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Explainable AI for Detection of Periodontal Bone Loss on CBCT Scans

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INTRODUCTION & AIM

Periodontal bone loss is a key diagnostic indicator of periodontitis severity and progression. Accurate assessment of alveolar bone levels is essential for early diagnosis, treatment planning, and monitoring disease progression. Cone-beam computed tomography (CBCT) provides high-resolution three-dimensional imaging of dental structures and is increasingly used in periodontal diagnostics. However, manual interpretation of CBCT scans can be time-consuming and is subject to interobserver variability.

Recent advances in artificial intelligence (AI), particularly deep learning, have demonstrated strong potential in automating radiographic image analysis. Despite promising accuracy, many AI systems remain difficult to interpret due to their “black-box” nature, which limits clinical acceptance.

Explainable artificial intelligence (XAI) techniques aim to increase transparency by visualizing which image regions influence model predictions.

Aim of the study:

To evaluate the performance and interpretability of an explainable AI model for automated detection of periodontal bone loss in CBCT scans and to assess its potential clinical utility.

METHOD

A deep learning framework based on a convolutional neural network (CNN) was developed for automated detection of periodontal bone loss.

Dataset
- 2,500 CBCT scans
- 1,000 patients
- Images annotated by experienced periodontists
- Ground truth labels based on alveolar bone loss presence and severity

Model architecture
- Convolutional Neural Network trained for binary classification (bone loss vs. no bone loss)

Explainability tools

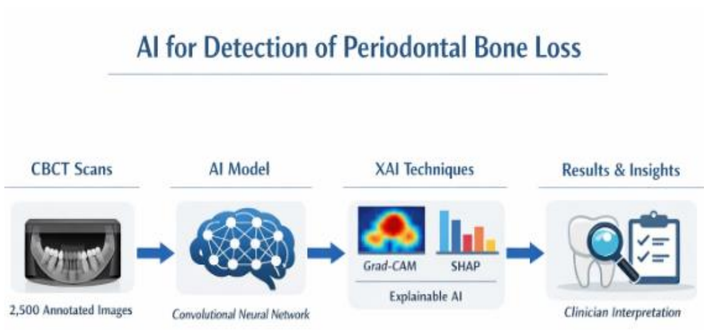
Two explainable AI methods were implemented:
- **Grad-CAM (Gradient-weighted Class Activation Mapping)**
  Generates heatmaps highlighting image regions that most strongly influence the CNN prediction.
- **SHAP (SHapley Additive exPlanations)**
  Quantifies the contribution of individual image features to the model's output.

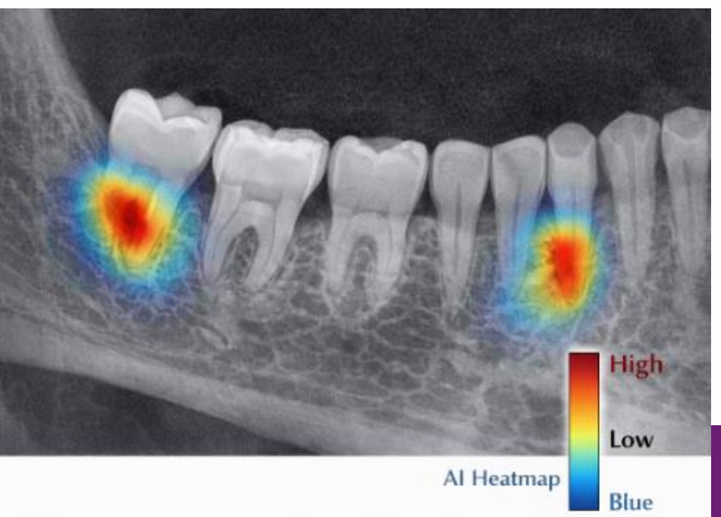
Evaluation metrics

Model performance was assessed using:
- Sensitivity
- Specificity
- F1-score
- Area Under the ROC Curve (AUC)

Clinical interpretability

Dental clinicians evaluated the usefulness of the generated heatmaps through structured questionnaires assessing:
- clarity of visualization
- diagnostic usefulness
- trust in AI-assisted decision making





RESULTS & DISCUSSION

The CNN demonstrated high diagnostic performance in detecting periodontal bone loss.

Model performance
- Sensitivity: **91%**
- Specificity: **88%**
- F1-score: **0.895**
- AUC: **0.94**

These results indicate strong discrimination between healthy and affected alveolar bone structures.

Explainability results

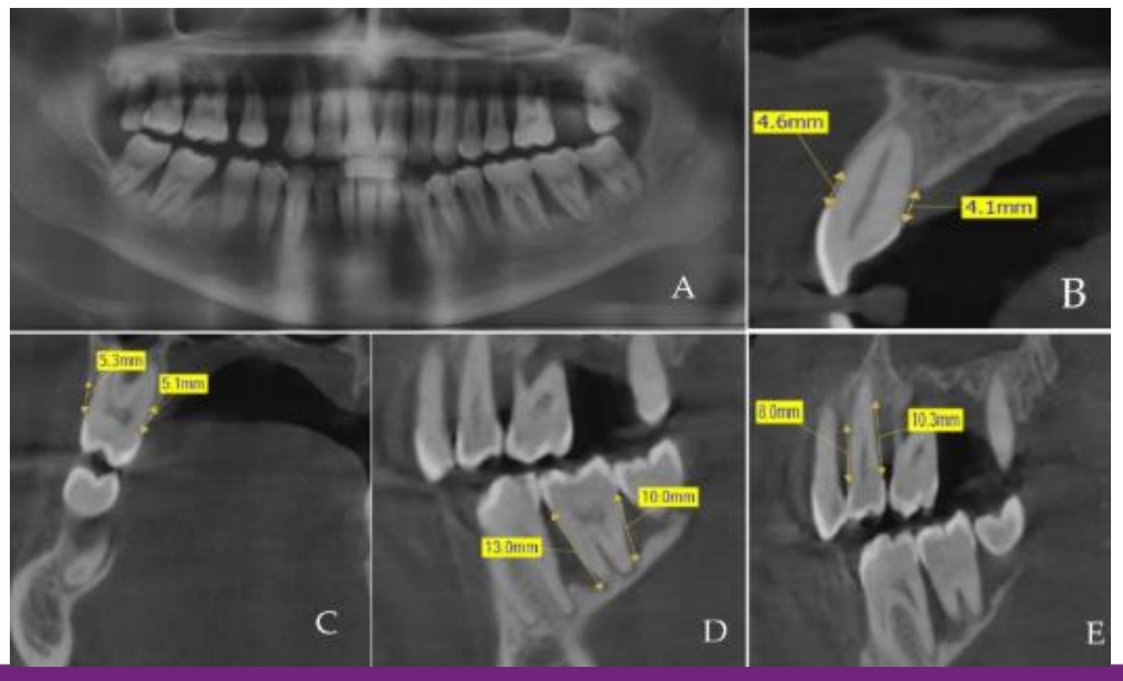
Grad-CAM and SHAP visualizations highlighted alveolar bone regions corresponding to periodontal destruction.
- Heatmaps corresponded with expert annotations in **87% of cases**
- Clinicians reported that visual explanations improved understanding of AI predictions

Clinician feedback

Survey responses indicated:
- **85% of clinicians** reported increased confidence in AI-supported diagnosis
- XAI outputs helped verify whether the model focused on clinically relevant regions
- No significant increase in image review time was observed

Discussion

The integration of explainable AI improves the transparency of deep learning models in dental radiology. Visualization of AI decision pathways allows clinicians to validate model predictions and reduces skepticism toward automated systems. This may facilitate clinical adoption of AI-assisted diagnostic tools.



CONCLUSION

Explainable artificial intelligence provides a reliable and interpretable approach for detecting periodontal bone loss in CBCT scans.

The proposed CNN model achieved high diagnostic accuracy while explainability methods such as Grad-CAM and SHAP provided meaningful visual insights into the model's decision-making process.

Integrating XAI into dental imaging workflows may:
- improve diagnostic accuracy
- reduce interobserver variability
- enhance clinician trust in AI systems
- support earlier detection of periodontal disease

FUTURE WORK / REFERENCES

Future research should focus on:
- expanding datasets with multi-center CBCT scans
- evaluating model performance across different imaging devices
- developing real-time AI decision support systems for dental clinics
- integrating AI tools directly into radiology software
- conducting prospective clinical trials to validate real-world effectiveness

Additionally, combining AI detection with automated quantification of bone loss severity could further support periodontal treatment planning.