.

Level of evidence. Level 5–Experimental study

CAT 2

Article. Evaluation of root canal debridement of human molars using the GentleWave System[2]
Authors. Brandi, M., et al.
Published. Oct. 2015
PubMed ID. 26275599

Methods. Cleaning efficacy was compared between GW and SNI in 45 extracted molars. Groups (n=15) comprised: untreated control, instrumentation to ×3 file sizes larger than first file to bind with SNI, and minimal instrumentation to 15/.04 with GW. Histological analysis measured debris removal in apical and middle root thirds.

Results/conclusion. GWS achieved 97.2% debris removal versus 67.8% with conventional irrigation ($p < 0.05$). GWS demonstrated superior cleaning in complex anatomies, particularly mesiobuccal canals of mandibular molars, suggesting enhanced efficacy over traditional methods.

Validity/applicability. Highly applicable for evaluating mechanical debridement efficacy in vitro, though in vivo studies are necessary to evaluate clinical applicability.

Level of evidence. Level 5–Experimental study

CAT 3

Article. Postoperative pain after treatment using the GentleWave System[3]
Authors. Grigsby, D., et al.
Published. Aug. 2020
PubMed ID. 32553417

Methods. Forty-four patients were enrolled in this randomized control trial that evaluated the intensity of reported post-operative pain following root canal treatment. Treatment groups comprised canal instrumentation with either SNI and PUI, or GW. Pain was evaluated using a 0-100 numerical rating scale, or NRS, at multiple time intervals.

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healing indicators, including reduction of radiolucencies and periodontal ligament reformation according to Strindberg's criteria.

Due to the relatively recent introduction of the GentleWave system, research is limited. However, existing studies demonstrate improved debridement and disinfection capabilities compared to standard needle irrigation methods. These enhancements to debridement and disinfection suggest potential for improved clinical outcomes, though additional research is needed to confirm long-term treatment outcomes and define optimal clinical protocols.

Keywords. Multisonic irrigation, root debridement, GentleWave system

Evidence search strategy

Mesh Terms:

- GentleWave system
- Multisonic irrigation
- Root canal treatment
- Endodontics

Results/conclusion. Maximum NRS scores were 40 (moderate) for GW and 80 (severe) for SNI. However, median pain levels remained low to mild for both groups, with no significant difference in postoperative pain within one week (p>0.05).

Validity/applicability. Clinically relevant with high validity as a randomized controlled trial that measures patient outcomes; however, its small sample size may limit generalizability.

Level of evidence. Level 1–Randomized control trial

Case Significance

The American Association of Endodontists, or AAE, defines root canal therapy success by three core goals:

- Remove irritants
- Fill and seal the canal
- Eliminate signs/symptoms

The selected PICO outcomes demonstrated in each study align directly with the core goals of root canal therapy, as defined by the AAE, and showcase the GentleWave system's superiority over standard irrigation methods.

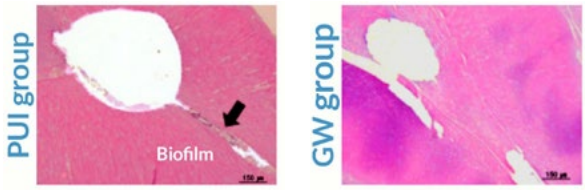

Figure 1. Remaining canal biofilm following treatment with passive ultrasonic irrigation (PUI) or GentleWave (GW) treatment.[1]

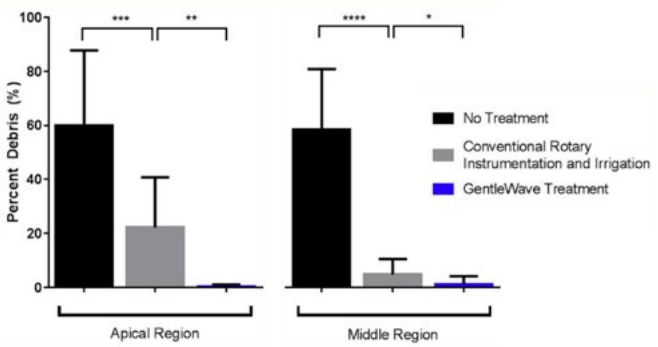

Figure 2. Remaining canal debris in the apical and middle regions following no treatment, conventional irrigation or GentleWave treatment.[2]

AAE Goal	Supporting Study	Key Findings
1 Remove irritants	Choi et al.	GW provides superior biofilm removal compared to passive ultrasonic activation, particularly in complex anatomical areas like the apical and isthmus regions
2 Fill and seal the canal	Molina et al.	GW removes 97.2% of debris, significantly outperforming traditional methods, ensuring canals are effectively cleaned and ready for obturation
3 Eliminate signs/symptoms	Grigsby et al.	GW successfully reduced pain, a key indicator of patient comfort and improved outcomes. However, no significant difference was found between treatment methods

Figure 4. Evidence-based alignment of GentleWave outcomes with AAE treatment goals.[4] Chart by Hunter Rothfus '27

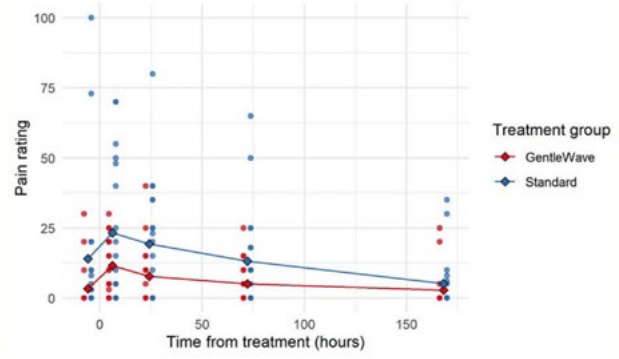

Figure 3. Post-operative pain levels following RCT with GentleWave versus standard irrigation.[3]

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Coronectomy: A safer alternative to complete extraction for high-risk mandibular third molars

Jack Klar '26
Mentor: Erik Richmond, D.M.D.

Background/case scenario

A 22-year-old male presents to the oral surgery clinic with pericoronitis associated with tooth #17. Panoramic imaging reveals the patient has all four wisdom teeth, pericoronitis associated with tooth #17 and mesio-angular impaction of tooth #32 causing significant deflection of the inferior alveolar nerve, or IAN, canal.

Clinical question

Does evidence in the literature support the use of coronectomy as an alternative to complete extraction of lower third molars determined via imaging to be in close proximity to the inferior alveolar nerve? If so, what are the indications for coronectomy versus complete extraction?

CAT 1

Article. Benefits of coronectomy in lower third molar surgery: A systematic review and meta-analysis[1]
Authors. Peixoto, A.O., et al.
Published. Jan. 2024
PubMed ID. 37925166

Methods. The authors conducted a systematic review and meta-analysis of 42 observational studies (29 cohort and 13 case-control) from six databases, focusing on patients undergoing lower third molar surgeries with high risk of IAN injury. They assessed outcomes like IAN injury, postoperative pain, infection and reoperation rates.

Results/conclusion. Coronectomy significantly reduced the risk of IAN injury, postoperative pain and dry socket compared to complete extraction. However, it was associated with a higher likelihood of reoperation due to root migration. The authors concluded that coronectomy is a viable option for patients at high risk of IAN injury, though clinicians must weigh the increased reoperation risk carefully.

POPULATION
Patients with lower third molars in close proximity to inferior alveolar nerve, or IAN

INTERVENTION
Coronectomy

COMPARISON
Complete extraction

OUTCOME
Decreased risk of IAN injury

Conclusion/reflection. Coronectomy is a safer alternative to complete extraction for third molar surgeries in patients with a high risk of inferior alveolar nerve, or IAN, injury. Particularly in cases where radiographic signs suggest close proximity to the IAN canal such as: deviation of IAN canal, root deviation or narrowing of IAN canal. While complete extraction remains a standard practice, it carries a potential risk of nerve damage and associated complications.

Keywords. Coronectomy, partial odontectomy, IAN injury, third molar

Evidence search strategy

Key words used:

- Coronectomy
- Partial odontectomy
- IAN injury
- Third molar

Validity/applicability. This is a systematic review and meta-analysis of observational studies but is limited by potential confounding factors inherent to observational data.

Level of evidence. Level 2–Systematic review

CAT 2

Article. Coronectomy versus total removal for third molar extraction: A systematic review[2]
Authors. Long, H., et al.
Published. July 2012
PubMed ID. 22622663

Methods. Systematic review examining four randomized and non-randomized controlled trials comparing coronectomy to total removal for third molar extractions with high nerve injury risk. Data was analyzed for outcomes including IAN injury, infection, dry socket and pain.

Results/conclusion. Coronectomy significantly reduced IAN injury risk compared to total removal, with minimal root migration and low reoperation rates. Other complications like infection, dry socket and postoperative pain showed no significant differences between the two techniques. The authors recommended coronectomy as a safer alternative for high-risk cases, emphasizing its efficacy in preventing nerve damage.

Validity/applicability. This systematic review includes randomized control trials, or RCTs, and controlled clinical trials, or CCTs. The inclusion of non-randomized trials slightly lowers its strength.

Level of evidence. Level 1–Systematic review

CAT 3

Article. Third mandibular molar coronectomy: A way to prevent iatrogenic inferior alveolar nerve injuries—A systematic review[3]
Authors. Lenfant, B., et al.
Published. June 2018
PubMed ID. n/a

Methods. The authors performed a systematic review of 19 studies, including randomized controlled trials, cohort studies and meta-analyses, to evaluate the safety and effectiveness of coronectomy. They analyzed

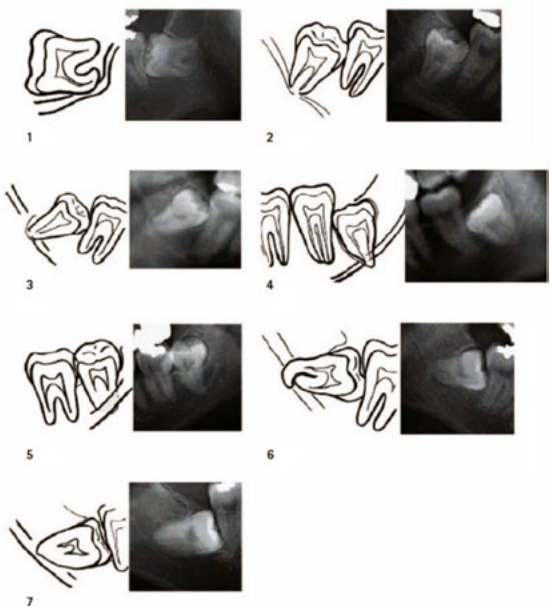

Figure 1. Variations of impacted third molars and increased risk of IAN injury. 1) canal deviation, 2) canal narrowing, 3) periapical radiolucency, 4) root narrowing, 5) root darkening, 6) root curving, and 7) canal lamina dura loss.[4]

Figure 2. Coronectomy procedure a) incision, b) full thickness flap, c) alveolectomy, and d) crown separation.[3]

outcomes such as nerve injury risk, infection and root migration. The study also included a review of operative techniques.

Results/conclusion. Coronectomy showed a lower incidence of nerve injury and dry socket compared to complete extraction, with manageable postoperative infections and root migration stabilizing within months. The study concluded that coronectomy is effective in reducing neurological complications and offers favorable outcomes for at-risk patients, provided proper follow-up is maintained. It was also noted that endodontic treatment of roots was not necessary.

Validity/applicability. This review includes RCTs, cohort studies and meta-analyses, with RCTs contributing the strongest support.

Level of evidence. Level 1–Systematic review

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Optimizing endodontic disinfection: Comparing multisonic (GentleWave®) and passive ultrasonic irrigation

Taylor Dobbeck '26, Luke George '26
Mentor: Eun Park, D.D.S. Ph.D.

Background

Apical periodontitis, a biofilm-mediated disease, necessitates root canal therapy for bacterial eradication. While sodium hypochlorite demonstrates potent antibacterial properties, conventional syringe irrigation often proves inadequate in achieving complete disinfection due to the complex morphology of the root canal system and resilient biofilm characteristics. Consequently, sonic and ultrasonic activation techniques have been developed, using high-frequency vibrations to augment biofilm disruption through fluid dynamic forces and cavitation phenomena.

Conventional endodontic instrumentation typically requires canal preparation to a size of #30/0.06 to ensure adequate irrigate penetration into the apical third. However, in minimally prepared canals, traditional syringe needles and ultrasonic inserts may prove ineffective due to spatial constraints. During passive ultrasonic irrigation, or PUI, file-to-wall contact can lead to oscillation damping and unintended dentin removal, risks that are amplified in minimally prepared canals. These challenges underscore the necessity for insert-free irrigation systems, such as those employed by multisonic irrigation (GentleWave®, Sonendo Inc.) in minimally invasive endodontics.

This caseCAT aims to compare the root canal disinfection efficacy of GentleWave, or GW, in minimally prepared canals versus passive ultrasonic irrigation, or PUI, in conventionally prepared canals, under ex vivo conditions.

Clinical question

Can infected root canals be disinfected despite minimal instrumentation?

POPULATION
Extracted posterior teeth with infected canals

INTERVENTION
GentleWave®, or GW, multisonic system

COMPARISON
Passive ultrasonic irrigation, or PUI

OUTCOME
Superior canal disinfection

Conclusion/reflection. GW system addresses the clinical limitations of minimally invasive endodontics by generating hydrodynamic cavitation through a sound bar positioned in the access cavity, thereby eliminating the need for intracanal inserts. The system creates an acoustic field of broadband frequencies through microbubble implosion, facilitating irrigate delivery throughout the root canal system. This technology enables effective irrigation in minimally prepared canals (#15 or #20 tip size), supporting the growing model of minimally invasive endodontic preparation that prioritizes tooth structure during access cavity preparation and canal instrumentation.

Keywords. Endodontic disinfection, multisonic irrigation, GentleWave, passive ultrasonic irrigation

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CAT 1

Article. Multispecies biofilm removal by a multisonic irrigation system in mandibular molars[1]
Authors. Coaguila-Llerena, H., et al.
Published. Aug. 2022
PubMed ID. 35976101

Methods. Twenty-two autoclaved mandibular molar mesial roots were inoculated using subgingival plaque from a single donor in order to simulate a mature multispecies biofilm that is representative of primary root canal infection. The canals were instrumented to respective irrigation system protocols: GWS 20.06 (V-Taper, SSWhite) and PUI 35.04 (Vortex Blue, Dentsply Sirona), n = 11 for each treatment group. Microbiological samples in the form of dentin debris were captured by paper points and submitted for qPCR and NGS both pre- and post-irrigation treatment. qPCR explored % reduction of reads and 16s rRNA NGS was used to evaluate multispecies biofilm removal for the respective irrigation techniques.

Results/conclusion. Both irrigation techniques significantly reduced PCR and NGS findings but had equivalent reduction percentages, indicating that neither option was superior. The authors also suggest that initial qPCR/NGS reads in their study were higher than in clinical cases, suggesting that the ex vivo teeth may be more challenging to disinfect than necrotic teeth.

Validity/applicability. PUI and GW are both valid systems for biofilm removal but are equal in their effectiveness. These systems may even disinfect better in-vivo.

Level of evidence. Level 3–Comparative Study

CAT 2

Article. The effect of ultrasonic and multisonic irrigation on root canal microbial communities: An ex vivo study[2]
Authors. Park, K. H., et al.
Published. Nov. 2023
PubMed ID. 37983635

Methods. Twenty-three necrotic mandibular molars with a PARL were extracted and immediately stored to preserve a clinically accurate microbial/pulp community. Mesial canals (UIA n = 11, GWS n = 12) were

Evidence search strategy

Key words used:

- GentleWave, multisonic
- Passive ultrasonic irrigation
- Biofilm removal
- Endodontic irrigation system

	PUI file size	GW file size	n	Methods to Assess	Outcome Measures
CAT 1	35.05 (Vortex Blue)	20.06 (V-taper)	22 MN molars	qPCR / 16s rRNA NGS	Multispecies biofilm removal
CAT 2	30.04 (Vortex Blue)	20.04 (Vortex Blue)	23 MN molars	qPCR / 16s rRNA NGS	Microbial diversity and load
CAT 3	35.04 (Vortex Blue)	15.04 (Vortex Blue)	48 MX premo lars	ELISA targeting LTA	*E. faecalis* LTA presence

Figure 1. Table comparing methods of the three studies.
Table by Taylor Dobbeck '26 and Luke George '26

Figure 2a. Sonendo GentleWave® unit with CleanFlow™ procedure instrument, Sonendo® (2025). *Image from* www.gentlewave.com/doctor/gentlewave-system.

instrumented and treated following respective irrigation system protocols: GWS 20/.04 (Vortex Blue) UIA 30/.04 (Vortex Blue). They were measured for microbial diversity and load using qPCR and NGS. Three samples were obtained: S1 (crown surface after disinfection), S2 (root canal after access), S3 (root canal post-irrigation).

Results/conclusion. Both systems significantly lowered microbial load, but did not see significant changes in the microbial diversity. qPCR demonstrated that GW significantly reduced more microbial load than UIA. Specifically, GW was associated with Prevotella reduction, while UIA reduced eubacterium.

Validity/applicability. This study finds no difference in microbial community composition following ultrasonic treatment. However, this study finds that GW is more effective than PUI, despite both reducing microbial load.

Level of evidence. Level 3–Comparative Study

CAT 3

Article. Efficacy of GentleWave System and passive ultrasonic irrigation with minimally invasive and conventional instrumentation technique against Enterococcus faecalis lipoteichoic acid in infected root canals[3]
Authors. Velardi, J. P., et al.
Published. March 2022
PubMed ID. 35247369

Methods. Forty-eight extracted two-rooted maxillary first premolars were inoculated with E. faecalis Lipoteichoic acid, or LTA, a major virulence factor with high affinity for hydroxyapatite. After inoculation, the teeth were then divided into treatment groups (n=12) based on the irrigation system and conventional/minimal technique: MIT + GWS, CIT + GWS, MIT + PUI, CIT + PUI. MIT canals were enlarged to 15/0.04 using and CIT were enlarged to 35/0.04, both using Vortex Blue rotary files. Three samples were obtained for each group: S1 (canals irrigated with sterile water), S2 (after GWS/PUI treatment), and S3 (after cryogenic grinding and external disinfection). LTA presence in all teeth was confirmed using ELISA.

Results/conclusion. LTA was recovered from 100% of the PUI treated canals, with CIT being more effective than MIT. In contrast, LTA was recovered from 42% of the GW treated canals, regardless of technique.

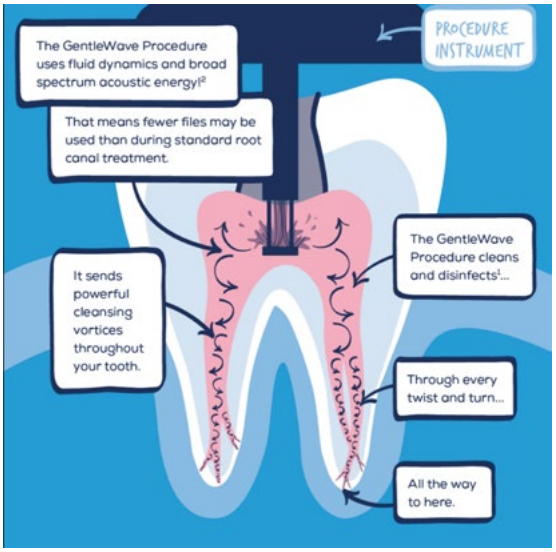

Figure 2b. GentleWave® System mechanism of action. *The GentleWave® Difference*. Elite Endodontics (2024). *Image from* www.endodontistpensacola.com/the-gentlewave-difference.

Figure 3. Irrisafe piezo tip for passive ultrasonic Irrigation. *Irri-safe F43807 files*. Henry Schein Dental. Image from www.henryschein.com/us-en/dental/p/small-equipment/power-scaling-tips-inserts/irri-safe-files-21mm/1170167.

Validity/applicability. Ultrasonic irrigation effectively eliminates virulence factors, with GW demonstrating superior performance. LTA also has strong affinity for hydroxyapatite, making it clinically significant.

Level of evidence. Level 3–Comparative Study

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A novel organ-on-a-chip model of multiple myeloma interactions with bone

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[1] OHSU School of Dentistry
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[3] OHSU Department of Biomedical Engineering

Introduction and objectives. Multiple myeloma, or MM, the most common hematological malignancy, is characterized by proliferation of neoplastic plasma cells leading to osteolytic craniofacial bone resorption in ~50% of patients.[1] These bone lesions, often presenting as "moth-eaten" defects in the calvaria and mandible, result from disrupted bone homeostasis—typically maintained by balanced osteoclast and osteoblast activity, with osteocytes playing a critical regulatory role (Figure 1).[2-4] Only a subset of patients with monoclonal gammopathy of undetermined significance (MGUS) progress to MM, a process that is not fully understood. In MM, osteocyte death and dysregulation, including reduced osteoprotegrin (OPG) and elevated sclerostin (SOST) and fibroblast growth factor 23, or FGF23, are reported to contribute to focal bone lesions.[5-7] While 2D co-culture and transwell models suggest a Notch signaling mechanism in osteolytic lesions, they fail to replicate the complex bone microenvironment.[8-10]

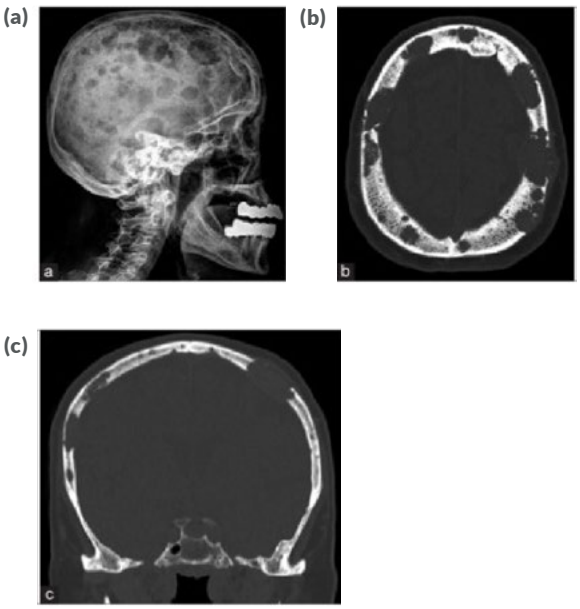

Figure 1. Multiple myeloma dysregulates the bone remodeling axis. Calvaria in patients with multiple myeloma may have a moth-eaten appearance, evident on radiographs. (a) Lateral skull radiograph demonstrating the classic "raindrop skull" appearance. (b and c) Axial and coronal brain computed tomography, "bone window," shows variable-sized, well-defined osteolytic lesions of the calvarial vault; the largest lesion measures 2.4 cm at the left frontal bone.[2]

Our technique for cell-laden biomineralization has been shown to enable more accurate matrix modeling, including intrafibrillar mineralization with embedded mature osteocytes (Figure 2).[11] We aimed to recreate the cellular and extracellular dynamics of MM-associated osteolytic lesions using a microfluidic bone-on-a-chip system. In this work, we ask the question: How does the triad of osteoblasts, osteocytes, and osteoclasts interact with multiple myeloma cells to drive osteolytic lesion formation, and how can these interactions inform therapeutic strategies?

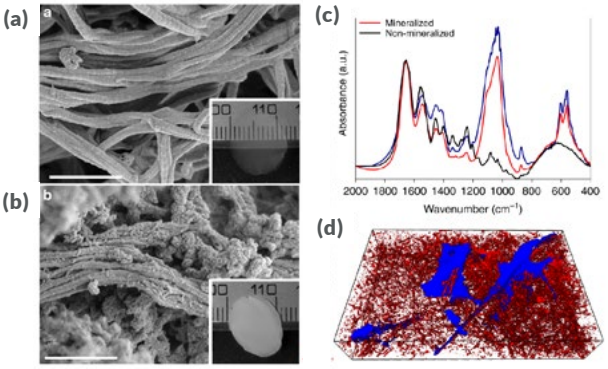

Figure 2. Cell-laden bioinspired collagen mineralization allows for development of realistic bone disease modeling. Mineralization of collagen with amorphous calcium phosphate enables nanoscale mineralization (a and b) with similar chemical composition to native bone (c). This form of mineralization is sufficient to promote osteoblast differentiation into osteocytes (d).[11]

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Materials and methods. The bone-on-a-chip platform integrates a microfluidic device with a 3D mineralized collagen matrix to mimic the bone microenvironment. Our group has shown that differentiation of osteoblasts into osteocytes is directed by matrix stiffness due to intrafibrillar mineralization.[11] Osteogenic precursor cells were encapsulated within the central channel, where they differentiated and formed a mineralized matrix. Macrophages introduced through a lateral channel were differentiated into mature osteoclasts. Following osteoclast and osteocyte differentiation, patient-derived MM cells were added to the system with a soft extracellular matrix. Markers for MM identification included CD38 and syndecan/CD138.[12] This model enables the study of interactions between osteocytes, osteoclasts and MM cells, allowing for real-time observation of osteolytic processes and potential mechanisms of MM-induced bone destruction.

Results and discussion. Primary cells were collected from patients with multiple myeloma via bone marrow biopsy. Multiple myeloma cells, which accumulate in the bone marrow through clonal expansion of plasma cells, can be grown in vitro long-term with a custom stem cell medium. Using fluorescent imaging, we characterized the interactions between the main contributors—osteocytes, osteoclasts and MM cells—and assessed progression and proposed mechanisms of osteolysis in the presence of MM. Importantly, we have successfully co-cultured primary patient MM cells in this context to observe their behavior in a near-physiological bone microenvironment. This model was developed initially using a commercially available 3-channel microfluidic chip. The complete system detailed includes collagen mineralization over three days, embedded osteocytes (OCy), multinucleated osteoclasts (OCl) and multiple myeloma cells (Figure 3). Cells from patients with multiple myeloma aggregate at the mineralized matrix interface and gradually enter the engineered bone (Figure 4). CD38+SYN+ cells were observed to migrate into the mineralized matrix by day 7, affecting osteocyte viability.

Conclusion and future studies. The multiple myeloma on-a-chip model replicates key elements of MM bone biology seen in patients, including osteocyte apoptosis and myeloma-matrix interactions. This bone-on-a-chip system represents a significant advance in modeling bone disease in multiple myeloma, bridging the gap between traditional in-vitro studies and in vivo conditions. It serves as a valuable tool for preclinical drug testing and for unraveling the complex mechanisms of MM-induced bone

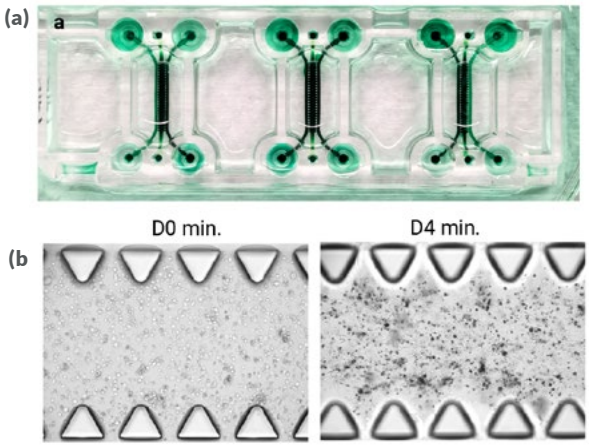

Figure 3. Cell-laden collagen loaded into the microfluidic multiple myeloma on-a-chip model mineralizes over three days. (a) Commercial chip used for pilot experiments. (b) Unmineralized collagen containing osteoblasts (left) and appearance of mineralized nodules by day 4 (right). *Images by Daniela Roth, et al.*

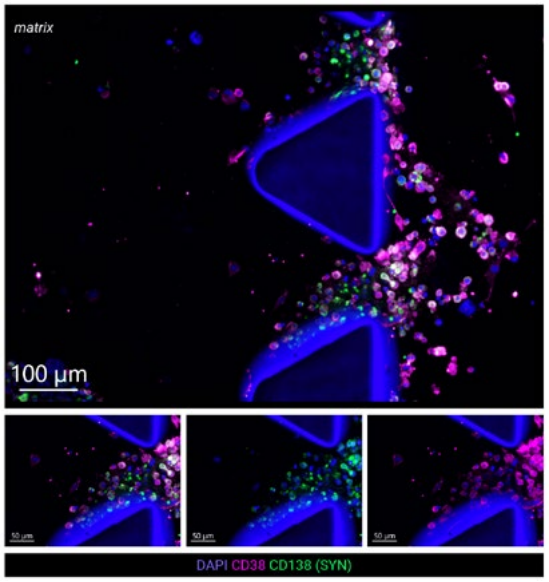

Figure 4. Cells from patients with multiple myeloma aggregate at the mineralized matrix interface. Immunofluorescent staining for cell surface markers of multiple myeloma (CD38: magenta, CD138/Syndecan: green). Nuclear counterstain is blue. Samples were fixed with 4% PFA and demineralized prior to staining on-chip. CD38+SYN+ cells were observed to migrate into the mineralized matrix by day 7 (left side of image). *Image by Daniela Roth, et al.*

loss, providing a primary cell-compatible platform for patient-specific studies that can directly inform therapeutic strategies aimed at mitigating bone damage in MM.

Acknowledgements

We acknowledge funding from the NIH/National Institute of Dental and Craniofacial Research (R01DE029553 and R21CA263860 to LEB), an NIDCR PORT Training Grant (to DMR), and the Knight Cancer Institute's Cancer Early Detection Advanced Research Center. The authors are grateful to the members of the Knight Cancer Precision Biofabrication Hub, Cancer Early Detection Advanced Research (CEDAR) group, and the Advanced Light Microscopy Core for their support in this work. We thank Dr. Eli Traer, McKenna Finley and Szu-Wei Lin, in particular, for providing primary multiple myeloma cells for this work.

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Enhancing biocompatibility with functionalized melamine-reinforced self-healing microcapsules for dental restorative biomaterials

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Introduction. Fifty percent of resin-based dental restorations fail within 10 years, primarily due to recontamination of dental tissues and fractures in the restorative materials. Typically, restorations that fracture catastrophically initially develop microcracks caused by masticatory forces and thermal variations, which then propagate and merge. A proposed strategy to address this challenge involves equipping restorative materials with the ability to autonomously repair microcracks as they form. This is achieved by incorporating microcapsules containing a healing agent into the polymeric network. When microcracks form, the microcapsules rupture, releasing the healing agent, which polymerizes in-situ, thereby repairing the damaged area and preventing further microcrack propagation. The most used systems are based on poly(urea-formaldehyde), or PUF, microcapsules, and although the results are promising, the potential release of formaldehyde from these systems is a significant concern due to its cytotoxicity and potential adverse effects on oral tissues. In other fields, modification of PUF networks by melamine incorporation and chemical functionalization have emerged as promising strategies to chemically bind and potentially reduce residual formaldehyde emission. Therefore, this study aims to design, synthesize and characterize a toolkit of alternative microcapsules by integrating melamine and functionalizing agents based on methacrylate and thiol into the outer shell polymeric network (Figure 1), while also evaluating their potential to minimize formaldehyde release and enhance biocompatibility.

Objective. To synthesize and characterize self-healing poly(urea-formaldehyde) microcapsules modified with melamine and surface functionalized with thiol or methacrylate silane to minimize formaldehyde release and enhance biocompatibility.

Materials and methods. Triethylene glycol dimethacrylate, or TEGDMA, was encapsulated in microcapsules with shells composed of either PUF or melamine-modified, or PUMF, via a double emulsion reaction.

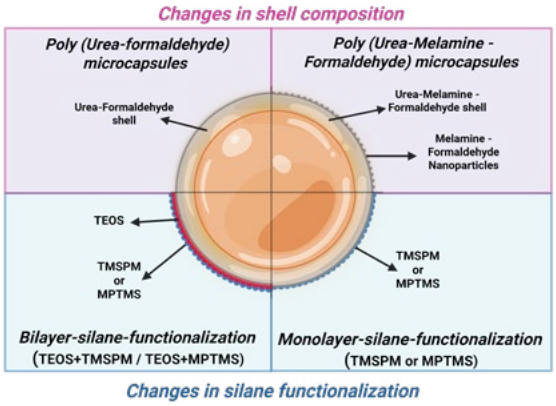

Figure 1. Schematic representation of the various microcapsules used in the present study by incorporating melamine and silane functionalization. *Image by Sivashankari Rajasekaran using Biorender software.*

Following synthesis, the surface of the microcapsules was functionalized with methacrylate silane 3-(trimethoxysilyl) propyl methacrylate, or TMSPM, or the thiol-based silane 3-mercaptopropyl trimethoxysilane, or MPTMS, either individually or in combination with a tetraethyl orthosilicate, or TEOS, pre-coating. The microcapsules were then subjected to morphological and physicochemical characterization, as well as evaluation of formaldehyde release and biocompatibility.

Results. Overall, the incorporation of melamine proved to be a promising strategy for enhancing the stability of the microcapsules and improving their resistance to shell functionalization protocols. Regarding formaldehyde emission, the concentrations released by all tested microcapsules did not significantly affect the metabolism of mammalian cells. The shell functionalization treatments influenced the biological performance of the microcapsules, with the MPTMS single treatment demonstrating the most promising results.

Conclusion. In summary, the functionalization of self-healing microcapsules produces greater biocompatibility, and melamine reinforcement enhances mechanical and thermal stability. These combined outcomes may culminate in the development of a self-healing resin composite that offers significant biosafety and potential extension of the clinical lifespan of dental restorations, thereby enhancing overall oral health care.

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Inhibition of dentinal collagen degradation by matrix metalloproteinases using quaternay ammonium methacrylates

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Introduction. Dentin's organic matrix consists primarily of type I collagen, which is degraded by matrix metalloproteinases, or MMPs, activated during caries progression or the adhesive bonding process (Figure 1). Chlorhexidine, or CHX, effectively inhibits MMPs but leaches out rapidly, limiting its long-term efficacy. Quaternary ammonium methacrylate, or QAM-based adhesives, provide antimicrobial benefits and being co-polymerized with the adhesive, could provide sustained MMP inhibition. This study evaluates the antimicrobial and anti-enzymatic properties of a QAM-based dental adhesive. The null hypotheses tested were that the QAM-based adhesive does not significantly differ from 1) the control adhesive, or 2) the 2% CHX-based adhesive in preserving the collagen matrix or exhibiting antimicrobial activity.

Methods. MMP inhibition was assessed using a fluorescence-based assay with recombinant MMP-2, incubated with varying concentrations of CHX or QAM (Figure 1E). Fluorescence intensity indicated enzymatic activity. The shear storage modulus (Figure 1F) of demineralized dentin slices was measured using a rheometer after incubation in treatment solutions. Collagen degradation was evaluated by hydroxyproline quantification after incubation in artificial saliva. Two-step, total-etch adhesives were formulated with BisGMA/HEMA, with 10 wt% DMAHDM added for the QAM-modified adhesive. The degree of conversion was analyzed via FTIR after solvent evaporation and photoactivation (Figure 1A). For biofilm assays, *S. mutans* were cultured on adhesive discs for 24 hours. Planktonic growth was measured via OD600, biofilm viability using luminescence and biomass through crystal violet staining.

Abstract

Several approaches to prevent the degradation of dentinal type 1 collagen by matrix metalloproteinases, or MMPs, have been attempted, including the use of quaternary ammonium methacrylates, or QAMs, and chlorhexidine, or CHX. Sheer modulus, percent conversion and various assays were used to assess the physical, chemical and biological of both inhibitors compared to a control. The results suggest that a QAM-based adhesive more effectively inhibited MMPs, biofilm formation and strengthened dentin.

Keywords. Quaternary ammonium methacrylates dental adhesives, matrix metalloproteins, antimicrobials, biofilm

Results. Dentin discs incubated with 2% CHX or 10% QAM for 72 hours exhibited a significant increase in shear storage modulus (p = 0.006, Fig. 1F), indicating improved mechanical stability. Hydroxyproline assay results showed the highest collagen degradation in the H_2O group (35.4 µg/mL), with significantly lower degradation in CHX (20.8 µg/mL) and QAM (21.8 µg/mL) groups (p= 0.005), suggesting effective collagen preservation (Figure 1G). Ethanol/water treatment led to intermediate degradation (29.7 µg/mL). The degree of conversion was highest in the 10% QAM group. CHX and QAM significantly reduced bacterial growth (OD600, Figure 1B), biofilm biomass (Figure 1C) and viability (Figure 1D), with QAM being the most effective (p < 0.001 for all). Stereomicroscopy confirmed reduced biofilm formation in CHX and QAM groups compared to the control. These findings highlight the antimicrobial and enzymatic inhibition properties of QAM-modified adhesives, demonstrating their potential for improving the longevity of dental restorations by reducing bacterial colonization and collagen degradation.

Conclusions. Both 2% CHX and 10% QAM enhanced dentin stability and inhibited collagen degradation. QAM showed superior antimicrobial effects and improved polymerization, suggesting its potential to strengthen dentin and prevent biofilm formation in adhesive restorations.

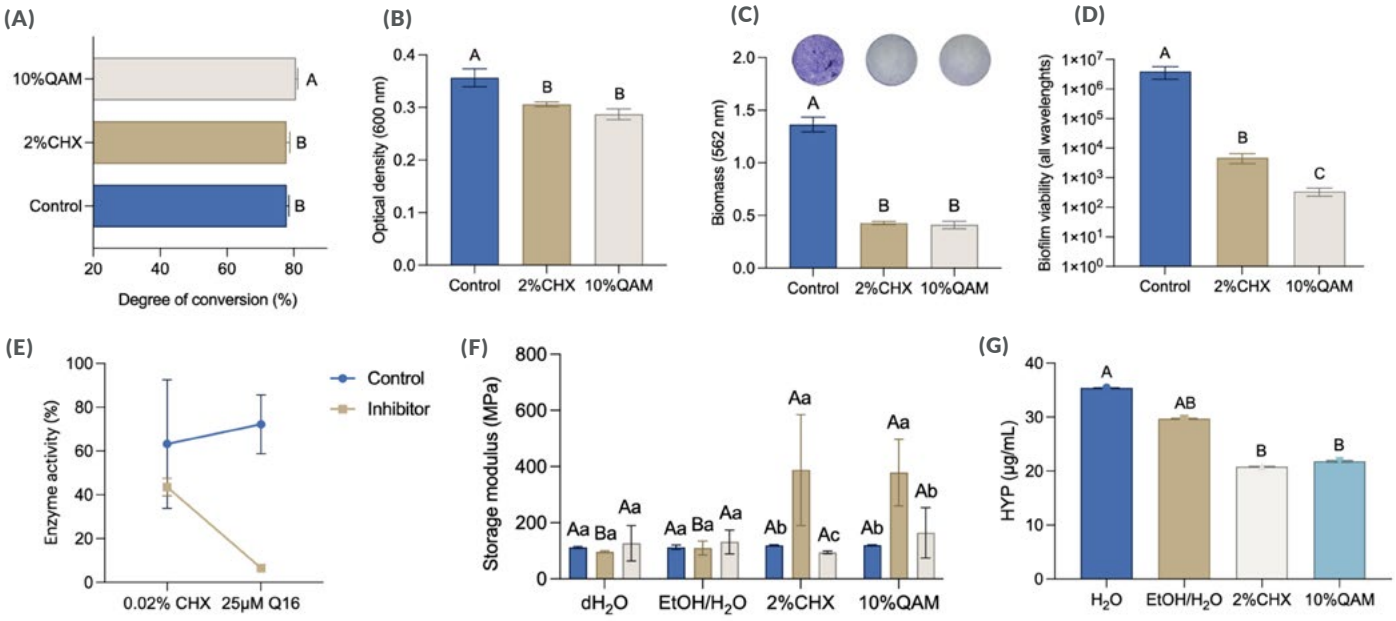

Figure 1. Evaluation of experimental adhesives containing 2% chlorhexidine (CHX) or 10% quaternary ammonium methacrylate (QAM). **(A)** Degree of conversion, **(B)** Planktonic growth (OD600), **(C)** Biofilm biomass, and **(D)** *S. mutans* biofilm viability, **(E)** MMP-2 enzyme inhibition by CHX and QAM, **(F)** Dentin shear storage modulus **(G')** at baseline, 72h, and 1 week post-treatment, **(G)** Collagen degradation quantified by hydroxyproline release. Statistical differences are indicated by distinct letters (p < 0.05); error bars represent standard deviation.
Charts by Peter Nguyen '27, et al.

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Mechanistic study of the antibiofilm effect of QAM-based materials

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Objectives. This study aims to elucidate the mechanism through which the combination of chain length and charge in QAM-containing materials affects biofilm inhibition. Neutral molecule analogs carrying both positive and negative charges (zwitterion) were used as direct comparators to quaternary ammonium (positively charged) molecules.

Methods. BisGMA/TEGDMA (50/50wt%), 0.1wt% DMPA and 70wt% filler were combined with 0 (control) or 10wt% quaternary-ammonium methacrylate (QAM, positive charge) with 6- or 16-carbon side chain length (Q6 or Q16), or a zwitterion molecule with 16-carbon side chain (Z16, neutral) at several mol ratios. Discs were photocured (700 mWcm2, 1 min/side), and stored for 24 hours. Degree of conversion, or DC, was measured in near-IR. Discs were then incubated with *S. mutans* (1% sucrose, TH media, 24-hours, 37°C/5%CO2). The biofilm viability and biomass were assessed with crystal violet and luciferase assays. The % area of the disc covered with crystal violet-stained bacteria was measured with ImageJ software. Data were analyzed with one-way ANOVA/Tukey's test (α=0.05).

Results. DC was statistically similar for all groups, ranging from 64.3±10.4 to 74.2±4.4% (p=0.117, Figure 1A). Biofilm biomass (p<0.001, Figure 1B), viability (p<0.002, Figure 1C) and surface coverage (p<0.001, Figure 1D) decreased with the increase in Q16 concentration. Q6 alone did not affect biofilm, but the addition of Q16 at any ratio led to reduction in biofilm, similar to Q16 alone. Q16/Z16 combinations had a similar trend, but the biomass was reduced at a higher Q16 ratio (Fig. 1E). Since Q6 or Z16 alone or in combination have no antimicrobial effect, it can be inferred that charge concentration is the main driver of antibiofilm activity.

Abstract

Quaternary ammonium compounds are often used in cleaning products such as hand sanitizers, wipes and sprays due to their antimicrobial properties. When combined with a methacrylate, it creates a quaternary ammonium methacrylate, or QAM, that sustains antimicrobial properties in polymer surfaces. This study investigates the role that charge concentration and methacrylate chain length has on the antimicrobial effect. Samples with fixed rations of short chain QAM, long chain QAM and a QAM zwitterion were created and compared. The results suggest that charge is responsible for the antimicrobial effect, but side chain length also plays a significant role.

Keywords. Biofilm, quaternary ammonium methacrylate, antimicrobial, bactericidal mechanism

Conclusion. The side chain length was not the main factor in biofilm disruption with positively charged molecules, since at the same charge concentration, a mixture of long and short chains led to the same antibiofilm effect as the long chain alone.

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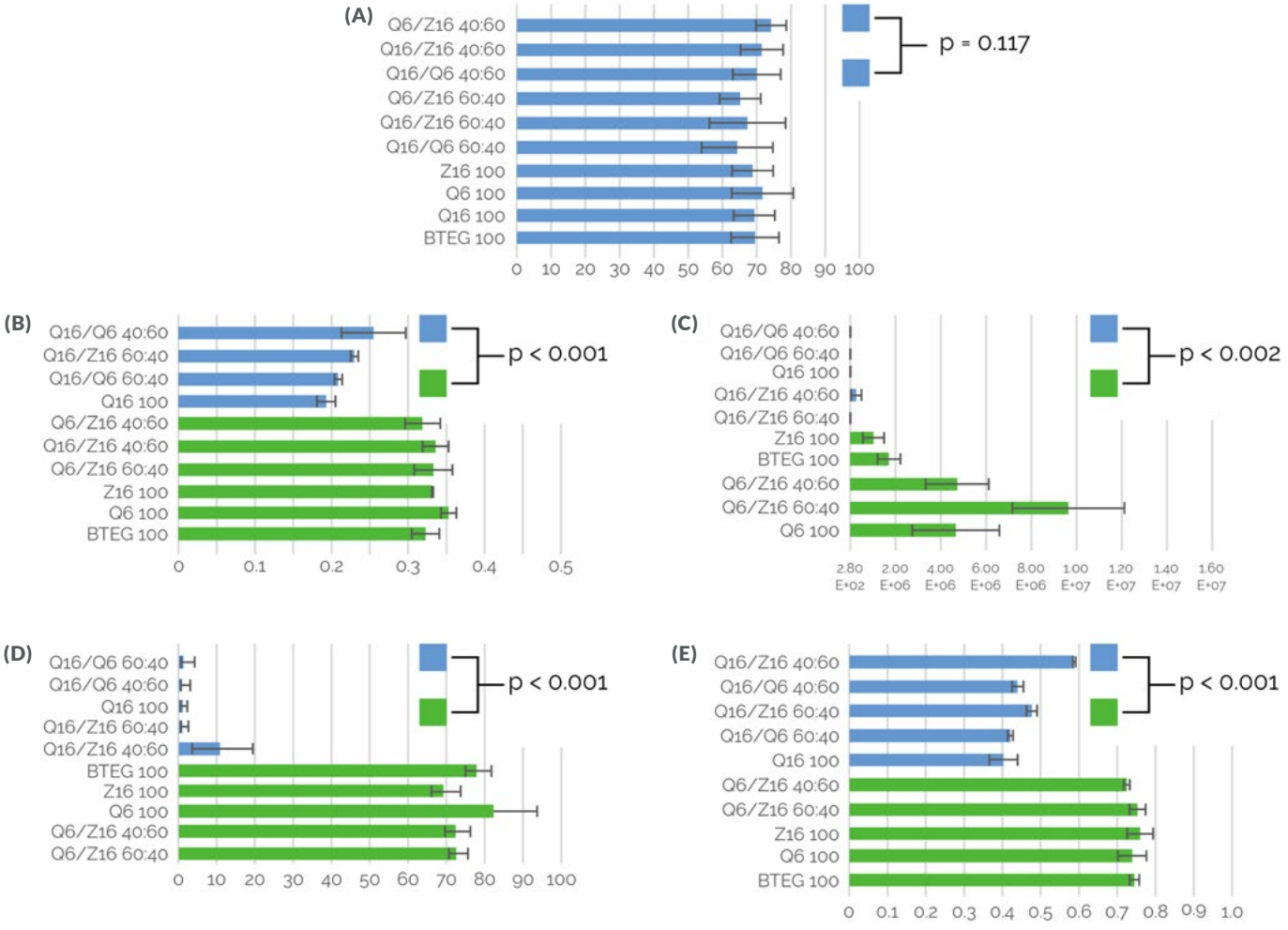

Figure 1. Evaluation of experimental resin composite containing 16-carbon chain QAM (Q16), 6-carbon chain QAM (Q6), or 16-carbon chain zwitterion (Z16). **(A)** Degree of conversion, **(B)** Planktonic growth (OD600), **(C)** *S. mutans* biofilm viability, **(D)** Surface coverage, **(E)** Surface biomass. Statistical differences are indicated by distinct color, p values are included in each graph, and error bars represent standard deviation. *Charts by Peter Nguyen '27, et al.*

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Every dental professional's role in improving Indigenous oral health

Rachel Meek, D.M.D. '22

After generations of oppression, abuse and forced displacement, the Indigenous population in the United States faces poverty, malnutrition, homelessness, isolation (by physical or transportation barriers) and discrimination that limits access to meaningful and culturally competent oral health care. Decades spent without culturally specific and effective care delivery has led to significant distrust and anxiety around the dental profession in the Indigenous community. As some result of this, American Indian and Alaska Native, or AI/AN, people face a severe and disproportionate burden of oral disease in the United States.[1] AI/AN children are three times more likely to have early childhood caries than non-AI/AN children.[2] AI/AN adults are twice as likely to have untreated decay and more likely to report tooth loss than non-AI/AN adults.[3] Further, native patients are less likely to have seen a dentist in the last year and over three times more likely to visit the emergency department for tooth pain than non-native patients.[1]

It would be incorrect to identify these disparities and their consequences as a problem only for those oral health professionals working on Indian reservations. According to the 2020 U.S. Census, among the 6.79 million native people living in our country, only 22% reside on reservations and about 60% reside in metropolitan areas.[4] AI/AN patients seek care in all oral health spaces—public health facilities, yes, but corporate offices, private practice, hospitals, and academic settings, as well. Therefore, every dental professional has a role to play in improving the AI/AN community's experiences and oral health outcomes.

This, however, is not easy. There are many obstacles to overcome. Federal oral health programs are underfunded. Tribal clinics are understaffed and overwhelmed. Urban programs are limited in the care they can provide. Indigenous values are not recognized or understood widely in private and corporate practice, often leading to distrust and poor patient outcomes. Many academic institutions fail to admit AI/AN students, accurately represent and include the Indigenous community in research and teach professional students about caring for native patients. Studies have shown that increasing workforce diversity—native dentists seeing native patients—is one of the best ways to increase access and improve health equity and care quality.[5] Yet, while 2% of the U.S. population identifies as native, only 0.2% of dentists do.[4,6]

As one of those 0.2% of dentists, currently practicing and receiving care in a tribal community, I can attest that the barriers to and discrimination in care are real. I can also attest that, although more difficult to identify and develop than the stark problems we face, meaningful solutions do exist.

In the public health setting, increased and reliable fundingfor more services in urban and remote areas would improve access to care. Public health administrators and providers can seek out

philanthropic institutions, grants and public funds for support. Advocacy efforts, especially with specialty societies and organizations like the American Dental Association and its components, can be directed toward Medicare and Medicaid reform that benefits providers and patients. Recruiters in rural and tribal areas can be intentional in their offerings to ensure providers, especially those providers with Indigenous identity, have the support—personally and professionally—that promotes retention and community integration. This is being done effectively now through the Indian Health Service Health Professions Scholarship, which provides year-for-year tuition awards in health professional programs, like dental school, to native students in exchange for a service commitment in native communities following graduation.

The private sector needs access to education regarding Indigenous patients' needs, tribal resources and proactive ways to overcome barriers to establishing dental homes. Cultural competency continuing education can be helpful. The Society of American Indian Dentists, or SAID, Indian Health Service, or IHS, and National Indian Health Board, or NIHB, offer such courses and additional resources, including native providers to connect with and share personal concerns or recommendations. Understanding the identity of specific patients and their unique concerns and resources is important, as well. Providers should feel empowered to ask their Indigenous patients questions and develop individualized plans of action to improve oral health outcomes.

Academic institutions can partner with representative organizations like the SAID and NIHB to ensure research and studies are conducted inclusively. Schools can add focus to recruiting AI/AN applicants and use the knowledge of public health and Indigenous faculty to develop culturally informed and native-developed coursework for oral health professional students. The Oregon Health and Science University School of Dentistry's new Wy'east Dentistry program, led by Chloe Craig, D.M.D. (a Cherokee dentist), is a great example of using native providers and educators to help increase native representation in the academic sphere to improve AI/AN oral health.

Oral health professionals involved in organized dentistry and advocacy efforts can be open to novel solutions to Indigenous barriers to care—both physical and cultural. The discussion surrounding dental community health aides and dental therapists, among other access to care solutions proposed by the native community, is an important one that requires an open mind and compassion on all sides.

Reversing oral health inequities is the responsibility of everyone in the oral health profession. A great place to begin understanding the complexity this issue is CareQuest Institute for Oral Health's 2023 White Paper, titled American Indian and Alaskan Native communities face a 'disproportionate burden of Oral disease': Reversing inequities onvolves challenges and opportunities. This work details the hard work done already by many professionals to start addressing the native population's burdens and challenges and illustrates evidence of these strategies starting to work. There is hope.

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A New Zealand perspective on community water fluoridation

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Community water supplies are a common good, serving whole populations with drinkable water. Past populations lived where fresh water was available, or dug wells to access hidden water, or constructed aqueducts to bring water across considerable distances. Modern water supplies add considerable additional steps to this process by treating water that would otherwise be unfit for human consumption. Water treatment can include adding flocculation agents such as aluminium sulphate, pH balancing agents such as lime, disinfectant agents such as chlorine and fluoride. Each of these steps is intended to make the water safer or more potable for human consumption, except for fluoridation.

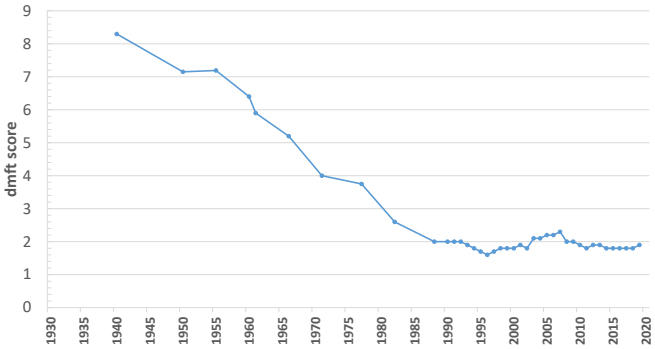

Figure 1. Count of decayed, missing and filled teeth among New Zealand children at age 5 years.[5]

Early research on fluoridation in New Zealand was conducted in Hastings in the 1950s and 1960s,[1,2] following the discovery of the oral health effects of fluoridation in the U.S. years earlier.[3,4] Since the 1960s, around half of New Zealand's public water supplies have been fluoridated, fluoride toothpastes have been adopted since the 1970s, and clinical dental care gained a more preventive focus throughout this time, with the use of in-office fluorides and introduction of fissure sealants. Caries rates declined through the 1950s-1970s, but average decayed, missing, and filled teeth statistics (at least in younger children) have changed little since the 1970s (Figure 1).[5]

Dunedin, a southern city in New Zealand, has had a fluoridated water supply since 1967. Dunedin is home to New Zealand's only school of dentistry and is also the location of the Dunedin Multidisciplinary Health and Development Study, a lifecourse study of health and development in a birth, cohort of those born in Dunedin in one calendar year from April 1, 1972, to March 31, 1973.6 This study is over 50 years old and has maintained a high participation rate across 15 assessment waves, which have been conducted at birth and ages 3, 5, 7, 9, 11, 13, 15, 18, 21, 26, 38, 45, and 52 years (currently underway). The study reported on many aspects of health and development and resulted in the publication of over 1,400 scientific articles and reports.[6] Oral health has been an integral part of the study from an early stage, and some of

the initial reports from the study considered the oral health effects of community water fluoridation.

Dunedin was fluoridated before the Dunedin Study began. Some study participants resided in areas of the city that did not have fluoridation. There is a less steep socioeconomic gradient in dental caries experience among those residing in fluoridated areas than those residing in areas that were not.[7] Similar findings were observed among participants of another New Zealand cohort, called the Christchurch Health and Development Study cohort. Christchurch city only partly fluoridated at that time.[8] These cohort studies reported similar findings on child dental caries experience and community water fluoridation during childhood.5 More recently, a paper from the Dunedin Study reported associations of childhood exposure to community water fluoridation with trajectories of permanent dentition dental caries experienced into adulthood.[9] Approximately 11% of participants had a high rate of permanent dentition dental caries. Those who spent the first 5 years of life in an unfluoridated area had significantly greater risk of having a high rate of dental caries through to age 45 years (Figure 2).[9]

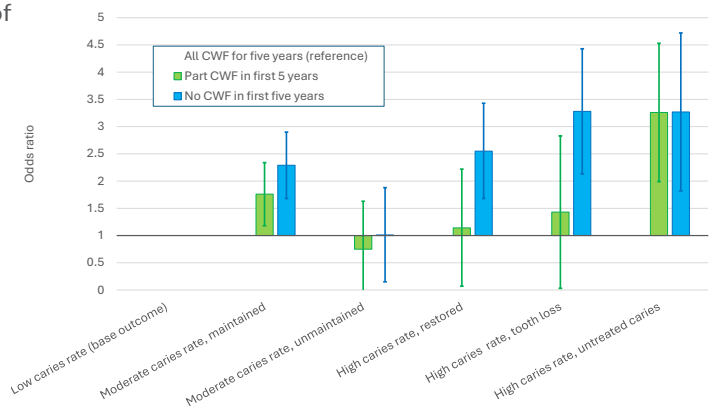

Figure 2. Trajectories of permanent dentition dental caries experience to age 45 years by fluoridation exposure in the first five years of life.[9]

Despite the oral health benefits of community water fluoridation, the intervention has many detractors. Some see community water fluoridation as irrelevant for oral health, since it does not directly address risk factors for dental caries such as poor oral hygiene and sugar consumption. Another common concern is that of undesirable control over the population, and that fluoridation is emblematic of a nanny state. This is usually coupled with concerns about other potential health effects of fluoride exposure. A large number of such claims about fluoride health effects have been made in the past, many being based on speculation or limited research.[10] However, concerns about some issues persist, particularly the association of higher levels of fluoride exposure with adverse effects on IQ.[11]

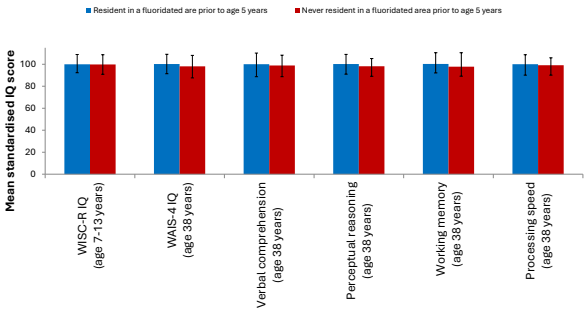

Figure 3. Fluoridation and IQ outcomes in the Dunedin Study.[13]

A 2012 review claimed fluoride to be an important neurotoxicant, based on studies of higher levels of fluoride exposure mainly due to environmental contamination.[12] This raised concerns about potential IQ effects of lower levels of fluoride exposure, such as those encountered in community water fluoridation. The first paper to investigate IQ in association with community water fluoridation was the Dunedin Study, which reported no meaningful associations of fluoride with IQ (Figure 3),[13] including after considering

total fluoride exposure.[14,15] However, this is just one study, and there is a need for other research to verify these findings. Some original studies claim association of fluoride with IQ,[16] while others report no associations with IQ or that analyses claiming such associations are flawed.[17] Some reviews claim associations while others recommend caution in the interpretation of findings.[18,19] Economic analyses similarly have opposing conclusions, claiming serious economic harm due to IQ effects[20] or the possibility of an economic benefit.[21] The U.S. National Toxicology Program recently published a monograph that reported there was insufficient data to determine if 0.7 mg/L of fluoride in water had a negative effect on children's IQ and recommended that more research is needed in order to understand potential risks.

In 2021, an Act of New Zealand Parliament was passed on fluoridation. This changed the authority for decision-making on community water fluoridation from local councils to New Zealand 's director general of health. This resulted in the issuance of several directives to local authorities, including that they must implement new fluoridation programs. The programs are expected to raise the proportion of the those receiving fluoridated water closer to two thirds of the population.

Furthermore, since new implementations of community water fluoridation were focused on more socioeconomically deprived regions of New Zealand, it is likely that the planned expansion will result in reduction of socioeconomic inequalities in access to optimally fluoridated water. In the U.S., approximately two-thirds of the population receive fluoridated water,[22] while this figure is closer to half of the population for New Zealand. However, there have been issues with performance of community water fluoridation programs in New Zealand in recent years, with a number of ostensibly fluoridated water supplies only being fluoridated some of the time.[23] This finding has implications for previous estimates and ongoing work to evaluate the effectiveness of community water fluoridation in the New Zealand population. This has created opportunities for research, given that levels of fluoridation have been used that do not match a standard threshold level.

The question remains, is community water fluoridation justified? Should water fluoridation be used to help reduce the population burden of dental caries in the interests of the common good? Should it be avoided due to unknown health risks and issues with personal choice? Can there be a balance between the utilitarian and libertarian viewpoints?

A 2014 paper argued that the Stewardship model could be applied to community water fluoridation as a public health measure, in that it helps address child dental caries, may reduce inequalities and does not require people to change their lifestyles to experience the benefits.[24]

Ongoing fluoridation programs need to be supported by an agenda of ongoing research. The oral health benefits of community water fluoridations are well-established, but is it right to claim, 'no fluoride risk?' The safety of fluoridation is not unfalsifiable. There is a need for ongoing research on new strategies to identify new ways to improve oral health, and to verify thresholds for effectiveness and safety of fluoride in drinking water.

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7. Coon E, Berndt M, Jan A, et al. Advanced Terrestrial Simulator (ATS) v0.88 (Version 0.88). Zenodo; 2020, March 25. https://doi.org/10.5281/zenodo.3727209

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[data set] 5. Oguro, M, Imahiro, S, Saito, S, Nakashizuka, T. Mortality data for Japanese oak wilt disease and surrounding forest compositions, Mendeley Data, v1; 2015. http://dx.doi.org/10.17632/xwj98nb39r.1

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All authors are to have made substantial contributions to:

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