

Fit Accuracy of Conical Connection Implant System Components – 2D Tolerance Displacement

Tan Beng Kai Charles*, Tan Ming Yi‡, See Toh Yoong Liang*, Janice Tan Zhi Hui*, Keson Tan Beng Choon‡
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Introduction

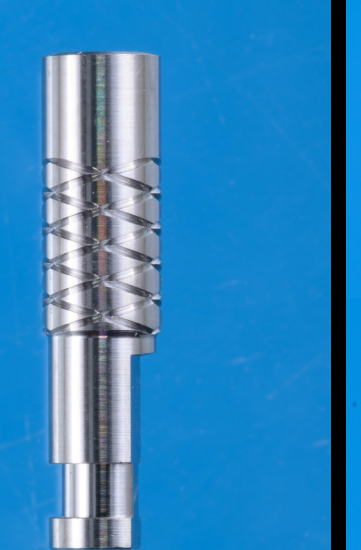
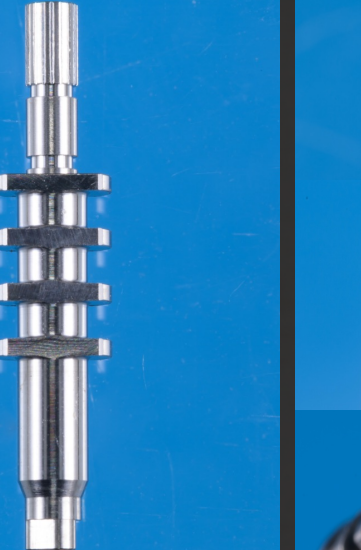
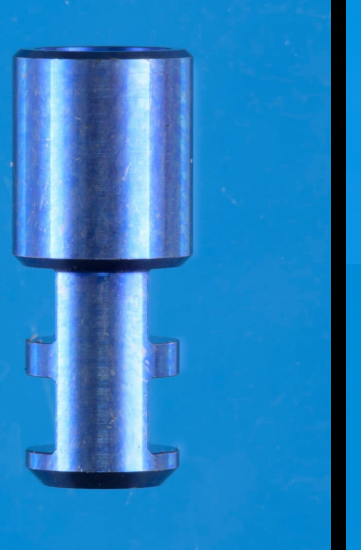
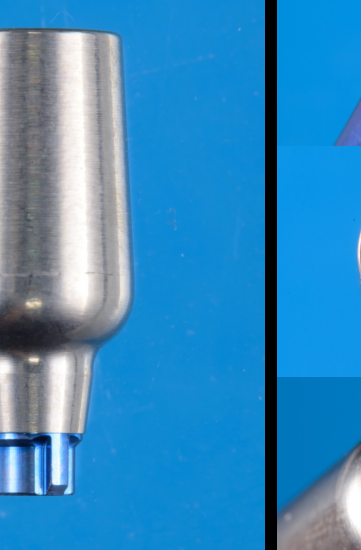
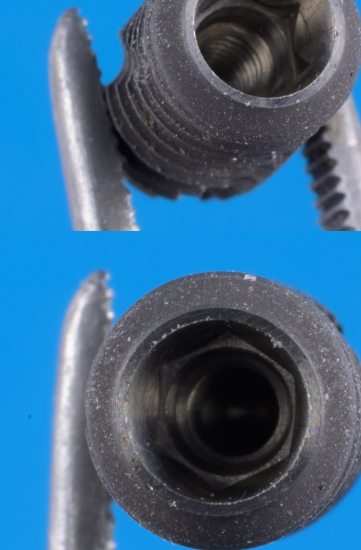
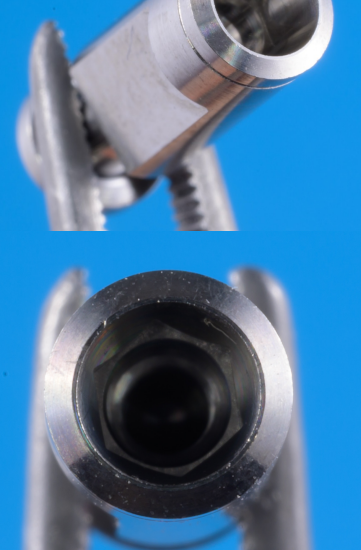
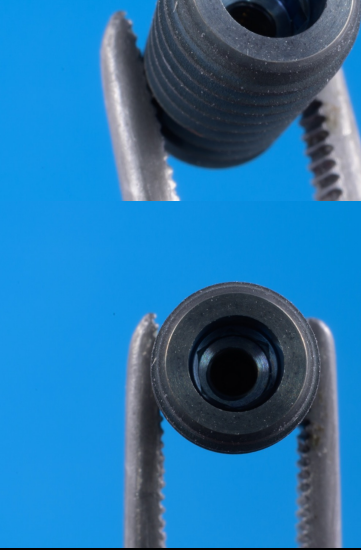
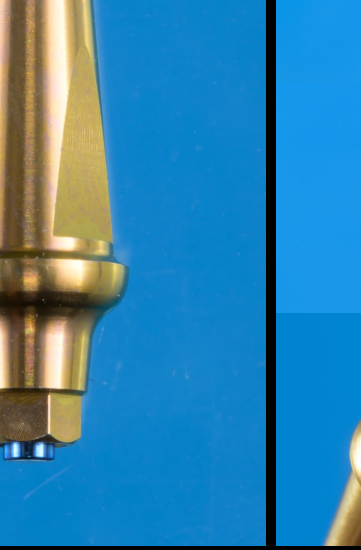
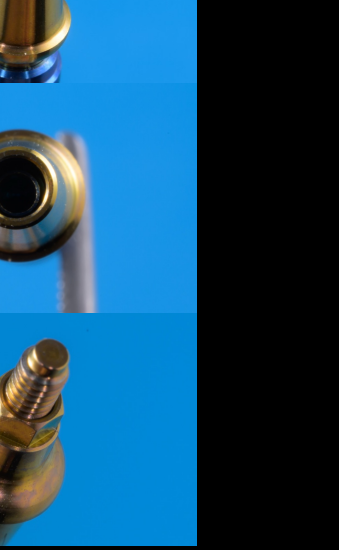
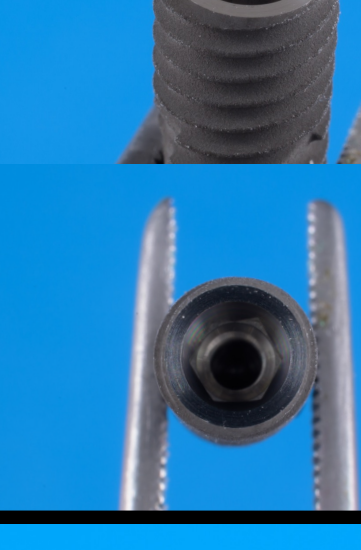
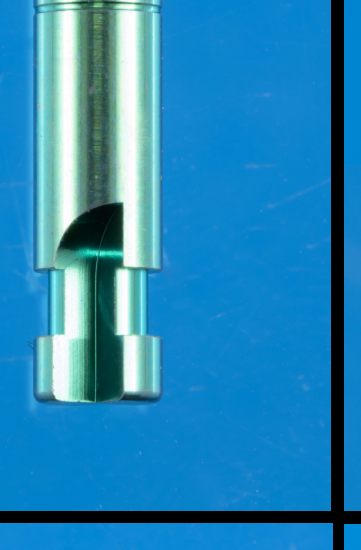
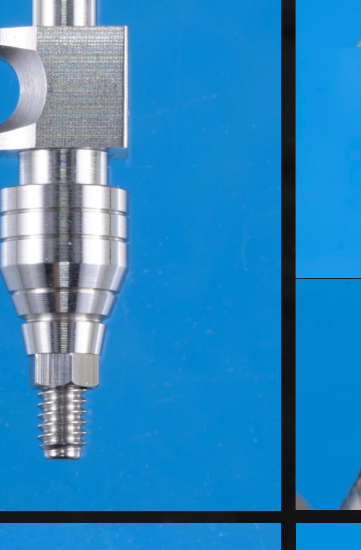
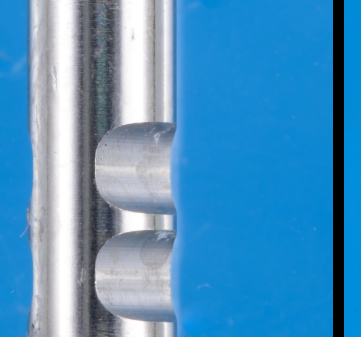
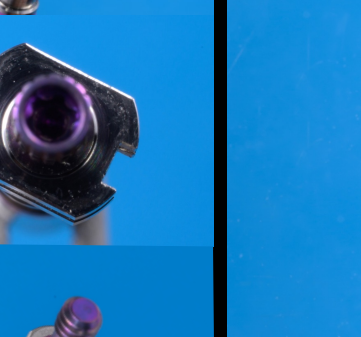
- The fit accuracy of conical connection implant systems is unknown.
- Whether differences in fit accuracy exist between conical connection implant systems and within system components is unknown.
 - Existing studies on accuracy of fit mainly evaluate external hexagonal implant system components^{10, 23, 24, 27}; linear tolerances in the horizontal plane range from 22 to 100 μm ²⁴.
- The effect of torque on fit accuracy of conical connection implant system components is also unknown.
 - Besides the implant-abutment connection, implant system manufacturers provide vague instructions of “hand tightening” (manual torque application) for the implant-impression coping, replica-impression coping, replica-abutment interfaces³⁶⁻⁴⁵.
- Manual torque application is known to have significant variation, and can be affected by factors including tooth position³², implant driver size³³ or operator size³¹.

Objectives

- To evaluate if differences exist in fit accuracy (two-dimensional (2D) tolerance displacements) of impression copings and abutments when connected to implants or replicas for six conical connection implant systems.
- To evaluate the effect of torque on fit accuracy of conical connection implant system components.

Materials and Methods

- (n=10) Ten each of implants, replicas, impression copings and abutments of six conical connection implant systems were randomly assigned to 10 groups.
- Systems evaluated:
 - Anthogyr AXIOM Regular (ANT)
 - Biohorizons Camlog CONELOG® Screw-line (CON)
 - Dentium Superline (DEN)
 - MegaGen Anyridge (MEG)
 - Osstem TSIII (OSS)
 - Straumann Bone Level RC (STR)
- Connections evaluated:
 - Implant-Impression coping (I-C)
 - Replica-Impression Coping (R-C)
 - Replica-Abutment (R-A)
 - Implant-Abutment (I-A)
- Torque magnitudes evaluated:
 - 5 Ncm
 - 10 Ncm
 - 15 Ncm
 - Manufacturer recommended torque (I-A)
- Components were measured using a coordinate measuring machine (Global Silver Performance, Brown & Sharpe, USA) with a 1.0 mm and 3.0 mm diameter ruby probe tip (Renishaw, UK) and metrological software PC-DMIS for Windows (v2019.R1, Hexagon Metrology, Brown & Sharpe, USA).

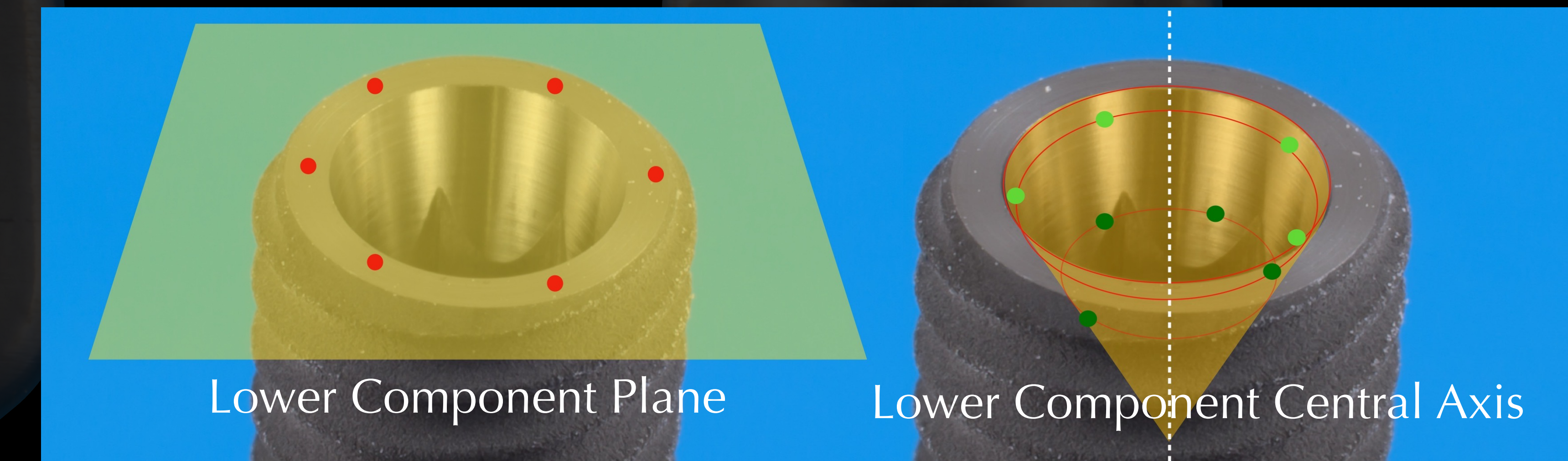
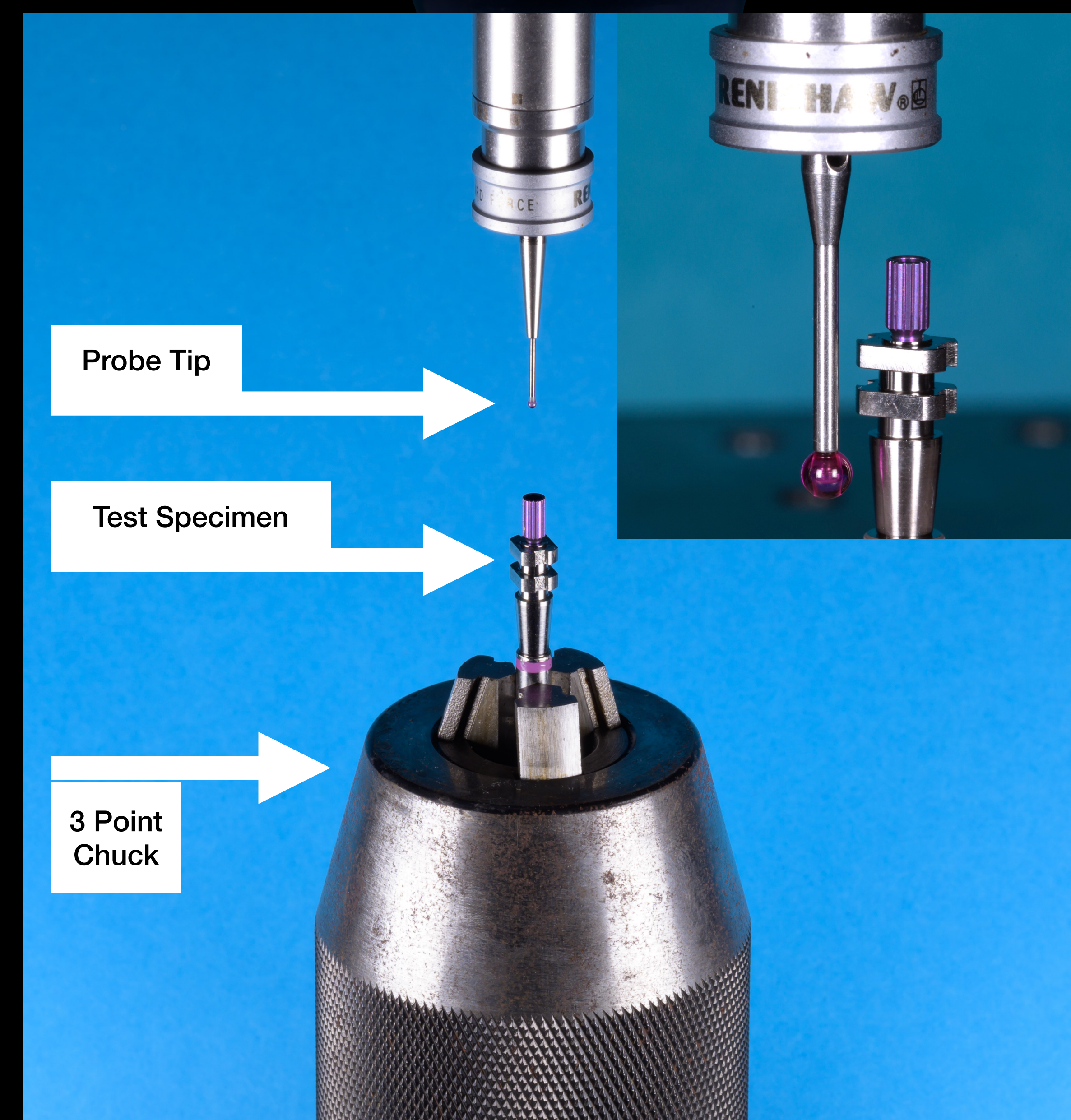
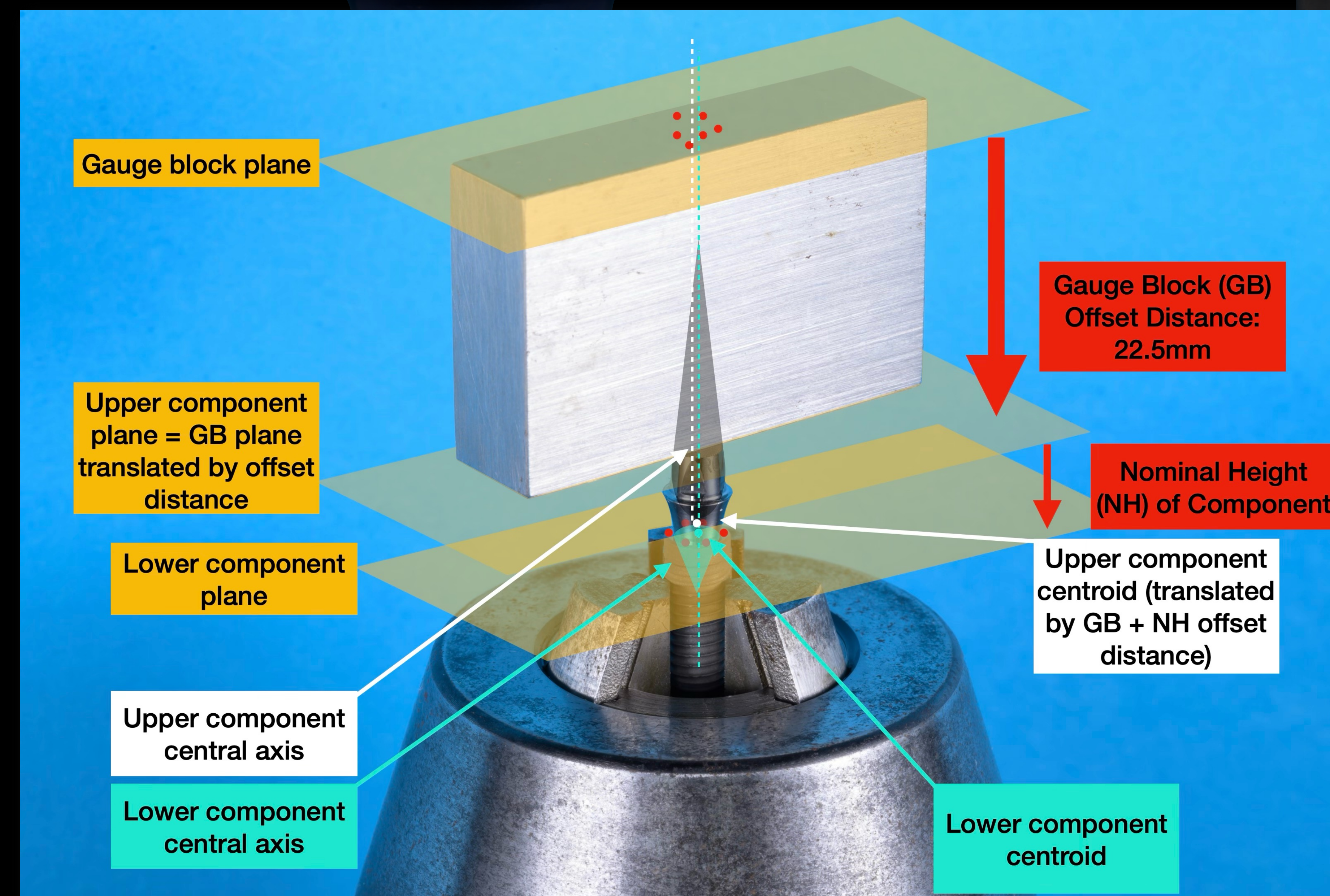
	Implant		Replica		Impression Coping		Abutment	
Anthogyr A Straumann Group Brand								
biohorizons camlog								
Dentium For Dentists By Dentists								
MEGAGEN								
OSSTEM IMPLANT								
straumann								

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Materials and Methods

1. Measurable geometric surfaces (planes, cones, cylinders) on the implant components with threshold values of 5 μm were identified.
2. Lower components (implant or replica) were secured in a 3-point chuck bolted to the granite platform of the CMM.
3. The upper component was fastened to the lower component and tightened using a calibrated torque gauge (Model 6BTG, Tohnichi, Japan).
4. Lower and upper component centroids were derived by intersecting their respective component planes (6 probe hits) with their central axis (8 probe hits over 2 levels). Using the centroid coordinates, linear distortion was calculated.
5. For components not easily measurable or machined to an edge, a standardized gauge block (22.5mm, VGB-112-1, Vertex Machinery Co., Ltd, Taiwan) was positioned and an offset plane used to calculate the component centroid.
6. Step 2 was repeated at 5, 10 and 15 Ncm for the I-C, R-C, R-A connections, and at the respective manufacturer specified torque at I-A connection.
7. After each upper component had completed all measurements, it was disconnected, and the lower component centroid re-verified.



- Linear distortion was calculated using three linear displacement values (d_x , d_y , d_z) for each connection with these formulae:

$$d_x = X_t - X_b$$

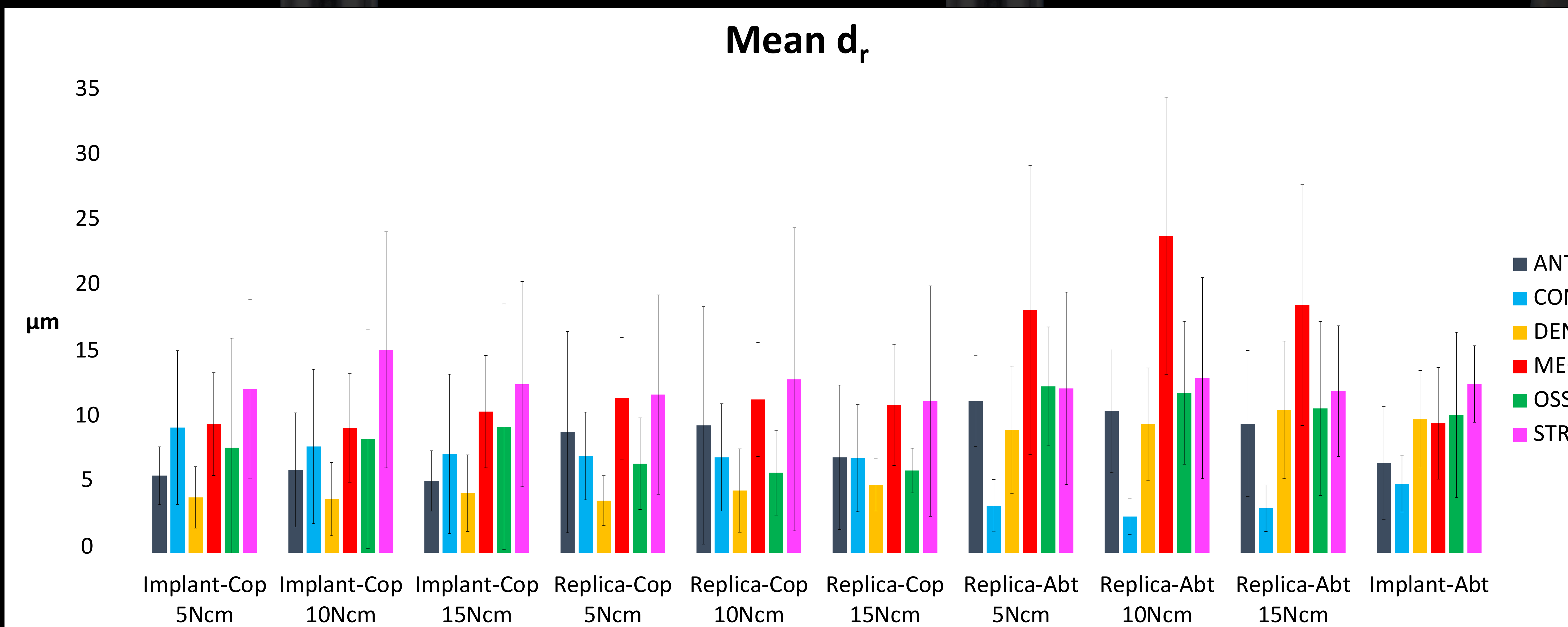
$$d_y = Y_t - Y_b$$

- X_t = x-coordinate of the upper component (abutment or impression coping)
- X_b = x-coordinate of the lower component (implant or replica)
- Y_t = y-coordinate of the upper component (abutment or impression coping)
- Y_b = y-coordinate of the lower component (implant or replica)
- As each component was measured individually to derive its individual nominal height (NH), d_z was offset, resulting in a value of 0. Therefore, the two-dimensional tolerance displacement (d_r) was calculated using this formula:

$$d_r = \sqrt{d_x^2 + d_y^2}$$

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Results

- Overall, mean d_r ranged from $3 \pm 1\mu\text{m}$ (CON, R-A, 10Ncm) to $24 \pm 10\mu\text{m}$ (MEG, R-A, 10Ncm).
- Mean d_r of I-C connections ranged from $4 \pm 2\mu\text{m}$ (DEN, 10Ncm) to $15 \pm 9\mu\text{m}$ (STR, 10Ncm), R-C connections ranged from $4 \pm 2\mu\text{m}$ (DEN, 5Ncm) to $13 \pm 11\mu\text{m}$ (STR, 10Ncm), R-A connections ranged from $3 \pm 2\mu\text{m}$ (CON, 15Ncm) to $24 \pm 10\mu\text{m}$ (MEG, 10Ncm).
- Two-way ANOVA found that variations in torque magnitude had no significant effect on d_r but implant system had a significant effect on d_r at I-C, R-C, R-A connections.
- Mean d_r of I-A connections ranged from $5 \pm 2\mu\text{m}$ (CON, 20Ncm) to $13 \pm 3\mu\text{m}$ (STR, 35Ncm) and one-way ANOVA found that system had a significant effect on d_r .
- One-way ANOVA showed no significant differences in mean d_r between component connections within systems ANT, OSS and STR, while significant differences were noted for CON, DEN and MEG.

Mean two-dimensional tolerance displacement, d_r (μm)					
Connection	System	Torque (SD)			Manufacturer Recommended
		5 Ncm	10 Ncm	15 Ncm	
Implant-Impression Coping (I-C)	ANT	6 (2)	6 (4)	5 (2)	-
	CON	9 (6)	8 (6)	7 (6)	-
	DEN	4 (2)	4 (3)	4 (3)	-
	MEG	10 (4)	9 (4)	11 (4)	-
	OSS	8 (8)	9 (8)	9 (9)	-
	STR	12 (7)	15 (9)	13 (8)	-
Replica-Impression Coping (R-C)	ANT	9 (8)	10 (9)	7 (5)	-
	CON	7 (3)	7 (4)	7 (4)	-
	DEN	4 (2)	5 (3)	5 (2)	-
	MEG	12 (5)	11 (4)	11 (5)	-
	OSS	7 (3)	6 (3)	6 (2)	-
	STR	12 (7)	13 (11)	11 (9)	-
Replica-Abutment (R-A)	ANT	11 (3)	11 (5)	10 (5)	-
	CON	4 (2)	3 (1)	3 (2)	-
	DEN	9 (5)	10 (4)	11 (5)	-
	MEG	18 (11)	24 (10)	19 (9)	-
	OSS	12 (4)	12 (5)	11 (6)	-
	STR	12 (7)	13 (8)	12 (5)	-
Implant-Abutment (I-A)	ANT	-	-	-	7 (4) at 25 Ncm
	CON	-	-	-	5 (2) at 20 Ncm
	DEN	-	-	-	10 (4) at 30 Ncm
	MEG	-	-	-	10 (4) at 35 Ncm
	OSS	-	-	-	10 (6) at 30 Ncm
	STR	-	-	-	13 (3) at 35 Ncm

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Discussion

- Differences in fit accuracy between conical connection implant systems and components
 - This study suggests that the fit accuracy of conical connection implant system components is significantly different between systems and between component connections within each system. However, for single implant restorations, the statistically significant differences in d_r between implant systems and component connections are likely clinically insignificant.
 - Nevertheless, these inaccuracies may be cumulative and significant in multi-implant prostheses.
- Differences in fit accuracy between external hexagonal systems and conical connection implant systems
 - Machining tolerances previously measured by Ma et al²⁴ for external hexagonal implant system components ranged from 22 to 100 μm . This study identified a mean fit accuracy (2D tolerance displacement, d_r) of 3 ± 1 to 24 ± 10 μm for conical connection implant system components.
 - Differences in these tolerance measurements could be attributed to improvements in fabrication methods, more precisely mated componentry and the “self-centering” design of conical connection implant system components
- Variations in Torque Magnitude
 - This study suggests that variations in torque magnitude from 5, 10 or 15 Ncm do not significantly affect d_r for the respective component connections. This could be due to the “self-centering” effect of conical connection components.
 - However, this does not suggest that manufacturers’ vague instructions of “hand tightening” should be relied upon. Instead, consistent controlled torque application should be applied at each connection, especially when multiple implants and dis- and re-connection of components during fabrication is required.

Conclusions

- At I-C, R-C, R-A and I-A connections, significant differences in d_r were found between implant systems and connections.
- No significant differences in d_r were found at I-C, R-C and R-A connections between torque magnitudes.

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