

AutoSpline: Automated Dental Arch Curve Detection from CBCT A Geometric and Learning-Based Platform

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PAPER #30



INTRODUCTION & MOTIVATION

Paired CBCT and panoramic radiographs (PX) from the same patient are scarce within public databases. However, public CBCT datasets can supply the 3D source, then curved planar reformation (CPR) synthesizes a matching PX without another exposure. Each image remains paired with its source CBCT. CPR needs a patient-specific arch spline, yet **manual tracing limits scale**. Previous **centroid-based geometric methods** fit splines through tooth-label centers. Missing teeth remove these anchors, and metal artifacts can shift them, pulling the curve into bone or soft tissue and distorting the panorama.

AutoSpline automates this step to enable **mass creation of paired CBCT–PX datasets**. Our ultimate goal is to use paired 2D radiographs to **reconstruct 3D CBCT anatomy**.

CBCT DATASET & BENCHMARK

ToothFairy2 provides 3D cone-beam CT volumes with voxelwise FDI tooth-number labels and jawbone masks. The **411-case source cohort** includes incomplete dental arches and extensive restorations.

DENTAL CHARACTERISTICS · SOURCE COHORT (n = 411)

Missing teeth	<div><div></div></div>	95.9% (394)
Missing key teeth*	<div><div></div></div>	91.0% (374)
Implant labels	<div><div></div></div>	93.2% (383)
Crowns	<div><div></div></div>	38.0% (156)
Bridges	<div><div></div></div>	19.2% (79)

Jaw completeness: both jaws 163; lower only 247; neither 1. The benchmark contains **163 expert splines** from complete-jaw cases, evaluated with five-fold stratified cross-validation.

*Key teeth: first six per quadrant; at least one missing. Categories overlap. Jaw coverage differs from dentition. Age and sex distributions are not reported.

EXPERT ANNOTATION & SPLINE QUALITY

Select a representative axial slice

One dental expert reviewed each CBCT in 3D Slicer and chose an axial slice that best represented the dental arch.

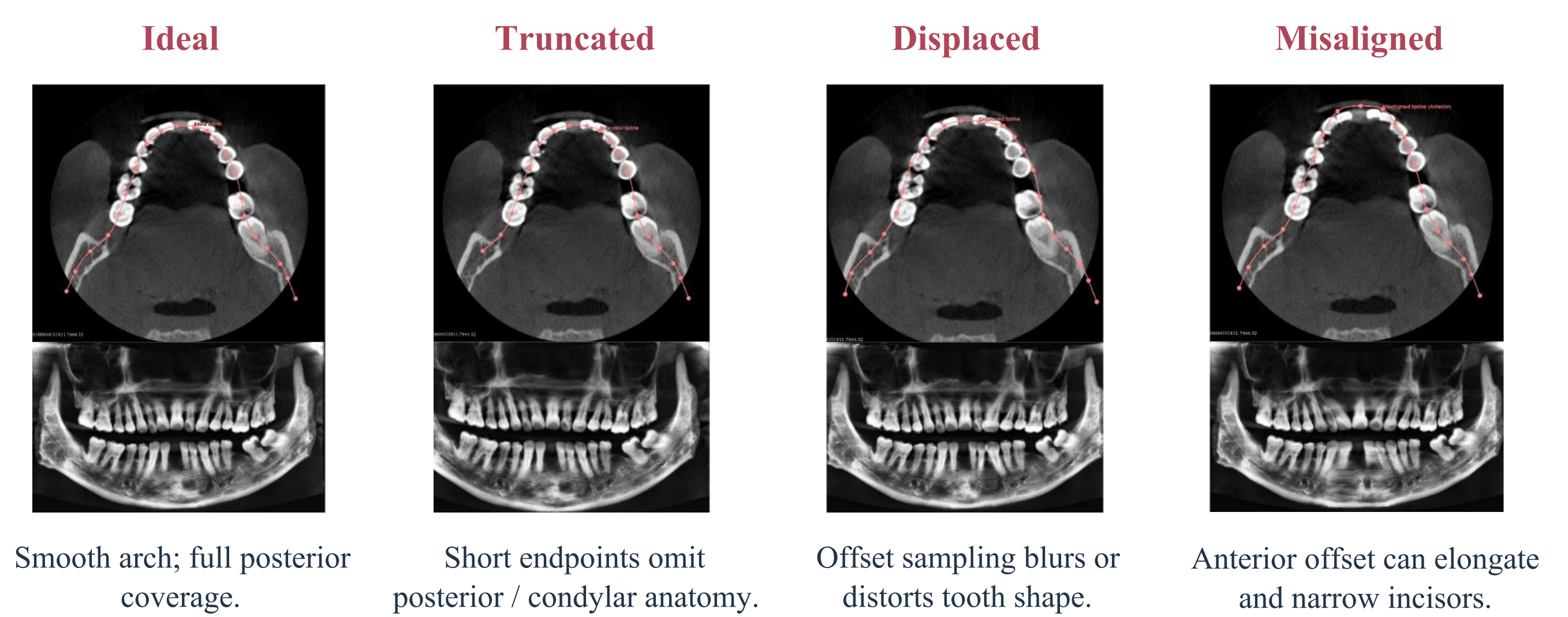
Trace the anatomy, including the posterior arch

The expert placed control points centered between both jaw bones and extended the curve past the condyles to preserve posterior coverage.

Export a reproducible geometric reference

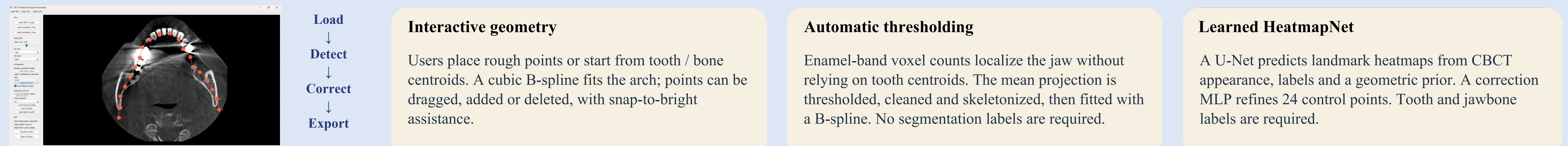
FCSV files store the 3D landmark coordinates. For learning, each reference curve is resampled to 24 points on a 256 × 256 canvas.

The spline sets the CPR focal trough: a 5 mm slab sampled along the arch. Poor placement changes the anatomy included in the synthetic PX.



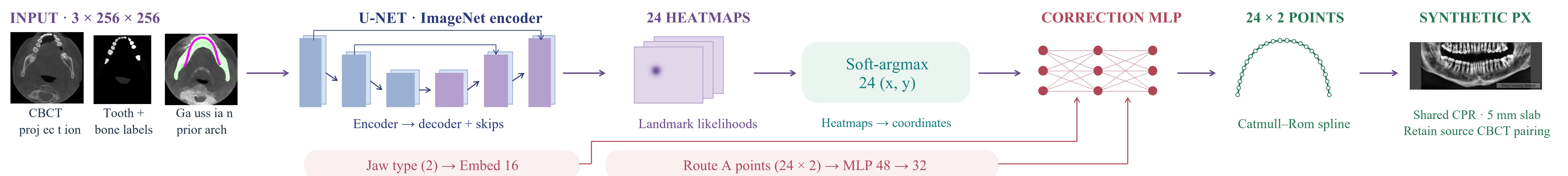
PUBLIC GUI · THREE COMPLEMENTARY DETECTION METHODS

We built AutoSpline as a **free, open-source GUI**. Users load a CBCT, choose a detection method, inspect and edit the control points, then export FCSV landmarks or synthesize a panoramic image.



HEATMAPNET · ILLUSTRATED LEARNING PIPELINE

Route C detail · schematic representations



RESULTS · GEOMETRY & IMAGE QUALITY

Route	MCD ↓	SSIM ↑	PSNR ↑	Time
A Geometric	5.79	0.418	10.44	Interactive
B Thresholding	3.24	0.453	10.86	~6 s
C HeatmapNet	5.06	0.542	12.81	~10 s

Full-set comparison. MCD: distance between 100 matched curve samples (mm); PSNR: dB. CPU time includes detection + CPR per jaw.

HELD-OUT CV · MCD (mm)

Residual regr.	17.2
PolyLaneNet	8.2
BézierLaneNet	8.1
HeatmapNet	4.3

4.3 mm · 47% below BézierLaneNet



Case F_018. SSIM / PSNR compare synthetic PX with the expert-spline CPR reference.

CONCLUSION & NEXT STEPS

Take-home. AutoSpline supports scalable CBCT–PX synthesis. Thresholding gives the lowest curve error; HeatmapNet gives the best panoramic similarity (SSIM 0.542; +20% vs. B).

Why metrics differ. CPR also depends on depth and posterior coverage, so lower MCD need not yield a better panorama.

Limitations. HeatmapNet requires segmentation labels; one expert supplied the references. Synthetic PX targets cannot establish agreement with acquired radiographs. Difficult cases can distort incisors.

Next steps. Optimize HeatmapNet for rendered panoramic quality, expand expert annotations, and develop a label-free variant. Extend synthesis to cephalograms and study 3D CBCT reconstruction from paired 2D radiographs.

