



Comparison of 3D Accuracy of Conventional and Digital Workflows for Implant Full-Arch Fixed Dental Prosthesis Frameworks

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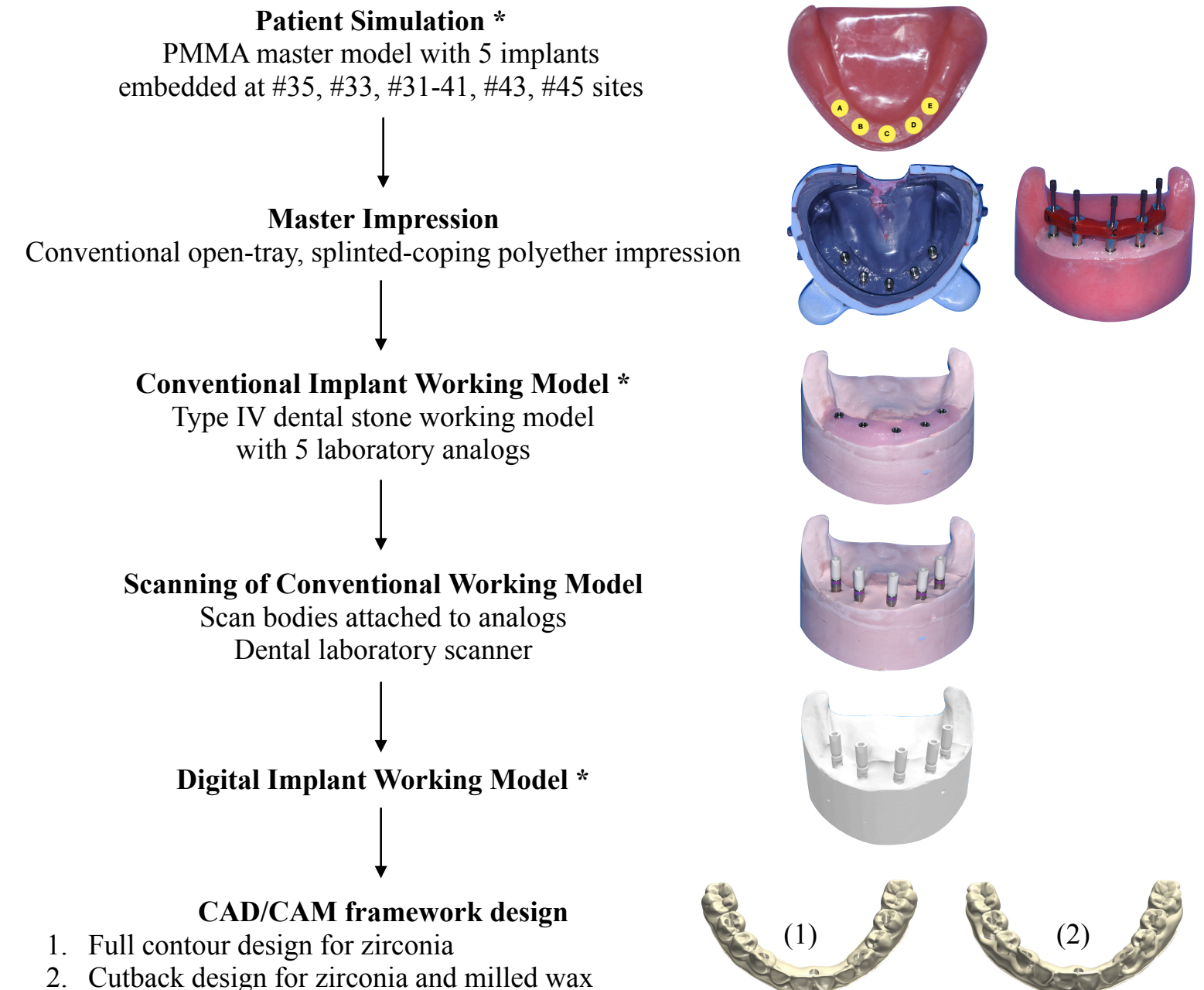
Introduction

- To date, literature on the accuracy of implant prosthodontic procedures has been largely focused up to the impression stage.
- Yet, the final production of a passively fitting prosthesis is a culmination of several clinical and laboratory procedures, each with its own potential for contributing to the overall distortion.
- Few studies have attempted to determine the cumulative distortion at the end of the fabrication workflow.
- There is scarce evidence on the influence of digital workflows and various framework designs on the three-dimensional (3D) accuracy of implant full-arch fixed dental prosthesis (FAFDP) frameworks.

Objectives

1. To quantify and compare 3D accuracy of conventional and digital workflows in the fabrication of implant full-arch fixed dental prosthesis (FAFDP) frameworks.
2. To investigate the influence of framework design on the 3D accuracy of digitally fabricated FAFDP frameworks

Materials and Methodology



* Indicates CMM measurement of implants embedded in master models and test models

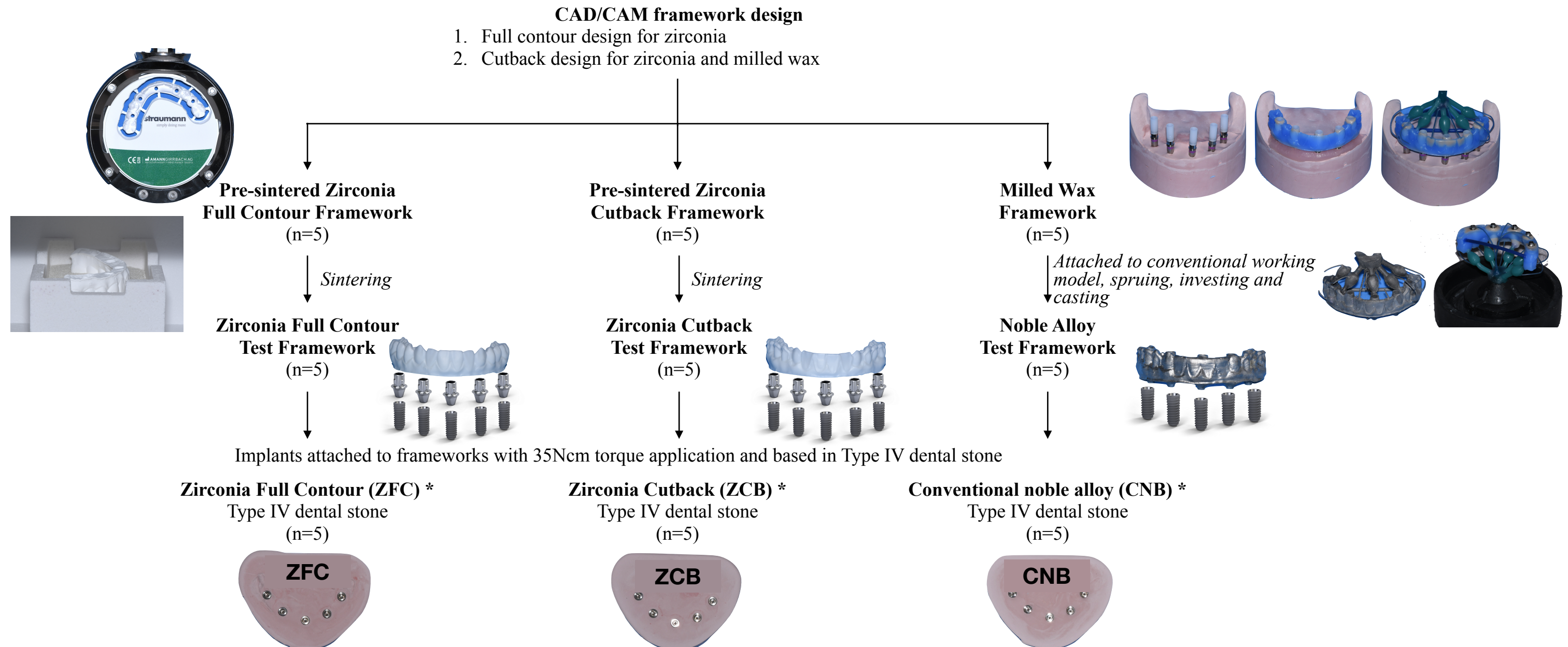


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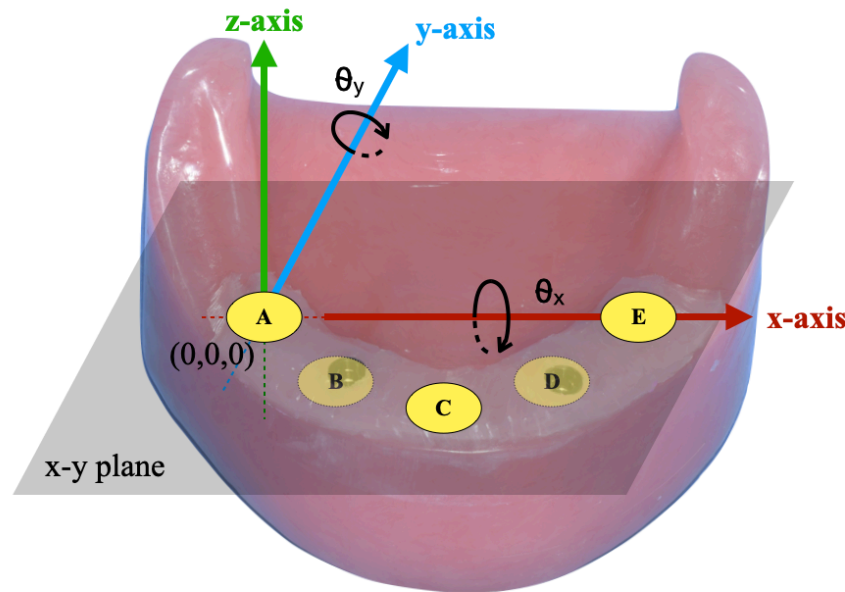


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Materials and Methodology



- Centroid positions and central axes of implants in the master and test models were measured with a coordinate measuring machine (CMM) and compared
- Local coordinate system:**
 - Origin — centroid of implant A
 - X-Y plane — implants A, C, E
 - X-axis — implants A, E
- Distortion parameters:**
 - Four linear distortion parameters (d_x , d_y , d_z , d_R)
 - Two angular distortion parameters ($d\theta_x$, $d\theta_y$)
 - 3D distance distortion values (ΔR , $\% \Delta R$)

Results (linear)

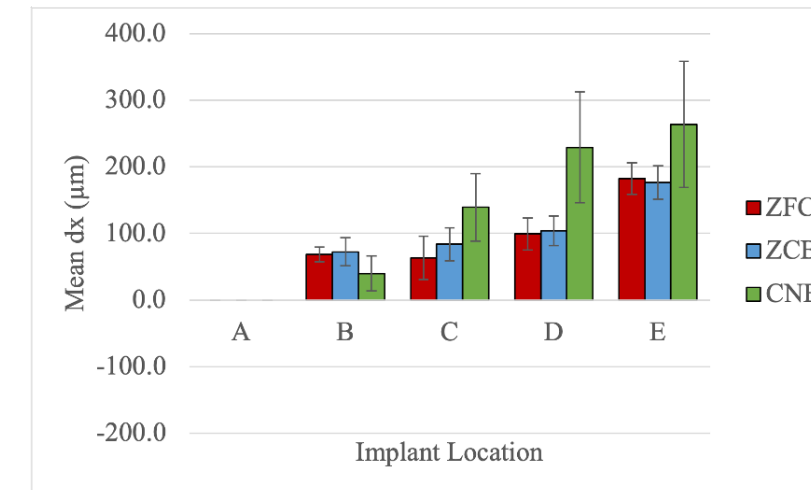


Figure 4: Linear distortions – Mean d_x

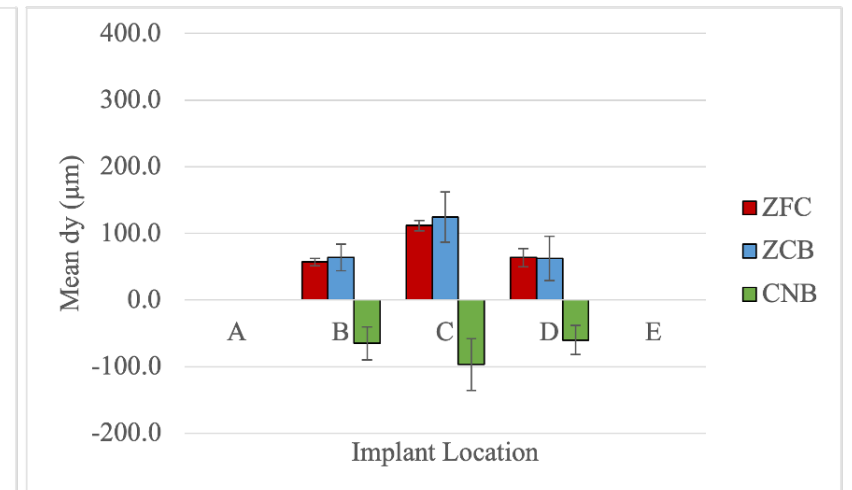


Figure 5: Linear distortions – Mean d_y

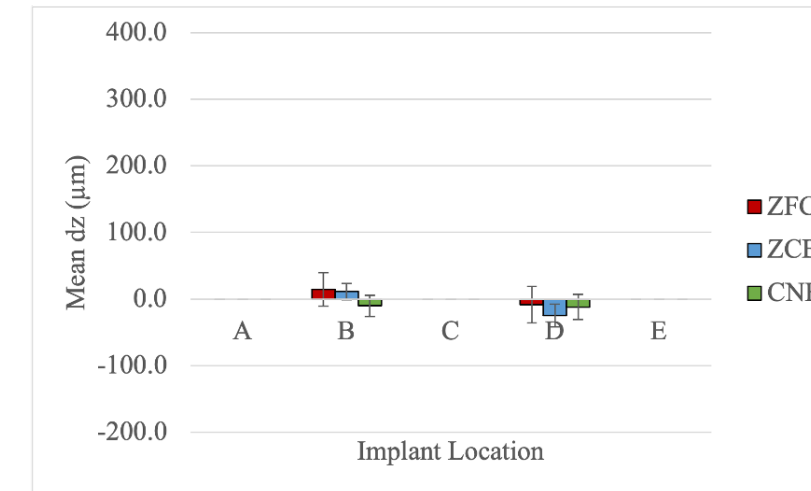


Figure 6: Linear distortions – Mean d_z

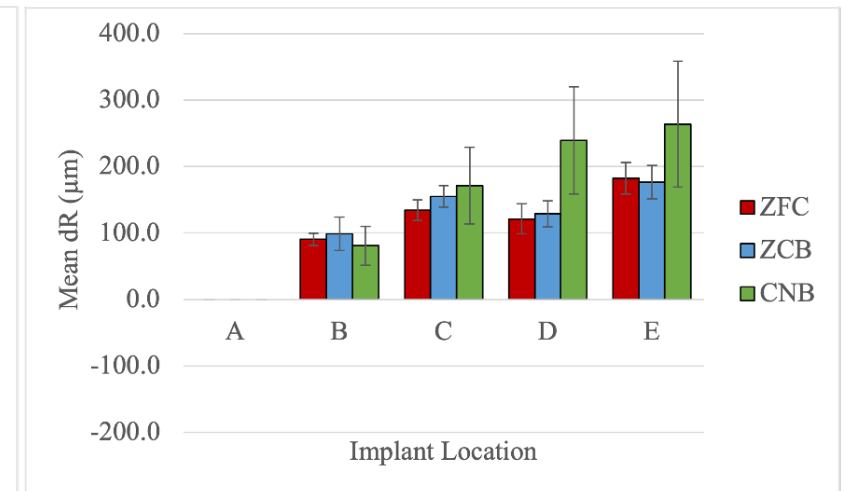


Figure 7: Global linear distortions – Mean d_R

- One-way ANOVA found significant differences among groups for d_x , d_y , d_z at some implant locations, but there was no clear pattern on the poorest performing group.
- For the global linear distortion d_R , statistical difference was found at implant D where CNB fared the worst.



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Results (angular)

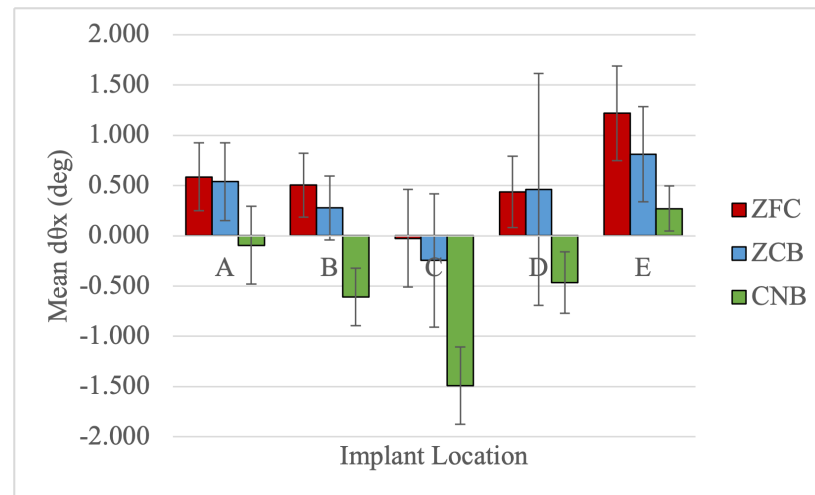


Figure 8: Angular distortions – Mean $d\theta_x$

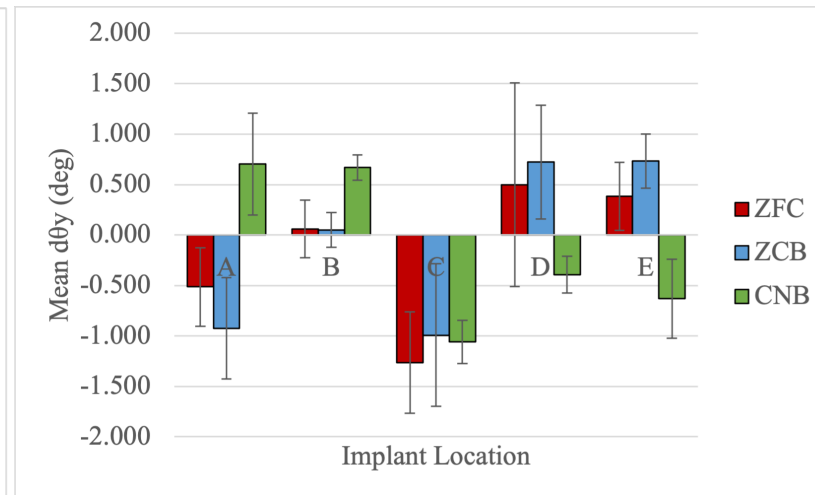


Figure 9: Angular distortions – Mean $d\theta_y$

- One-way ANOVA found significant differences among groups for $d\theta_x$ and $d\theta_y$ at some implant locations, but there was no clear pattern on the poorest performing group.

Results (3D reference distance distortions)

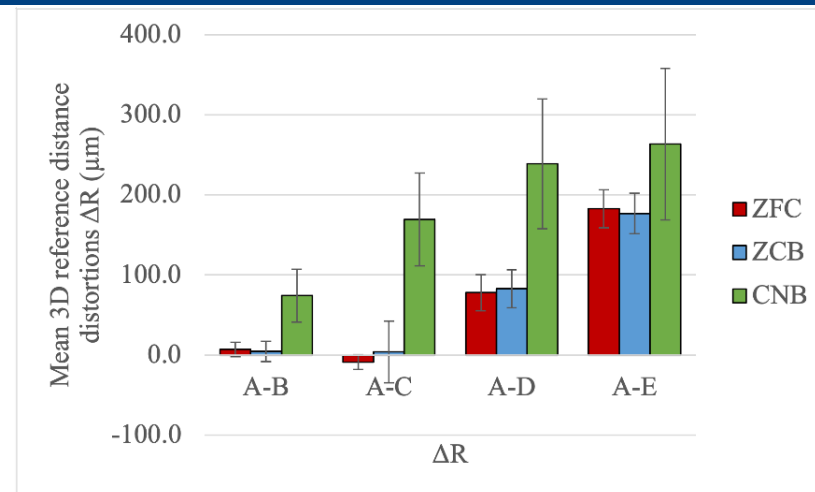


Figure 10: Mean 3D reference distance distortion (ΔR)

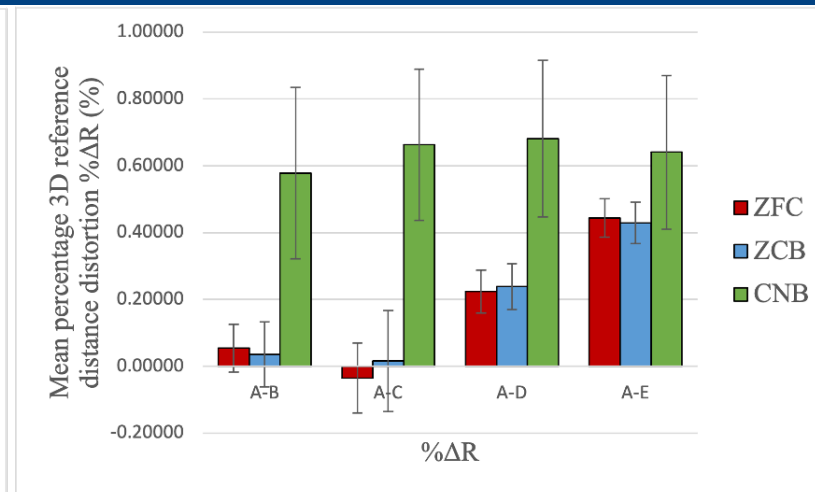


Figure 11: Mean percentage 3D reference distance distortion ($\% \Delta R$)

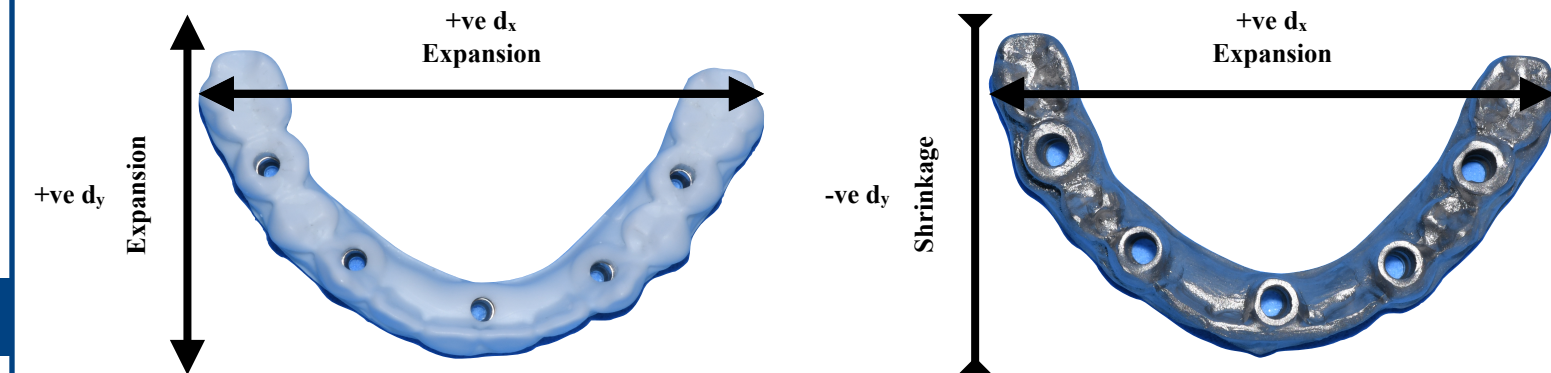
- CNB exhibited the worst accuracy in ΔR and $\% \Delta R$ for all reference distances except A-E.

Discussion

Framework design had **no significant influence** on fit of milled zirconia FAFDP frameworks.

Linear distortion

- Amongst the three linear distortion parameters, the largest values were found in the x-direction and the smallest values were found in the z-direction.
- A trend of increasing magnitude of mean d_R was observed with increasing implant distance from the origin, implant A.



Possible errors in the digital workflow:

- Scanning procedure
- Sintering process of zirconia

Possible errors in the conventional workflow:

- Wax distortion
- Expansion of investment
- Shrinkage of casting alloy

3D reference distance distortion

There is a general trend of increasing 3D reference distance distortion (ΔR) with increasing distance from the origin, implant A, in all three groups (ZFC, ZCB, CNB).

- $\% \Delta R$ increased with increasing distance from the origin in ZFC and ZCB.
- $\% \Delta R$ was relatively consistent regardless of increasing distance from the origin in CNB.



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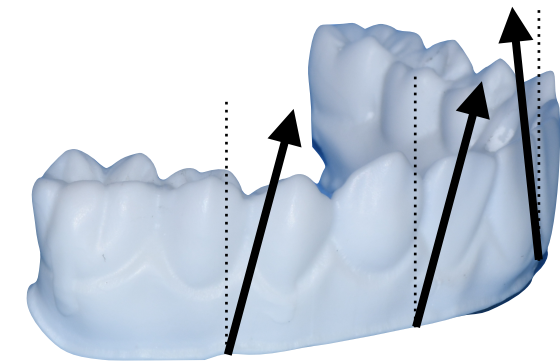
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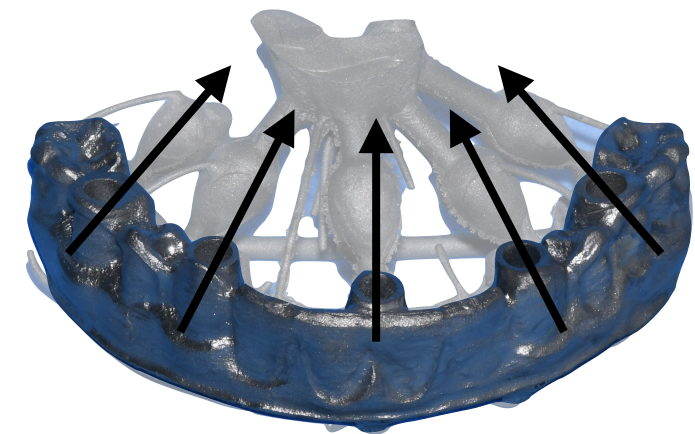
Discussion

Angular distortion

The clinically significant value of angular distortion is unknown.



- ZFC and ZCB had a trend for positive $d\theta_x$ values, except for implant C.
- Positive $d\theta_x$ values indicate tilting of the implants towards the anterior mandible.
- Negative $d\theta_x$ values indicate tilting of the implants towards the posterior mandible.
- The value of $d\theta_x$ decreased from implants A-C, then increased from C-E.
- There is no consistent pattern of angular distortion about the y-axis ($d\theta_y$) in ZFC and ZCB



- For CNB, the pattern of angular distortion about the x- and y-axes ($d\theta_x$, $d\theta_y$) is consistent with the conventional method of spruing.

Conclusion

1. There was no difference between ZFC and ZCB for all parameters.
2. CNB fared poorest for ΔR and $\% \Delta R$ for three of four reference distances, as well as for d_R for one of four implant positions.

References

- Tan, K.B.C., *The clinical significance of distortion in implant prosthodontics: Is there such a thing as passive fit?* Ann Acad Med Singapore, 1995(24): p. 138-57.
- Tan, K.B.C., et al., *Three-dimensional analysis of the casting accuracy of one-piece, osseointegrated implant-retained prostheses*. The International Journal of Prosthodontics, 1993. **6**: p. 346-63.
- Tan, M.Y., et al., *Comparison of Three-Dimensional Accuracy of Digital and Conventional Implant Impressions: Effect of Interimplant Distance in an Edentulous Arch*. Int J Oral Maxillofac Implants, 2019. **34**(2): p. 366-380.
- Tan, J.Z.H., et al., *Three-dimensional positional accuracy of intraoral and laboratory implant scan bodies*. J Prosthet Dent, 2021.
- Nicholls, J.I., *The measurement of distortion: Mathematical considerations*. J Prosthet Dent, 1978. **39**: p. 339-343.
- Nicholls, J.I., *The measurement of distortion: Concluding remarks*. 1980. **43**: p. 218-223

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