A Theoretical Analysis of Component-Level Vertical Restorative Error

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OBJECTIVE

The aim of this study was to theoretically assess the vertical location error associated with conical implant-abutment junction interfaces.

BACKGROUND

Vertical location error can be described as the inaccurate transfer of the coronal seating datum throughout the restorative process, which can result in improper occlusion. This datum is either a defined seating surface as with a conventional "horizontal" type implant-abutment assembly, or, in a conical implant system, it is a theoretical location established when the mate occurs. Precise control of this vertical position is critical to ensure an accurate restorative outcome (Fig 1).

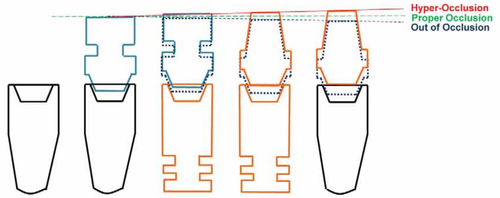


Figure 1- Vertical displacement error in the restoration process

There are many potential sources of contributing error such as design tolerances, manufacturing defects, mating component surface finishes, displacement and/or deformation due to screw torque, improper screw torque, and impression taking and/or cast fabrication. In the current study, the assessment was limited to geometric irregularities, specifically the manufacturing tolerances. Horizontal connections were excluded from this analysis because the seating surfaces mate together at a constant position and are unaffected by the error currently being assessed.

MATERIALS AND METHODS

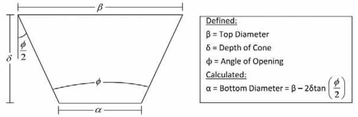


Figure 2 - The (3) geometric variables used to define a conical connection.

Vertical location error (ρ) is a result of mating components discrepancies. Due to the conical variables (Fig. 2), there are (12) possible configurations (Fig. 3). These scenarios can be categorized into (4) groups based on the mating contact and the conical diameter relationship.

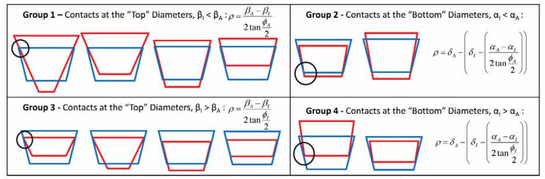


Figure 3 – Potential misaligned mating configurations (Implant, Abutment)

The total vertical error (ρ_{total}) is the calculated discrepancy between the location of the abutment in the implant analog and the abutment in the implant (Fig. 4).

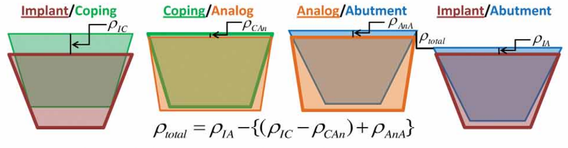


Figure 4 – The calculated error accumulation throughout the restoration process.

A second set of equations was created to limit the abutment travel to be no lower than the implant surface (see lower right illustration in Table 2). Although this "Pass-Through Restriction" may be viewed as excessive, it allowed for two analyses to be conducted in which the vertical location error is mathematically bounded. The actual vertical location error distribution likely falls somewhere between the two conditions, and is ultimately dictated by the limitations associated with the full interfacing geometry of the specified implant and abutment.

A test system (Table 1) was defined. The maximum/minimum single component interaction errors were calculated based on the extreme conditions within the test system parameters.

Top Diameter (β)	Depth of Cone (δ)	Angle of Opening (ϕ)
4.0 mm ± 0.05 mm	1.5 mm ± 0.05 mm	20° ± 1°

Table 1 – Test System Dimension Values and Tolerances.

Values for each dimension of the (4) components (Implant, Coping, Analog, and Abutment) were assigned by a random number selection Excel command. The tolerance was chosen from a normalized distribution, and each of the (12) dimensions was adjusted by the respective selection. These values were used to calculate the accumulated error, with and without the Pass-Through Restriction, for (10,000) system sets, and to create probabilistic distributions.

RESULTS AND DISCUSSION

The extreme maximum and minimum value conditions were calculated for single interactions between components:

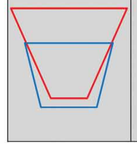
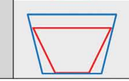
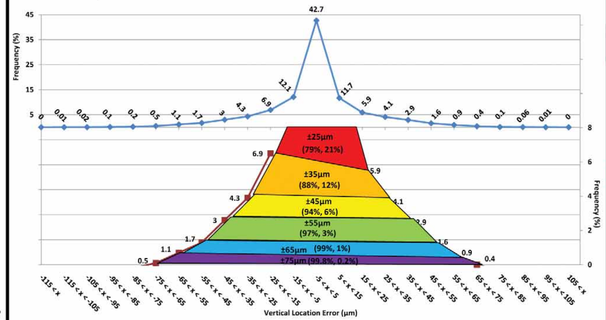
Maximum (Maximum Abutment/ Minimum Implant)		Minimum (Minimum Abutment/ Maximum Implant)	
	+420 µm		No Pass-Through Restriction -298 µm
			Pass-Through Restriction -100 µm

Table 2 – Maximum and Minimum Single Interaction Errors

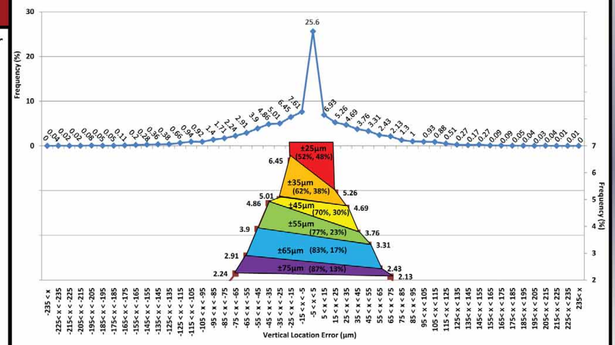
The distributed error values for the full system interactions were concentrated well within the limits set by the single interaction errors. This is a result of error cancellation as the components are assembled during the restorative process.

Pass-Through Restriction	Average	Standard Deviation	Range
Without	0 µm	21 µm	-108µm to +103µm
With	-3 µm	50 µm	-234µm to +228µm

Table 3 –Comparison of the Statistical Error Distributions



Graph 1 – *Without Pass-Through Restriction.* Top Graph: Frequency (%) of error in 10 µm increments centered about 0 µm. Bottom Graph: Frequency (%) of error restricted to values outside of ±45µm (% inside range, % outside range)



Graph 2 – *With Pass-Through Restriction.* Top Graph: Frequency (%) of error in 10 µm increments centered about 0 µm. Bottom Graph: Frequency (%) of error restricted to values outside of ±45µm (% inside range, % outside range)

Further study, and bench-top assessment with actual components, may reveal that conical connections are more sensitive to the other causes of vertical location error, such as torque control, because they lack a defined seating surface. In a study performed by Dailey et al. (JOMI 2009; 24:251-256), it was observed that torque alone could displace an abutment into a conical connection by as much as 21 µm for every 5 Ncm of applied torque.

CONCLUSION

Based on this theoretical analysis, one can conclude that conical connection designs are susceptible to a unique, and not insignificant, form of vertical location error.

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Ross Towse, Danielle Ouellette and Zach Suttin conducted this research while employed by BIOMET ***3i.***