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Influence of Implant Depth on the Accuracy and Precision of Intraoral Scanning in Anterior Immediate Implant Placement: An in Vitro Comparative Study of Varying Implant Depths

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Introduction

Immediate implant placement and provisionalization (IIPP) has proven to be a viable option to shorten treatment time. Despite the documented success¹, the process of making a provisional crown during surgery could be time consuming. With the help of digital workflow, the crown can be designed and fabricated after implant placement.

However, several studies²⁻⁸ have shown decreased scanning accuracy when the implants are deeply placed. Therefore, the purpose of this *in vitro* study is to compare the accuracy and precision of intraoral scanning in different implant depths at immediate implant placement settings. A case report will also be presented to show the workflow.

Null Hypothesis

No difference of accuracy and precision when scanning implant in an immediate implant placement setting with varying depths.

Materials and Methods

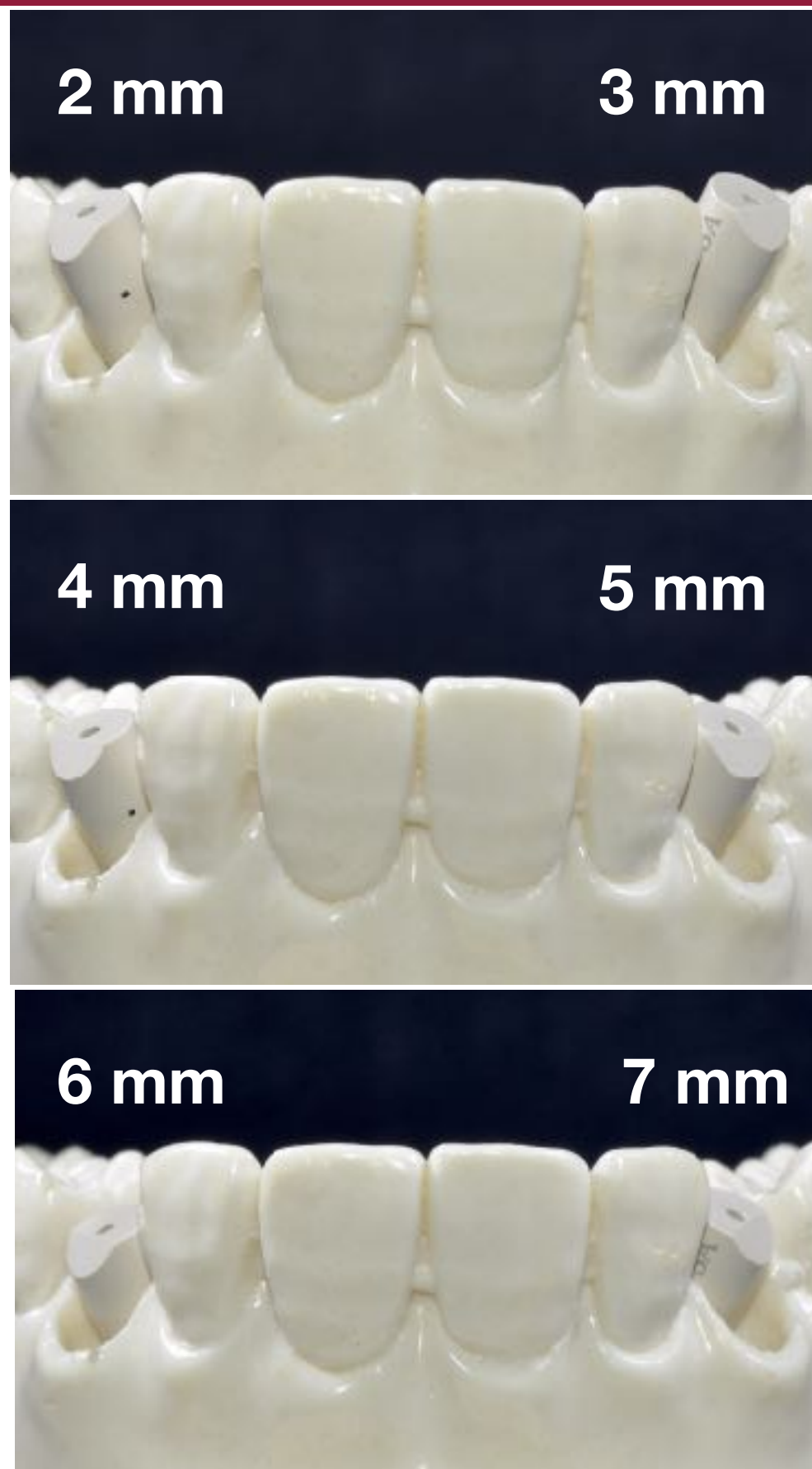
Three identical custom-made epoxy resin models were fabricated to mimic texture of natural bone. In the models, teeth #6 and #11 represents extraction sockets with identical Class I Sagittal Root Position⁹. Six dental implants (Nobel Replace, Nobel Biocare) were placed at different depths (2, 3, 4, 5, 6, 7 mm apical to facial gingival margin) (Fig 1).



Fig. 1 (a) Implant position: The distances to the facial, palatal, mesial, and distal margins are 3.5, 1, 0.5 and 0.5 mm, respectively (b) 2mm implant depth (scan body showed 9 mm) (c) 7mm implant depth (scan body showed 4 mm)

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4. Gómez-Polo M, et al. Influence of implant angulation and clinical implant scan body height on the accuracy of complete arch intraoral digital scans. *J Prosthet Dent*. 2024;131(1):119-127.
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7. Choi YD, et al. Effects of scan body exposure and operator on the accuracy of image matching of implant impressions with scan bodies. *J Prosthet Dent*. 2020;124(3):379.e1.
8. Sequeira, Vivia, et al. "Accuracy of digital impressions at varying implant depths: an in vitro study." *Journal of Prosthodontics* 32.1 (2023): 54-61.
9. Kan JYK, et al. Classification of sagittal root position in relation to the anterior maxillary osseous housing for immediate implant placement: a cone beam computed tomography study. *Int J Oral Maxillofac Implants*. 2011;26(4).

**(a) 3 Models with Scan Body
6 Different Implant Depths**



(b) Digital Scan



Desktop Scanner



Intraoral Scanner
20 scans on each model
two examiners

(c) Scan Files (STLs)

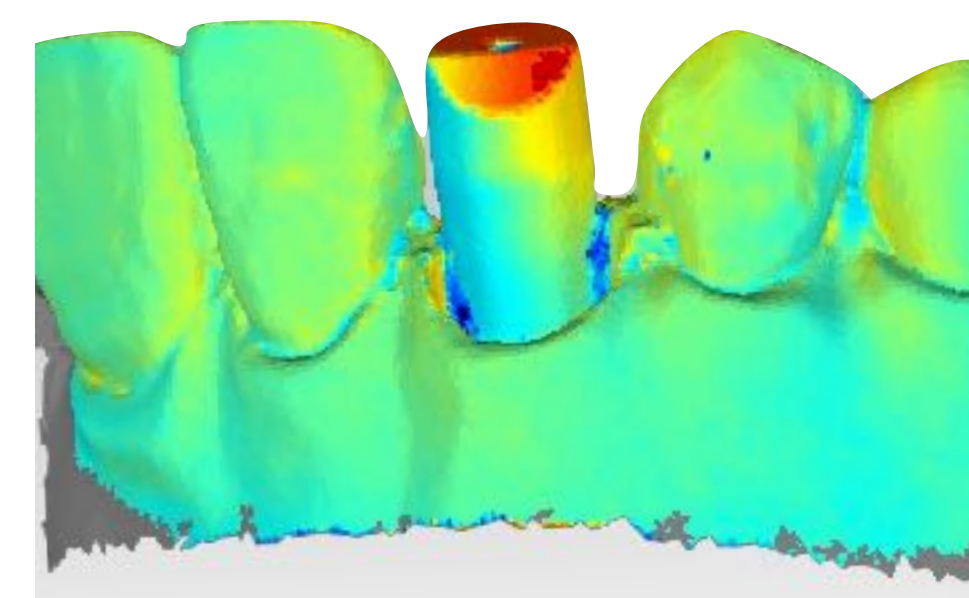


Reference Scan Files



240 Scan Files

(d) Data Analysis



Superimpose Scan Files

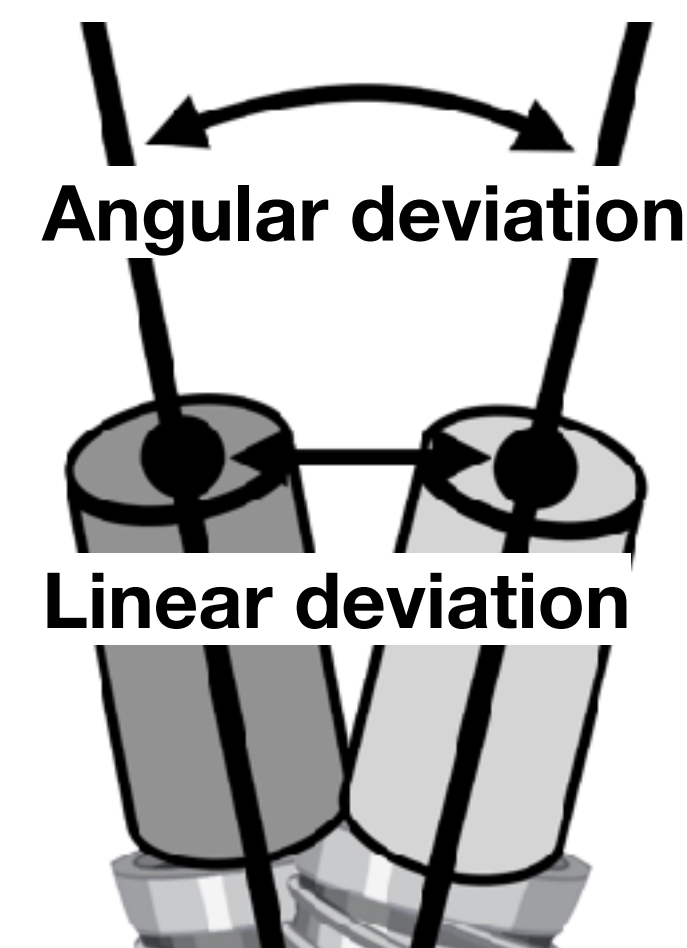


Fig. 2 Workflow for data acquisition: (a-c) Intraoral scanning images (TRIOS 4, 3Shape) were obtained 20 times on each models by two independent examiners, resulting in a total of 240 scans (120 scans per examiner) and analyzed with desktop scanning images (D710, 3Shape) by a matching software (Geomagic Control X 2015, 3D Systems). (d) Desktop scanning images were served as references. Accuracy and precision of implant placement was evaluated by superimposing images and quantifying linear and angular deviations by mathematical algorithm.

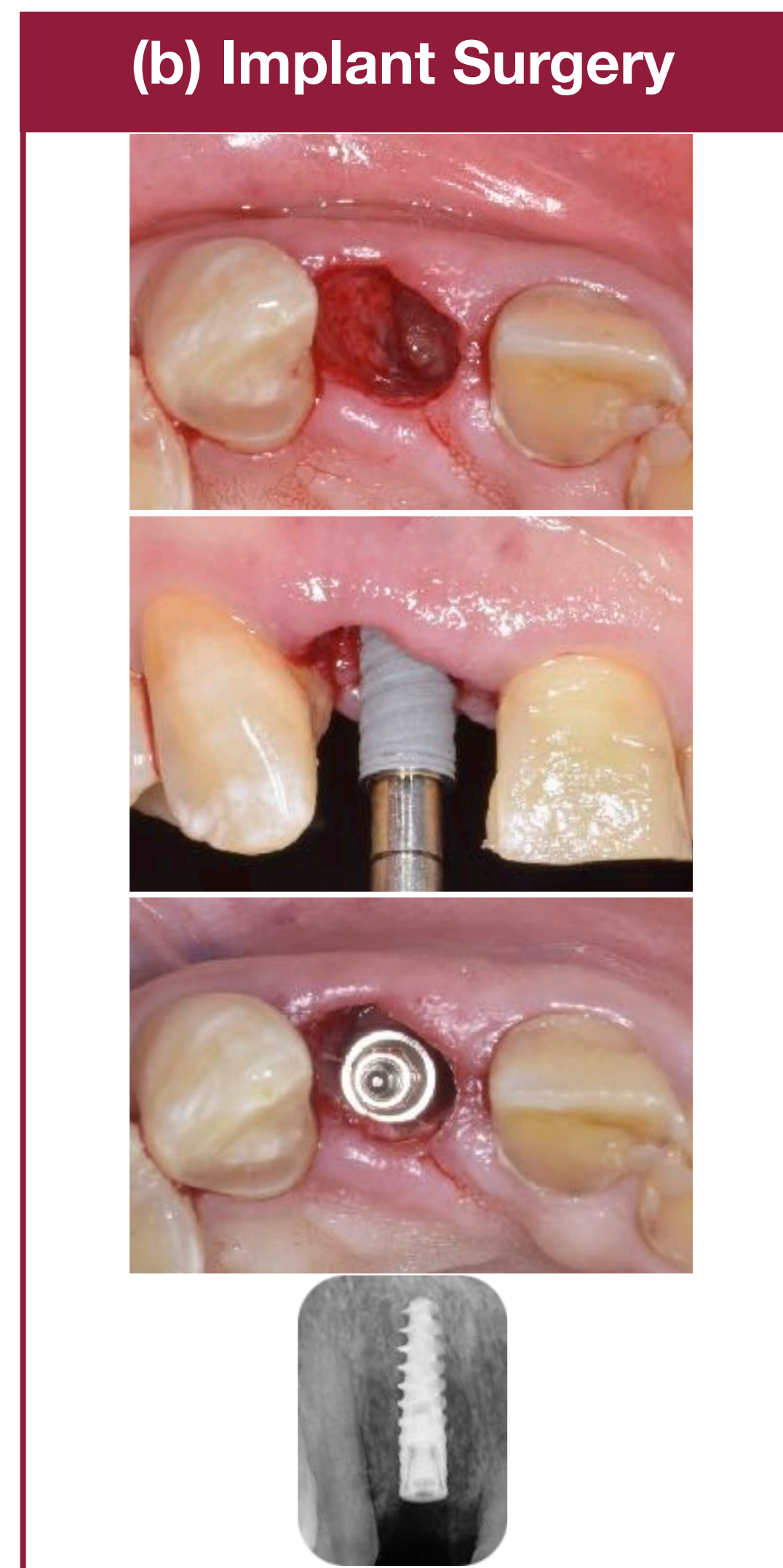
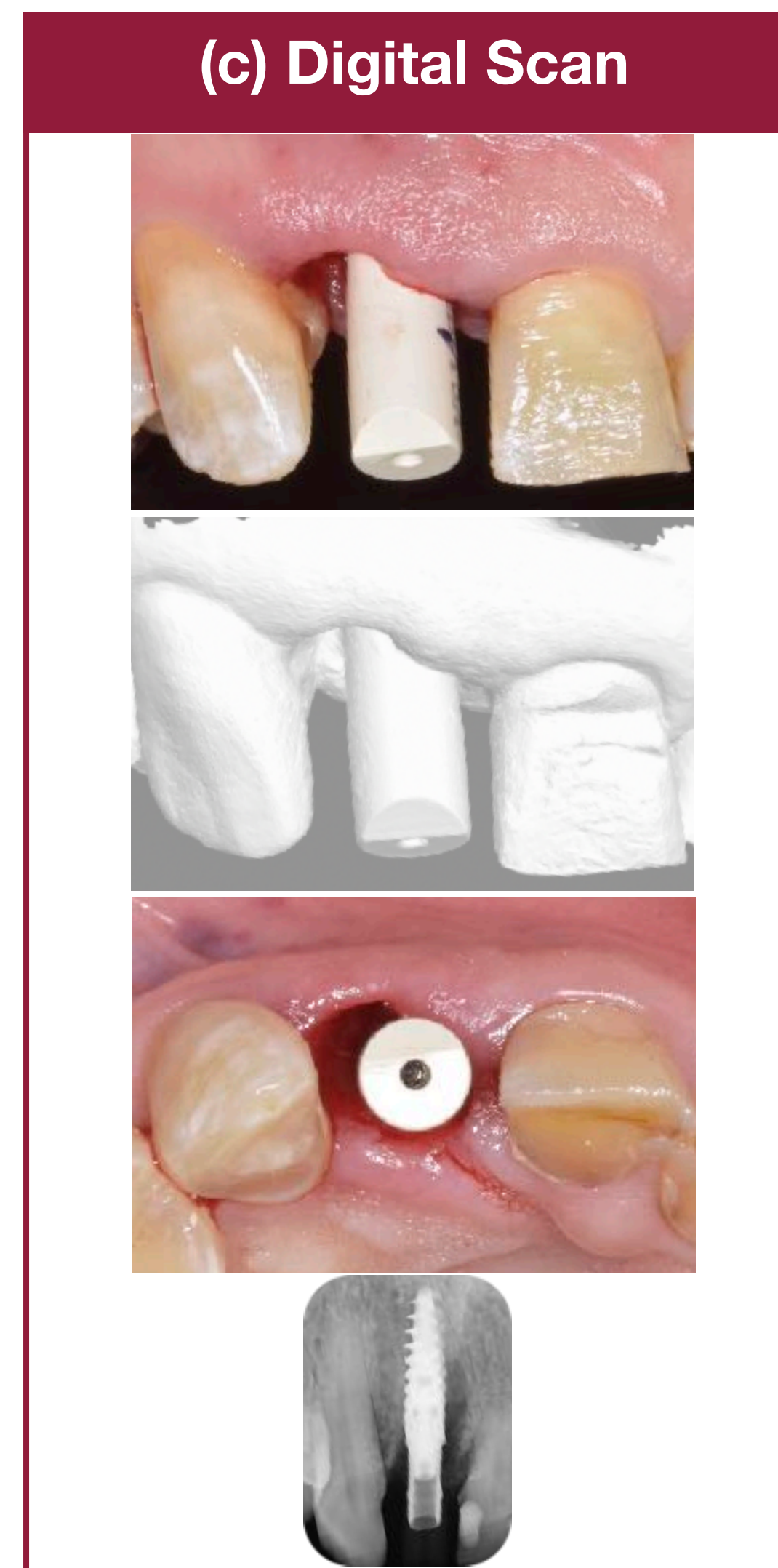


Fig. 3 Clinical Case: (a) Immediate implant placement and provisionalization (IIPP) was performed on a fractured right lateral incisor (#7). (b) The fractured tooth was extracted using a periotome to minimize trauma,, followed by placement of a NobelActive 3.5 × 13 mm implant, positioned 3 mm apical to the gingival margin. (c) Digital impression was obtained using a TRIOS 4 intraoral scanner with a scan body. (d) Provisional restoration was digitally designed and milled from PMMA, delivered without the need for adjustments.

Result

Both Pearson's and Kendall's Tau correlation analyses showed **no statistically significant correlations** were found between implant depth and any of the measured linear or angular deviations (Fig.4). The intraclass correlation coefficient (ICC) indicated poor inter-rater reliability for both angular (0.266, 95% CI: -0.284, 0.770) and linear (0.253, 95% CI: -0.304, 0.765) deviations (Fig. 5).

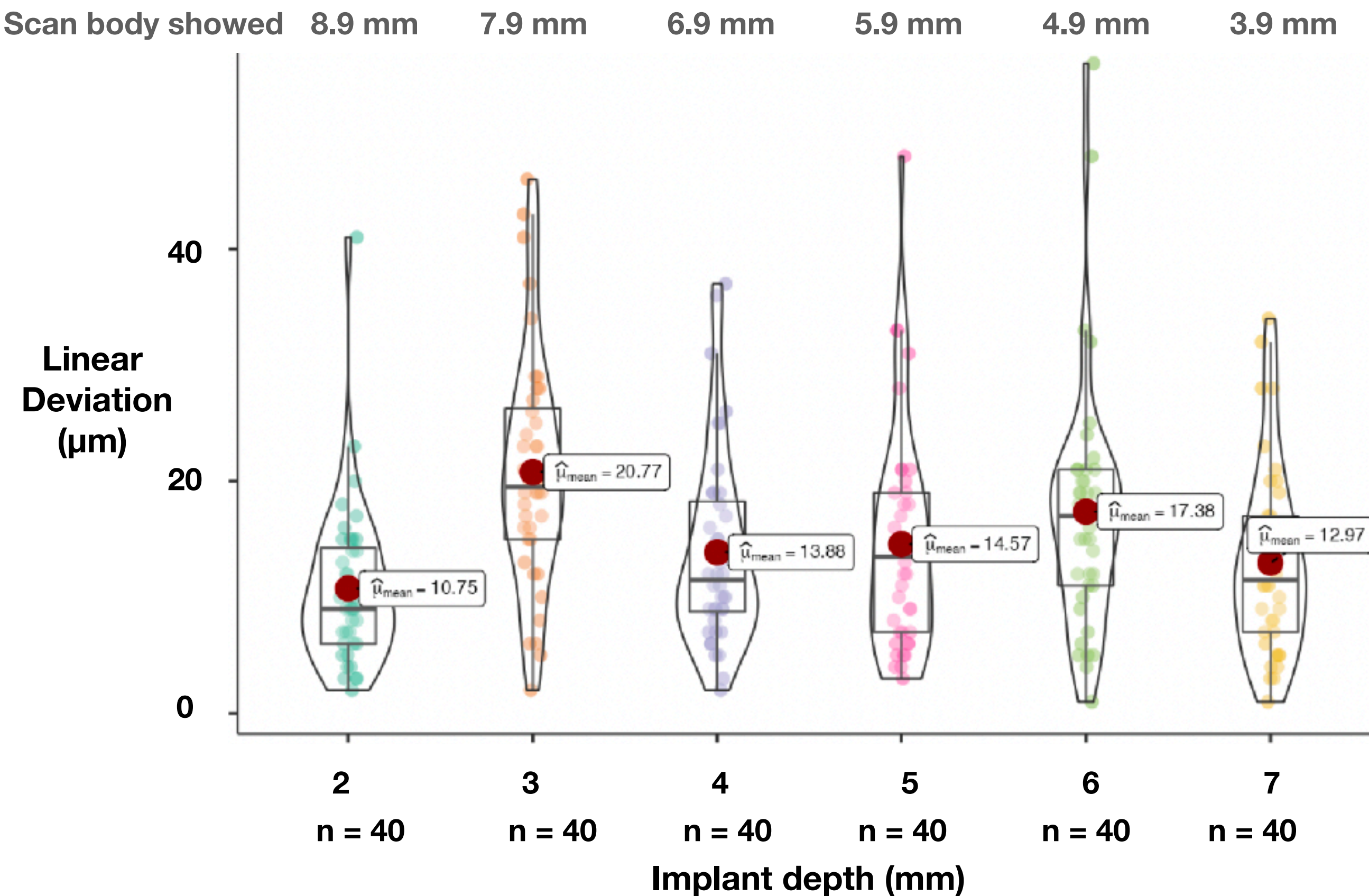


Fig. 4 Violin-Box Plot of Linear Deviation; Implant depth does not significantly affect scanning accuracy.

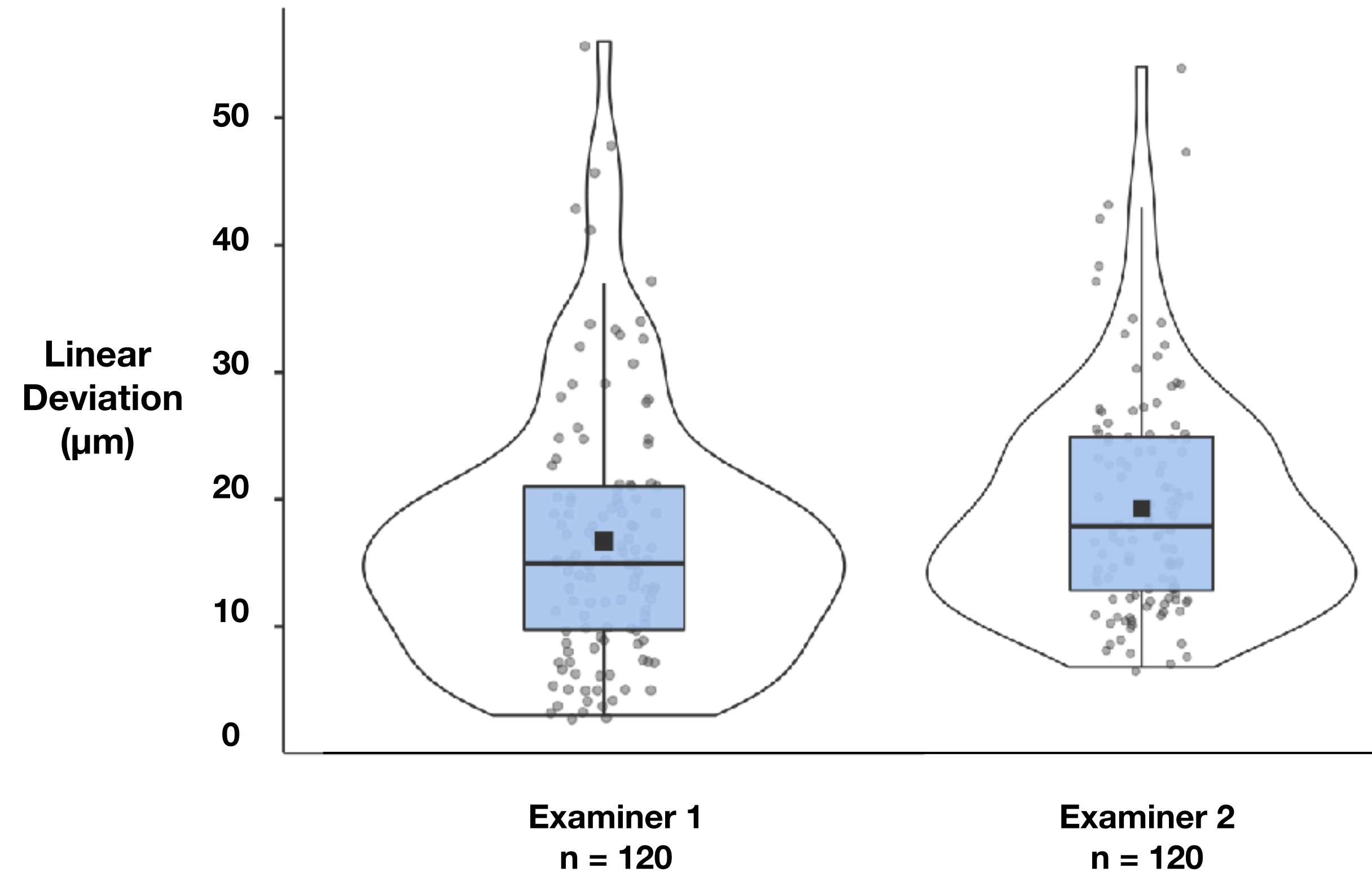


Fig. 5 Violin-Box Plot of Linear Deviation Examiners 1 and 2; The ICC between two examiners was low. However, digital scanning consistently showed high accuracy (< 30 μm).

Discussion

Previous studies have shown controversial results on the influence of implant depth. Some studies showed the accuracy of digital scan affect by implant depth with decreased accuracy as the implant depth increased (showing less scan body surface)²⁻⁸. On the contrary, some studies showed scanning accuracy may not be affected by the implant depth^{10,11}. Similarly, in the present study, consistent results was observed regardless of implant depths and examiners ($P>0.05$). It could be partially attributed to the newer intraoral optical scanner (Trios 4, 3Shape) usage⁶ and the single immediate implant placement setting.

Unlike the previous studies^{2,4,6-8,11}, the present study scanned only single implants incorporated with two adjacent teeth. Previous studies have shown increased scanning accuracy as well as superimposition processes in scanning short span area¹².

The clinical case (Fig. 3) further supports the feasibility of immediate implant placement and provisionalization (IIPP) using a digital workflow. The digital scan obtained with an intraoral scanner allowed for an efficient and precise workflow, leading to the design and milling of a provisional restoration without the need for additional adjustments. This highlights the

practical application of digital technology in streamlining implant procedures while reducing operative time without compromising accuracy.

The ICC between two examiners was low (0.25). However, this result further demonstrated that, regardless of the operators, digital scanning consistently showed high accuracy ($<30\text{ }\mu\text{m}$), well within the clinically acceptable threshold (Fig. 5), as some researchers suggest that up to $120\text{ }\mu\text{m}$ is acceptable¹⁴ and clinical acceptable outcomes (Fig. 3).

Conclusion

Within the limitation of this bench study, in anterior immediate implant placement setting, the scanning images showed consistent high accuracy ($< 30\text{ }\mu\text{m}$) regardless of the depth of the implant placements. Digital workflow using scan bodies should be clinically applicable for immediate implant placement and provisionalization scenarios.

Table. 1 Compare to Other Studies

3 mm Depth	Linear deviation (μm)
The present study	20.8 ± 10.2
Laohverapanich et al. 2021	86.0 ± 5.6
Taghva et al. 2023	53.7 ± 3.6

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