

Economical approach to obtaining full-arch implant scan with smartphone and deep learning: An in vitro investigation on trueness and precision

Fatma Mohamed DDS, MS, PhD, Zhaozhao Chen DDS, MS, PhD, Fei Liu DDS, PhD, Berna Saglik DDS, MS, Gusatvo Mendonca DDS, MS, PhD, Junying Li DDS, MS, PhD
Department of Biologic and Materials Sciences & Prosthodontics, University of Michigan School of Dentistry



Background

Fixed full-arch implant-supported prostheses have been a reliable treatment for edentulous patients for over 40 years. Digital workflows are becoming popular, with accurate 3D scans essential for implant treatment success. However, **obtaining 3D scans requires costly devices like intraoral scanners, desktop scanners, or photogrammetry, priced between \$10,000 and \$40,000**. Intraoral scanners are common but controversial for full-arch implants due to stitching errors. Exploring economical approaches may lower the cost of this process. Here, **we proposed a novel, economical method for obtaining full-arch implant scans using smartphone video and deep learning**.

Objective

This study aims to **compare the accuracy of full-arch implant scans using a smartphone camera and deep learning model with the intraoral scan method, hypothesizing no significant difference between the two approaches**.

Material and methods

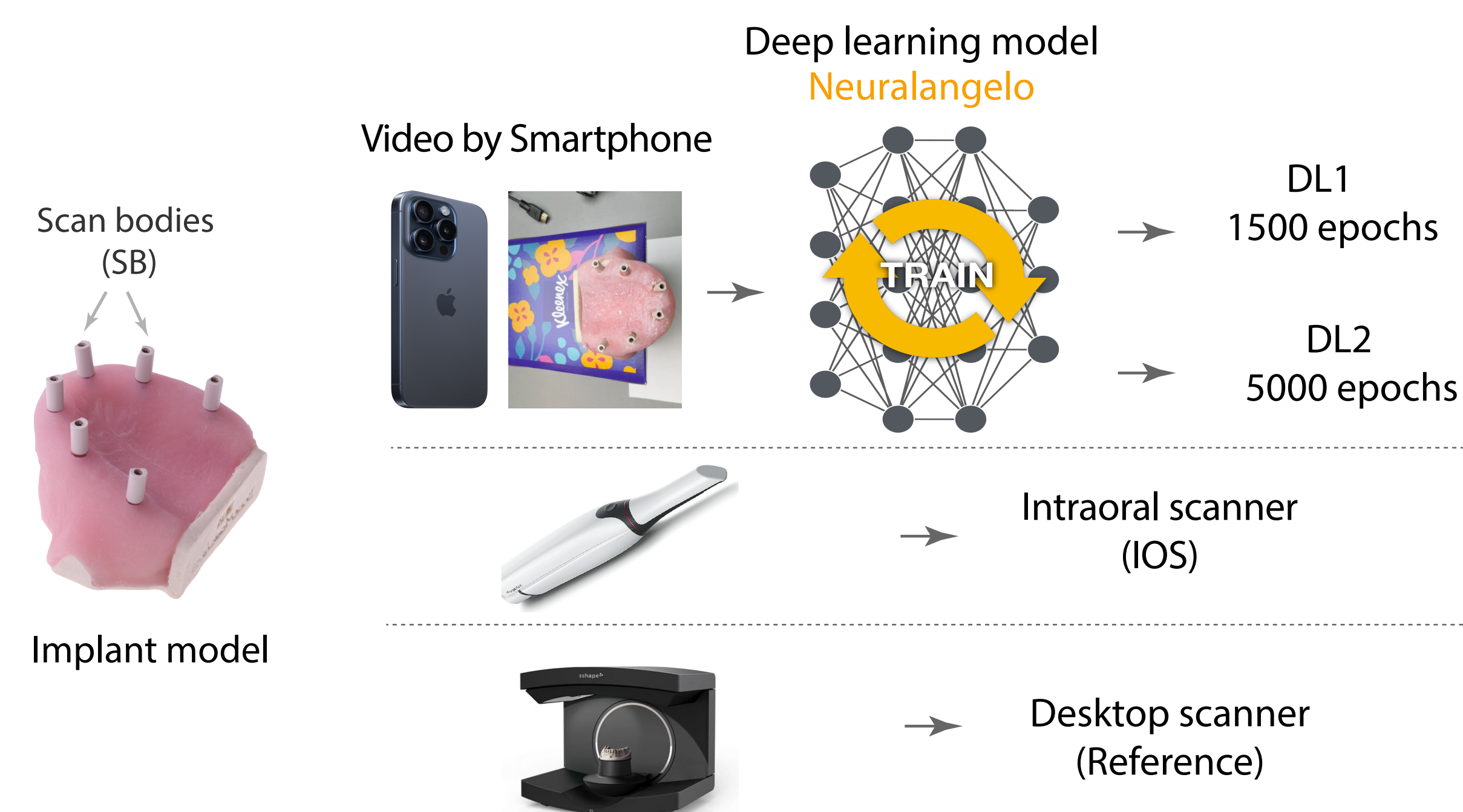


Figure 1. Study design: A maxillary edentulous model with six dummy implants and scan bodies (SB) was used (SB1 to SB6). Three scan groups were tested: (1) **deep learning (DL)** 3D reconstruction with **1500 epochs (DL1)**, (2) **5000 epochs (DL2)**, and (3) **intraoral scanner (IOS)**. A **desktop scanner (LS3; Kavo)** generated the reference model. Each method was **repeated 10 times**. In the **DL1 and DL2** groups, scans were generated from **smartphone videos** filmed with an **iPhone 15 Pro Max** from 10 cm away. The 30-second 4K videos were converted to 1080p .m4v files, processed by COLMAP, and visualized using Jupyter Notebook to adjust the model's position. The 3D mesh was extracted, converted to STL files for comparison. In the **IOS group**, the model was scanned with an intraoral scanner (Trios4; 3Shape A/S), following the recommended scan path, verified for accuracy, and exported as STL files.

Results

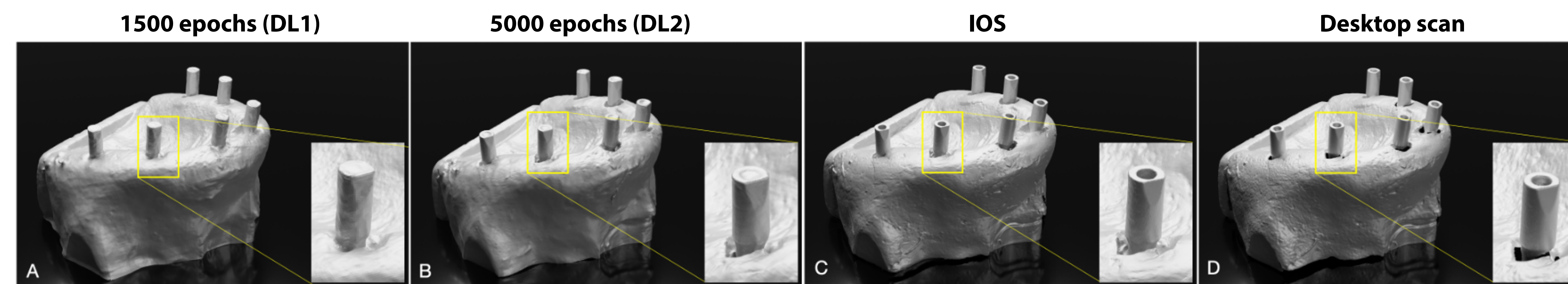


Figure 2. (A-B) Scan generated by **deep learning (DL)** using a high-fidelity neural surface reconstruction model (Nerualangelo) trained with batch_size=2 and dict_size=22). Checkpoints were saved at 1500 epochs for the DL1 group (A) and 5000 epochs for DL2 (B). One **epoch means** the dataset runs forward and backward through the neural network for one time. The 3D mesh was extracted with a resolution of 900 and block size of 128, then converted to STL files. **C.** Scan created with intraoral scanner (**IOS**), **D.** Scan created with **desktop scanner** (reference). The magnified yellow inset shows one scan body for each group.

Smartphone-deep learning digital scans (5000 epochs) exhibit trueness and precision comparable to intraoral scanner

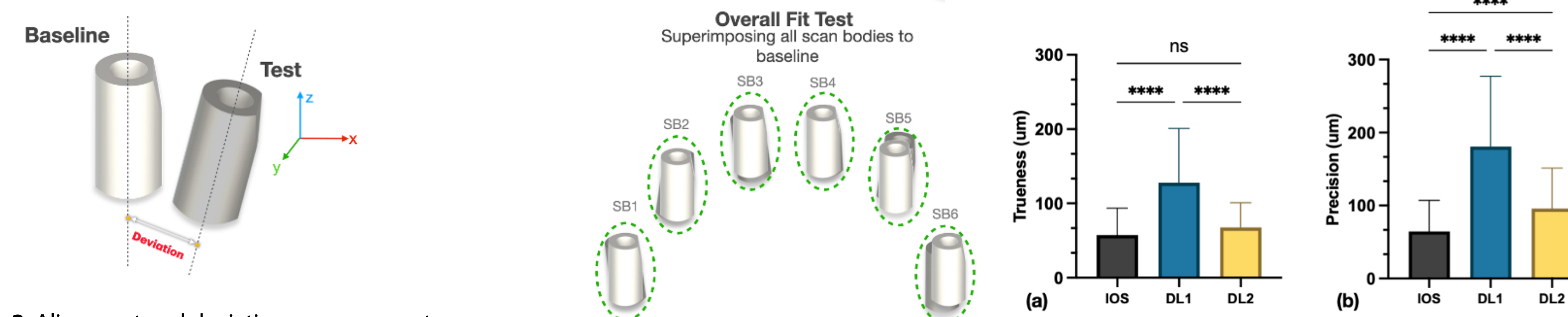


Figure 3. Alignment and deviation measurements. Accuracy was assessed by **trueness** (deviation from the reference model) and **precision** (consistency within each group) according to ISO standards.

Figure 4. Comparison of trueness and precision of different groups (**aligned by all scan bodies: Overall fit test**). DL2 group trained for 5000 epochs showed no difference compared with IOS, except for the precision. **ns**: not significant.

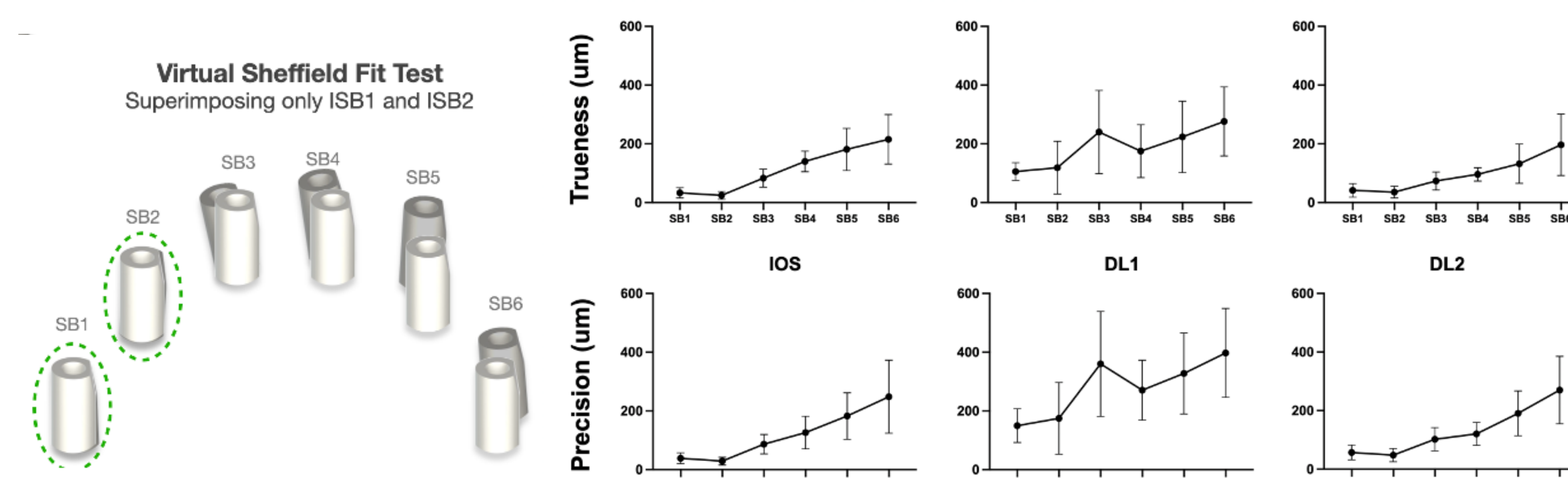


Figure 5. Comparison of trueness and precision of different groups (**aligned by scan bodies one and two: Virtual Sheffield test**). Starting from SB3, the DL2 group showed the highest trueness compared to the other groups.

Beginning from SB1, the DL2 group demonstrated similar precision as IOS but superior precision when compared to the DL1 groups.

Bars indicate mean, error bars indicate SD. One-way ANOVA with post-hoc tests. **** indicates $P < 0.0001$

Discussion

- This study is the first to evaluate full-arch implant scan accuracy using a smartphone and deep learning.
- Results showed that DL2 exhibited comparable accuracy to intraoral scanners at 5000 epochs, offering a cost-effective alternative; however, there were slight differences in overall fitting precision.
- In AI model training, higher epochs generally improve performance. We chose 5000 epochs based on Li et al (2023). Further research is needed to determine the optimal number for full-arch implant scanning plant model scanning.
- In underdeveloped areas without dental scanners, our new technique allows a dental cast to be video-recorded, uploaded, and processed by AI to create a 3D model for diagnostics or prosthesis fabrication.
- This proof-of-concept study highlights that current technology is not yet suitable for patients due to challenges with limited viewing angles and poor lighting conditions intraorally. *The TelScope smartphone attachment can be a promising solution.
- While DL2 shows similar accuracy to IOS, this does not confirm its suitability for full-arch implant scans, as IOS accuracy remains controversial. Further research is needed before this cost-effective deep learning method can be used clinically.

Conclusion

In the in vitro environment, combining smartphone videos with a deep learning model generated full arch implant scans with accuracy comparable to a commercial intraoral scanner.

Acknowledgements and References

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- Andriessen et al. J Prosthet Dent. 2014 Mar;111(3):186–94.
Brånemark PI, Svensson B, van Steenberghe D. Clin Oral Implants Res. 1995 Dec;6(4):227–31.
Flügge et al. d Clin Oral Implants Res. 2018 Oct;29 Suppl 16:374–92.
Gómez-Polo et al. J Prosthodont. 2023 Dec;32(S2):208–24.
Paratelli et al. J Prosthet Dent. 2023 Jun;129(6):844–54.
Li J, Chen Z, Nava P, Yang S, Calatrava J, Wang HL. Clin Implant Dent Relat Res. 2024 May 15.
Li et al. arXiv; 2023 [cited 2024 May 18]. Available from: <http://arxiv.org/abs/2306.03092>.
*<https://hollandhealthcareinc.com>

✉ fmohamed@umich.edu