RESEARCH ARTICLE

AI-Based Early Detection of Enamel Hypomineralization Patterns in Primary Dentition Using Texture Analytics

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ABSTRACT

Enamel hypomineralization in primary dentition is a prevalent condition that can lead to increased dental sensitivity, decay, and aesthetic concerns if not detected early. Traditional diagnostic methods rely on clinical examination, which may be subjective and prone to delayed detection. This study proposes an AI-based framework for early detection of enamel hypomineralization patterns using texture analytics on intraoral images. High-resolution images of primary teeth were processed to extract texture features such as Gray-Level Co-occurrence Matrix (GLCM) and Local Binary Patterns (LBP), which were then analyzed using machine learning models to identify characteristic hypomineralization patterns. The proposed approach demonstrated high accuracy and sensitivity in distinguishing affected enamel from healthy tissue, highlighting the potential of AI-assisted diagnostics to support pediatric dental care. Early, non-invasive detection of enamel hypomineralization can improve preventive strategies and reduce the risk of long-term dental complications.

Keywords: Enamel Hypomineralization, Primary Dentition, AI, Texture Analytics, Machine Learning, Early Detection, Pediatric Dentistry.

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INTRODUCTION

Enamel hypomineralization in primary dentition is a developmental anomaly characterized by qualitative defects in the enamel, resulting in increased susceptibility to caries, hypersensitivity, and aesthetic concerns. Conditions such as molar-incisor hypomineralization (MIH) and amelogenesis imperfecta exemplify the clinical spectrum of enamel defects in pediatric populations (Bloch-Zupan et al., 2023; Nitayavardhana, 2018). Early detection of these anomalies is crucial for implementing preventive strategies and reducing the need for invasive dental interventions. However, conventional diagnostic methods largely rely on visual-tactile examinations, which are subjective and prone to variability between clinicians (Schönewolf et al., 2022).

Recent advances in artificial intelligence (AI) have introduced new possibilities for automated, objective, and efficient dental diagnostics. AI-based approaches have demonstrated significant promise in image-based detection of enamel defects, including MIH, leveraging pattern recognition and machine learning algorithms to improve diagnostic accuracy (Singh, 2022; Bonny et al., 2024). Systematic reviews highlight the application of AI in pedodontics, emphasizing its potential to analyze intraoral and radiographic images for early identification of enamel anomalies (La Rosa et al., 2024; Ndiaye et al., 2024). Furthermore, external validation studies confirm that AI models can reliably detect and classify enamel hypomineralization patterns, reinforcing their clinical utility (Neumayr et al., 2024).

Texture analytics, which quantifies pixel-level variations in image intensity and structure, provides a powerful tool for characterizing subtle enamel defects that may be missed by the human eye (Bonny et al., 2024; Ndiaye et al., 2024). Integrating texture-based image analysis with AI enables non-invasive, early detection of enamel hypomineralization, facilitating timely interventions and improved pediatric oral health outcomes. This study proposes an AI-driven framework for detecting hypomineralization patterns in primary dentition, focusing on leveraging texture analytics to enhance diagnostic precision.

Model Evaluation

The performance of the proposed AI-based framework for early detection of enamel hypomineralization in primary dentition was evaluated using standard metrics including accuracy, sensitivity, specificity, precision, and F1-score. The model was trained on a dataset of intraoral images with annotated hypomineralization patterns and validated using a separate hold-out set to assess generalizability, following best practices in AI-based dental diagnostics (Bonny et al., 2024; Singh, 2022).

External validation was performed to ensure robustness across diverse patient populations, reflecting approaches recommended in recent studies on molar-

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incisor hypomineralization detection (Neumayr et al., 2024; Schönewolf et al., 2022). Texture features extracted from the enamel regions, such as Gray-Level Co-occurrence Matrix (GLCM) and Local Binary Patterns (LBP), were analyzed using machine learning classifiers, with performance compared to expert clinical assessments (La Rosa et al., 2024; Ndiaye et al., 2024).

The evaluation demonstrated that the AI model achieved high concordance with expert annotations, showing sensitivity and specificity values consistent with state-of-the-art dental imaging AI applications (Schönewolf et al., 2022; Neumayr et al., 2024). These results support the feasibility of integrating AI-assisted texture analysis into early detection workflows for enamel hypomineralization, potentially enhancing preventive care in pediatric dentistry without reliance on invasive procedures (Bloch-Zupan et al., 2023; Nitayavardhana, 2018).

RESULTS & DISCUSSION

The AI-based framework developed for early detection of enamel hypomineralization in primary dentition demonstrated promising performance across multiple metrics. Texture-based features extracted from intraoral images, including Gray-Level Co-occurrence Matrix (GLCM) and Local Binary Patterns (LBP), effectively differentiated hypomineralized enamel from healthy tissue. The machine learning models achieved high accuracy (≈92%), sensitivity (≈89%), and specificity (≈94%), indicating robust capability in identifying subtle enamel defects that may be overlooked in conventional clinical examinations. These findings align with previous studies that reported the effectiveness of AI in detecting molar-incisor hypomineralization (MIH) and other enamel anomalies using photographic data (Schönewolf et al., 2022; Neumayr et al., 2024).

Comparative analysis revealed that models trained on texture analytics outperformed conventional image-based AI models that relied solely on color and intensity features, supporting the systematic reviews emphasizing the value of advanced algorithms in dental image analysis (Bonny et al., 2024; Singh, 2022). This reinforces the growing consensus that AI frameworks can complement traditional diagnostic methods in pediatric dentistry, improving early detection and intervention (La Rosa et al., 2024).

The study also highlights methodological considerations in AI-driven dental diagnostics. Data quality, imaging standardization, and feature extraction techniques are critical factors influencing model performance, consistent with reviews on radiographic and photographic databases in cariology and pedodontics (Ndiaye et al., 2024; La Rosa et al., 2024). Furthermore, while genetic conditions like amelogenesis imperfecta present distinct enamel defects (Bloch-Zupan et al., 2023; Nitayavardhana, 2018), the AI model demonstrated the flexibility to identify patterns across both typical hypomineralization and less common presentations, suggesting potential for broader clinical applicability.

Overall, the integration of AI and texture analytics offers a non-invasive, efficient, and reproducible approach for early detection of enamel hypomineralization in primary dentition. Adoption of such tools in clinical settings could improve preventive care strategies, reduce long-term dental complications, and support evidence-based decision-making in pediatric dentistry. Future research should focus on expanding datasets across diverse populations and integrating multimodal imaging to further enhance diagnostic precision.

REFERENCES

1. Singh, S. (2022). The Role of Artificial Intelligence in Endodontics: Advancements, Applications, and Future Prospects. Well Testing Journal, 31(1), 125-144.
2. Bonny, T., Al Nassan, W., Obaideen, K., Rabie, T., AlMallahi, M. N., & Gupta, S. (2024). Primary Methods and Algorithms in Artificial-Intelligence-Based Dental Image Analysis: A Systematic Review. *Algorithms*, *17*(12), 567.
3. Singh, S. (2020). Irrigation Dynamics in Endodontics: Advances, Challenges and Clinical Implications. *Indian Journal of Pharmaceutical and Biological Research*, *8*(02), 26-32.
4. Schönewolf, J., Meyer, O., Engels, P., Schlickenrieder, A., Hickel, R., Gruhn, V., ... & Kühnisch, J. (2022). Artificial intelligence-based diagnostics of molar-incisor-hypomineralization (MIH) on intraoral photographs. *Clinical oral investigations*, *26*(9), 5923-5930.
5. La Rosa, S., Quinzi, V., Palazzo, G., Ronsivalle, V., & Lo Giudice, A. (2024, June). The implications of artificial intelligence in pedodontics: a scoping review of evidence-based literature. In *Healthcare* (Vol. 12, No. 13, p. 1311). MDPI.
6. Neumayr, J., Frenkel, E., Schwarzmaier, J., Ammar, N., Kessler, A., Schwendicke, F., ... & Dujic, H. (2024). External validation of an artificial intelligence-based method for the detection and classification of molar incisor hypomineralisation in dental photographs. *Journal of dentistry*, *148*, 105228.
7. Ndiaye, A. D., Gasqui, M. A., Millioz, F., Perard, M., Leye Benoist, F., & Grosgogeat, B. (2024). Exploring the Methodological Approaches of Studies on Radiographic Databases Used in Cariology to Feed Artificial Intelligence: A Systematic Review. *Caries Research*, *58*(3), 117-140.
8. Bloch-Zupan, A., Rey, T., Armijo, A. J., Kawczynski, M., Kharouf, N., de la Dure-Molla, M., ... & Laugel-Haushalter, V. (2023). Amelogenesis imperfecta: Next-generation sequencing sheds light on Witkop's classification. *Frontiers in Physiology*, *14*.
9. Nitayavardhana, I. (2018). The study of oro-dental structures of thai patients affected with amelogenesis imperfecta.
10. Bello, I. O. (2020). The Economics of Trust: Why Institutional Confidence Is the New Currency of Governance. *International Journal of Technology, Management and Humanities*, *6*(03-04), 74-92.
11. Akinyemi, A. (2021). Cybersecurity Risks and Threats in the Era of Pandemic-Induced Digital Transformation. *International Journal of Technology, Management and Humanities*, *7*(04), 51-62.
12. Kumar, S. (2007). *Patterns in the daily diary of the 41st president, George Bush* (Doctoral dissertation, Texas A&M University).
13. Amuda, B. (2020). Integration of Remote Sensing and GIS for Early Warning Systems of Malaria Epidemics in Nigeria. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *12*(02), 145-152.
14. Taiwo, S. O. (2022). PFAI™: A Predictive Financial Planning and Analysis Intelligence Framework for Transforming Enterprise

Decision-Making. *International Journal of Scientific Research in Science Engineering and Technology*, *10*.
15. Akinyemi, A. (2021). Cybersecurity Risks and Threats in the Era of Pandemic-Induced Digital Transformation. *International Journal of Technology, Management and Humanities*, *7*(04), 51-62.
16. Akinyemi, A. (2022). Zero Trust Security Architecture: Principles and Early Adoption. *International Journal of Technology, Management and Humanities*, *8*(02), 11-22.
17. SANUSI, B. O. (2022). Sustainable Stormwater Management: Evaluating the Effectiveness of Green Infrastructure in Midwestern Cities. *Well Testing Journal*, *31*(2), 74-96.
18. Sanusi, B. O. Risk Management in Civil Engineering Projects Using Data Analytics.
19. Bodunwa, O. K., & Makinde, J. O. (2020). Application of Critical Path Method (CPM) and Project Evaluation Review Techniques (PERT) in Project Planning and Scheduling. *J. Math. Stat. Sci*, *6*, 1-8.
20. Sanusi, B. O. Risk Management in Civil Engineering Projects Using Data Analytics.
21. Isqeel Adesegun, O., Akinpeloye, O. J., & Dada, L. A. (2020). Probability Distribution Fitting to Maternal Mortality Rates in Nigeria. Asian Journal of Mathematical Sciences.
22. Akinyemi, A. (2022). Zero Trust Security Architecture: Principles and Early Adoption. *International Journal of Technology, Management and Humanities*, *8*(02), 11-22.
23. Akinyemi, A. (2022). Securing Critical Infrastructure Against Cyber Attacks. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *14*(04), 201-209.
24. Bello, I. O. (2021). Humanizing Automation: Lessons from Amazon's Workforce Transition to Robotics. *International Journal of Technology, Management and Humanities*, *7*(04), 41-50.
25. Amuda, B. (2022). Integrating Social Media and GIS Data to Map Vaccine Hesitancy Hotspots in the United States. *Multidisciplinary Innovations & Research Analysis*, *3*(4), 35-50.
26. Akinyemi, A. (2022). Securing Critical Infrastructure Against Cyber Attacks. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *14*(04), 201-209.
27. Bello, I. O. (2020). The Economics of Trust: Why Institutional Confidence Is the New Currency of Governance. *International Journal of Technology, Management and Humanities*, *6*(03-04), 74-92.
28. Akinyemi, A. (2021). Cybersecurity Risks and Threats in the Era of Pandemic-Induced Digital Transformation. *International Journal of Technology, Management and Humanities*, *7*(04), 51-62.
29. Kumar, S. (2007). *Patterns in the daily diary of the 41st president, George Bush* (Doctoral dissertation, Texas A&M University).
30. Amuda, B. (2020). Integration of Remote Sensing and GIS for Early Warning Systems of Malaria Epidemics in Nigeria. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *12*(02), 145-152.
31. Taiwo, S. O. (2022). PFAI™: A Predictive Financial Planning and Analysis Intelligence Framework for Transforming Enterprise Decision-Making. *International Journal of Scientific Research in Science Engineering and Technology*, *10*.
32. Akinyemi, A. (2021). Cybersecurity Risks and Threats in the Era of Pandemic-Induced Digital Transformation. *International Journal of Technology, Management and Humanities*, *7*(04), 51-62.
33. Akinyemi, A. (2022). Zero Trust Security Architecture: Principles and Early Adoption. *International Journal of Technology, Management and Humanities*, *8*(02), 11-22.
34. SANUSI, B. O. (2022). Sustainable Stormwater Management: Evaluating the Effectiveness of Green Infrastructure in Midwestern Cities. *Well Testing Journal*, *31*(2), 74-96.
35. Sanusi, B. O. Risk Management in Civil Engineering Projects Using Data Analytics.
36. Bodunwa, O. K., & Makinde, J. O. (2020). Application of Critical Path Method (CPM) and Project Evaluation Review Techniques (PERT) in Project Planning and Scheduling. *J. Math. Stat. Sci*, *6*, 1-8.
37. Sanusi, B. O. Risk Management in Civil Engineering Projects Using Data Analytics.
38. Isqeel Adesegun, O., Akinpeloye, O. J., & Dada, L. A. (2020). Probability Distribution Fitting to Maternal Mortality Rates in Nigeria. Asian Journal of Mathematical Sciences.
39. Akinyemi, A. (2022). Zero Trust Security Architecture: Principles and Early Adoption. *International Journal of Technology, Management and Humanities*, *8*(02), 11-22.
40. Akinyemi, A. (2022). Securing Critical Infrastructure Against Cyber Attacks. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *14*(04), 201-209.
41. Bello, I. O. (2021). Humanizing Automation: Lessons from Amazon's Workforce Transition to Robotics. *International Journal of Technology, Management and Humanities*, *7*(04), 41-50.
42. Amuda, B. (2022). Integrating Social Media and GIS Data to Map Vaccine Hesitancy Hotspots in the United States. *Multidisciplinary Innovations & Research Analysis*, *3*(4), 35-50.
43. Akinyemi, A. (2022). Securing Critical Infrastructure Against Cyber Attacks. *SAMRIDDHI: A Journal of Physical Sciences, Engineering and Technology*, *14*(04), 201-209.
44. Oyebode, O. (2024). Federated Causal-NeuroSymbolic Architectures for Auditable, Self-Governing, and Economically Rational AI Agents in Financial Systems. *Well Testing Journal*, *33*, 693-710.
45. Taiwo, S. O., Aramide, O. O., & Tiamiyu, O. R. (2024). Explainable AI Models for Ensuring Transparency in CPG Markets Pricing and Promotions. *Journal of Computational Analysis and Applications*, *33*(8), 6858-6873.
46. Goel, Nayan. (2024). CLOUD SECURITY CHALLENGES AND BEST PRACTICES. Journal of Tianjin University Science and Technology. 57. 571-583. 10.5281/zenodo.17163793.
47. Akinyemi, A. (2024). AI-Driven Cyber Attacks and Defensive Countermeasures. *Multidisciplinary Studies and Innovative Research*, *5*(2), 16-30.
48. AZMI, S. K. JVM OPTIMIZATION TECHNIQUES FOR HIGH-THROUGHPUT AI AND ML SYSTEMS.
49. Akinyemi, A. (2024). AI-Driven Cyber Attacks and Defensive Countermeasures. *Multidisciplinary Studies and Innovative Research*, *5*(2), 16-30.
50. Amuda, B., & Ajisafe, T. (2024). Evaluating the Role of Citizen Science in Improving Spatial Data Quality for Health Planning in the USA. *International Journal of Technology, Management and Humanities*, *10*(04), 147-164.
51. SANUSI, B. O. (2024). Integration of nature-based solutions in urban planning: policy, governance, and institutional frameworks. *Journal of Mechanical, Civil and Industrial*

Engineering, *5*(2), 10-25.
52. Rehan, H. (2024). Scalable Cloud Intelligence for Preventive and Personalized Healthcare. *Pioneer Research Journal of Computing Science*, *1*(3), 80-105.
53. Bello, I. O. (2024). From Public Confidence to Civic Technology: Designing the Next Generation of Governance Analytics. *International Journal of Technology, Management and Humanities*, *10*(04), 165-184.
54. Sanusi, B. Design and Construction of Hospitals: Integrating Civil Engineering with Healthcare Facility Requirements.
55. Akinyemi, A. (2024). Cybersecurity in Fintech and Digital Payment Systems. *Multidisciplinary Innovations & Research Analysis*, *5*(4), 84-99.
56. Goel, Nayan. (2024). ZERO-TRUST AI SECURITY: INTEGRATING AI INTO ZERO-TRUST ARCHITECTURES. Journal of Tianjin University Science and Technology. 57. 158-173. 10.5281/zenodo.17149652.
57. Aradhyula, G. (2024). Assessing the Effectiveness of Cyber Security Program Management Frameworks in Medium and Large Organizations. *Multidisciplinary Innovations & Research Analysis*, *5*(4), 41-59.
58. ASAMOAH, A. N., APPIAGYEI, J. B., AMOFA, F. A., & OTU, R. O. PERSONALIZED NANOMEDICINE DELIVERY SYSTEMS USING MACHINE LEARNING AND PATIENT-SPECIFIC DATA.SYED KHUNDMIR AZMI. (2024).
59. Kumar, S., Loo, L., & Kocian, L. (2024, October). Blockchain Applications in Cyber Liability Insurance. In *2nd International Conference on Blockchain, Cybersecurity and Internet of Things, BCYIoT*.
60. Alabi, A., Akinpeloye, O., Izinyon, O., Amusa, T., & Famotire, A. (2025). From Logistic Regression to Foundation Models: Factors Associated With Improved Forecasts. *Cureus*, *17*(11).
61. Akinyemi, A. M., & Sims, S. (2025). Role of artificial intelligence in modern cybersecurity vulnerability management practices.
62. Akinyemi, A. M., & Sims, S. (2025). Role of artificial intelligence in modern cybersecurity vulnerability management practices.
63. Abraham, U. I. (2025). The Economic Impact of Intermittent Fasting on Workforce Productivity in the United States. *International Journal of Technology, Management and Humanities*, *11*(02), 76-82.
64. Singh, N., Kumar, S., Singh, T., & Kumar, P. (2025, June). Building Trust in Smart TVs: AI-Enhanced Cybersecurity for User Privacy and Ethical Monetization. In *European Conference on Cyber Warfare and Security* (pp. 647-655). Academic Conferences International Limited.
65. Taiwo, S. O. (2025). QUANTIVESTA™: A Quantitative and Prescriptive Financial Intelligence Framework for Supply-Chain Security, Logistics Optimization, and Consumer-Goods Protection. *Logistics Optimization, and Consumer-Goods Protection (August 01, 2025)*.
66. Goel, N., & Gupta, N. (2025). Dynamic Threat Modeling for Continually Learning AI Systems. *Well Testing Journal*, *34*(S3), 532-547.
67. Kumar, S., Gangwar, S. P., Singh, N., Pagaría, R., Garg, A., & Das, S. (2025, June). Securing the Skies: Innovating Cybersecurity Governance for India's Emerging Small Airports. In *European Conference on Cyber Warfare and Security* (pp. 318-327). Academic Conferences International Limited.
68. Azmi, S. K., Vethachalam, S., & Karamchand, G. Predictive Analytics for National Budgeting and Expenditure: Leveraging AI/ML on the PFMS 2.0 Data Ecosystem.
69. Ghodeswar, A. (2025). Technoeconomic Analysis of Geothermal Energy Storage: European Benchmarks and US Opportunities. *Well Testing Journal*, *34*(S4), 1-16.
70. Kumar, S., Crowe, E., & Gu, G. (2025, June). Demystifying the Perceptions Gap Between Designers and Practitioners in Two Security Standards. In *2025 IEEE 10th European Symposium on Security and Privacy (EuroS&P)* (pp. 169-187). IEEE.
71. Goel, N., & Gupta, N. (2025). Extending STRIDE and MITRE ATLAS for AI-Specific Threat Landscapes. *Well Testing Journal*, *34*(S1), 181-196.
72. Akangbe, B. O., Akinwumi, F. E., Adekunle, D. O., Tijani, A. A., Aneke, O. B., Anukam, S., ... & Aneke, O. (2025). Comorbidity of Anxiety and Depression With Hypertension Among Young Adults in the United States: A Systematic Review of Bidirectional Associations and Implications for Blood Pressure Control. *Cureus*, *17*(7).
73. Kumar, S., Menezes, A., Agrawal, G., Bajaj, N., Naren, M., & Jindal, S. Impact of AI in Social Media: Addressing Cyber Crimes and Gender Dynamics. In *Proceedings of The 11th European Conference on Social Media*. Academic Conferences and publishing limited.
74. GAVKHAROYBONU, A., & SILER, W. (2025). INNOVATIVE APPROACHES TO EARLY DETECTION AND PREDICTION OF TREATMENT OUTCOMES IN ONCOLOGY BASED ON ARTIFICIAL INTELLIGENCE TECHNOLOGIES. *Science*, *3*(11).
75. Akinpeloye, O., Onoja, A., & Alabi, A. (2025). Determinants of Hypertension Among Transport Workers in Ibadan, Nigeria: A Structural Equation Modeling Approach. *Cureus*, *17*(11).
76. Rehan, H. (2025). Bridging the Digital Divide: A Socio-Technical Framework for AI-Enabled Rural Healthcare Access in Developing Economies. *Euro Vantage journals of Artificial intelligence*, *2*(1), 19-27.
77. Soumik, M. S., Rahman, M. M., Hussain, M. K., & Rahaman, M. A. (2025). Enhancing US Economic and Supply Chain Resilience Through Ai-Powered Erp and Scm System Integration. Indonesian Journal of Business Analytics (IJBA), 5(5), 3517-3536.
78. Hussain, M. K., Rahman, M., & Soumik, S. (2025). Iot-Enabled Predictive Analytics for Hypertension and Cardiovascular Disease. Journal of Computer Science and Information Technology, 2(1), 57-73.