CarioNet

Predicting Proximal Caries Progression Using Machine Learning

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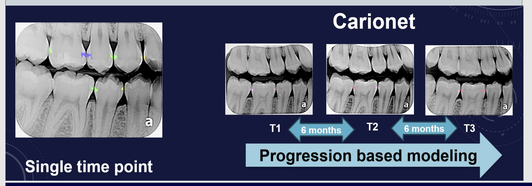
Introduction & Objective

Caries diagnosis is inconsistent even at the same risk level[1] .Treatment thresholds vary across clinicians[2] .This variability influences restorative thresholds and can shorten tooth longevity through a replacement cycle[3].

Objective: Develop and evaluate CarioNet, a machine learning model to predict 18-month proximal caries progression from longitudinal bitewing radiographs.

Clinical relevance: Early prediction of proximal caries progression supports conservative, preventive care and helps preserve tooth structure in pediatric patients.



Methods: Data Preparation

Data Selection

- ✓ **Retrospective** chart review
- ✓ **5,862** patient records
- ✓ **Age:10–17** years
- ✓ **Permanent dentition**
- ✓ **Inclusion criteria:**
- Proximal posterior caries with no prior treatment across timepoints
- Clear contacts with minimal distortion
- Asymptomatic lesions

Dataset

Phase I: Segmentation
✓ 203 bitewings from single visits

Segmentation
Defines the full lesion boundary (vs. detection)

Phase II: Progression
✓ 148 longitudinal lesion series
✓ ≥3 serial recalls

Progression
Detects stage change (e.g., E1 → D1) over 18 months

Clinician consensus

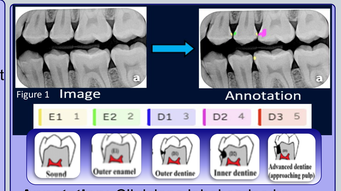
Phase I: ICDAS[4] classification
✓ **Independent review:**
- Pediatric dental resident
- Oral radiology resident

Inter rater κ = 0.65[1]

✓ **Consensus:** adjudication by third reviewer

Phase II: Reliability
✓ 3-month washout: re-classification of 15% Phase I data
✓ **Intra-rater κ = 0.775**

Annotation



Annotation: Clinicians label caries by consensus; the model learns from these annotations (Figure 1)
Phase I : 203 annotations→ segmentation
Phase II: 364 annotations→ progression prediction

Methods: Machine Learning workflow

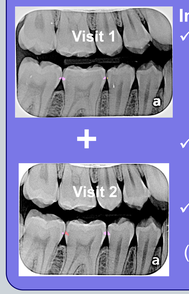
Segmentation

✓Four models tested; **U-Net++** gave best performance

✓F1=0.51 (moderate overlap between predicted and actual lesion boundaries

✓16% improvement over prior benchmark (Azhari et al, F1=0.44)

Progression



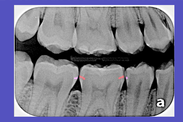
Inputs
✓ Caries classification (ICDAS) from Visit 1 and Visit 2

✓ Lesion size (From segmentation)

✓ Rate of size change: (△Size/ △Time)

Prediction

CarioNet predicted Vs Clinician`s observed Visit 3 ICDAS caries classification



✓ Output: predicted ICDAS (visit 3)
✓ Ground truth: clinician classification
✓ Evaluation: prediction vs. observation

Results

Model performance

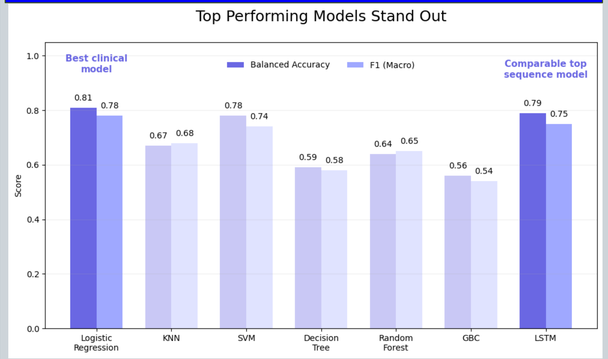


Figure 2

Performance metrics

Table 1	Model tested	Sensitivity(Recall)	PPV (Precision)
Logistic Regression		**0.81 (0.71, 0.90)**	**0.84 (0.78,0.89)**
LSTM		0.79 (0.71,0.87)	0.80 (0.65,0.96)
KNN		0.67 (0.56,0.78)	0.74 (0.63, 0.85)
SVM		0.78 (0.71, 0.84)	0.81 (0.76, 0.86)
Decision Tree		0.59 (0.47, 0.72)	0.63 (0.47,0.79)
Random Forest		0.64 (0.50, 0.79)	0.73 (0.57,0.90)
GBC		0.56 (0.39, 0.73)	0.61 (0.41, 0.80)

Table 2	Logistic Regression	Balanced accuracy	Predicted Progressed
Actual Non-progressed		**0.70 (Correct)**	0.30
Actual Progressed		0.35	**0.65 (Correct)**

Key findings:

✓ 80% non progressing caries (E2→E2)
✓ D2 and D3 combined into “advanced caries(DX)” category
✓ Stratified cross validation used to ensure balance
✓ 7 models tested: **Logistic regression** performed best (Figure 2)
✓ F1= 0.78 (balance of precision and recall) (Figure 2)
✓ Balanced accuracy= 0.81 accounts for dataset imbalance (Figure 2)
✓ Sensitivity= 0.81 (71-90%) PPV= 0.84 (78-89%) (Table 1)
✓ CarioNet accurately predicted ICDAS classification change for both progressing and non progressing lesions (Table 2)

Discussion

80% non-progressing lesions reflects clinical reality. Progressive lesions are often treated and lost to follow-up. Despite this imbalance CarioNet achieved strong performance **(Sensitivity 0.81, PPV 0.84)**

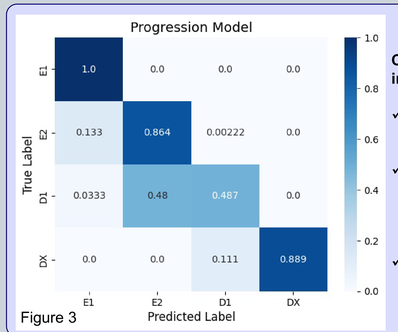


Figure 3

Confusion matrix insights (Figure 3)

✓ Highest accuracy: Early enamel and advanced dentin lesions
✓ Errors mainly between adjacent stages→ reflects inherent diagnostic uncertainty at enamel-dentin junction
✓ Greatest challenge: E2-D1 boundary

Why is E2-D1 Boundary challenging?

✓ Variability in radiographic interpretation at enamel-dentin junction
✓ Pixel size overlap between E2 and D1(Figure 4)

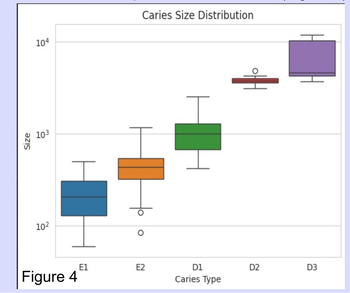


Figure 4

Conclusion

CarioNet shows that proximal caries progression can be predicted from longitudinal bitewings (Sensitivity 0.81 (0.71,0.90) , PPV 0.84 (0.78,0.89), supporting conservative care. These findings suggest prediction models may support earlier risk-based intervention and conservative management strategies in pediatric dental care.

References

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