Short Communication

The Three-Dimensional Casting Distortion of Five Implant-Supported Frameworks

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The aim of this study was to assess three-dimensional distortion in cast full-arch, screw-retained titanium implant frameworks. A conventional commercial laboratory one-piece casting was used implementing the lost-wax technique. Five wax patterns were fabricated on a die-stone cast poured from a plaster impression of a five-implant brass analog. A reflex microscope was used to determine the three-dimensional casting error. Significant differences were found in distortion between wax patterns and castings, which, given the need to keep within 150 µm of misfit for passivity, were larger than the wax frameworks by between 416 and 477 µm. The greatest distortion occurred at the terminal implant abutments and in the vertical dimensions, but the distortion was inconsistent, indicating its three-dimensional nature. It is doubtful whether any conventionally cast titanium framework can be made to the degree of accuracy required to fit passively on its abutments because of the multiple variables inherent in this process. *Int J Prosthodont 2009;22:248–250.*

An implant-supported prosthesis superstructure should exhibit a passive fit when connected to multiple abutments. Jemt[1] proposed that a maximum of half a screw turn, corresponding to a misfit of approximately 150 µm, should be clinically acceptable. Distortions of implant superstructures arise throughout the procedures involved in their fabrication. Assessment of fit usually involves linear distortion measurements and to date, no three-dimensional (3-D) studies of one-piece titanium frameworks have been reported. Furthermore, mathematically calculated values are often used to derive 3-D distortion.[2] The purpose of this investigation was to measure the 3-D distortion of one-piece, as-cast titanium frameworks by direct measurements in three dimensions using a reflex microscope.

Materials and Methods

A stone cast was poured from a brass analog cast containing five implants (Southern Implants) and five standardized wax patterns were made on UCLA non-hex sleeves (SB5, Southern Implants) by a single technician in a commercial laboratory. Three horizontal and three vertical titanium pins were incorporated into each wax framework, with indentation points on their terminal ends, made using a Vickers indentation apparatus (Leco M-400 Hardness Tester), to serve as measuring reference points (Fig 1).

The wax frameworks were invested, cast in titanium, and finished according to a standardized procedure using the same batches of each material throughout. Each point was labeled, as well as three points on the flat surface of the cast representing the horizontal reference plane (Fig 2).

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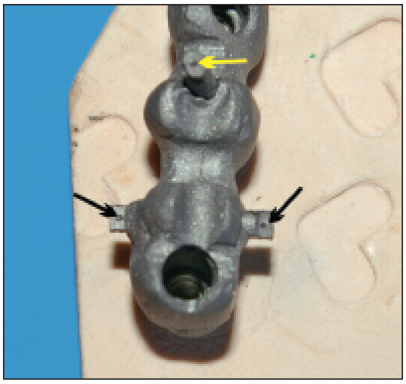

Fig 1 Arrows show the indentation points on the reference pins, which are identified on the reflex microscope.

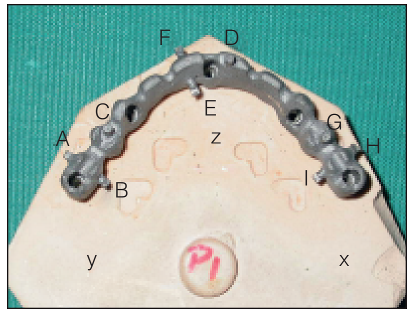

Fig 2 Titanium framework on the master cast showing the positioning of reference pins and points.

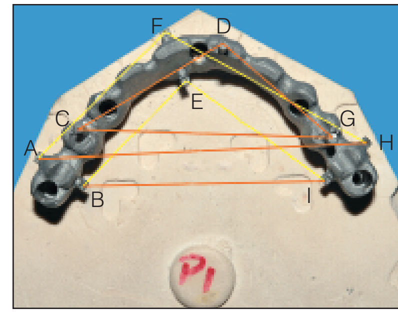

Fig 3 Distortions between the wax and cast frameworks. Statistically significant differences are shown by orange lines; yellow lines are not statistically significant.

Table 1 Results of Paired *t* Tests for Distance Measurements (mm)

ID	A–F	F–H	A–H	B–E	E–I	B–I	C–D	D–G	C–G
Cast-wax 1	0.845	0.097	0.433	1.699	1.133	0.615	0.381	0.381	0.597
Cast-wax 2	1.434	1.426	0.393	−0.182	0.427	0.507	0.446	0.446	0.778
Cast-wax 3	0.146	0.451	0.334	−0.502	−0.015	0.363	1.304	1.304	0.495
Cast-wax 4	0.235	0.204	0.282	0.408	0.27	0.403	0.402	0.402	0.331
Cast-wax 5	−0.031	0.227	0.389	0.473	0.487	0.418	0.557	0.557	0.482
Mean	0.5258	0.4810	0.3662	0.3792	0.4604	0.4612	0.6180	0.4651	0.5366
SD	0.6053	0.5474	0.0580	0.8431	0.4232	0.1008	0.3894	0.2741	0.1650
P value	.0620	.0595	.0001*	.1857	.0359*	.0003*	.0119*	.0096*	.0009*

* = Statistically significant.

Table 2 Results of Paired *t* Tests for Offsets From the Reference Plane (mm)

ID	A	B	C	D	E	F	G	H	I
Cast-wax 1	0.082	0.21	0.37	0.172	0.728	−0.211	0.537	1.335	1.35
Cast-wax 2	0.756	1.238	0.932	0.665	0.052	0.709	0.954	0.753	0.774
Cast-wax 3	0.701	0.845	0.339	0.35	0.91	0.551	−0.1	−0.021	−0.173
Cast-wax 4	0.792	0.285	1.224	0.327	−0.109	0.086	−0.245	−0.247	−0.542
Cast-wax 5	0.174	0.104	0.332	0.242	0.475	0.225	0.443	0.26	0.115
Mean	0.5009	0.5364	0.6394	0.3511	0.4112	0.272	0.3178	0.416	0.3047
SD	0.3435	0.4858	0.4137	0.1891	0.4338	0.3670	0.4898	0.6350	0.7572
P value	.0155*	.0345*	.013*	.0071*	.0507	.0864	.1102	.1084	.2095

* = Statistically significant.

Each wax pattern and subsequent casting was secured onto the master cast with a single brass screw (BSS2, Southern Implants) in the central incisor area. To avoid distortion, the screw was fastened using a hand-operated screwdriver until tactile feedback indicated that the screw had started to engage. The same operator tightened all screws.

Using a reflex microscope (Reflex Measurement), an instrument which allows for measurement in three dimensions to a high degree of precision,[3] distances were measured for each wax framework and its casting between the points on the reference pins: three each for the outside (AF, FH, AH) and inside (BE, EI, BI) horizontal pins, three for the vertical pins (CD, DG, CG), and between each pin and its offset from the horizontal plane xyz. The same set of measurements was taken for each casting.

Measurements were analyzed using *t* tests and three-way analysis of variance. For the latter, the random effects were each of the specimens; the fixed effects were the wax versus cast frameworks and the distance measurements.

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Results

For the distance measurements, the wax frameworks ($P = .0446$), cast frameworks ($P < .0001$), and distance measures ($P < .0001$) were all statistically significantly different from each other and indicated expansion of the castings. To determine where this had occurred, 18 paired *t* tests were applied for each of the nine horizontal distance measurements (Table 1) and nine offset measurements (Table 2) to test for differences in the average wax and cast measurements of each pair.

Figure 3 illustrates the significant distortions between the wax and cast frameworks.

The results for the offset measurements from the reference plane (Table 2) indicate that significant changes occurred at points A ($P = .0155$), B ($P = .0345$), C ($P = .013$), and D ($P = .0071$).

Discussion

It is known that cast prostheses can show large variations in accuracy of fit. By measuring points away from the cylinders, this study has clarified the 3-D nature of casting distortion. Distortion may contribute to delayed component failures[4] since screw tightening may hide the existence of prestress within the components and framework, and it is not possible to rely on bone physiologic mechanisms to compensate for poor fit.

The sample size in this study was limited and standardized procedures were used in the casting process. They were carried out in the same manner for all castings in a commercial laboratory to better reflect the reality of this process. All specimens showed distortions between wax and cast frameworks that were consistently well above the 150 μm limit proposed by Jemt,[1] and so it was felt that there would be little to gain from increasing the sample size. Thus, in order to limit distortion, other techniques must be used such as casting in separate units or vertical sectioning followed by indexing; laser-welding techniques have also been recommended for cast titanium frameworks.[5]

The use of a single screw to secure the framework is commonly recommended for assessment of clinical fit,[1] and it appears to be very sensitive to certain types of distortion, such as rotational displacements that lift opposing cylinders.[4] This could explain the multidimensional pattern of distortion, particularly that occurring at the terminal abutments. Thus, the evidence produced by this 3-D distortion analysis cautions against clinical reliance on the one-screw test to assess passivity of fit.

Conclusion

Within the limitations of this study, the results show that as-cast titanium frameworks are inaccurate and imprecise when judged against the 150 μm requirement for passivity of fit.[1] These distortions are 3-D and can be attributed to factors inherent in the casting process.

Acknowledgments

The authors would like to thank Southern Implants for kindly donating the implant components, Chris Boschoff and his technicians at BosTech Laboratory who carried out the laboratory work and generously assisted with the laboratory costs, Prof F. Botha (University of Pretoria) who assisted with the reflex microscope, and Prof P. Fatti (University of the Witwatersrand) for the statistical advice.

References

1. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: A study of treatment from the time of prosthesis placement to the first annual checkup. Int J Oral Maxillofac Implants 1991;6:270–276.
2. Jemt T, Lie A. Accuracy of implant-supported prostheses in the edentulous jaw: Analysis of precision of fit between cast gold-alloy frameworks and master casts by means of a three-dimensional photogrammetric technique. Clin Oral Implants Res 1995;6:172–180.
3. Scott PJ. The reflex plotters: Measurements without photographs. Photogrammetric Record, 1981;10:435–446.
4. Tan KB, Rubenstein JE, Nicholls JI, Yuodelis RA. Three-dimensional analysis of the casting accuracy of one-piece, osseointegrated implant-retained prostheses. Int J Prosthodont 1993;6:346–363.
5. Jemt T, Henry P, Lindén B, Naert I, Weber H, Wendelhag I. Implant-supported laser-welded titanium and conventional cast frameworks in the partially edentulous jaw: A 5-year prospective multicenter study. Int J Prosthodont 2003;16:415–421.

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