Comparison of Interface Relationships Between Implant Components for Laser-welded Titanium Frameworks and Standard Cast Frameworks

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With the introduction of new techniques for the fabrication of frameworks for implant-supported prostheses comes the need to understand how the components used compare to those used for conventional cast frameworks. The relationship of measured machining tolerances between conventional implant components and those components used for stereo laser–welded implant frameworks was determined using a standardized protocol. Statistically significant differences in the horizontal interface relationship were found between paired implant components, which had a mean range from 23.1 to 51.7 µm. From a laboratory and clinical perspective, machining tolerances of implant components represent a variable associated with their manufacturing, which can ultimately affect the fit of a completed prosthesis.

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Key words: implant components, machining tolerances, titanium feet

The critical importance of maintaining a consistent interface relationship between implant components in the process of transfer from the oral cavity to the dental laboratory and vice versa cannot be overemphasized.[1,2] Jemt and Linden reported a new technology of framework fabrication employing machined titanium prosthodontic implant components, called "feet," which are assembled rather than cast using a fabrication process termed stereo laser–welding.[3] Jemt and Lie reported on a photographic transfer technique, referred to as stereophotogammetry, as an alternate method that eliminated the need for making a master impression.[4] With these increasingly sophisticated "high-tech" approaches to the fabrication of implant-supported prostheses, the importance of maintaining the interface relationship between components assumes an ever increasing role.

A number of investigators have addressed issues related to machining tolerances of implant components.[5–7] Also, several implant manufacturers have claimed to have machining tolerances that exceed those of a yet-to-be-determined gold standard. Another manufacturer has expressed a need to build "freedom" into the design of implant component mating surfaces.[8] It has been demonstrated by sophisticated measuring techniques that far exceed the average clinician's visual or tactile capability that it is impossible to detect clinically the exactness of fit at the interface of machined implant components.[9,10] Furthermore, with the ever increasing use of implant components designed to address esthetic concerns, incorporating emergence profiles below tissue level, visual assessment of fit either clinically or radiographically presents the clinician with even greater challenges.

Ma et al compared first- and second-generation Nobel Biocare (Nobel Biocare, Westmont, IL) implant prosthodontic components, ie, tapered-head fixation design versus flat-head fixation design.[11] There were statistically significant differences for almost all the interface relationships of the components evaluated, with the second-generation design appearing to be more accurate.

This investigation compares the interface relationships between titanium implant prosthodontic

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Fig 1 Titanium “feet” fastened to standard abutments.

Table 1 Nobel Biocare Implant Components Tested

Component type	Product no.
Impression coping	DCB 026
Square guide pin, flat head, 10 mm	DCA 094
Abutment replicas, brass	DCB 015
Gold cylinder, 4.0 mm	DCA 072
Stainless steel analog	DCB 175
Gold screw, flat head, slot	DCA 075
Titanium abutment,* 5.5 mm	SDCA 005
Titanium implant* (3.75 × 13 mm)	SDCA 018

*Nobel Biocare, Göteborg, Sweden.

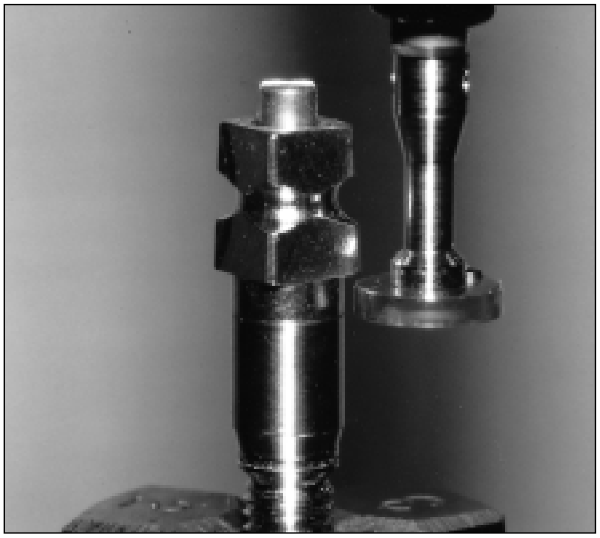

Fig 2 The measurement stylus positioned to a location just above the interface between the square impression coping and a standard abutment.

components used in the fabrication of stereo laser–welded frameworks to the interface relationships of second-generation (flat-head screw fixation design) implant prosthodontic components previously reported by Ma et al.[11]

Materials and Methods

Titanium “feet” and stainless steel abutment replicas (n = 5) were randomly selected from component inventory of the Procera Laboratory in Göteborg, Sweden (Fig 1). Stainless steel replicas were used in this fabrication technique because they are considered to be less likely to distort during the fabrication process, compared to the softer brass abutment replicas generally used when fabricating a conventional cast implant framework. These components were used to compare their interface relationships with the second-generation components (flat-head screw fixation design) previously reported.[11] The same protocol and measurement techniques, as well as measurement armamentaria, were employed. Implant component types and their product numbers used in this study are listed in Table 1.

Paired Component Measurements. The following interface relationship measurements were recorded (data for the first 3 items from Ma et al[11]):

- Second-generation gold cylinder/abutment = SGGC/A
- Second-generation impression coping/abutment = IC/A
- Second-generation impression coping/second-generation brass analog = IC/SGBA
- Titanium foot/abutment = TF/A
- Titanium foot/stainless steel analog = TF/SSA
- Impression coping/stainless steel analog = IC/SSA

Comparisons of these interface relationships for analysis were as follows (an asterisk denotes data from Ma et al[11]):

IC/SGBA* versus IC/SSA
IC/SGBA* versus IC/A*
IC/A* versus IC/SSA
TF/SSA versus IC/SSA
IC/A* versus TF/A
TF/SSA versus TF/A
SGGC/A* versus TF/A
SGGC/SGBA* versus TF/SSA

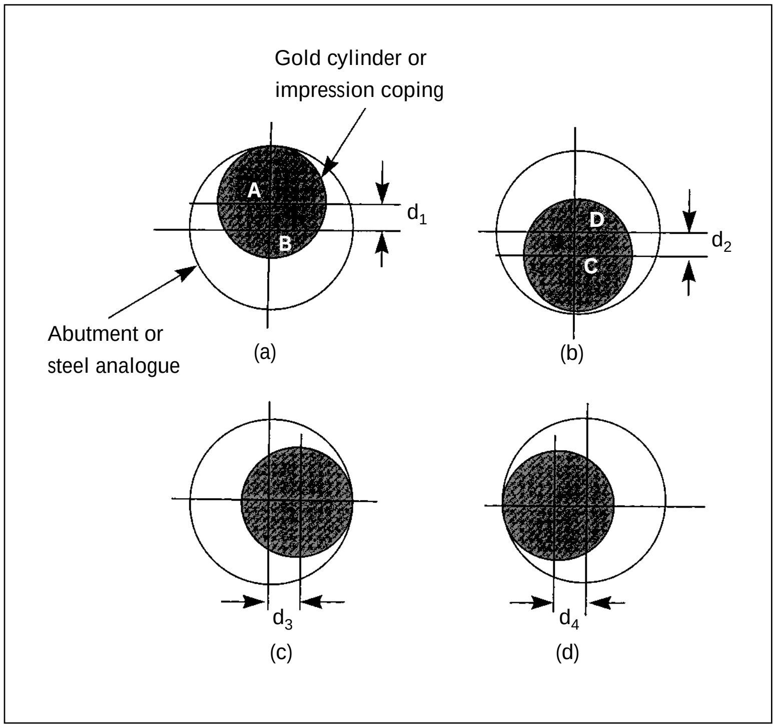

Fig 3 Tolerance measurements of paired components displaced in opposite directions. Points B and D are computed centers of abutment or steel analog. Points A and C are computed centers of components to abutment or steel analog

Measurements with the Coordinate Measurement Machine. The coordinate measurement machine has been described previously.[11] The base components, an abutment or abutment replicas (brass or stainless steel) secured to a 13-mm-long by 3.75-mm-diameter implant (Nobel Biocare), were secured in a tripod stand to stabilize and hold them in a fixed position. Care was taken not to distort the component's fit surface by engaging the implant below the abutment/implant interface or the component (brass or stainless steel replicas) in the measurement stand at a distance from the interface, thereby holding the component securely and at the same time facilitating access for the measurement stylus to a location just below the interface between the mated components (Fig 2).

Either the gold cylinder, the titanium foot, or the impression coping was initially secured to the base components. An initial coordinate in the horizontal plane was made between the components. A 6.0-mm-diameter disc stylus was used to record the 2-dimensional position (Fig 3, points B and D) of the base component and the position (Fig 3, points A and C) of the prosthetic component (gold cylinder, impression coping, or titanium foot). Twenty circumferential points of contact of each component combination were recorded, and the center of the component was calculated. For components that had configurations that were not cylindric above the fit surface, such as the titanium feet and square impression copings, measurements were performed by recording 8 points on the component's surface near the interface of the mated base component with manual positioning of the disc-shaped stylus, rather than by automated measurements. A previous feasibility investigation has shown that the accuracy of these 2 approaches is comparable.[12]

After the initial position of the mated components was recorded, 4 sets of measurements were made for each mated component pair, as shown in Fig 3. First, the gold screw or laboratory guide pin was loosened; the operator intentionally shifted the component horizontally away from himself (d_1) and then retightened the fixation screw and recorded its new position. Second, the fixation screw was loosened again and the component was shifted to the operator's right (d_3), resecured, and measured. Third, the screw was loosened again and the component was shifted toward the

Table 2 Means and Standard Deviations of Data (d1 + d2, d3 + d4) in µm

Interface comparison (mean and SD)					*P* value (2-tailed *t* test)
IC/SGBA	(51.7 ± 21.7)	versus	IC/SSA	(37.6 ± 13.8)	*P* < .001
IC/SGBA	(51.7 ± 21.7)	versus	IC/A	(31.9 ± 14.2)	*P* < .001
IC/A	(31.9 ± 14.2)	versus	IC/SSA	(37.6 ± 13.8)	*P* < .043
TF/SSA	(34.5 ± 18.0)	versus	IC/SSA	(37.6 ± 13.8)	*P* = .33 NS
IC/A	(31.9 ± 14.2)	versus	TF/A	(24.1 ± 10.3)	*P* < .002
TF/SSA	(34.5 ± 18.0)	versus	TF/A	(24.1 ± 10.3)	*P* < .001
SGGC/A	(23.1 ± 8.3)	versus	TF/A	(34.5 ± 18.0)	*P* = .60 NS
SGGC/SGBA	(37.1 ± 16.4)	versus	TF/SSA	(34.5 ± 18.0)	*P* = .45 NS

IC = second-generation impression coping; SGBA = second generation brass analog; SSA = stainless steel analog; A = abutment; TF = titanium foot; SGGC = second-generation gold cylinder.

operator (d_2) and then secured with the screw. Fourth and last, the component's fixation screw was loosened, shifted to the operator's left (d_4), retightened, and measured again.

This measurement sequence was repeated for each component on its respective base component, ie, for each of the 5 titanium feet there was a corresponding abutment matched to it for the paired measurement sequence. This measurement protocol was the same for the gold cylinder/abutment, impression coping/abutment, impression coping/brass analogue, and impression coping/stainless steel analogue. The database was then recorded as a 5-by-5 measurement series for each set of components.

Statistical Analysis. The Shapiro-Wilk analysis, combined with a normal probability plot of the data, was done to assess whether or not the data sets were random and had a normal distribution. The data demonstrated a normal distribution and were therefore analyzed with a 2-tailed Student's *t* test.

Results

Table 2 lists the differences among the paired groups based on analysis derived from the 2-tailed *t* tests. The means and standard deviations presented are a combined mean and standard deviation of $d_1 + d_2$ and $d_3 + d_4$ positions. The data presented therefore represent the total range of tolerances between components. No statistically significant differences were noted for comparisons between second-generation gold cylinders and titanium feet when their fitting surfaces were related to the abutments. Also, no statistically significant differences were noted for comparisons between titanium feet or impression copings when they were interfaced with the stainless steel analogs. All other paired comparisons demonstrated statistically significant differences ($P \leq 0.05$), as listed in Table 1.

Discussion

While the majority of implant-prosthodontic rehabilitative procedures are considered to be successful, there have been reports of early and late complications related to loosening and/or failure of either the fixation or abutment screws.[13,14] This investigation demonstrated that statistically significant differences existed at the interface relationship between the components associated with transfer of information from the oral cavity to the dental laboratory. It is important to note that these differences exist in research reports, which document quantitative change occurring in the impression phase, master cast, casting, indexing, and soldering for conventional framework fabrication.

The difference between what clinically results as being accurate or inaccurate (passive versus non-passive fit) in regard to interface relationships has been shown to be difficult to clearly define.[15] Tolerances, as they relate to interface relationships between mated component surfaces, do not in themselves cause inaccurate fit. Rather, these tolerances are designed into the Nobel Biocare system to provide for a range of "freedom" that allows micromovement.

It could be speculated that, despite the potential for improved accuracy achieved via stereo laser–welding technology, variation of interface relationships between components could contribute to compromise in the final fit achieved with a titanium framework. Neither the laboratory technician nor the prosthodontist ever really knows whether or not the master cast is an "exact" 3-dimensional representation of the patient's abutment positions. If increased accuracy can be achieved with stereo laser–welding and the frameworks so fabricated "fit" the master cast, differences between the master cast and the patient resulting in the transfer could impact negatively on clinical "fit."

Whether "freedom" is built into the components' design and is asserted by the manufacturer to be necessary for successful patient treatment, is not being challenged by this investigation. One can only speculate as to what the potential is to achieve greater accuracy if differences between the mating surfaces associated with the transfer of information from the oral cavity to the laboratory and back to the patient were minimized or, better yet, eliminated. Specifically, the need for exact duplication of the patient's abutment positions in the laboratory is essential to ultimately produce an accurate interface relationship at the prosthesis/abutment interface. It is appreciated that limitations and variations exist in the process of machining implant components. Manufacturers generally are to be commended for their dedication to producing high-quality implant components. New technological advances, such as stereo laser–welding, may be able to improve fit. Could the resultant fit be improved further with increased accuracy of the transfer of information from the laboratory to the operatory?

If "freedom" is needed for the completed restoration to survive under functional loading when secured to its abutments, perhaps it could be created after the prosthesis is assembled and ready for placement. In so doing, stringent control of interface relationships could exist during the fabrication phase and then be modified to allow for micromovement during function. It seems that much still needs to be learned about this complex interface relationship, but a newfound respect for its complexity has gained wider appreciation as more clinical experience and research evolve.

Conclusions

Measured differences in the mating surface relationships between various implant components for conventional cast frameworks versus titanium laser-welded frameworks have been calculated and compared using a standardized protocol. Comparison of the paired interface relationships demonstrated statistically significant differences for all paired comparisons except for the titanium foot abutment versus impression coping/stainless steel analog, the second-generation gold cylinder/abutment versus titanium foot/abutment, and the gold cylinder/brass analog versus titanium foot/stainless steel analog.

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