0982

Quantitative Benchtop Characterization of Abutment Stability and Fit

M. Kofron[1], M. Carstens[2], H. Wen[2]

[1]Technology Development, Zimmer Biomet Dental, Palm Beach Gardens, Florida, United States
[2]Research, Zimmer Biomet Dental, Palm Beach Gardens, Florida, United States

BACKGROUND

A tight fit of the abutment on the implant contributes to abutment stability and clinical success [1]. Due to consistency of implant sizes and the commonality of the internal hexagon connection, abutments and implants fabricated by different manufacturers have been clinically joined. The purpose of this study was to quantitatively measure abutment fit of original equipment manufacturer (OEM) and aftermarket (AM) definitive abutments on the Tapered Screw-Vent® implant system (Zimmer Biomet). We hypothesized the OEM abutment would demonstrate less rotational freedom and micromotion and greater pull force as compared to AM abutments.

MATERIALS & METHODS

Components Evaluated: Test groups consisted of one OEM (Zimmer Biomet) and five aftermarket (AM1 – AM5) (BioHorizons, Implant Direct, MIS, BlueSky Bio, or Glidewell) abutments.

Pre-Load Loss: Pre-load loss was measured as the difference between the initial torque applied to each abutment screw, per the manufacturer's instructions for use, and the reverse torque required to remove the screw, after 20 minutes. Measurements were obtained using a digital torque gauge [model: BGI Mark-10; Wagner Instruments, Copiague, NY]. Each abutment screw was removed prior to measurements of abutment micromotion, rotational freedom, and pull force.

Abutment Angular Rotation (AAR): AAR (n=5) was measured as the absolute difference between the maximum clockwise and counterclockwise movements. Briefly, the implant system, with the abutment screw removed, was inverted and secured in a collet. The abutment was lowered into a low melting point metal reservoir. Once cured, the assembly was centered (0°) in the equipment. To measure relative angular movement, the abutment was rotated and released. The resultant angles achieved, in clockwise and counterclockwise rotational directions were recorded (Figure 1).

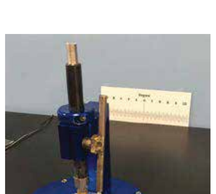

Figure 1. Abutment Angular Rotation (AAR) equipment measured the degrees of clockwise and counterclockwise rotation the abutment can withstand when seated on the implant.

Abutment Micromotion (AMM): While under cyclic loading, AMM measured the length of micromotion at the base of the abutment relative to a stationary implant. Briefly, implants were mounted in resin at bone level (0mm resorption). Implant assemblies were subjected to a 200N force at a 30° angle with respect to the implant axial axis for 600 cycles using the Instron E3000 materials testing system. The deflection was detected using a Laser Doppler Vibrometer connected to a data acquisition system [Model: OMS LaserPoint LPO1; Optical Measurement Systems, Laguna Hills, CA] (Figure 2B).

Abutment Pull Force (APF): APF *(n=5)* measured the force required to separate the abutment and implant. Briefly, the abutment was placed on the implant and the screw was torqued to the manufacturer's recommended value using a digital torque gauge. The abutment screw was reverse torqued and removed. Next, the implant was inverted and secured in a collet. The abutment was lowered into a previously heated low melting point metal reservoir. Once cured, the force required to separate the implant and abutment was recorded using an Instron materials testing system [model: E3000; Instron, Norwood, MA] (Figure 2A).

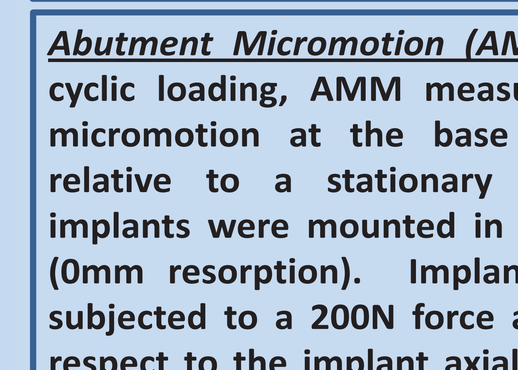

Figure 2. An Instron E3000 test system measured [A] APF, abutment pull force and [B] abutment micromotion, AMM.

Statistical Analysis: Data are presented as mean ± standard deviation. Statistical analysis used a one-way Analysis of Variance to determine the presence of statistical significance ($\alpha = 0.05$) and a Tukey's post-hoc test ($p<0.05$) to determine which groups were significantly different. Pearson Correlation Coefficient was calculated between reverse torque measurements and each connection test measurement.

RESULTS

Pre-Load Loss: In the laboratory, pre-load loss characterizes the degree of abutment settlement on the implant. After 20 minutes, pre-load loss ranged from 9.7 ± 7.2Ncm and 1.9 ± 3.4Ncm, with no significant difference between groups (data not shown).

Abutment Angular Rotation (AAR): The OEM abutment was the only abutment to exhibit 0° rotational freedom, which was significantly less than the AM groups. AM3 failed to engage the implant hex and 360° rotation was measured. For the remaining AM groups total rotation ranged from 1.85° ± 0.45° to 3.25° ± 0.18° (Figure 3).

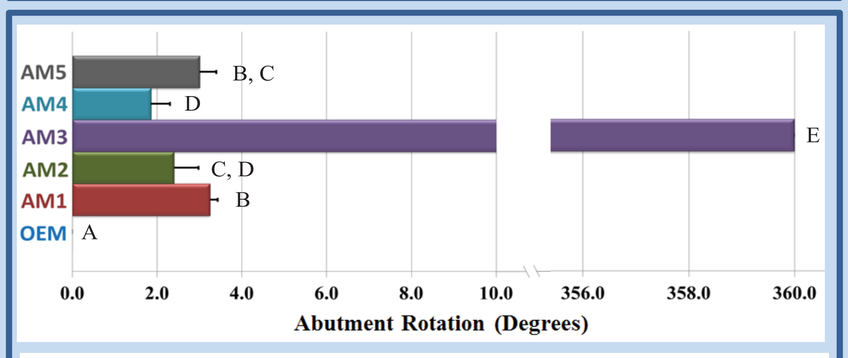

Figure 3. Abutment Angular Rotation ranged from 0° for the OEM abutment to 360° for AM3. The OEM abutment, whose connection is specifically machined for placement on the implant, was the only group to exhibit no rotation. Test groups not sharing the same letter are statistically significant.

Abutment Micromotion (AMM): AM1 and AM2 demonstrated no significant difference in micromotion as compared to OEM. OEM, AM1 and AM2 demonstrated significantly less micromotion as compared to AM3, AM4, and AM5. AM5 had significantly greater micromotion as compared to all other abutments (Figure 4).

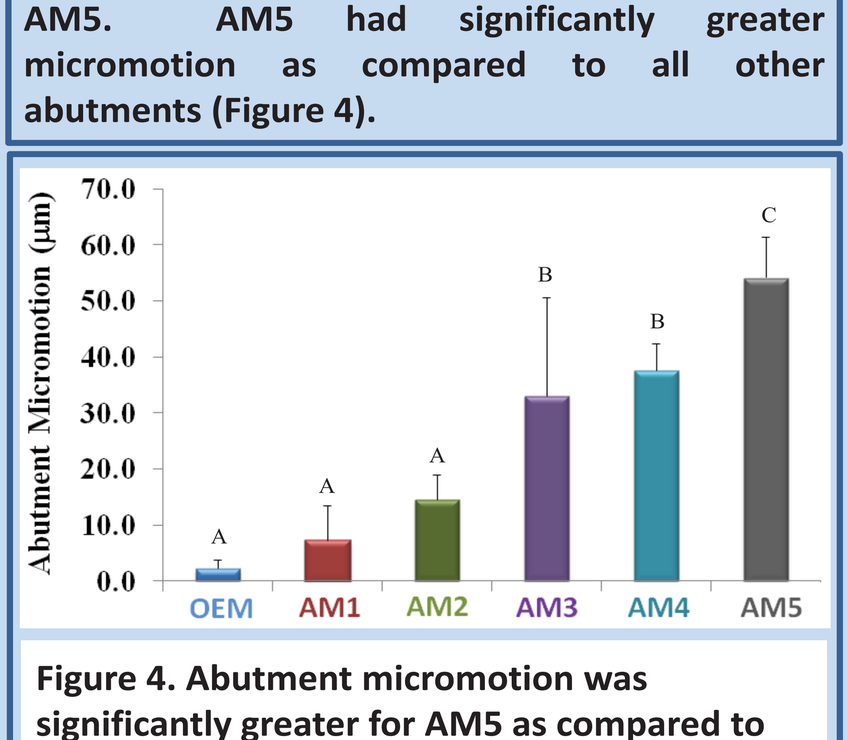

Figure 4. Abutment micromotion was significantly greater for AM5 as compared to all other groups. OEM demonstrated the least amount of micromotion and was not significantly different from AM1 and AM2. Test groups not sharing the same letter are statistically significant.

Abutment Pull Force (APF): The OEM abutment required a pull force 172.9 ± 57.0N (Figure 5).

AM abutments failed to demonstrate an interference fit with the hex or conical portion of the implant connection and all AM specimens had a pull force of zero (Figure 5).

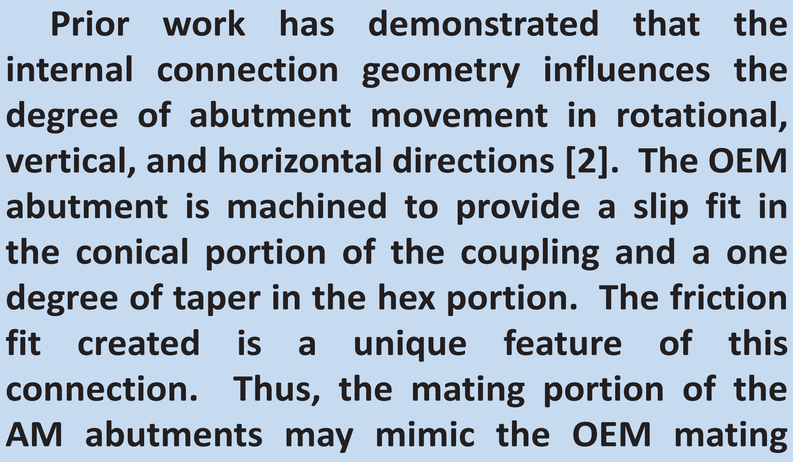

Figure 5. Abutment pull force demonstrated that AM abutments failed to demonstrate an interference fit with the hex of the implant. OEM had a significantly greater pull force as compared to all AM abutment test groups.

DISCUSSION

Prior work has demonstrated that the internal connection geometry influences the degree of abutment movement in rotational, vertical, and horizontal directions [2]. The OEM abutment is machined to provide a slip fit in the conical portion of the coupling and a one degree of taper in the hex portion. The friction fit created is a unique feature of this connection. Thus, the mating portion of the AM abutments may mimic the OEM mating portion, but not provide a friction fit. As a result, the AM abutments exhibit significantly greater abutment rotation, a trend towards or significantly greater abutment micromotion, and an absence of measureable pull force. These findings indicate no static frictional force was established in the connection once the abutment screw had been torqued to the manufacturer's recommended value. Thus, the AM connections are considered non-self locking [1]. Connections with rotational freedom greater than 2° can result in vibration and micromovement between the components during functional loading, which subsequently decrease the clamping force until screw-joint failure occurs [3-4].

During study implementation, abutment screw removal prior to testing means these pre-clinical test results may not be indicative of clinical performance. Abutment screw removal allowed for a more direct physical assessment of the tightness and stability of the fit between the abutment and implant.

CONCLUSIONS

When the abutment screw is torqued, the abutment undergoes settlement at the initial contact points with the implant. Abutment settlement into the connection leads to loss of preload and stabilizes the abutment. Based on the measurements obtained, OEM abutments demonstrated greater stability on the implant as compared to all AM abutments evaluated. The static friction, established by the OEM friction-fit connection, provides a feature encompassing anti-rotation, a resistance against vertical pull forces, and a resistance to horizontal forces. The selection of an implant connection with self-locking features that will resist micromovement due to horizontal, vertical, and rotational forces is likely to provide better performance under biomechanical loading in the oral environment.

REFERENCES

[1] Zipprich H, et al. Micromovements at the implant-abutment interface: Measurement, causes, and consequences. Implantologie 2007; 15(1): 31-46.
[2] Kofron MD, et al. Quantitative contribution of friction-fit™ to connection strength and stability. (2017, September) American Academy of Periodontology, Boston, P097.
[3] Binion PP. The evolution and evaluation of two interference-fit implant interfaces. Postgraduate Dent 1996; 3(1): 3-13.
[4] Binion PP. The effect of implant/abutment hexagonal misfit on screw joint stability. Int J Prosthodont 1996; 9(2): 149-160.

For Information contact: Michelle Kofron, PhD at Michelle.Kofron@zimmerbiomet.com.

This research was funded by Biomet *3i*, LLC.