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Comparison Of Accuracy Of Mandibular Canal Segmentation Tool Using Manual Method And Artificial Intelligence In Cone Beam Computed Tomography

Dr. Jebarani Jeevitha S[1], Dr. Prasanthi Sitaraman*[2]

[1]Postgraduate Student, Department of Oral Medicine and Radiology, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, India

[2]Senior Lecturer, Department of Oral Medicine and Radiology, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, India

***Corresponding Author:**

Dr. Prasanthi Sitaraman,

Senior Lecturer, Department of Oral Medicine and Radiology, Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, India

Email ID: prasanthis.sdc@saveetha.com

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ABSTRACT

Background: Cone Beam Computed Tomography (CBCT) has become an essential imaging modality in the visualization of the maxillofacial region, gradually replacing traditional CT due to its superior imaging capabilities and reduced radiation exposure. Accurate assessment of the mandibular canal (MC) is vital for preoperative planning to avoid complications during surgical procedures. Artificial Intelligence (AI)-driven tools, such as nerve canal segmentation software, offer rapid and precise tracing of the Inferior Alveolar Nerve Canal (IANC), extending from the mandibular foramen to the mental foramen. This study aims to evaluate and compare the accuracy of AI-driven segmentation with manual tracing methods to assess their reliability and potential for clinical applications.

Materials And Methods: This study included 100 large field-of-view (16 × 17 cm) CBCT scans taken for routine screening, acquired using the CS 9600 machine with exposure parameters of 120 KVp, 5 mA, and 24 s. The CBCT scans were analysed using CS imaging software. The inclusion criteria focused on scans from individuals over 18 years of age without any pathologies, fractures, or prior surgeries affecting the mandible. Exclusion criteria included individuals under 18 years of age, patients with syndromes affecting mandibular growth, and post – mandibular surgeries.

The mandibular canal was traced using an AI-driven nerve canal segmentation tool and the results were compared with manual tracings performed by two observers with varying levels of experience (2 and 6 years). The overlap of the traced canals was categorized as complete, partial, or no overlap. Additionally, the diameter of the traced canal was assessed, with AI-driven tools defaulting to 2.5 mm. Screenshots of the traced canals in reconstructed panoramic views were used for comparison, and transparency adjustments were applied to evaluate overlaps.

Results: The AI-driven segmentation demonstrated high accuracy, with 94% of cases showing complete overlap between AI and manual tracings, 5% showing partial overlap, and only 1% displaying no overlap. Morphological assessment revealed consistency in tracing quality across most cases. The AI tool maintained the default canal diameter of 2.5 mm with no significant deviations in 98% of cases. The remaining 2% exhibited minor variations, highlighting potential limitations in specific cases with unique anatomical variations. These findings underline the reliability of AI tools in accurately identifying and tracing the mandibular canal, with results comparable to manual methods.

Conclusion: The study demonstrates that AI-driven nerve canal segmentation tools offer a highly accurate and time-efficient approach for assessing the mandibular canal, with results closely aligning with manual tracings. While AI tools showed minimal discrepancies in a small percentage of cases, they hold significant promise as a complementary tool in preoperative planning and diagnostic workflows. However, further research incorporating larger datasets and varied imaging parameters is essential to optimize the use of AI tools in clinical practice.

Keywords: *Mandibular canal, artificial intelligence, CBCT, segmentation, manual tracing, nerve canal assessment.*

1. INTRODUCTION

Cone Beam Computed Tomography (CBCT) has revolutionized the field of maxillofacial imaging, offering enhanced visualization with reduced radiation exposure compared to traditional Computed Tomography (CT). Its precise imaging capabilities have made it indispensable for assessing anatomical structures such as the mandibular canal (MC), which is crucial for preoperative planning and avoiding complications during surgical procedures [1, 2]. The mandibular canal houses the inferior alveolar nerve, and accurate delineation of this structure is vital for dental implant placement, orthognathic surgeries, and other invasive dental procedures [3, 4].

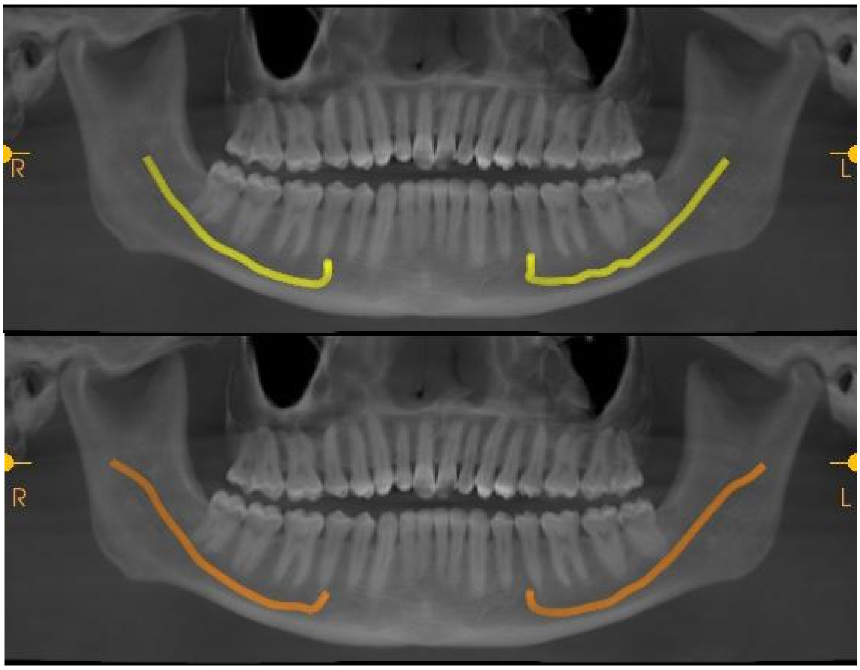
Manual tracing of the MC, while considered the gold standard, is time-intensive and susceptible to operator variability. Artificial Intelligence (AI)-driven tools, such as nerve canal segmentation software, have emerged as promising alternatives, offering rapid and precise identification of the Inferior Alveolar Nerve Canal (IANC) from the mandibular foramen to the mental foramen. These tools leverage advanced machine learning algorithms to automate segmentation, potentially reducing human error and variability [5, 6]. Previous studies have demonstrated the efficacy of AI in various applications, including segmentation of anatomical structures, automated diagnosis, and treatment planning [7,8].

AI-based mandibular canal segmentation has been investigated using tools like coDiagnostix and deep learning methods, which have shown promising results in terms of speed and accuracy. For instance, Lahoud et al. (2021) demonstrated the potential of AI for rapid and accurate segmentation of dental anatomical structures, emphasizing its applicability in clinical workflows [2]. Similarly, Jaskari et al. (2020) utilized deep learning methods for mandibular canal segmentation and reported high accuracy and consistency in their results [9].

Despite these advancements, the reliability of AI tools compared to manual tracing methods remains a topic of debate. While AI tools significantly reduce the time required for segmentation, their accuracy in detecting anatomical variations and their ability to maintain consistent canal diameter in different scenarios need further validation [4, 9]. For example, Issa et al. (2022) noted that while AI-driven methods perform well under standardized conditions, their efficacy can be compromised when applied to datasets acquired from different imaging parameters [8]. Thus, the integration of AI into clinical practice requires careful consideration and comparison with established manual methods.

This study aims to evaluate and compare the accuracy of mandibular canal segmentation using AI-driven tools and manual tracing methods. Using a dataset of 100 CBCT scans, the overlap and consistency of the traced canals were assessed across three categories: complete overlap, partial overlap, and no overlap. Furthermore, the accuracy of AI-driven tools in maintaining the default canal diameter was analysed. This research seeks to determine whether AI tools can serve as reliable and efficient alternatives to manual methods, thereby enhancing clinical workflows and diagnostic precision.

By addressing these objectives, the study contributes to the growing body of literature on AI applications in dentistry and highlights the potential of integrating AI-driven segmentation tools into routine clinical practice. Additionally, it underscores the importance of balancing automation with clinical expertise, ensuring that these tools complement rather than replace the clinician's role in patient care [2, 10].



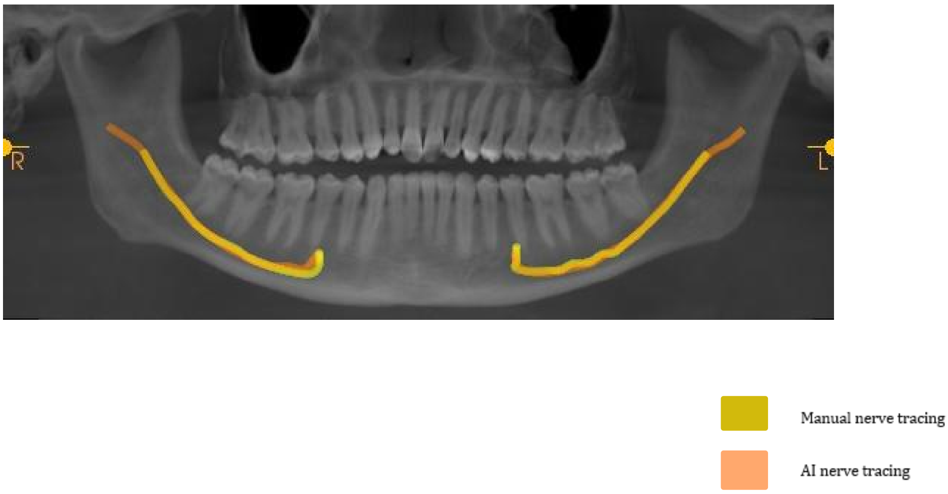


Figure 1: Comparing Manual & AI for Mandibular Canal Nerve Tracing

2. MATERIALS AND METHODS

Study Design and Population

This study involved a retrospective analysis of 100 large field-of-view (16 × 17 cm) Cone Beam Computed Tomography (CBCT) scans acquired for routine screening. All scan volumes were obtained using the CS9600 machine with standardized exposure parameters of 120 KVp, 5 mA, and 24 seconds. The scan volumes were reviewed using CS Imaging software to ensure uniformity in data acquisition and analysis.

Inclusion Criteria

Participants included in this study were adults aged 18 years or older. Scan volumes covering the mandible completely and of good diagnostic quality were included.

Exclusion Criteria

Exclusion criteria included individuals under 18 years of age, patients with a history of craniofacial trauma, congenital birth defects involving the mandible, and surgeries involving the mandibular body. Any CBCT scan volumes that did not meet the quality parameters or were acquired using different imaging devices were also excluded.

Tracing and Assessment of Mandibular Canal

The right and left mandibular canal were traced for each selected scan volume twice – first manually and then using the AI – driven tool. Tracings were compared by overlapping the AI-generated tracing and the manual tracing. The overlap was categorized into three levels: complete overlap, partial overlap, and no overlap. Screenshots of the traced canals in reconstructed panoramic views were used for visual assessment. The diameter of the traced canals was measured in cross-sectional slices, and any deviations in the AI-detected diameter were noted.

Data Analysis

The results were analysed using descriptive statistics. The percentage overlap between AI and manual tracings, as well as the consistency in canal diameter were calculated. Statistical significance was determined using one-way ANOVA with Tukey's multiple comparisons.

3. RESULTS

Accuracy of AI and Manual Tracings

The AI-driven nerve canal segmentation demonstrated a high level of accuracy compared to manual tracings. Of the 100 CBCT scan volumes:

- Complete Overlap: Observed in 94% of cases, indicating near-perfect alignment between AI and manual tracings.
- Partial Overlap: Detected in 5% of cases, showing moderate agreement with minor discrepancies.
- No Overlap: Found in only 1% of cases, highlighting potential challenges in cases with anatomical variations.

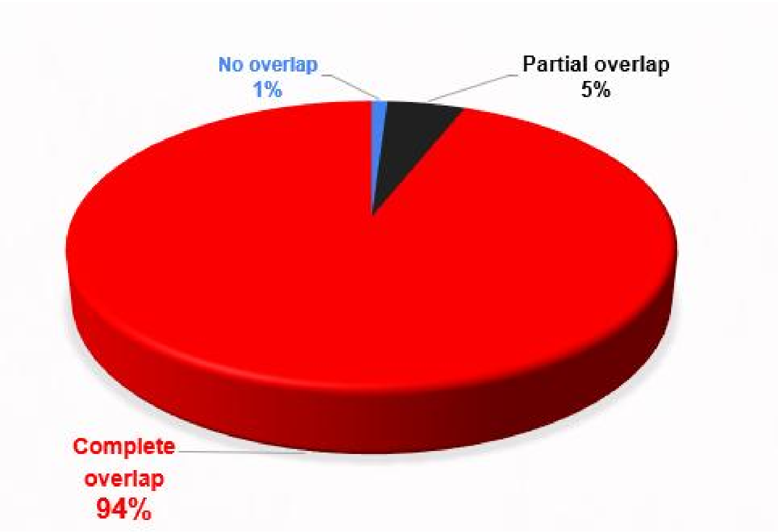


Figure 2: Mandibular canal assessment following integration of manual tracing and AI generated tracing

Canal Diameter Consistency

The AI tool maintained a default canal diameter of 2.5 mm with 98% consistency, showing no significant deviations. In the remaining 2% of cases, minor variations were observed, likely due to anatomical anomalies or AI recognition limitations.

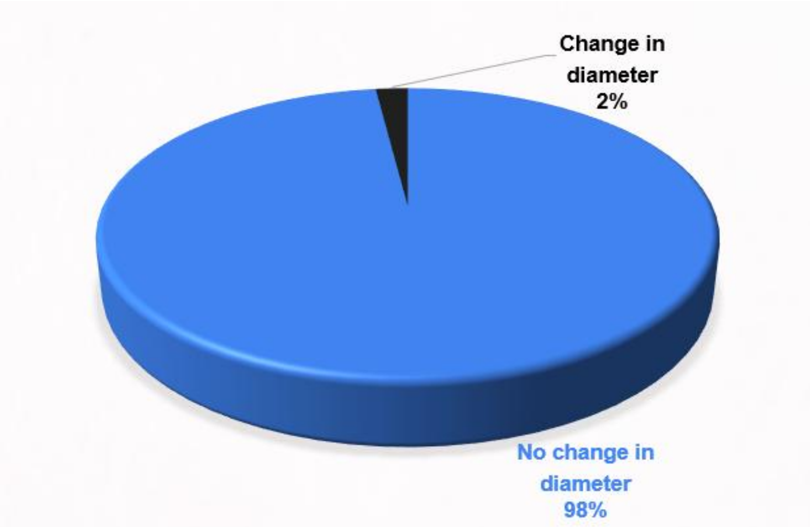


Figure 3: Percentage Distribution of Diameter Changes in Traced Mandibular Canal

Visualization and Morphological Assessment

Morphological evaluation confirmed the reliability of AI tracings, with visual assessments showing well-aligned tracings in the majority of cases. Screenshots of the tracings in reconstructed panoramic views further validated the alignment and consistency.

4. DISCUSSION

The integration of Artificial Intelligence (AI) into diagnostic imaging workflows represents a transformative development in modern dentistry, particularly in mandibular canal (MC) segmentation. This study highlights the significant accuracy and consistency of AI-driven segmentation tools in tracing the Inferior Alveolar Nerve Canal (IANC) compared to manual methods. The findings align with previous research that has validated the effectiveness of AI in anatomical segmentation tasks, demonstrating its potential to improve diagnostic precision and efficiency [9].

The high rate of complete overlap (94%) between AI-generated and manually traced canals emphasizes the reliability of AI tools. This finding is consistent with studies such as those by Lahoud et al. (2021) and Jaskari et al. (2020), which reported similar accuracy levels in automated segmentation of dental anatomical structures [10]. Such results underscore the capability of AI to replicate human expertise in identifying and tracing complex anatomical landmarks, offering a valuable adjunct to manual methods.

The 5% of cases showing partial overlap and the 1% with no overlap highlight the challenges posed by anatomical variations or irregularities, which can affect the precision of AI tools. Issa et al. (2022) noted similar discrepancies, emphasizing the importance of rigorous validation and the need for clinician oversight when employing AI in clinical workflows [8]. These findings underscore the importance of continuous refinement of AI algorithms to address variability across patient populations.

Consistency in canal diameter was observed in 98% of cases, further validating the precision of AI segmentation tools. Minimal deviations in diameter, noted in 2% of cases, may reflect inherent anatomical differences or limitations in AI resolution. Studies like those by Kwak et al. (2020) have similarly acknowledged the need for AI systems to adapt to diverse anatomical presentations to maintain high accuracy levels [11].

The time-efficiency of AI-driven segmentation tools offers a significant advantage, particularly in preoperative planning. Unlike manual tracing, which is time-intensive and prone to operator variability, AI tools provide rapid and reproducible results. This is particularly critical in complex cases requiring precise canal delineation, where AI can serve as a reliable adjunct to enhance surgical outcomes [12,13].

Despite these benefits, it is crucial to emphasize that AI tools are not intended to replace clinician expertise. Instead, they should be viewed as complementary aids, enhancing the accuracy and efficiency of diagnostic workflows while allowing clinicians to focus on more nuanced aspects of patient care. As highlighted by Lahoud et al. (2022), combining AI tools with human oversight ensures the robustness and reliability of diagnostic processes, particularly in cases involving anatomical anomalies or pathology [6].

Overall, this study reaffirms the potential of AI in mandibular canal segmentation and its broader implications for dental imaging and surgical planning. However, it also emphasizes the need for further validation, larger datasets, and diverse imaging conditions to ensure these tools are adaptable and universally applicable across clinical scenarios.

5. LIMITATIONS AND FUTURE SCOPE

Limitations

This study has certain limitations that should be acknowledged. The dataset included scan volumes from a single imaging device with standardized exposure parameters, limiting the generalizability of the findings to scan volumes obtained using different devices or settings. Additionally, the study focused solely on adult cases with no pathological conditions, which may not represent the broader patient population.

Future Scope

Future research should incorporate larger datasets with varied imaging parameters and include scan volumes from different devices to enhance the robustness of AI segmentation tools. Investigating the performance of AI in cases with anatomical anomalies or pathologies could provide further insights. Machine learning models with more diverse training datasets could improve the adaptability and accuracy of AI tools in clinical practice [14].

6. CONCLUSION

The study demonstrates that AI-driven mandibular canal segmentation is a highly accurate and efficient method, closely aligning with manual tracings in the majority of cases. The minimal discrepancies observed highlight the robustness of AI tools while underscoring the importance of clinical validation. AI tools hold immense potential as complementary aids in diagnostic workflows, enhancing precision and efficiency in mandibular canal assessment. Further studies are warranted to expand the applicability of these tools across diverse clinical scenarios, ensuring their seamless integration into routine practice.

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