THE DIMENSIONAL CHANGE OF CAST IMPLANT BARS AFTER LABORATORY PROCEDURE

Ji-Yung Kwon, D.D.S., M.S.D., Chang-Whe Kim, D.D.S., M.S.D., Ph.D., Young-Jun Lim, D.D.S., M.S.D., Ph.D., Myung-Joo Kim, B.Sc., D.D.S., M.S., Ph.D.
Department of Prosthodontics, College of Dentistry, Seoul National University

Statement of Problems. The precision of fit between the bearing surfaces of implant abutments and the prosthesis framework has been considered fundamental to implant prosthodontic protocol.

Purpose. The study aimed to investigate the effect of laboratory procedure on the dimensional accuracy of cast implant bars.

Material and methods Thirty implant bars were fabricated on a metal master model. The gap distances were measured at the right implant abutment replica-gold cylinder interface after casting procedure. The bar length data of precasting and postcasting state were collected and analyzed.

Results. The mean gap distance found after casting was 106.3 μm for buccal side, 122.1 μm for distal side and 117.1 μm for the lingual side. The mean bar length was 17964.7 μm at precasting measurement, 17891.6 μm at postcasting measurement. The mean change of bar length was - 73.1 μm.

Conclusion. Even though the techniques used in this study strictly followed the guidelines established in the literature, the 30 cast implant bars evaluated all yielded gap distances that were beyond acceptable accuracy. There was a statistically significant difference between precasting and postcasting bar length ($P<0.01$). There was a decreasing tendency in bar length after casting procedure. It was necessary to correct this dimensional change from laboratory procedure by some corrective methods.

Key Words
Cast implant bar, Coordinate measuring machine, Gap distance, Passive fit

Cast implant bars are used for the fabrication of implant supported and retained prostheses. The most simplistic approach usually consists of two implants in the canine areas and a gold bar connecting them together. The mechanical assembly of this prosthesis usually consists of implants, abutment, abutment screw, gold cylinder, gold screw, implant bar and removable prosthesis. An implant bar can be prefabricated or customized. Plastic bar patterns can be cast with type III or type IV gold alloys and are commonly used because of their low cost and ability to be shaped and contoured according to soft and hard tissue morphology. The bar design that would allow for the optimum structural adequacy is a length of less than 18mm with at least 2mm of gingival extension (vertical stiffener).[1]

The forgiveness of the periodontal membrane present in the traditional fixed prosthesis is not available with osseointegrated implants. The precision of fit or the closeness of the clearance between the bearing surfaces of the implant abutment and implant component housed within a prosthesis framework has been questioned as being a significant factor in: stress transfer[2], the biomechanics of load distribution, the occurrence of complications[3], and the response of the host tissues at the biological interface.[4]

Most authors agree on the requirement for a passive fit between the prosthesis framework and the implant fixtures.[5,6] In previous studies, a correlation has been found between screw loosening and deficits in the marginal fit of screw-retained partial dentures.[7-9] According to Rangert[2] the passive fit should exist at the 10 micron level and is required to achieve an optimum load distribution. The Procera® system (Nobelbiocare, Westmont, IL, USA) is claimed to have an accuracy of fit within the 30 micron level.[10]

One 5-year clinical study on prostheses that were considered to have clinically acceptable fit, with measured mean center point misfits ranging from 91 to 111μm, did not find a statistical correlation between degree of misfit and marginal bone loss.11 An animal study showed that prosthesis misfit causes significant bone strain, and it has been suggested that bone strain may contribute to initial marginal bone loss.[12] Bone strain caused by misfit may be of greater importance for implant survival in soft bone and for early implant loading.[12] Another animal study on implants placed in baboon mandibles that supported prostheses with 2 degrees of fit did not find a difference in bone response.[13] It should be noted that the prostheses in the baboon study were not in occlusion, which normally superimposes substantial dynamic cyclic functional loads onto misfit loads.

There are many factors that can influence the precision of fit achieved, including the manufacture of implant components and the several clinical and laboratory steps involved in the restoration of the edentulous situation. Impression taking, production of the master cast, and framework fabrication accumulatively influence the fit observed by the clinician when the framework is fitted to the abutments in the oral environment. Conventional dental laboratory techniques do not allow the fabrication of a rigid bar assembly with an acceptable degree of accuracy of fit. The error is due mostly to the inconsistency of volumetric and linear expansion of the fabrication materials used, which include gypsum products, waxes(or pattern resin), investment, and casting metal. Potential distortion can be generated at any step of the fabrication process.[14-18]

The purpose of this study was to investigate the effect of laboratory procedure on the dimensional accuracy of cast implant bars.

MATERIAL AND METHODS

1. Fabrication of metal master model and cast implant bars

Thirty implant bars were fabricated on a metal master model (Fig. 1). The master model was composed of 2 standard abutment replicas (Osstem, Seoul, Korea) permanently fixed into a tightly fitted hole. The abutments were 18mm apart and marked left (L) and right (R) on the metal block.

The distance between abutment replicas measured by a contact coordinate measuring machine (contact CMM) (UPMC 850 Ultra, Carl Zeiss, Oberkochen, Germany) was 17970.1 μm. Premachined gold cylinders (Osstem, Seoul, Korea) and round plastic bar patterns of 2 mm diameter were used for the fabrication of implant bars.

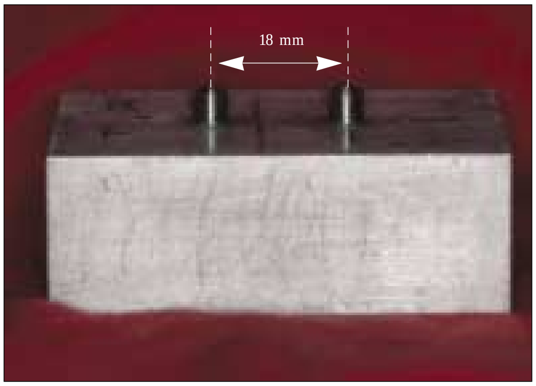

Fig. 1. Metal master model with two standard abutment replicas.

Fig. 2. Transfer jig adapted to the metal master model. The transfer jig divided into two pieces bucco-lingually was used to reduce the horizontal error occurring from mac hining tolerance of a gold cylinder.

It needed a custom transfer jig for this study because the standard deviation of the distances between two center positions should have been reduced. So, the transfer jig divided into two pieces bucco-lingually was used to reduce the horizontal error occurring from mac hining tolerance of a gold cylinder (Fig. 2).

The tolerance of a gold cylinder in screwing arbitrarily was measured with the contact CMM. The distance between the center position of a gold cylinder and the center position of the right abutment replica was measured. The distance was measured 10 times in the same way. Without the transfer jig, the mean distance between two center positions was 10 μm, and the standard deviation was 6.7 μm. Using the transfer jig, the mean distance was 5.0 μm and the standard deviation was 1.1 μm (Fig. 3).

The premachined gold cylinders were screwed on the abutment replicas with gold screws (Osstem, Seoul, Korea), and the plastic bar patterns were positioned between the gold cylinders in the same location using a silicone matrix. The plastic bar patterns were luted to the gold cylinders with pattern resin material (Pattern resin, GC America Inc., Chicago, IL, USA). At pattern state, the precasting measurements were performed.

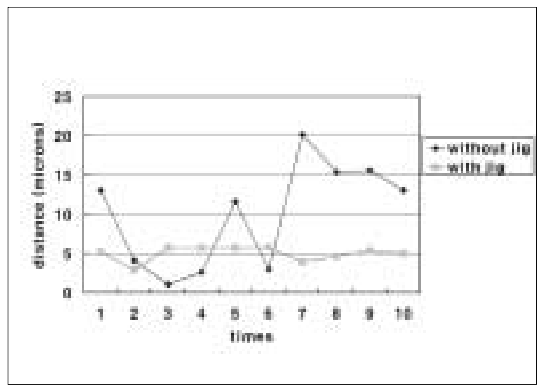

Fig. 3. Distance between two centers of a gold cylinder and an abutment replica (when repeatedly tightened with a gold screw ten times arbitrarily).
Without the transfer jig, the mean distance between two center positions was 10 μm, and the standard deviation was 6.7 μm. Using the transfer jig, the standard deviation of the length between two center positions was reduced and the average distance was 5.0 μm and the standard deviation was 1.1 μm.

Before casting, the specimens were marked from 1 to 30 on the axial walls of the gold cylinders on both sides of the bar using a round carbide bur for discrimination, and they were sprued, and invested in a gypsum-bonded investment (Prestobalite, Whip Mix Corp., Louisville, KY, USA). The Asbestos liner was laid out on the inner surface of the casting rings to obtain enough setting expansion in order to adequately compensate for alloy shrinkage in the casting process. All 30 bars were cast using type III gold alloy (Gold 78.0%, Platinum 1.0 %, Silver 11.5 %, Copper 8.5 %, Others (< 1%): Ir, Zn) (Aurofluid® 2PF, Metalor, Neuchatel, Switzerland) according to the manufacturer's recommendations. The conventional lost wax technique, used with centrifugal casting machines, was performed. Great care was taken to avoid damaging the interface surfaces of the gold cylinders; the bulk of investment was removed with an air chisel, followed by ultrasonic cleansing submerged in a hydrofluoric acid substitute solution. Air abrasion and polishing was avoided. In this way, thirty cast implant bars were fabricated.

2. Coordinate Measuring Machine

1) Contact Coordinate Measuring Machine

A contact coordinate measuring machine (contact CMM) (UPMC 850 Ultra, Carl Zeiss, Oberkochen, Germany) (Fig. 4) of moving-bridge type was used for measuring bar length. All measurements were made by the same operator, an experienced CMM machinist. The manufacturers claim a resolution of 0.08 μm and a reliability of ± 0.2 μm for repeated measurements against a known datum. This reflects the inherent accuracy of the machine in well-defined circumstances and can not be applied to any other measurement setup. The machine has a probe, which can be positioned at any desired x, y, z location within the machine's working space of $850 \times 700 \times 600$mm. A selection of round, ruby-tipped probes of varying sizes was available for use, ranging from 1 to 4 mm in diameter. The probe tip can approach the surface to be measured in either the z-axis or the x-y plane. When the probe tip touches the surface to be measured, an on / off switching mechanism freezes the reading and allows highly accurate and repeatable measurements of the x, y, z coordinates. Prior to each measuring sequence, the machine is calibrated against a datum sphere of known dimensions, according to the manu-

Fig. 4. Contact coordinate measuring machine (UPMC 850 Ultra, Carl Zeiss, Oberkochen, Germany).

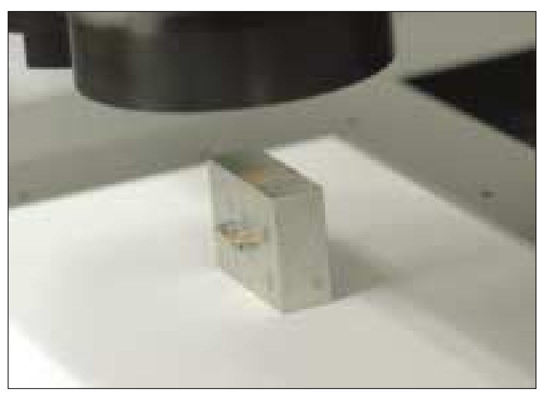

Fig. 5. Noncontact profile measuring machine (Video-Check-L-400, Werth Messtechnik GmbH, Giessem, Germany) measuring gap distance.
The integral segmented LED illumination and the 3D CCD camera allow an area of the measured component to be illuminated and viewed.

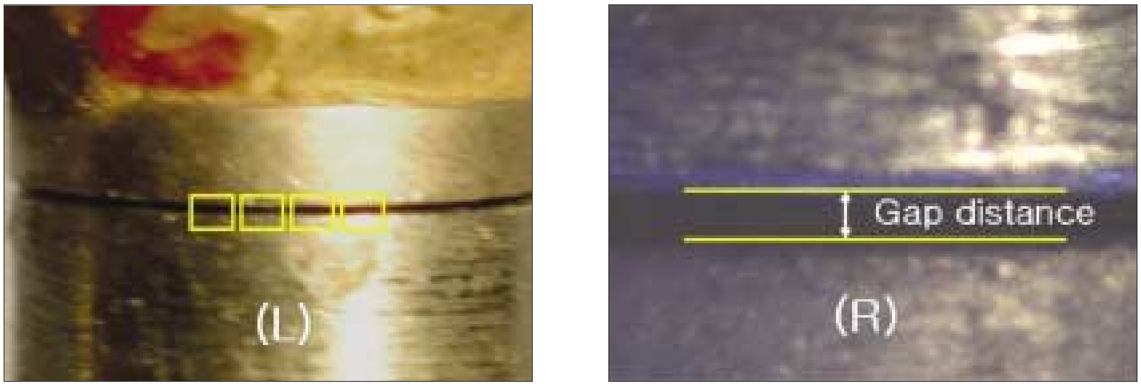

Fig. 6. Measurement of gap distance using the noncontact PMM.
(L) Four 'regions of interest' (ROI) were captured with the CCD camera at each side, followed by measuring and finding an average of the gap distances.
(R) ×160 magnification image at the interface of the right abutment replica-gold cylinder.

facturer's instructions. The CMM was linked to a computer and data handling was carried out by an software program.

2) Non-Contact Coordinate Measuring Machine

A noncontact profile measuring machine (noncontact PMM) (Video-Check-L-400, Werth Messtechnik GmbH, Giessem, Germany) was used to measure gap distances (Fig. 5). It has a laser and camera sensor. In this study, only a camera sensor was used. The integral segmented LED illumination and the 3D CCD camera allow an area of the measured component to be illuminated and viewed. Software control of the illumination allows the user to optimize the image for each measurement. The whole field of view (FOV) or specific regions of interest (ROI) within the FOV of 1.3×1.0 to 13×10 (mm) can be used to select one or more features for measurement(e.g. Hole Diameters, Edge Positions). The non-contact PMM applications include: measurement of small features (e.g. holes) which are difficult to access with contact probes, measurement of soft or easily deformed components, measurement of printed circuit boards.

3. Precasting and postcasting measurement

The contact CMM for precasting bar length measurement was used. The probe tip touched the inner surface of two gold cylinders of a bar to be measured, and the distance between two center points was calculated.

The data of postcasting bar length measurements were collected on thirty specimens in the same manner as the precasting measurements.

Postcasting gap measurements were made at the right implant abutment replica-gold cylinder interface with the non-contact PMM after casting procedure. The 1-screw technique was applied to evaluate casting fit. Only the left abutment replica was torqued to 10 Ncm by a contra-angle torque driver (3i/Implant Innovations Europe, Copenhagen, Denmark) based on White's protocol[19] using a new screw and left the right abutment without a screw. After careful alignment of the specimens using the resin jig, gap distances were measured at buccal, distal, and lingual surface of the master cast abutments. Four regions of interest (ROI) were captured with the CCD camera at each side, followed by measuring and finding an average of the gap distances (Fig. 6).

4. Statistical analysis

The SPSS program for Windows (Version 10.0.7) (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Statistical significance between precasting and postcasting bar length was evaluated using paired t test ($P<0.05$).

RESULTS

Gap distance was measured at the right implant abutment replica-gold cylinder interface. A mean gap distance was calculated by measuring the gap at the buccal, distal, and lingual aspects with non-contact PMM (Video-Check-L 400, Werth Messtechnik GmbH, Germany) for each specimen. The mean gap distance found after casting was 106.3 μm for buccal side, 122.1 μm for distal side and 117.1 μm for the lingual side (Table I).

The bar length was measured with the contact CMM. The probe tip touched the inner surface of two gold cylinders of a bar to be measured, and the distance between two center points was calculated. The mean bar length was 17964.7 μm for the precasting measurements, 17891.6 μm for the postcasting measurements. There was a decreasing tendency in bar length after casting procedure. A paired sample t-test was performed on precasting and the postcasting bar length. The mean bar length change was - 73.1 μm. There was a statistically significant difference of $P<0.01$ between precasting and postcasting bar length (Table II).

Table I. Gap distance after casting procedure

	N	Gap distance (μm) Mean SD
Buccal side	30	106.3 ± 30.8
Distal side	30	122.1 ± 34.2
Lingual side	30	117.1 ± 30.7

Data were shown by mean and standard deviation.

DISCUSSION

To achieve optimum distribution of the loading forces through the screw joint, there must be a precise, passive fit between the implant abutment and the implant fixture. The increased dimensional accuracy may be of importance for implant-supported prostheses, because there is no periodontal ligament at the bone-implant interface and minimal physiologic movement compared to that seen with natural dentition. According to the criteria proposed by Rangert and Jempt et al[2], a gap of 10 μm or less is necessary for the fit to be passive. The precision of fit between the bearing surfaces of implant abutments and the prosthesis framework has been considered fundamental to implant prosthodontic protocol. However,

Table II. Bar length of precasting and postcasting measurement (μm)

	N	Mean	Std. Deviation	P value
Precasting bar length	30	17964.7	22.4	P<0.01[1]
Postcasting bar length	30	17891.6	35.3	

Data were shown by mean and standard deviation. Statistical significance between precasting and postcasting bar length was evaluated using paired t test.

1) There was a statistically significant difference between precasting and postcasting bar length (P<0.01).

the biologic impact of prosthesis misfit on osseointegration remains unclear.

A nonpassive fit can lead to bone loss, abutment fractures, and connecting screw breakage; the last of these is by far the most common complication of a nonpassive fit.[20] It is likely the forces caused by misfit itself interact with the substantial, repetitive, and dynamic forces of masticatory function that may lead to mechanical fatigue of prostheses, screw, and implant. While the effect of prostheses misfit on osseointegration is largely unknown, it appears that misfit causes bone strain, which may affect osseointegration.[12] Such effects may be more important when bone quantity or quality is compromised or in early loading situations.

Numerous techniques using optical and tactile methods have been reported to evaluated the fit of implant castings in clinical and laboratory settings, including a stylus contact technique, laser videography, and photogrammetric analysis.[12,21,22] The "one-screw" method described by White was used to evaluate the fit in this investigation.19 This method has been shown to be a sensitive technique capable of detecting small amounts of casting misfit.

The fabrication of an implant bar assembly involves a variety of clinical and laboratory steps, including impression development, master cast fabrication, bar assembly wax-up, sprue and investment techniques, and finally casting and finishing procedures. The potential exists at each of these steps to generate a distortion that may result in a nonpassive fit of the restoration.

Currently, the conventional lost wax technique, used with centrifugal casting machines, is the most common method of implant prosthesis fabrication. However, the resultant misfitting castings often require corrective sectioning and soldering.

Even though the techniques used in this study strictly followed the guidelines established in the literature, the 30 cast implant bars evaluated all yielded gap distances that were beyond acceptable accuracy.[13], and the bar length decreased after casting. Inconsistencies in the linear and volumetric expansion of the materials used made such inaccuracy unavoidable. It was necessary to correct this dimensional change from laboratory procedure by some corrective methods.

CONCLUSION

Within the limitations of this study, the following may be concluded about the change of implant bar assemblies after casting:

1. Even though the techniques used in this study strictly followed the guidelines established in the literature, the 30 cast implant bars evaluated all yielded gap distances that were beyond acceptable accuracy.
2. There was a statistically significant difference between precasting and postcasting bar length ($P<0.01$). There was a decreasing tendency in bar length after casting procedure.
3. It was necessary to correct this dimensional change from laboratory procedure by some corrective methods.

REFERENCES

1. Bidez MW, McLoughlin SW, Chen Y et al. Finite element analysis of two-abutment Harder bar designs. Implant Dent 1993;2:107-114.
2. Rangert B, Jemt T, J?rneus L. Forces and moments on Brånemark implants. Int J Oral Maxillofac Implants 1989;4:241-247.
3. Jemt T, Linden B, Lekholm U. Failures and complications in 127 consecutively placed fixed partial prostheses supported by Brånemark implants: from prosthetic treatment to first annual checkup. Int J Oral Maxillofac Implants 1992;7:40-44.
4. Hoshaw S, Brunski J, Cochran G. Mechanical loading of Brånemark fixtures affects interfacial bone modelling and remodelling. Int J Oral Maxillofac Implants 1994;9:345-360.

5. Zarb GA, Symington JM. Osseointegrated dental implants: preliminary report on a replication study. J Prosthet Dent 1983;50:271-276.
6. Sones AD. Complications with osseointegrated implants. J Prosthet Dent 1989;62:581-585.
7. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5years. Int J Oral Maxillofac Implants 1994;9:169-178.
8. Binon PP. The effect of implant / abutment hexagonal misfit on screw joint stability. Int J Prosthodont 1996;9:149-160.
9. Pietrabissa R, Gionso L, Quaglini V, Martino E, Simion M. An in vitro study on compensation of mismatch of screw versus cement-retained implant supported fixed prostheses. Clin Oral Implants Res 2000;11:448-457.
10. Jemt T, Linden B. Fixed implant-supported prostheses with welded titanium frameworks. Int J Periodont Rest Dent1992;12:177-184.
11. Jemt T, Book K. Prosthesis misfit and marginal bone loss in edentulous implant patients. Int J Oral Maxillofac Implants 1996;11:620-625.
12. Jemt T, Lekholm U. Measurements of bone and framework deformations induced by misfit of implants superstructures. A pilot study in rabbits. Clin Oral Implants Res 1998;9:272-280.
13. Carr AB, Gerard DA, Larsen PE. The response of bone in primates around unloaded dental implants supporting prostheses with different levels of fit. J Prosthet Dent 1996;76:500-509.
14. Carr AB, Stewart RB. Full-arch implant framework casting accuracy: preliminary in vitro observation for in vivo testing. J Prosthodont 1993;2: 2-8.
15. Linke BA, Nicholls JI, Faucher RR. Distortion analysis of stone casts made from impression materials. J Prosthet Dent 1985;54:794-802.
16. Assif D, Marshak B, Schmidt A. Accuracy of implant impression techniques. Int J Oral Maxillofac Implants 1996;11:216-222.
17. Humphries RM, Yaman P, Bloem T. The accuracy of implant master casts constructed from transfer impressions Int J Oral Maxillofac Implants 1990;5:331-336.
18. Gettleman L, Ryge G. Accuracy of stone, metal and plastic die material. J Calif Dent Assoc 1970;46:28-31.
19. White GE. Osseointegrated Dental Technology. Chicago: Quintessence 1995:123-124.
20. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implant in the treatment of the edentulous jaws Int J Oral Surg 1981;10:387-416.
21. 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.
22. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347-359.

Reprint request to:

Chang-Whe Kim, D.D.S., M.S.D., Ph.D.
Department of Prosthodontics, College of Dentistry,
Seoul National University,
28 Yeongun-Dong, Chongro-Gu, Seoul, 110-749, Korea
k43c46w@snu.ac.kr