Hierarchical Multi-Stage Deep Learning for Automated Dental Diagnosis

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Introduction & Problem Statement

- **Panoramic X-rays are the gold standard in dentistry but are dense and difficult to analyze manually.**
- **The Problem:**
  - High Complexity: A single image contains 32 teeth, overlapping structures, and subtle pathologies.
  - Human Error: Diagnosis is subjective and prone to fatigue.
  - Data Scarcity: High-quality medical annotations are expensive and rare.
- **Project Goal:**

  Build an automated AI system that mimics a dentist's cognitive workflow:
  Orient → Enumerate -> Diagnose.

The Proposed Solution (Hierarchical Pipeline)

Stage 1 (The Locator):

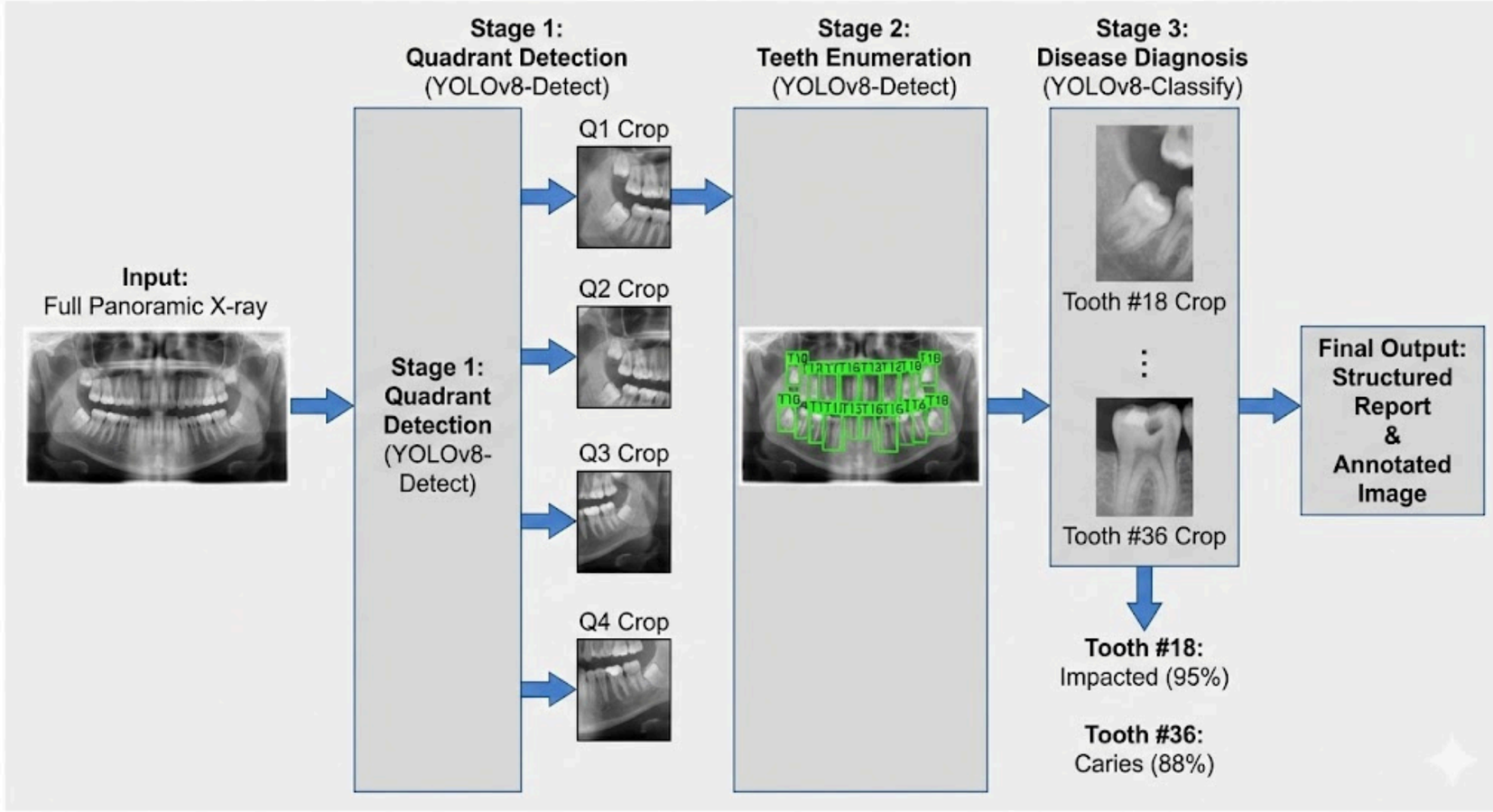
Detect Quadrants (YOLOv8-Nano).

Stage 2 (The Indexer):

Detect & Number Teeth 1-32 (YOLOv8-Small).

Stage 3 (The Doctor):

Classify Diseases on individual tooth crops (YOLOv8-Classify).



The Proposed Solution (Hierarchical Pipeline)

The Limitation:

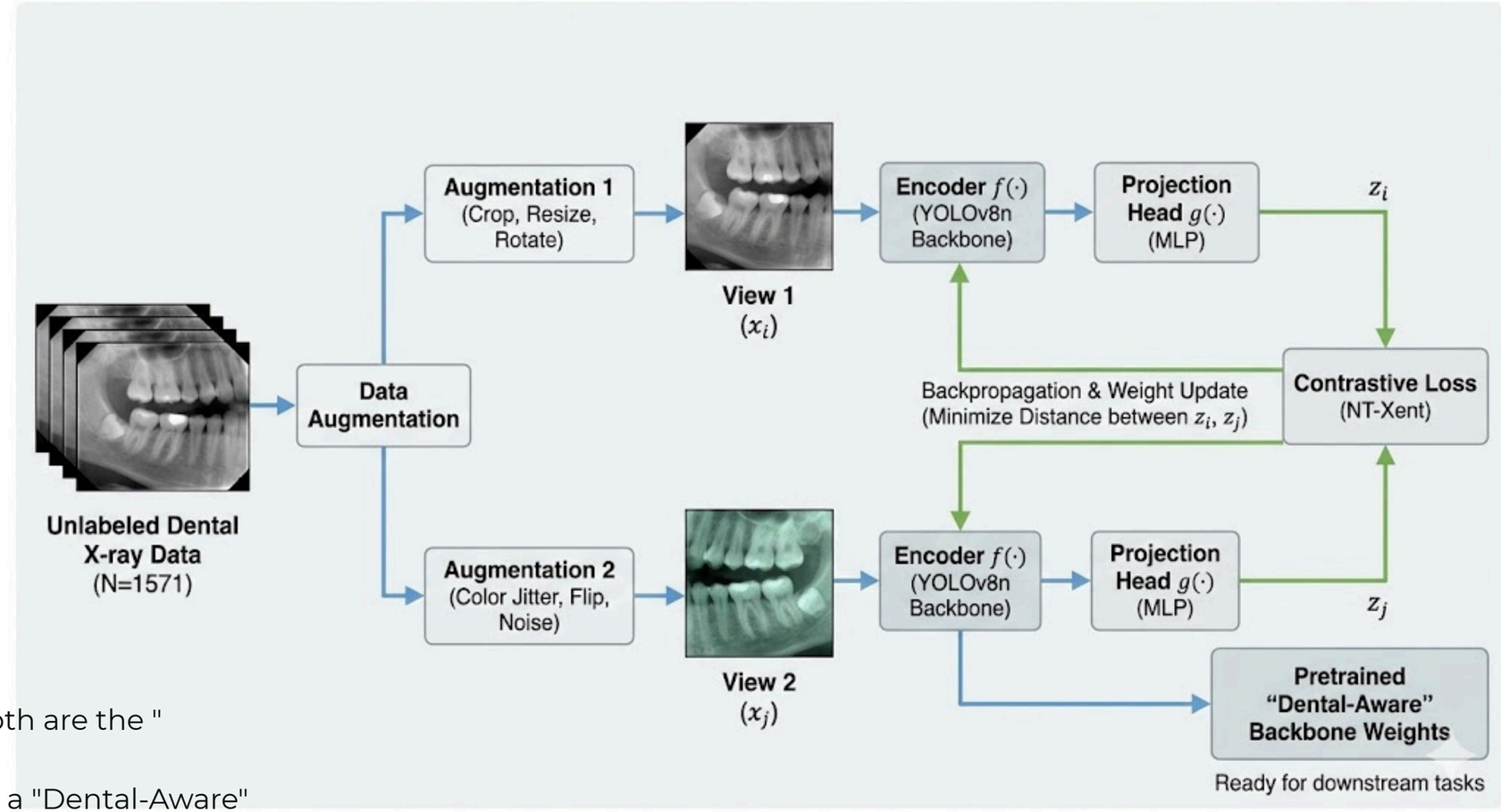
Standard models use "COCO Weights" (trained on cats/dogs/cars), which transfer poorly to X-rays.

Our Approach:

Utilize the 1,571 unlabeled images provided in the dataset.

Method (SimCLR):

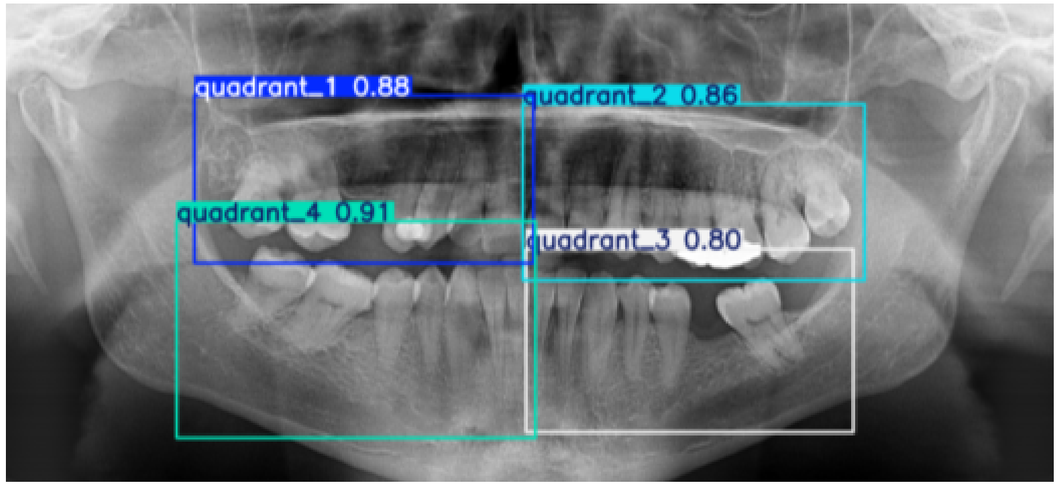
- Extracted the CSP-Darknet Backbone.
- Trained it to recognize that two different augmented views of the same tooth are the " same object."
- **Outcome:** Created yolov8n_dentex_ssl.pt – a "Dental-Aware" backbone used to initialize our models.



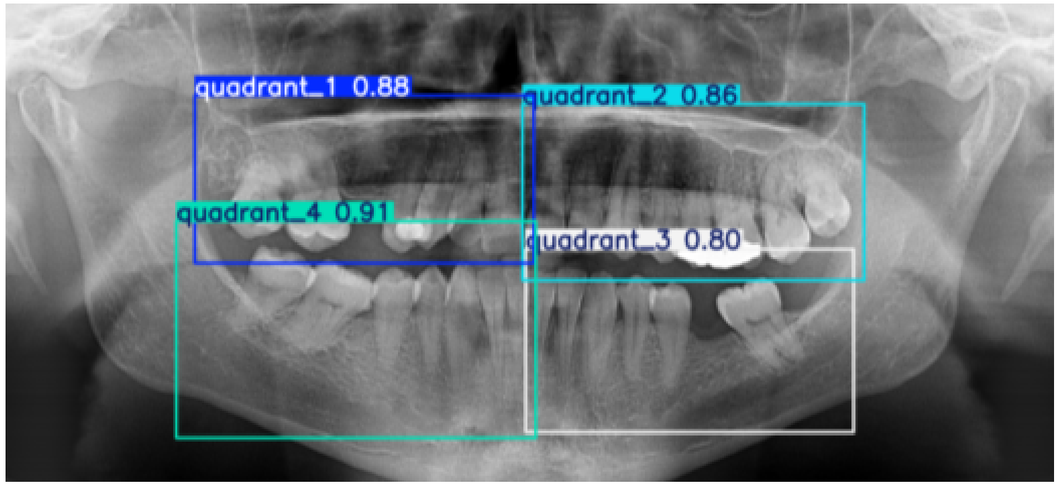
Stage 1 – Quadrant Detection

- **Goal:** Normalize the input. Break the complex panoramic view into 4 standardized regions.
- **Input:** Full Panoramic X-ray.
- **Output:** 4 Bounding Boxes (Q1, Q2, Q3, Q4).
- **Result:** robust detection that handles different jaw shapes and alignments.

With Yolo’s Backbone Pretraining



Without Yolo’s Backbone Pretraining



Stage 2 – Teeth Enumeration

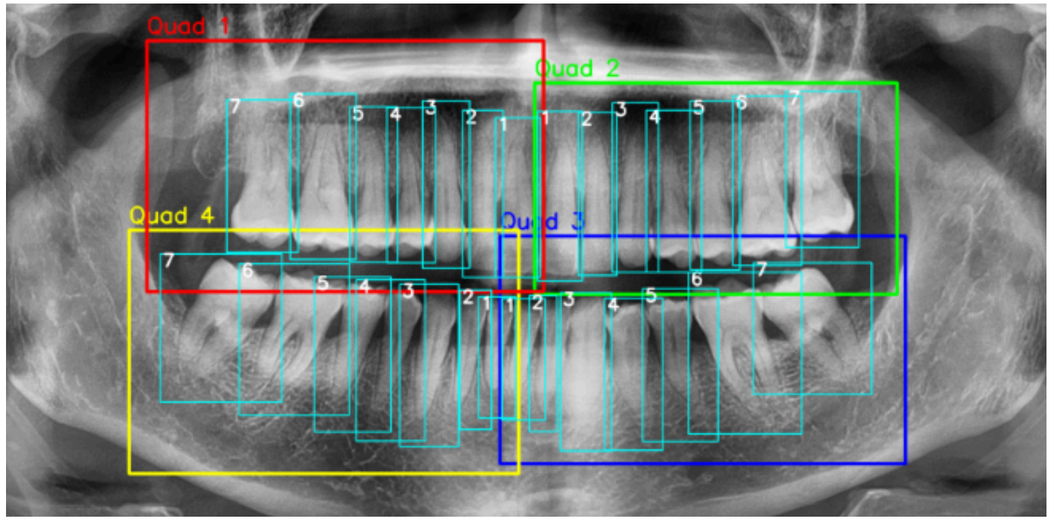
- **Goal:** Assign a unique ID (FDI Notation 11–48) to every tooth.
- Input: Cropped Quadrant images.
- **Strategy:** Treated every tooth (e.g., Tooth 11 vs. Tooth 21) as a unique class (0–31).
- **Results:**

  mAP50: ~96% (Outstanding).

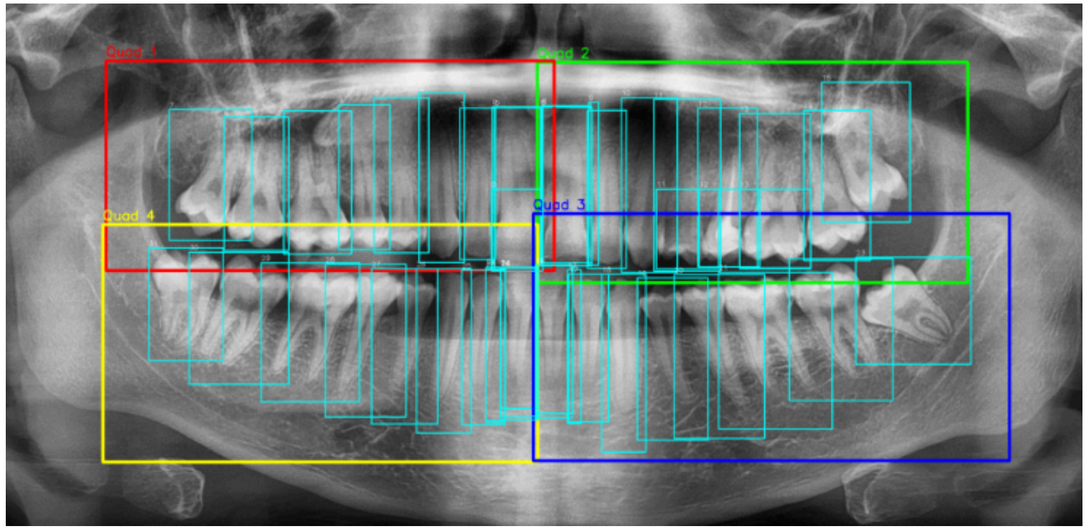
  Wisdom Teeth Accuracy: ~95% (Solved the hardest class).

  Precision/Recall: >92%.

With Yolo's Backbone Pretraining



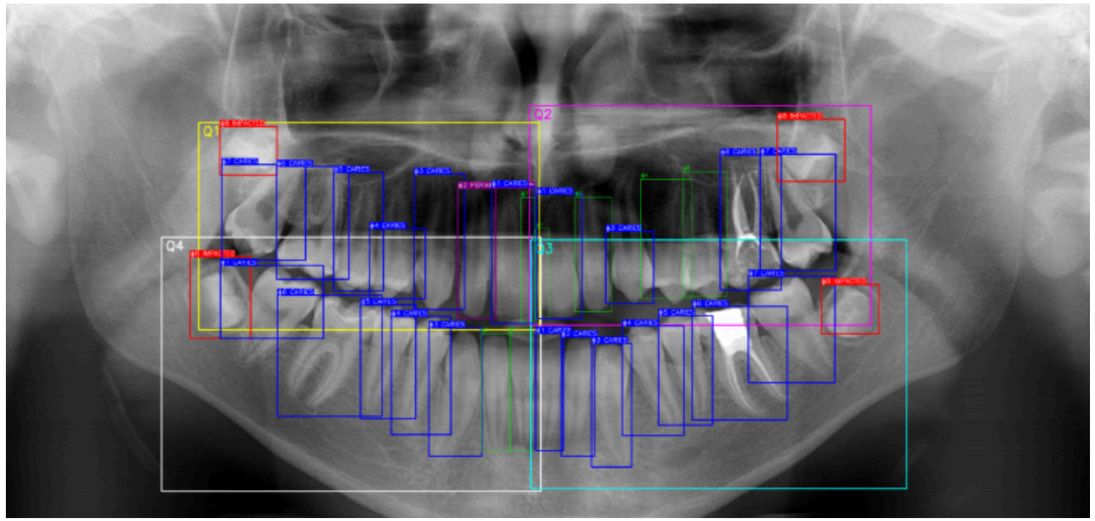
Without Yolo's Backbone Pretraining



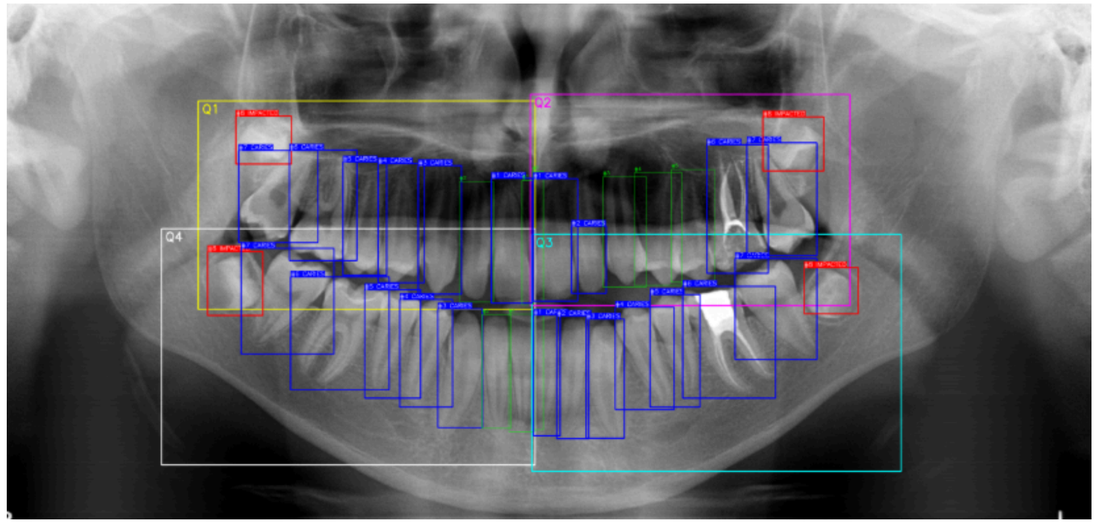
Stage 3 – Disease Diagnosis

- **Goal:** "Biopsy" each tooth crop to classify pathology.
- **Classes:** Impacted, Caries, Deep Caries, Periapical Lesion, Healthy.
- **Challenge:** Overfitting due to small disease dataset.
- **Solution:** Used the SSL-pretrained backbone to improve generalization.
- **Accuracy:** Achieved ~85% baseline accuracy with robust validation performance.

With Yolo's Backbone Pretraining

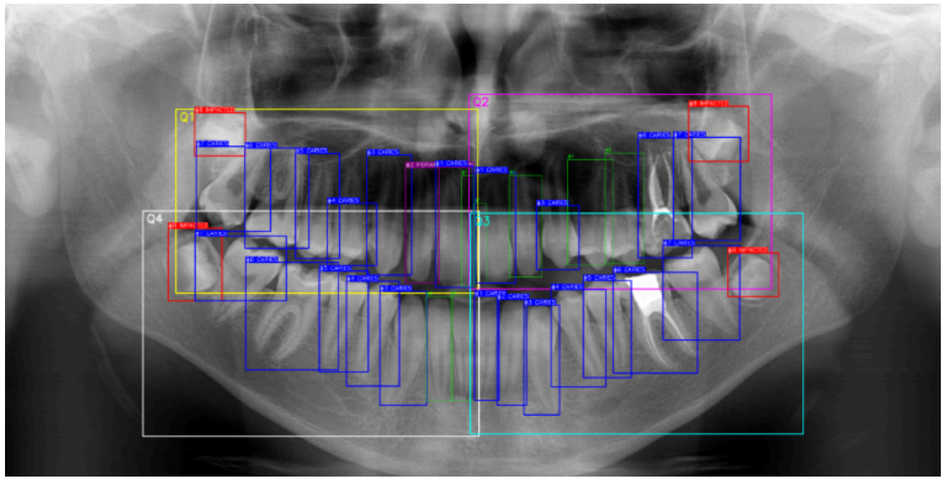


Without Yolo's Backbone Pretraining



Conclusion

- **Summary:** We successfully engineered a robust, hierarchical CAD system.
- **Key Takeaway:** Integrating Self-Supervised Learning on unlabeled data significantly boosts performance in medical domains where labeled data is scarce.
- **Impact:** This system provides a "Second Opinion" for dentists, potentially reducing missed diagnoses and standardizing patient care.



Thank you