

Artificial Intelligence Segmentation Errors in Implant Planning Software Programs: An Overview

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BACKGROUND

Static computer-assisted implant surgery (s-CAIS) relies on the accurate integration of CBCT imaging and intraoral scans to transfer a prosthetically driven implant position to the surgical site using a static surgical guide. **Segmentation is a critical step in this digital workflow**, as errors may compromise guide fit and implant positioning, potentially leading to clinical complications. Although **AI-driven automated segmentation**, particularly deep-learning models such as **U-Net and related architectures**, has been incorporated into implant planning software to improve efficiency and accuracy, **clinically relevant segmentation errors persist**.

OBJECTIVE

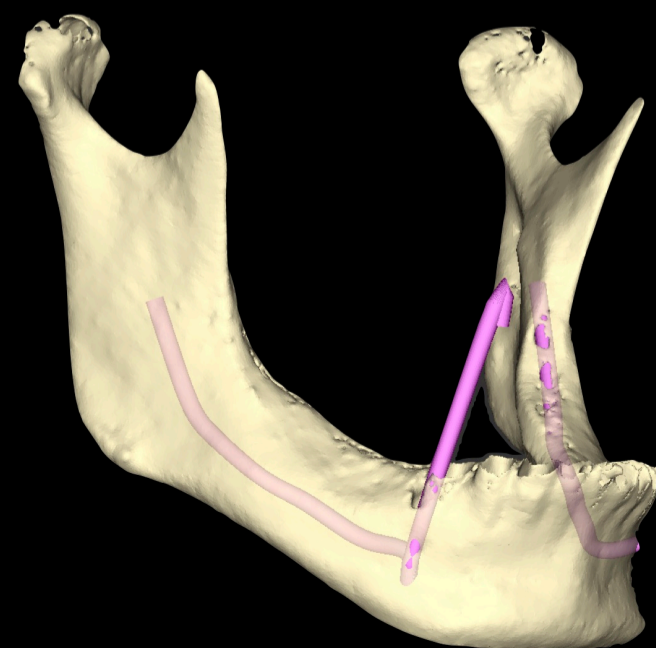
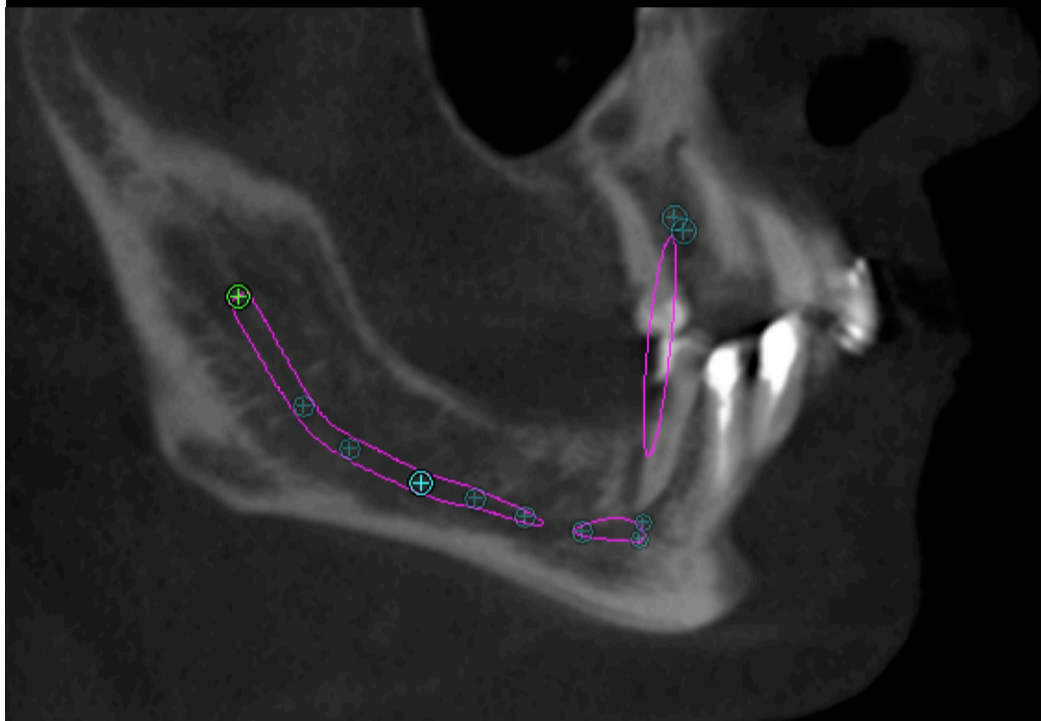
To **evaluate the accuracy and limitations of AI-based segmentation** in dental implant planning software and **identify** common sources of **segmentation errors**.

METHODS

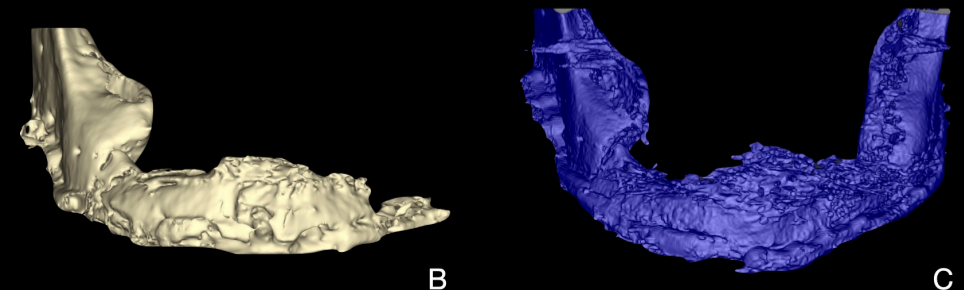
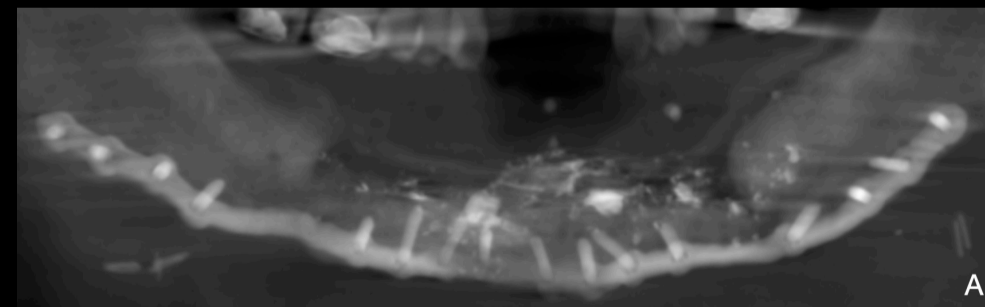
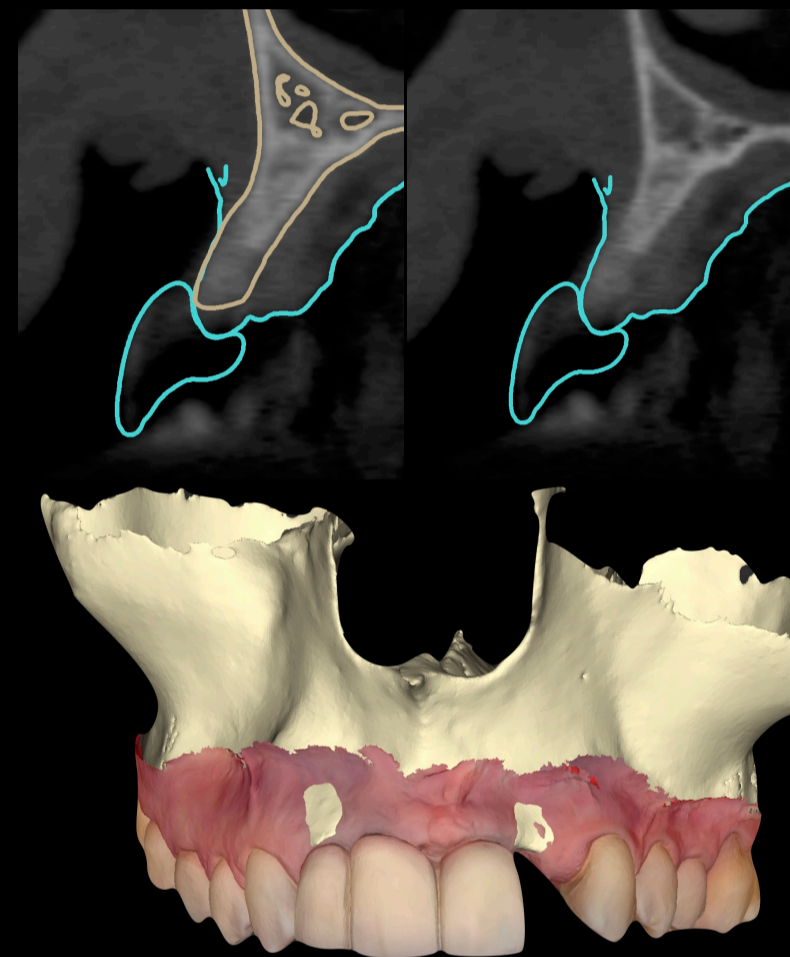
This study was conducted as a narrative literature review and educational practice overview based on direct exploration of dental implant planning software. **AI-based segmentation error patterns and available editing tools were qualitatively assessed across four systems** (coDiagnostiX, BlueSkyPlan, Atomica, and Relu) for illustrative purposes only, without formal performance comparison.

TYPE OF SEGMENTATION ERRORS

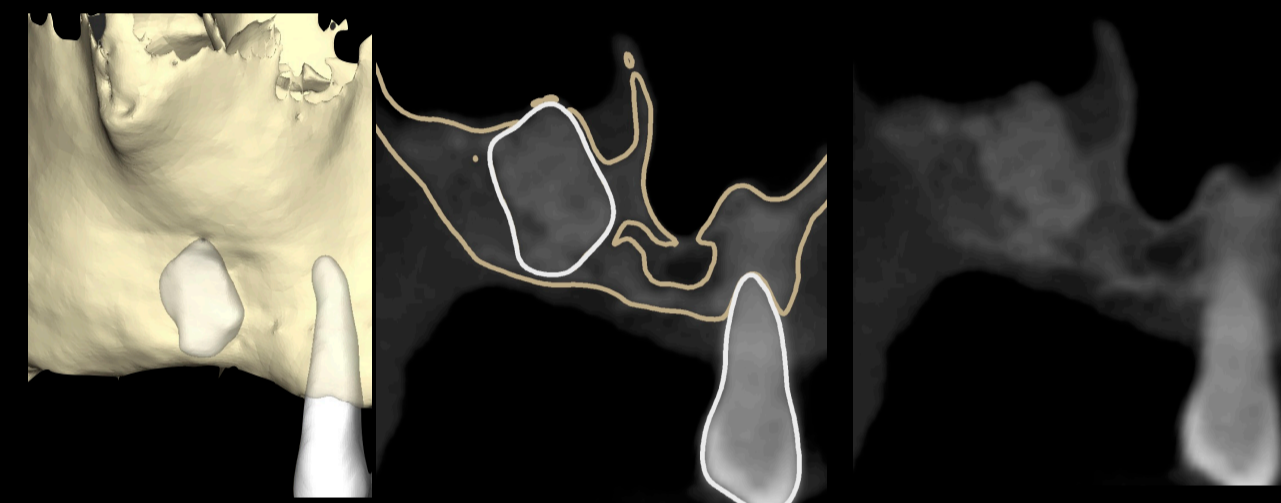
Boundary Errors



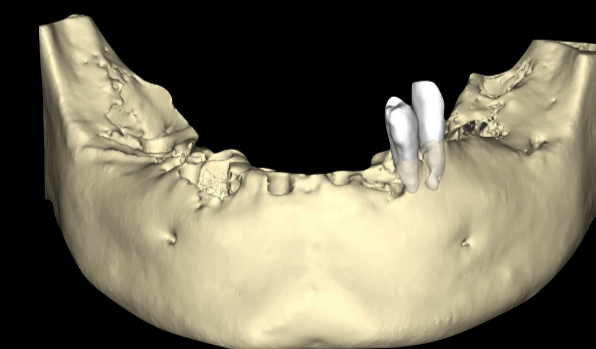
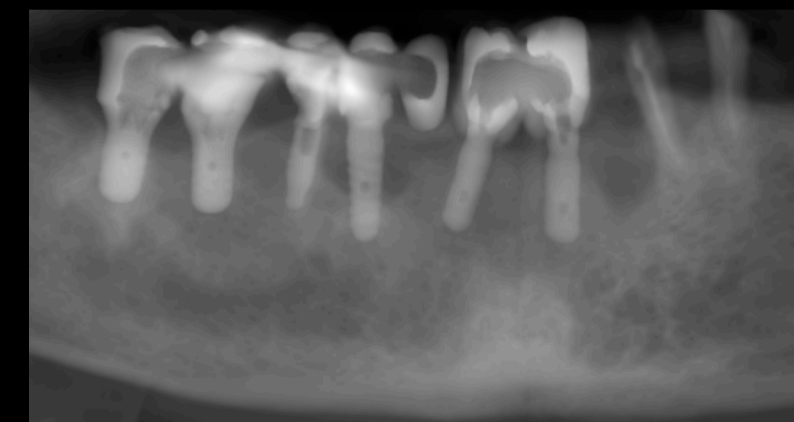
Over-Segmentation and Under-Segmentation



Misidentification or Non-Identifiability of Anatomical Landmarks and Implants



Misidentification of a bone graft by tooth



Un-identification of implants

Partial Volume Effect (PVE)

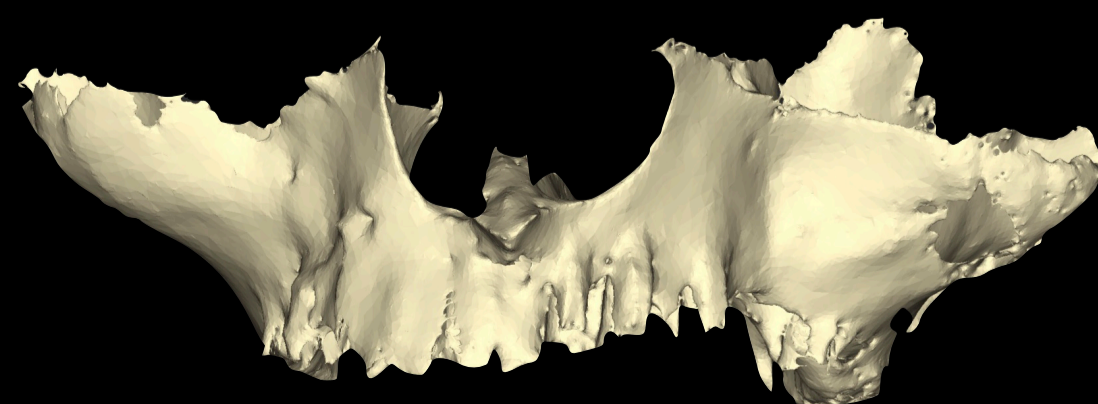
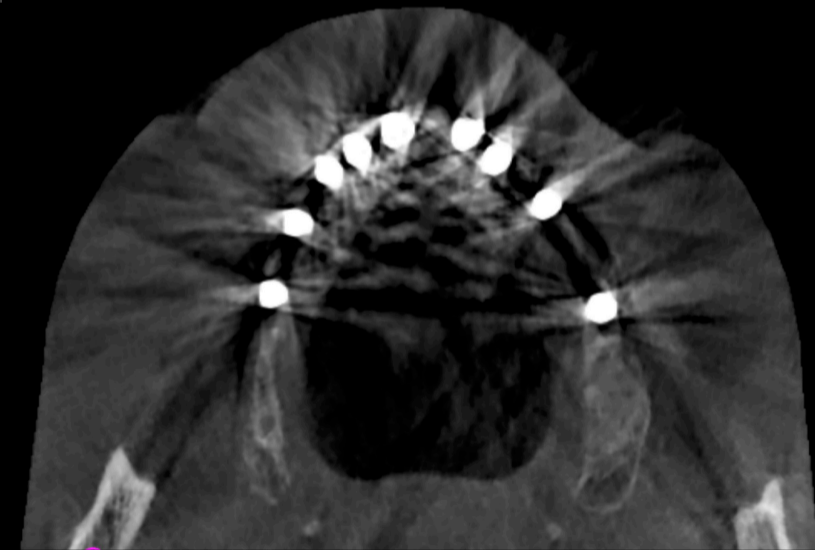
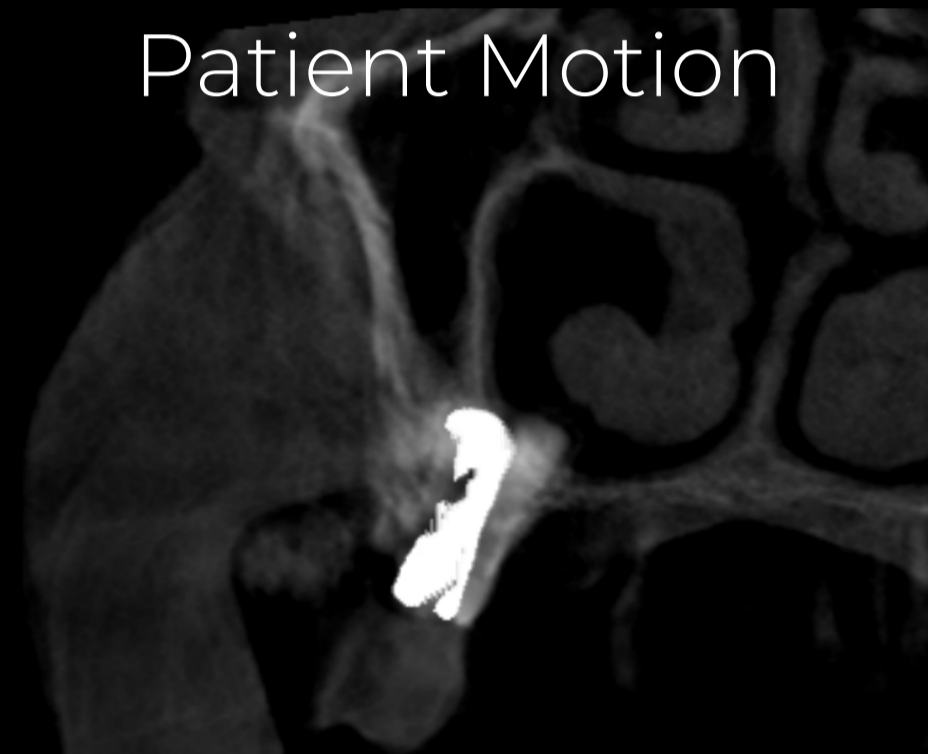
Partial volume effects occur when a voxel contains multiple tissue types, resulting in averaged intensity values and blurred boundaries leading to misclassification during segmentation and affect diagnostic accuracy or implant planning.

Imaging Limitations

Artifacts



Patient Motion

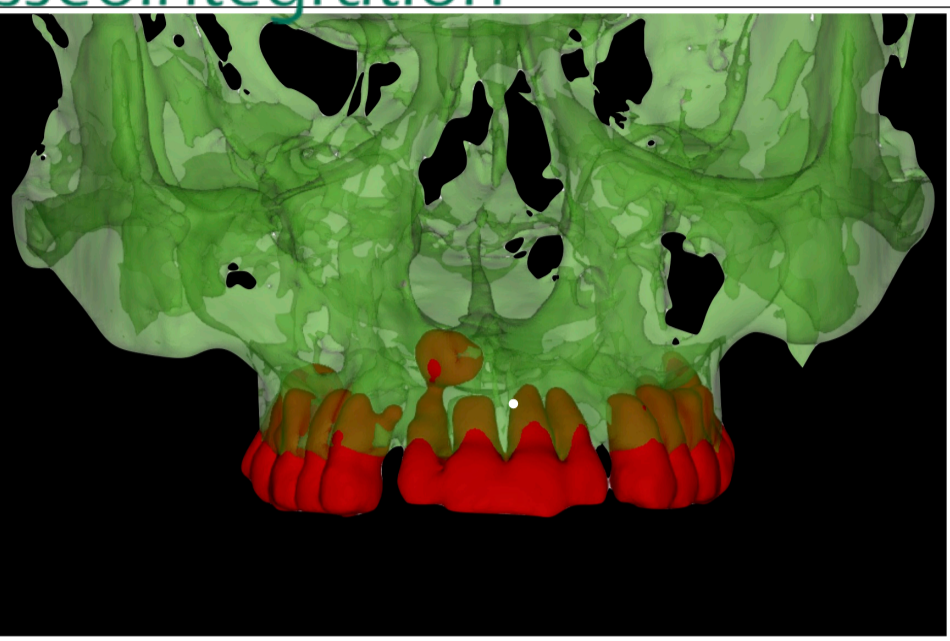


Algorithmic Limitations

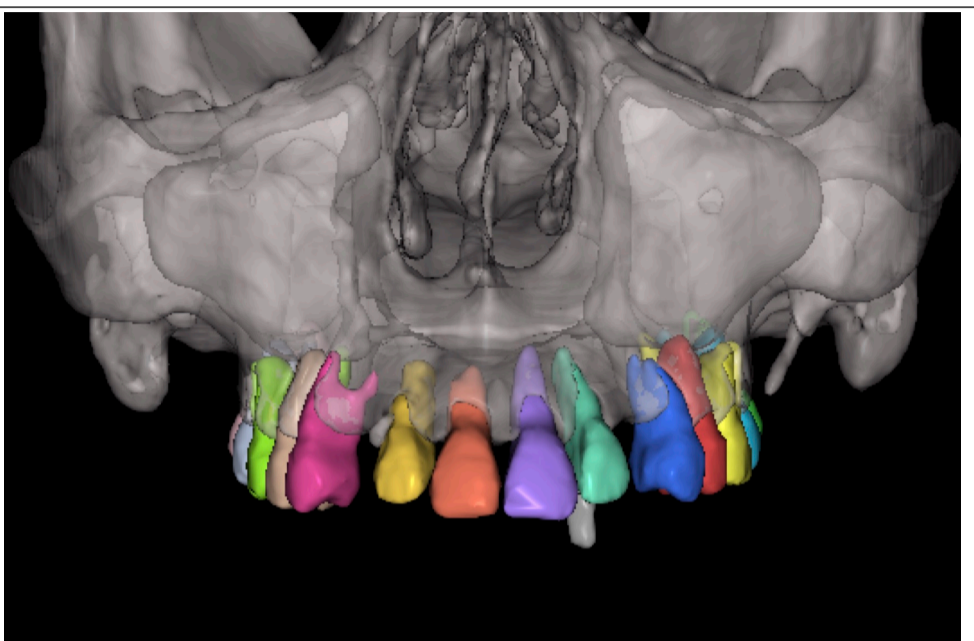
Despite their sophistication, **AI algorithms are limited by training datasets** that may not reflect the full diversity of patient anatomies, leading to reduced generalizability and **errors** in complex cases. Dataset bias further constrains algorithm accuracy.

Human Factors

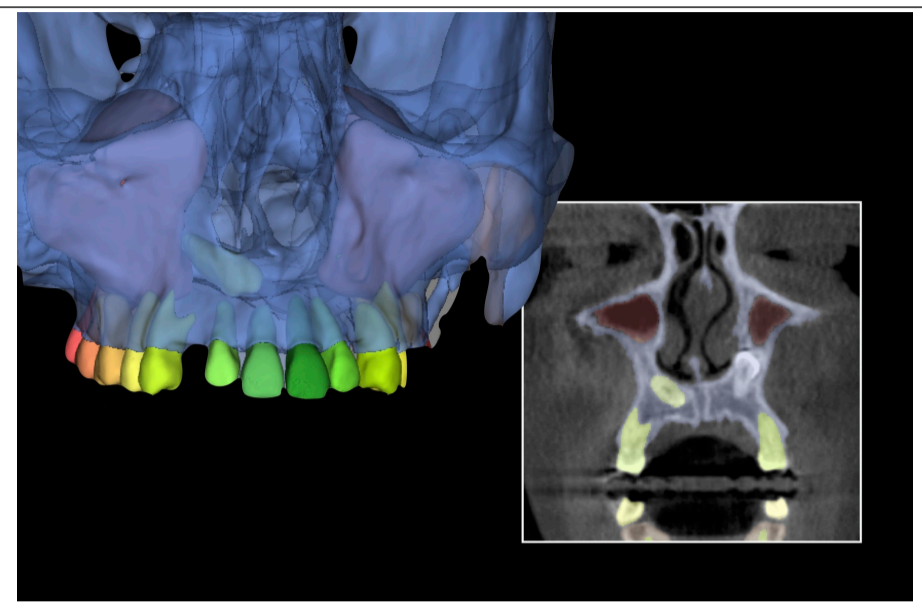
Human intervention is essential in segmentation, as clinician **experience** and **familiarity with the software directly influence accuracy**. Failure to identify subtle anatomical features or properly validate algorithm outputs may compromise treatment planning.



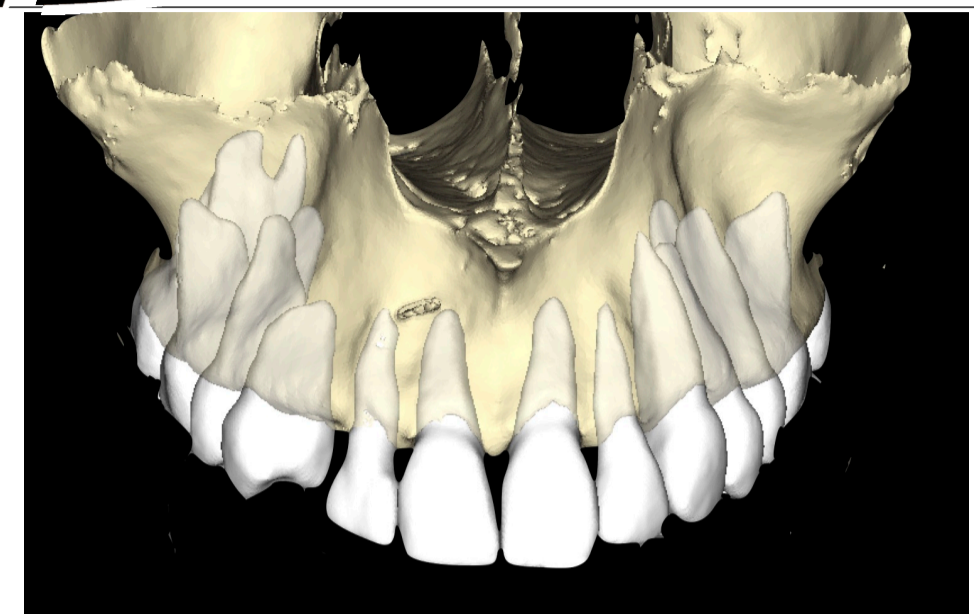
Atomica software showing the detection of the right impacted canine crown only.



BlueSkyPlan showing the inability of algorithm to spot impacted canines.

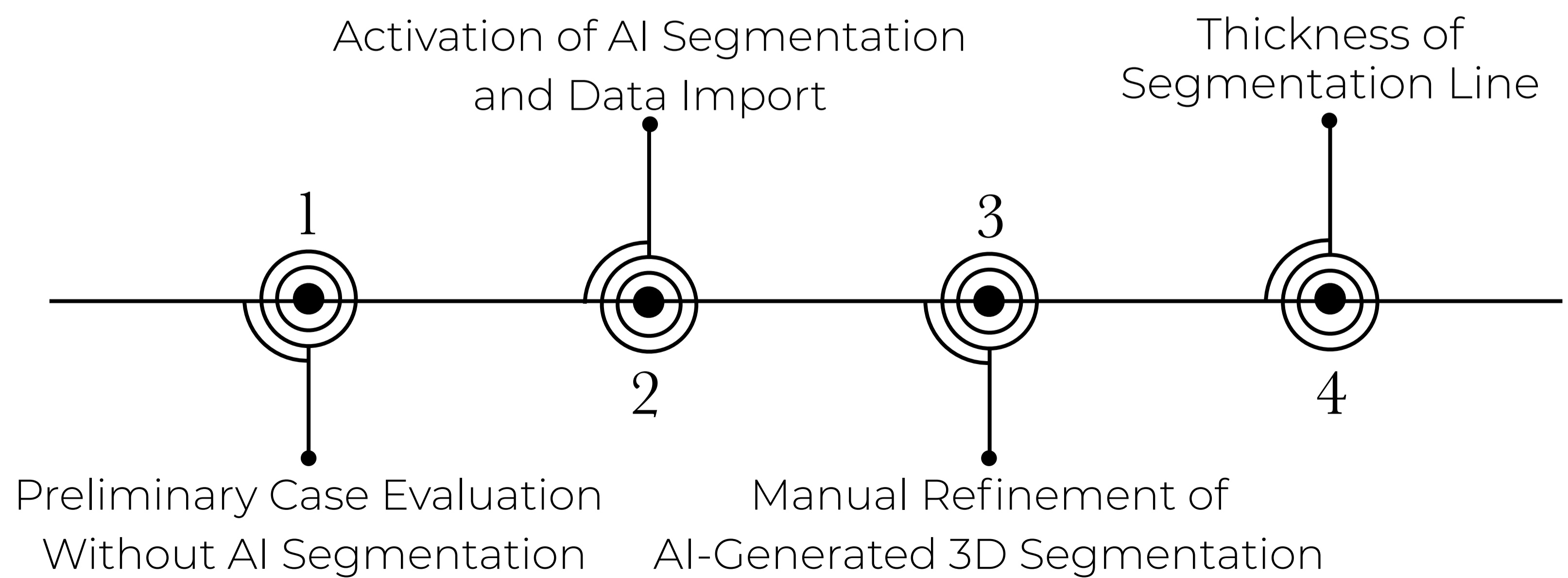


Relu showing the ability to detect the right impacted canine only



coDiagnostiX showing the inability to detect any of impacted canines.

Guidelines For Utilizing Artificial Intelligence In Implant Planning Software



DISCUSSION

AI-based segmentation has shown substantial improvement; however, **clinically relevant errors remain frequent**, particularly **boundary inaccuracies, mislabeling, incomplete segmentation, and over-segmentation**, often occurring near **critical anatomical structures**. Segmentation accuracy is highly context-dependent and is adversely affected by **metallic artifacts, anatomical variability, and case complexity**, thereby increasing the risk of implant planning errors. These inaccuracies may lead to **clinically significant consequences**, including **implant malpositioning, nerve injury, and sinus perforation**, and may propagate into **guided surgery workflows**, where even **minor segmentation discrepancies can result in positional deviations**. Consequently, **AI-driven segmentation should be regarded as a decision-support tool**, underscoring the need for **clinician verification** to ensure safe integration into implant planning workflows.

CONCLUSION

Errors in AI-driven segmentation remain a relevant limitation in digital implant planning with **direct clinical implications**. Improving **imaging quality, algorithm robustness, clinician training, and software refinement** is essential to enhance reliability and safety. **Future research should focus on real-time error-detection systems and more generalizable AI models**, supported by close collaboration between developers, clinicians, and researchers to ensure consistent and high-quality outcomes in implant dentistry.