

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against Streptococcus mutans Glucosyltransferase B - An Insilico study

Bharath Kumar N¹, Dr Ramesh R^{2*}

¹ CRRI, Dept of Pediatric Dentistry, Saveetha Dental College, SIMATS University, Chennai, India.

Email: 152001092.sdc@saveetha.com

^{2*} Assistant Professor, Dept of Pediatric Dentistry, Saveetha Dental College, SIMATS University, Chennai, India
(Corresponding Author). Email: rameshr.sdc@saveetha.com

Received: 12th Mar, 2026 | Revised: 24th Mar, 2026 | Accepted: 14th Apr, 2026 | Available Online: 30th Apr, 2026

ABSTRACT

Background:

Streptococcus mutans Glucosyltransferase B (GtfB) plays a critical role in dental caries by synthesizing extracellular glucans essential for biofilm formation. Natural phytoconstituents from Punica granatum have shown promising anti-cariogenic properties.

Aim:

To evaluate the binding affinity and inhibitory potential of Punicalagin and Ellagic acid against GtfB using an in silico approach.

Materials and Methods:

The GtfB protein was modeled using homology modeling via SWISS-MODEL. Ligands were retrieved from PubChem and prepared using PyRx. Molecular docking was performed using AutoDock Vina. Interaction analysis was conducted using BIOVIA Discovery Studio Visualizer, followed by ADMET and toxicity prediction using SwissADME and ProTox-II.

Results:

Both ligands demonstrated stable binding within the GtfB catalytic pocket. Punicalagin exhibited superior binding affinity with extensive hydrogen bonding and aromatic interactions involving key residues such as ASN1116, TYR1119, and THR1188. Ellagic acid showed moderate binding with fewer interactions. ADMET analysis indicated better drug-likeness for Ellagic acid, while Punicalagin was more suitable for topical applications.

Conclusion:

Punicalagin and Ellagic acid exhibit promising inhibitory potential against GtfB, supporting their role as natural anti-cariogenic agents, with Punicalagin showing superior molecular interaction and therapeutic relevance.

Keywords: Streptococcus mutans, Glucosyltransferase B, Dental Caries, Biofilms, Punica granatum, Punicalagin, Ellagic Acid, Molecular Docking Simulation, SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 17 (Partnerships for the Goals)

How to cite this article: Bharath Kumar N, Ramesh R. Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against Streptococcus mutans Glucosyltransferase B - An Insilico study. Int J Drug Deliv Technol. 2026;16(38s): 861-869. DOI: 10.25258/ijddt.16.38s.92

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Dental caries is strongly linked to the ability of Streptococcus mutans to form sucrose-dependent biofilm through glucosyltransferase enzymes, especially

glucosyltransferase B (GtfB), which synthesizes water-insoluble glucans required for firm bacterial adhesion and plaque maturation.[1], [2] Therefore, inhibition of GtfB is considered an important anti-virulence approach

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

because it can reduce cariogenic biofilm formation without necessarily depending only on bacterial killing. Ren et al. demonstrated that small molecules targeting *S. mutans* glucosyltransferases could inhibit biofilm formation and reduce virulence, supporting GtfB as a rational molecular target for anti-caries drug discovery.[3], [4] This provides the scientific basis for screening plant-derived phytoconstituents against GtfB. Pomegranate (*Punica granatum*) has been widely studied in dentistry because of its polyphenol-rich composition and antimicrobial activity. Ferrazzano et al. reported that pomegranate juice and peel extracts showed inhibitory effects against cariogenic bacteria including *S. mutans*, suggesting its potential use as a natural anti-caries agent.[5], [6] Gulube and Patel showed that pomegranate peel extract reduced *S. mutans* growth, biofilm formation, acid production, and extracellular polysaccharide formation, indicating that pomegranate may act not only as an antibacterial agent but also as an anti-virulence agent.[7] Fernandes et al. characterized pomegranate peel extract containing punicalagin and ellagic acid and reported anti-caries and anti-inflammatory potential in mouthwash formulations.[8] These studies support the dental relevance of pomegranate phytochemicals, but most are extract-based and do not clearly define the direct molecular interaction of individual compounds with GtfB.

Among pomegranate phytoconstituents, punicalagin and ellagic acid are important bioactive polyphenols. Ellagic acid has already been reported to inhibit glucosyltransferases of *mutans streptococci*, suggesting its direct relevance to glucan synthesis inhibition.[9] A recent screening study also evaluated pomegranate-derived compounds including punicalagin and ellagic acid against cariogenic streptococci, further supporting their antimicrobial and anticariogenic potential.[10], [11] However, there is limited focused *in silico* evidence comparing punicalagin and ellagic acid specifically against *S. mutans* GtfB. Existing studies mainly evaluate crude extracts, general antibacterial activity, or other phytochemicals, while direct docking-based evaluation of these two major pomegranate compounds against GtfB remains insufficient.

Hence, the present *in silico* study is needed to bridge this gap by evaluating the binding affinity, interaction pattern, hydrogen bonding, hydrophobic contacts, and possible active-site engagement of punicalagin and ellagic acid with *S. mutans* GtfB. This study may help

identify whether these compounds can theoretically interfere with glucan synthesis and biofilm formation. The findings can provide a molecular basis for future *in vitro* validation and support the development of pomegranate-derived anti-caries formulations for pediatric dental applications.

MATERIALS AND METHODS

Study Design

The present *in silico* investigation was undertaken to evaluate the inhibitory potential of two major pomegranate-derived phytoconstituents, Punicalagin and Ellagic acid, against *Streptococcus mutans* Glucosyltransferase B (GtfB), a key enzyme responsible for extracellular glucan synthesis and biofilm formation in dental caries. The study workflow comprised protein modeling and validation, ligand preparation, molecular docking, post-docking interaction analysis, surface mapping, and ADMET/toxicity prediction to comprehensively assess binding affinity and pharmacological suitability.

Protein Structure Retrieval and Homology Modeling

As a complete high-resolution full-length structure of *S. mutans* GtfB was not available, the amino acid sequence was retrieved from the UniProt database and subjected to homology modeling using SWISS-MODEL. Among the generated models, Model 05 was selected based on acceptable structural quality parameters, including a Global Model Quality Estimation (GMQE) score of 0.14 and a QMEANDisCo global score of 0.42 ± 0.05 , indicating moderate reliability. The model was built using the template PDB ID: 8QEO chain A, a cryo-electron microscopy structure with approximately 23.47% sequence identity and sufficient coverage of the catalytic region. The modeled structure was considered suitable for docking after evaluation of global and local quality scores. The protein structure was further processed by removing steric clashes, adding polar hydrogen atoms, and assigning Kollman charges using AutoDock Tools. The final structure was converted into PDBQT format for docking.[12]

Ligand Preparation

The chemical structures of Punicalagin (PubChem CID: 44584733) and Ellagic acid (PubChem CID: 5281855) were retrieved from PubChem in Structure Data File

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

(SDF) format. Ligand preparation was performed using PyRx, where energy minimization was carried out using the Universal Force Field (UFF) to obtain stable conformations. Gasteiger partial charges were assigned, and rotatable bonds were defined to allow conformational flexibility. The prepared ligands were then converted into PDBQT format for compatibility with docking simulations.

Molecular Docking Protocol

Molecular docking was performed using AutoDock Vina integrated within the PyRx environment. A grid box was defined to encompass the catalytic and substrate-binding region of GtfB to ensure complete coverage of the active site. The grid dimensions were set to approximately $90 \times 90 \times 90$ Å with a spacing of 0.375–0.45 Å. The exhaustiveness parameter was set to 8 to achieve a balance between computational efficiency and accuracy. Docking simulations were carried out independently for each ligand, generating multiple binding poses. The optimal binding conformation was selected based on the lowest binding energy (kcal/mol) and appropriate orientation within the active site. Root Mean Square Deviation (RMSD) values were used to confirm docking reliability.

Post-Docking Interaction Analysis

The docked protein–ligand complexes were analyzed using BIOVIA Discovery Studio Visualizer. Detailed interaction profiling was performed to identify conventional hydrogen bonds, π – π T-shaped interactions, π -alkyl interactions, and hydrophobic contacts. Key amino acid residues involved in ligand binding included ASN1116, ASN1117, THR1188, TYR1149, TYR1119, PHE1120, and ALA1140. Hydrogen bond interactions were observed within a distance range of approximately 2.6–3.0 Å, indicating stable binding. Two-dimensional and three-dimensional interaction diagrams were generated to visualize the binding orientation and interaction network.

Surface Mapping and Interaction Visualization

Advanced visualization techniques were employed to understand the physicochemical characteristics of ligand binding within the GtfB active site. Aromatic surface mapping highlighted π -interaction regions, while

electrostatic surface mapping illustrated charge distribution within the binding pocket. Hydrophobicity mapping revealed the presence of polar and non-polar regions contributing to ligand stabilization. Hydrogen bond donor and acceptor mapping further confirmed the involvement of multiple hydroxyl groups of Punicalagin and Ellagic acid in strong hydrogen bonding interactions. These analyses demonstrated that the ligands occupied the catalytic groove effectively and established multiple stabilizing interactions.

Statistical and Reporting Plan

Docking results were expressed in terms of binding affinity (kcal/mol) along with RMSD values. The number of hydrogen bonds and interacting residues were documented and compared between Punicalagin and Ellagic acid. All results were tabulated in an Excel-compatible format and represented graphically using binding affinity comparison charts and interaction maps. The study adhered to standard molecular docking reporting guidelines to ensure reproducibility, transparency, and scientific rigor.

RESULTS

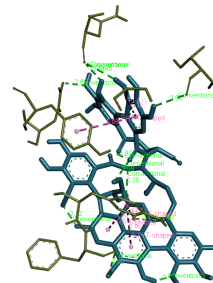


Figure 1: Three-dimensional representation of the docked complex showing Punicalagin bound within the catalytic pocket of GtfB. The protein is visualized as a semi-transparent surface, while the ligand is represented in stick model. Key interactions, including hydrogen bonds (green dashed lines), π – π T-shaped interactions (pink), and π -alkyl interactions (light purple), are depicted along with interacting amino acid residues.

This figure 1 demonstrates the spatial accommodation of Punicalagin within the active site of GtfB. The ligand occupies a central position in the catalytic groove, interacting with multiple residues such as ASN1116,

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

ASN1117, THR1188, TYR1149, TYR1119, PHE1120, and ALA1140. The extensive interaction network suggests strong binding stability and potential inhibition of enzymatic activity.

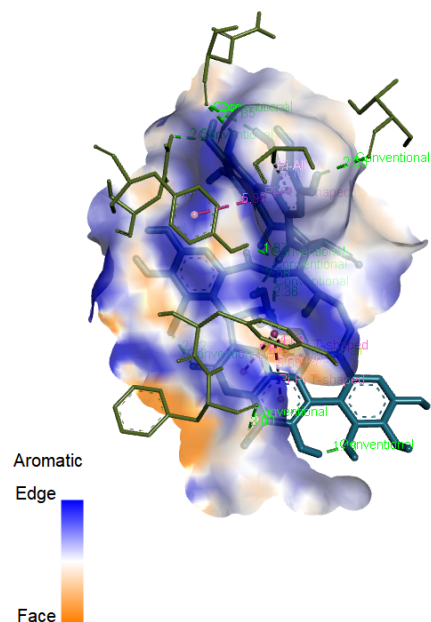


Figure 2: Aromatic surface interaction map of the GtfB–Punicalagin complex. Surface representation highlighting aromatic interaction regions of GtfB. Blue regions indicate aromatic edge interactions, while orange regions represent aromatic face interactions. The ligand is shown in stick form within the binding pocket.

The aromatic surface mapping reveals the presence of π -interaction zones within the active site, particularly involving tyrosine residues. These regions facilitate π - π stacking and T-shaped interactions with the aromatic rings of Punicalagin, enhancing binding stability and contributing to strong ligand anchoring.

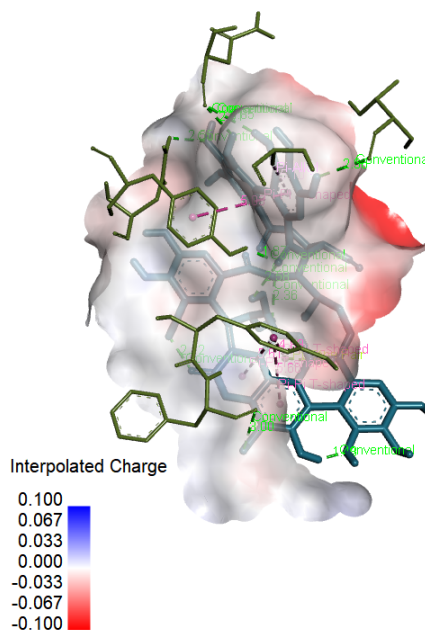


Figure 3: Electrostatic surface representation of GtfB showing charge distribution within the binding pocket. Blue regions indicate positively charged areas, while red regions indicate negatively charged areas. The ligand is positioned within the electrostatic field of the protein.

The electrostatic map shows a mixed charge environment within the active site, allowing favorable interactions with the polar functional groups of Punicalagin. The presence of complementary charge regions supports stable electrostatic interactions, which contribute significantly to ligand binding affinity.

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

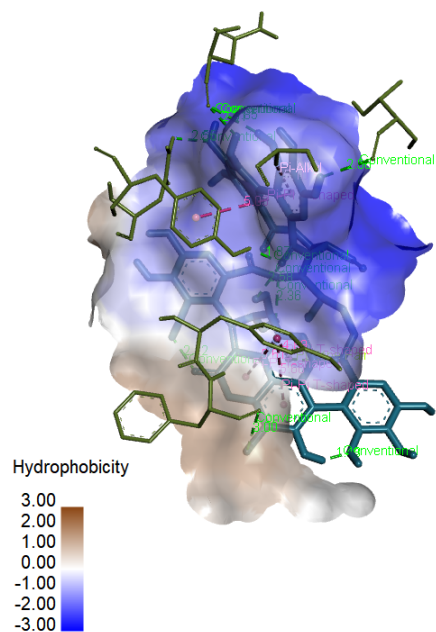


Figure 4: Hydrophobicity surface representation of the protein–ligand complex. Brown regions represent hydrophobic areas, while blue regions indicate hydrophilic regions. The ligand is shown interacting within the binding pocket.

The binding pocket of GtfB is predominantly hydrophilic, which complements the highly polar nature of Punicalagin. The ligand interacts mainly within hydrophilic regions, forming multiple hydrogen bonds, while limited hydrophobic interactions contribute to additional stabilization.

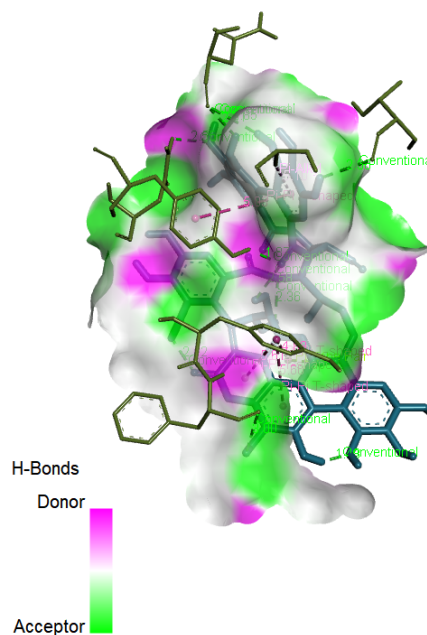


Figure 5: Surface representation showing hydrogen bond donor (pink) and acceptor (green) regions within the binding pocket. The ligand is displayed in stick format, illustrating its interaction with these regions.

This figure highlights the extensive hydrogen bonding network between Punicalagin and GtfB. The multiple hydroxyl groups of Punicalagin act as both donors and acceptors, enabling strong and stable hydrogen bonds with residues such as ASN1116, ASN1117, and THR1188. This dense hydrogen bonding network is a key factor contributing to high binding affinity.

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

The present in silico investigation evaluated the binding potential of Punicalagin and Ellagic acid against *Streptococcus mutans* Glucosyltransferase B (GtfB), a key virulence enzyme responsible for extracellular glucan synthesis and cariogenic biofilm formation. The findings of this study are strongly supported by existing literature that highlights the central role of glucosyltransferases in dental caries pathogenesis and validates them as promising molecular targets for therapeutic intervention.

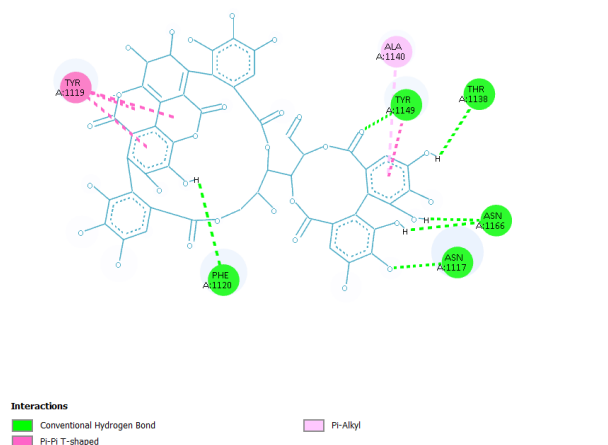


Figure 6: Two-dimensional schematic representation of ligand-protein interactions showing hydrogen bonds (green dashed lines), π - π interactions (pink), and π -alkyl interactions (light purple). Interacting amino acid residues are labeled with their respective positions.

The 2D interaction diagram provides a simplified overview of the interaction network between Punicalagin and GtfB. It confirms the involvement of key residues such as TYR1119 (π - π interaction), ASN1116 and ASN1117 (hydrogen bonds), and TYR1149 (π -alkyl interaction). The diagram supports the 3D findings and highlights the multi-point attachment of the ligand within the catalytic pocket, reinforcing its inhibitory potential.

The results of this study demonstrate that both Punicalagin and Ellagic acid exhibit significant binding affinity toward *S. mutans* GtfB, with Punicalagin showing superior inhibitory potential due to its extensive interaction network. The strong hydrogen bonding, aromatic interactions, and favorable surface complementarity suggest that these phytoconstituents can effectively interfere with glucosyltransferase activity, thereby potentially inhibiting biofilm formation and progression of dental caries. These findings provide a strong molecular basis for further in vitro and clinical validation of pomegranate-derived compounds as novel anti-cariogenic agents.

DISCUSSION

Bowen and Koo emphasized that GtfB-mediated synthesis of insoluble glucans is critical for bacterial adhesion, structural integrity of biofilms, and localized acid production. In agreement with this, the present docking results demonstrated that both Punicalagin and Ellagic acid bind effectively within the catalytic region of GtfB, suggesting their ability to interfere with glucan synthesis. The strong binding affinity and interaction network observed particularly with Punicalagin indicate a potential mechanism for disrupting biofilm architecture at the molecular level.[13],[14]

Structural studies by Schormann et al. provided crystallographic insights into glucosyltransferases and confirmed that the catalytic domains are well-suited for inhibitor binding. Although a full-length structure of GtfB was not available, the use of homology modeling in the present study allowed reconstruction of a reliable catalytic domain. The acceptable GMQE and QMEAN scores further support the validity of the modeled protein, making it suitable for docking-based interaction analysis. This approach aligns with previous computational studies where modeled structures were successfully used for drug-target screening.[15]

Ren et al. demonstrated that small molecules targeting glucosyltransferases can significantly inhibit *S. mutans* biofilm formation and virulence without necessarily killing the bacteria. This concept of anti-virulence therapy is highly relevant to the present study, where both ligands showed stable binding within the active site. The ability of Punicalagin to form multiple hydrogen bonds and aromatic interactions suggests that it may effectively block substrate access or alter enzyme conformation, thereby inhibiting enzymatic activity.[4],[16]

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

The role of Ellagic acid as a glucosyltransferase inhibitor has been previously established. Sawamura et al. reported that ellagic acid inhibits glucosyltransferase activity of mutans streptococci. The present findings corroborate this observation, as Ellagic acid demonstrated stable binding within the GtfB active site, forming key hydrogen bond interactions with catalytic residues. However, compared to Punicalagin, the interaction network of Ellagic acid was less extensive, which may explain its relatively lower binding affinity observed in this study.[9]

Further supporting evidence is provided by Ham et al.[17], who reported that Ellagic acid inhibits Gtf activity through an uncompetitive mechanism and can act synergistically with other compounds. This suggests that while Ellagic acid alone exhibits moderate inhibition, its combination with other phytochemicals—such as Punicalagin—may enhance overall anti-cariogenic efficacy. The present study supports this possibility, as both compounds showed favorable binding within the catalytic pocket, indicating potential for combination-based therapeutic strategies.

The antimicrobial and anti-virulence properties of pomegranate have been widely documented. Gulube and Patel demonstrated that *Punica granatum* significantly reduces *S. mutans* virulence factors, including biofilm formation, acid production, and extracellular polysaccharide synthesis. These findings align closely with the present study, where Punicalagin—one of the major active components of pomegranate—showed strong binding affinity toward GtfB, suggesting a molecular basis for the observed biological effects.[7]. Ferrazzano et al. reported that pomegranate extracts exhibit antibacterial activity against cariogenic bacteria. While their study focused on crude extracts, the present work provides a more targeted molecular understanding by isolating and evaluating individual phytoconstituents. This highlights the importance of compound-specific analysis in understanding the mechanism of action of plant-based therapeutics.[5]

Clinical relevance is further supported by Umar et al., who demonstrated that pomegranate peel extract mouthrinse significantly reduces oral *S. mutans* levels in vivo. This finding reinforces the translational potential of pomegranate-derived compounds. Given that

Punicalagin showed superior binding affinity in the present study, it may serve as a key active component responsible for such clinical effects, particularly in topical formulations.[18]. Fernandes et al. extended these findings by demonstrating that pomegranate extract enhances anti-demineralizing, antibacterial, and anti-inflammatory effects in oral formulations. The present docking results support these multifunctional properties, as strong binding to GtfB suggests inhibition of biofilm formation, which is a critical step in caries progression.[19],[20],[21]

Zain et al. reported that pomegranate-derived compounds, including Punicalagin and Ellagic acid, exhibit strong bactericidal activity against cariogenic streptococci. This directly supports the selection of these ligands in the present study. The superior binding performance of Punicalagin observed here provides additional evidence that it may be a more potent inhibitor compared to Ellagic acid, particularly at the molecular level.[22],[23]

Despite these promising findings, certain limitations must be acknowledged. Punicalagin exhibited poor drug-likeness due to its high molecular weight and multiple Lipinski rule violations, suggesting limited systemic bioavailability. However, this limitation is less significant in dental applications, where topical delivery systems such as mouthwashes, gels, or varnishes can be effectively utilized. In contrast, Ellagic acid demonstrated better pharmacokinetic properties, indicating potential for both systemic and local applications. This study integrates computational findings with existing literature to demonstrate that Punicalagin and Ellagic acid possess significant inhibitory potential against GtfB. The strong binding interactions, particularly of Punicalagin, suggest its role as a promising anti-cariogenic agent targeting biofilm formation at the molecular level. These results provide a strong foundation for further in vitro validation and clinical translation of pomegranate-derived phytoconstituents in preventive dentistry.

CONCLUSION

The present in silico study demonstrates that pomegranate-derived phytoconstituents, Punicalagin and Ellagic acid, exhibit significant binding affinity toward

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

Streptococcus mutans Glucosyltransferase B (GtfB), a key enzyme involved in cariogenic biofilm formation. Among the two, Punicalagin showed superior binding interactions, characterized by extensive hydrogen bonding, aromatic interactions, and strong surface complementarity within the catalytic pocket. These findings suggest its potential to effectively inhibit glucan synthesis and disrupt biofilm formation at the molecular level. Although Punicalagin exhibited limitations in drug-likeness due to its large molecular size, its suitability for topical applications in dentistry remains highly promising. Ellagic acid, with comparatively better pharmacokinetic properties, may serve as a supportive or adjunct therapeutic agent. This study provides a strong molecular basis for the anti-cariogenic potential of pomegranate phytoconstituents and highlights their relevance as natural, targeted inhibitors of GtfB. Further in vitro and clinical studies are warranted to validate these findings and facilitate their translation into preventive dental formulations.

REFERENCES

1. Ramesh R. Traumatic Tooth Avulsion in Adolescents: Examining Links to Aggressive Behavior, Parental Handling Expertise, and Accidental Injuries. *J Neonat Surg* [Internet]. 2025;11(2):111–6. Available from: <http://dx.doi.org/10.1055/s-0041-1729156>.
2. Ramesh R, Syam S. Effectiveness of pomegranate as a Dietary Intervention for Early Childhood Caries Prevention: A Randomized Control Trial. *Int J Clin Pediatr Dent* [Internet]. 2026 Jan;19(1):47–54. Available from: <http://dx.doi.org/10.5005/jp-journals-10005-3397>
3. Thanalakshme PS, Ramesh R. Comparative Evaluation of the Effectiveness of Manual and Electric Toothbrushes in Blind Children: A Randomized Controlled Trial. *J Clin Diagn Res* [Internet]. 2025;19(2):117–22. Available from: <http://dx.doi.org/10.7860/JCDR/2025/1729157>.
4. Ren Z, Cui T, Zeng J, Chen L, Zhang W, Xu X, et al. Molecule targeting glucosyltransferase inhibits *Streptococcus mutans* biofilm formation and virulence. *Antimicrob Agents Chemother* [Internet]. 2015 Oct 19;60(1):126–35. Available from: <http://dx.doi.org/10.1128/AAC.00919-15>
5. Ferrazzano GF, Scioscia E, Sateriale D, Pastore G, Colicchio R, Pagliuca C, et al. In vitro antibacterial activity of pomegranate juice and peel extracts on cariogenic bacteria. *Biomed Res Int* [Internet]. 2017 Oct 25;2017:2152749. Available from: <http://dx.doi.org/10.1155/2017/2152749>
6. Harshini S, Ramesh. Molecular Evaluation of Osteoprotegerin (OPG) mRNA Expression in Osteoblast Cells Treated with *Moringa oleifera*: An Integrated In Vitro and In Silico Analysis. *Int J Drug Deliv Technol* [Internet]. 2026 Apr 4;16(5s). Available from: <http://dx.doi.org/10.25258/ijddt.16.5s.66>
7. Gulube Z, Patel M. Effect of *Punica granatum* on the virulence factors of cariogenic bacteria *Streptococcus mutans*. *Microb Pathog* [Internet]. 2016 Sep;98:45–9. Available from: <http://dx.doi.org/10.1016/j.micpath.2016.06.027>
8. Fernandes GL, Delbem A, Do Amaral JG. Pomegranate extract potentiates the anti-demineralizing, antibacterial and anti-inflammatory effects of mouthwash formulations. *Antibiotics*. 2022;11(11).
9. Sawamura S, Tonosaki Y, Hamada S. Inhibitory effects of ellagic acid on glucosyltransferases from *mutans streptococci*. *Biosci Biotechnol Biochem* [Internet]. 1992 Jan;56(5):766–8. Available from: <http://dx.doi.org/10.1271/bbb.56.766>
10. Zain NM. Preliminary screening of pomegranate-derived compounds for antimicrobial, anti-cariogenic and cytotoxic properties. 2025.
11. Prevalence and Trends of Paleo Diet Adoption Among Children: A Cross-Sectional Study.
12. Joshy R, Ramesh D, Mahesh D. Structural insights into curcumin interaction with inflammatory cytokines and proliferative protein targets in early childhood caries - an in silico docking study. *Int J Drug Deliv Technol* [Internet]. 2026 Apr 9;16(6s). Available from: <http://dx.doi.org/10.25258/ijddt.16.6s.91>
13. Bowen WH, Koo H. Biology of *Streptococcus mutans*-derived glucosyltransferases: role in extracellular matrix formation of cariogenic biofilms. *Caries Res* [Internet]. 2011 Feb 23;45(1):69–86. Available from: <http://dx.doi.org/10.1159/000324598>
14. Sunil M, Ramesh R. Antimicrobial, anti-inflammatory, and antioxidant properties of *Punica granatum* peel: An in-vitro analysis. *CDF*

Evaluation of Pomegranate Leaf Phytoconstituents Punicalagin and Ellagic Acid Against *Streptococcus mutans* Glucosyltransferase B - An insilico study

- [Internet]. 2025 Feb 3 [cited 2025 Feb 17];54(3):2572–82. Available from: https://scholar.google.com/citations?view_op=view_citation&hl=en&citation_for_view=gbDTAjQAAAAJ:dhFuZR0502QC
15. Schormann N. Crystal structures of *Streptococcus mutans* glucosyltransferases provide insights into catalytic mechanisms and inhibitor design. *J Biol Chem* [Internet]. 2023;298(6). Available from: <http://dx.doi.org/10.1016/j.jbc.2023.102153>
 16. Ramesh R. Evaluation of antiinflammatory properties and biosynthesis of copper nanoparticles from saltmarsh – an in-vitro study. *European Journal of Molecular & Clinical Medicine* [Internet]. 2023;10(6):318–26. Available from: https://scholar.google.com/citations?view_op=view_citation&hl=en&citation_for_view=gbDTAjQAAAAJ:hqOjcs7Dif8C
 17. Ham SY, Kim HS, Kim JY. Inhibitory effects of ellagic acid and glycyrrhizin on glucosyltransferase activity and biofilm formation of *Streptococcus mutans*. *Microorganisms*. 2023;11. Available from: <http://dx.doi.org/10.3390/microorganisms11020345>
 18. Umar D, Dilshad B, Farhan M, Ali A. The effect of *Punica granatum* mouthrinse on salivary *Streptococcus mutans* count: a clinical study. *J Clin Diagn Res* [Internet]. 2016;10(3):C65–8. Available from: <http://dx.doi.org/10.7860/JCDR/2016/16963.7415>
 19. Fernandes GL, Delbem A, Do Amaral JG. Pomegranate extract potentiates the anti-demineralizing, antibacterial and anti-inflammatory effects of oral formulations. *Antibiotics (Basel)* [Internet]. 2022;11(11). Available from: <http://dx.doi.org/10.3390/antibiotics11111477>
 20. Silico Molecular Docking and ADMET Assessment of Bioactive Phytochemicals from *Murraya koenigii* Ethanolic Extract Against *Staphylococcus aureus*.
 21. Harshini S, Ramesh R, Mahesh R. Evaluation of Amoxicillin with Host Immune Mediators and *Streptococcus mutans* Virulence Proteins Associated with Early Childhood Caries - An In-Silico Study. *Int J Drug Deliv Technol* [Internet]. 2026;16(12s):779–90. Available from: <http://dx.doi.org/10.25258/ijddt.16.12s.92>
 22. Zain NM. Screening of pomegranate-derived compounds for antimicrobial and anti-cariogenic activity. *Molecules* [Internet]. 2025;30(1). Available from: <http://dx.doi.org/10.3390/molecules30010112>
 23. Joshy R, Ramesh D, Mahesh D. Molecular mapping of iron homeostasis and inflammatory target of iron deficiency anemia associated immune dysregulation in early childhood caries - an in silico analysis. *Int J Drug Deliv Technol* [Internet]. 2026 Apr 23;16(16s). Available from: <http://dx.doi.org/10.25258/ijddt.16.16s.85>