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Marginal Discrepancy of Components Utilized for Implant Framework Construction

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MARGINAL DISCREPANCY OF COMPONENTS UTILIZED FOR IMPLANT FRAMEWORK CONSTRUCTION

by

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Each person whose signature appears below certifies that this thesis in their opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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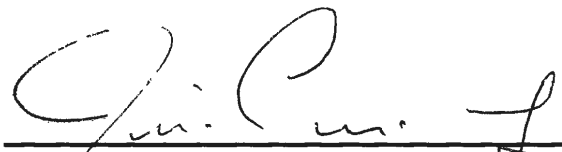

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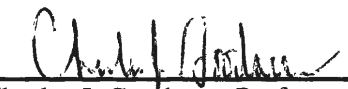

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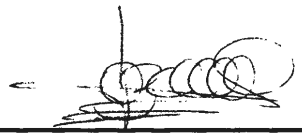

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ABSTRACT

MARGINAL DISCREPANCY OF COMPONENTS UTILIZED FOR IMPLANT FRAMEWORK CONSTRUCTION

By

Mathew T. Kattadiyil

This study evaluated marginal fit discrepancy of the abutment-implant body interface employing various components commonly utilized for implant framework fabrication. Four types of components (castable plastic patterns, premachined gold abutments, premachined titanium abutments and CAD-CAM custom premachined titanium abutments) were evaluated. Five castable plastic patterns and five premachined gold abutments from each of two manufacturers, five premachined titanium abutments and five CAD-CAM custom premachined titanium abutments were used. Components were affixed to a 3.75 × 10 mm dental implant and standardized measurements were obtained of the abutment-implant interface using a computer-assisted microscope at various experimental time intervals.

Measurements of the castable plastic components were recorded before and after casting as well as after finishing and polishing procedures. Measurements of the premachined gold abutments were obtained before and after casting. CAD-CAM custom premachined titanium abutments and CeraOne® premachined titanium abutments were measured as provided by the manufacturer. Means and standard deviations were computed for each group at the various time intervals. Group means comparisons using Student t-test and Student-Newman-Keuls method were statistically evaluated between each group as well as at each time interval.

Premachined gold and titanium abutments showed a statistically superior marginal fit compared to cast plastic abutment patterns at both Postcast and Finish measurement intervals.

Among the premachined abutments, Procera™ CAD-CAM titanium abutments exhibited improved marginal integrity though not significantly better when compared to both, gold abutments as well as the CeraOne® titanium abutments.

A significant improvement of the marginal fit was seen after careful laboratory finishing and polishing of the cast plastic abutment patterns. There was no significant alteration of the premachined gold abutment mating surfaces following casting. No significant differences were found in marginal discrepancy between identical abutments belonging to different manufacturers at the Postcast and Finish measurement intervals.

INTRODUCTION

Background

Implant dentistry has emerged as a viable and predictable therapy for the treatment of complete and partial edentulism. Implant survival statistics have been reported in excess of 85% for implants placed in mandibular bone and approaching 80% for implants placed in maxillary bone over 15 years.[1] Peri-implant bone loss is a major factor contributing to implant failure. Factors implicated in peri-implant bone loss include biomechanical overload[2, 3, 4] and microbiologic contamination.[5-8]

Misfit and Biomechanics

Prosthetic framework misfit has been evaluated as a factor capable of influencing dental implant biomechanics. Loss of osseointegration has been experimentally induced in animals through occlusal trauma.[2] Adell et al[9] and Ahlqvist et al[10] have stated that overloading of an oral implant can result in loss of the marginal bone or complete loss of osseointegration at implants where osseointegration had been achieved. Millington et al[11], have shown a positive relationship between the degree of fit discrepancy and superstructure stress. These findings suggest framework misfit is capable of increasing stress to implant superstructures as well as to the implant body and thus may be capable of inducing peri-implant bone loss.

Rangert and co-workers[12] evaluated framework misfit and suggest inaccurate fit may cause increased tension on gold screws as well as induce disproportionate stress distribution within anchorage units. In a one year evaluation of implant supported fixed prostheses, loose screws were a common finding.[13] Binon[14] has explored the effect of implant abutment misfit on screw joint stability and found that there is a direct correlation between hexagonal misfit and

screw joint loosening. These results suggest that implant framework misfit may have a strong impact on the common problem of screw loosening.

Jemt and co-workers[15-17] have examined framework misfit to ascertain optimal laboratory techniques to minimize marginal fit discrepancies. The authors report that current laboratory techniques for the fabrication of implant prostheses are incapable of producing perfectly passive component fit. Further studies by Jemt and Book[18] suggest that a certain degree of biologic tolerance for misfit may be present.

Misfit and Bacterial Contamination

Implant component misfit may be implicated with adverse bacterial contamination.[5-8] Persson and co-workers[19] analyzed the internal surfaces of Branemark implant framework components, which were clinically in place up to 8 years. Cell culture evaluation revealed the presence of abundant quantities of bacteria, including species, which have been implicated in peri-implant bone loss. Hermann et al[20], did a side by side comparison of nonsubmerged and submerged endosseous titanium implants in the canine mandible. They were able to demonstrate that the creation of a microgap between the implant and an abutment results in bone loss around the implant. Quirynen et al[21] proved the existence of bacterial leakage along the components of the Branemark® implant system, both at the junction between the abutment and the implant body, as well as along the abutment screw. A large variety of microorganisms ranging from gram positive cocci to gram negative rods were able to penetrate along these implant components. Mombelli et al[5] in an earlier study have associated some of the bacteria (Streptococcus constellatus, Bacteriodes species, Peptostreptococcus micros, Fusobacterium species) identified in the Quirynen[21] study with causing peri-implantitis. Ericsson et al[22] have associated the presence of an inflammatory infiltrate and bacterial leakage directly adjacent to the abutment-implant body

interface. A certain degree of microbial leakage related to marginal discrepancy has been shown to exist between the implant-abutment interface by Jansen et al.[23] In their study thirteen different implant-abutment combinations were subjected to an in vitro experiment, in which the penetration of bacteria was observed for ten assemblies of each type. Their conclusion was that all implant systems evaluated presented microbial leakage. These findings suggest framework fit discrepancy to be associated with peri-implant bone loss by promoting increased bacterial colonization within the implant components.

It can be argued that, areas of misfit or marginal discrepancy between implant components is an ideal location for potential plaque accumulation. Hence the effect of plaque accumulation around implant components is considered significant. Isidor[2] has reported marginal bone loss around implants which were allowed to accumulate plaque. He reported an average loss of 1.8 mm in the peri-implant bone level after18 months. Plaque accumulation might play a role in the etiology of peri-implantitis according to Jovanovic et al.[24] In a study done to assess regenerative potential of peri-implant bone defects with a submerged membrane technique they were able to cause peri-implant bone defects by encouraging plaque accumulation. Pontoriero et al[25] conducted a clinical study in humans to compare the clinical and microbiological parameters during the development of experimental gingivitis and periodontitis. They induced peri-implant mucositis by asking the patients to refrain from oral hygiene practices for three weeks. They demonstrated that there was a cause-effect relationship between the accumulation of bacterial plaque and the development of peri-implant mucositis. Teixeira et al[26] in a three year cross-sectional study found a significant correlation between mucosal inflammation and marginal bone loss around hydroxyapatite-coated implants.

Berglundh et al[27] demonstrated that the peri-implant mucosa which formed at titanium implants following abutment connection was similar in many ways to the attachment of gingival

tissues to teeth. According to Gould et al[28] the titanium surface of implants or abutments encourages the formation of a tight peri-implant cuff with hemidesmosomal attachments to the implant which can prevent bacterial contamination. A reduced marginal discrepancy between the implant components would help maintain a healthy environment and encourage the formation of such an attachment by decreasing plaque accumulation. The success of osseointegration may depend on a biologic barrier separating the internal from the external environment of the critical implant-bone interface thereby reducing bacterial contamination.

Direct Implant-Abutment Components used for Framework Fabrication

Currently there are a variety of techniques and components utilized for the fabrication of implant prosthetic frameworks. These include castable plastic patterns, premachined gold and titanium abutments. Machined components are believed to provide an improved marginal fit over castable patterns due to the inherent errors incorporated during waxing and casting procedures for the plastic components.

Byrne et al[29] in a study evaluating the fit of cast and premachined implant abutments concluded that the adaptation of abutments to implants was closer and the amounts of contact larger for assemblies with premachined and laboratory modified premachined abutments than for those with cast abutments. Dellow et al[30], upon evaluating interfacial fit of interchanged components of different dental implant systems concluded that manufacturing variations can result in as much as 100 micrometers of space between components.

An in vitro screw pre-load evaluation by Carr et al[31] comparing machined and plastic patterns revealed improved biomechanics using pre-fabricated machined components. Further, plastic patterns which were cast, finished and polished, provided improved screw pre-load over cast patterns, which were not manipulated.

Machined components despite their supposedly accurate fit have certain disadvantages over castable plastic patterns. They often pose esthetic difficulties in restoring single as well as multiple tooth implants, and are also difficult to work with when implant angulations are compromised and require correction. Castable plastic patterns (UCLA abutments) as advocated by Lewis et al[32] have an obvious advantage in this regard. They can be modified to correct unfavorable angulation of an implant body, and can also achieve superior results with respect to esthetics, since they can be customized for each particular clinical situation.

Machined abutments that could be modified and cast were developed to achieve a combination of superior fit and correction of angulation to suit esthetic needs. However, distortion of these components due to subsequent casting and firing cycles is a concern and needs to be evaluated.

Standardized single implant components have the advantage that prefabricated ceramic or gold alloy cylinders can be used as a base for the final restoration. However, the standard single abutment cylinder does not always allow the crown to follow the contour of the gingival margin when there is a different gingival level on the buccal and palatal surface of the restoration.[33] The ceramic abutment cylinder introduced by Nobel Biocare, CerAdapt™, is designed to allow preparation of the cylinder to allow more individual placement of the crown margin in relation to the soft tissue.[34]

The CeraOne® implant system by Nobel Biocare, was a modification of the original abutment to allow better control of the tightening of the abutment screw, as well as to allow the use of prefabricated ceramic or gold alloy cylinders.[35]

Recently, a new CAD-CAM machined titanium abutment was introduced (Procera™, Nobel Biocare) which has a similar degree of versatility as a castable plastic pattern. These titanium abutments are custom made and can achieve improved esthetic results as well as be

utilized in situations where the implant is located at a less than ideal angulation. This technique, first introduced by Andersson M[36] in 1983 is unique because it eliminates the conventional approach to framework fabrication using the lost wax casting technique. Rubenstein[37], Marchack[38] and Jemt[39] report that treatment outcome has been favorable with the Procera™ technique but there is no data available regarding the marginal fit of these components.

However, it must be mentioned that despite all the advantages and versatility offered by direct implant-abutment connections, frequent dis/reconnection of the abutments that might be required during fabrication could compromise the mucosal barrier and result in a more apically positioned zone of connective tissue as suggested by Abrahamsson et al[40], Berglundh et al[27] and Berglundh and Lindhe[41].

Objectives

The available data suggests that marginal discrepancy of the implant-abutment interface plays an important role in peri-implant bone maintenance, implant biomechanics and screw joint integrity. This study evaluated marginal discrepancy of the implant body-abutment interface using various components commonly utilized in implant prosthodontics. Four types of components (castable plastic patterns, premachined gold abutments, CeraOne® premachined titanium abutments and CAD-CAM custom premachined titanium abutments) were evaluated at various time intervals. The null hypothesis states that no differences in marginal discrepancy exist between these components.

MATERIALS AND METHODS

Measurement Apparatus

An alloy cube with dimensions of 20 mm was used as a reference to construct a template for the measurement base construction (Figure 1). Using an injection molding technique an acrylic resin cube base to be used for implant body fixation was made. One of the square surfaces of the acrylic resin cube, chosen as the superior surface was attached with a level gauge and the inferior surface embedded in laboratory stone confined by a base former. It was ensured that the bubble of the level gauge was located at the center and maintained in that position until the stone achieved final set. The cube with the base was then transferred to a laboratory-milling machine (Nouvag AF30, Switzerland) and the milling table moved, to again ensure that the vertical arm of the milling machine was perpendicular to the superior surface of the cube. This was done to ensure that the drilling process and the final placement of the implant was exactly perpendicular to the superior horizontal surface of the cube. Conventional implant twist drills (Branemark system™ Nobel Biocare Inc., Westmont IL) were attached to the laboratory milling machine and used sequentially to create a cylindrical hole of dimensions 3.75 x 10 mm exactly through the center, and perpendicular to the horizontal plane. One titanium-threaded dental implant with dimensions 3.75 x 10 mm (Branemark system™ Nobel Biocare Inc., Westmont IL) was then self-tapped into the acrylic resin block and served as a means for measurement. Using a high-speed dental handpiece an indentation was created on one face of the acrylic resin block as a way to standardize component positioning, repositioning and measurements (Figure 1). This measurement block was used to obtain all measurements taken for the castable plastic patterns, premachined gold abutments, CeraOne® and Procera™ CAD-CAM custom abutments. A Traveling Measuring Microscope (Mitutoyo Toolmakers Microscope Mfg. Co. Ltd, Japan) was utilized to measure component fit discrepancy, with accuracy of up to 1/1000 of a millimeter

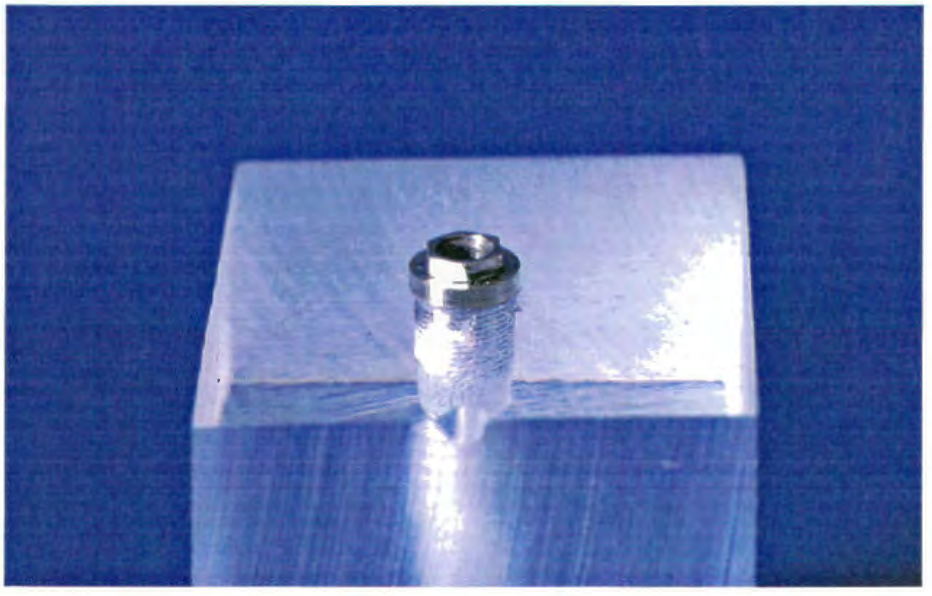

Figure 1: Measurement Apparatus

at 100x magnification. Four sides per component were measured using each side of the measurement cube base as a positioning reference. The largest marginal discrepancy per side was recorded. The measurements for this study were made from the Nobel Biocare implant body to the abutments excluding the rounded edge. Five components per group were evaluated which equates to twenty measurements per group. The principal investigator performed all the measurements in this study.

Measurements of the castable plastic components were recorded before and after casting as well as after finishing and polishing procedures. Measurements of the premachined gold abutments were obtained before and after casting. Measurements of the CAD-CAM custom premachined titanium abutments and CeraOne® premachined titanium abutments were obtained as provided by the manufacturer.

Calibration and Control Measurements

A single, additional gold abutment, separate from each of the other two gold abutment groups, was used as control for assessing the standard error of making repeated measurements and for evaluating the possibility of mating surface alterations of the measurement apparatus during the course of experimentation. Marginal discrepancy was evaluated with this gold abutment at the beginning and end of each group measurement. In order to standardize the waxing process, a wax pattern (Yeti Dental Produkte, Zeppelemistr, Germany) was created onto a castable plastic abutment (Figure 2) and a poly (vinyl siloxane) index (Reprosil® Caulk Division, Dentsply Int. Millford, DE) made. This index was used to develop standardized wax patterns for all subsequent components.

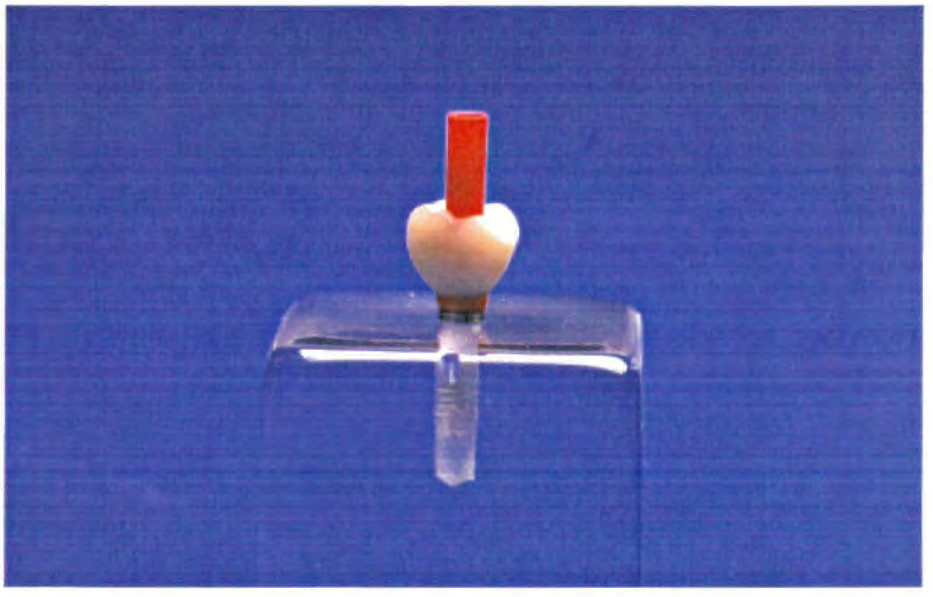

Figure 2: Standard wax pattern used for duplication

Component Evaluation

Four types of components (Premachined gold abutments, Castable plastic patterns, CeraOne® premachined titanium abutments and Procera™ CAD-CAM custom premachined titanium abutments) were evaluated for fit discrepancy. The components to be evaluated were categorized into six separate and distinct groups as shown in Table 1.

Premachined Gold Abutments

Five hexed premachined gold abutments from each of two manufacturers (Branemark System™ Nobel Biocare, Inc., Westmont IL and Implant Innovations® West Palm Beach, FL) which are compatible with the Nobel Biocare SDCA 001 implant body were used. Each gold abutment was affixed to the implant body, prior to casting, with the provided gold screw and tightened with a torque wrench (ITL Dental, Implant Technologies Ltd, Santa Ana, CA) to 32 Ncm as recommended, and measured as previously outlined. A standardized wax pattern was then created on each cylinder with the previously constructed index. An indentation was created in the wax pattern to coincide with the indentation on the acrylic resin measuring cube, in order to facilitate future component repositioning and reference. Following casting, each component was affixed to the implant body, and tightened to 32 Ncm and measured once again in order to evaluate casting process alterations on marginal fit discrepancy.

Castable Plastic Patterns

Five hexed plastic patterns from each of two manufacturers (Implant Innovations, West Palm Beach, FL, and Attachments International Inc., San Mateo, CA) which are compatible with the Nobel Biocare SDCA 001 implant body were used. Each plastic pattern was affixed to the implant body (Branemark System™ Nobel Biocare Inc., Westmont IL) with the provided screw

Table 1: Categorization of the Components to be evaluated into distinct Groups

Group No.	Component
Group I	Nobel Biocare Premachined Gold Abutments
Group II	Implant Innovations Premachined Gold Abutments
Group III	Attachments International Plastic Castable Abutment patterns
Group IV	Implant Innovations Plastic Castable Abutment Patterns
Group V	Nobel Biocare CeraOne® Premachined Titanium Abutments
Group VI	Nobel Biocare Procera™ CAD-CAM Premachined Titanium Abutments

and tightened to 10 Ncm with a torque wrench, TW10 (ITL Dental, Implant Technologies Ltd, Santa Ana, CA). For measurement standardization, a 10 Ncm torque wrench was utilized to tighten the screws and affix the plastic components to the implant body. This torque was selected as it was the least force that could be applied by a commercially available torque wrench. This would most closely simulate laboratory procedures which commonly employ firm finger pressure and also ensure measurement standardization. Each plastic pattern was measured as previously outlined. A standardized wax form was created on each pattern with the previously constructed index. An indentation was created in the wax pattern to coincide with the previously created indentation on the acrylic resin measuring cube. This was done to facilitate future component repositioning and for reference. Following casting, the mating surface of each component was evaluated under a microscope at 10x magnification and all obvious surface nodules (if any) were removed. The casting was then affixed to the implant body using the provided screw and tightened using a 32 Ncm torque wrench (ITL Dental, Implant Technologies Ltd, Santa Ana, CA) and measured again.

Following measurements, the components were finished and polished using conventional lapping tools provided by Attachments International, Inc. San Mateo, CA. A new lapping tool was used for each component. Prior to lapping, a metal lathe (Attachments International, Inc. San Mateo, CA) was used to remove any internal casting defects that would hinder ideal screw tightening. The metal lathe was inserted into the component and turned approximately 6-8 times using finger pressure. The lapping procedure was conducted for as long as necessary to achieve what was believed to be a clinically acceptable mating surface by a Prosthodontist experienced in implant framework fabrication. Great effort was made to achieve the most ideal mating surface possible. An alignment tool supplied by the manufacturer was also used to ensure the stability of the castings and maintain the correct alignment of the components during the lapping procedure.

A diamond polishing paste (Attachments International, Inc. San Mateo, CA) was used between the mating surface of the casting and the polishing surface of the lapping tool. The motor was run at approximately 10,000 RPM. After they were run for 8-10 second periods, the mating surface was evaluated. The procedure was repeated until an acceptable mating surface was achieved. Approximately 5-10 minutes were needed to complete the entire lapping procedure for each component. Each casting was then affixed to the implant body using the provided screw tightened to 32 Ncm using a torque wrench, and measured a third time.

CeraOne® Premachined Titanium Abutment

Following manufacturer's protocol (Nobel Biocare Inc., Westmont IL) five CeraOne® titanium abutment cylinders were affixed to the implant body using a gold screw tightened with a torque wrench (ITL Dental, Implant Technologies Ltd, Santa Ana, CA) to 32 Ncm as recommended and measured as described previously. An indentation was created on each abutment to coincide with the indentation on the acrylic resin measuring cube, in order to facilitate future component repositioning and reference.

CAD-CAM Custom Premachined Titanium Abutments

Following manufacturer's protocol (Procera™, Nobel Biocare Inc., Westmont IL) computer generated information describing the implant body position and desired wax pattern form was sent to the manufacturer (Nobel Biocare, Goteborg, Sweden) for processing. Using CAD-CAM technology, five custom titanium abutments were manufactured. The fabrication of Procera™ CAD-CAM abutments involves the precision milling of commercially pure titanium blocks based on the computer assisted scanning information and design that is forwarded via modem with the laboratory work authorization form.

An indentation was created on each abutment to coincide with the indentation on the acrylic resin measuring cube, in order to facilitate future component repositioning and reference. Each CAD-CAM casting was affixed to the implant body using the provided gold screw tightened with a torque wrench (ITL Dental, Implant Technologies Ltd, Santa Ana, CA) to 32 Ncm as recommended, and measured as described previously.

The number, screw type and treatment of abutments comprising the six groups and control are given in Table 2.

Table 2: Number, Screw type and Treatment of Abutments comprising six Groups and Control

Group	Abutment type	n	Screw type	Precast Torque	Postcast Torque	Treatment
I	Gold *	5	Gold alloy	32Ncm	32Ncm	Cast-to
II	Gold •	5	Gold alloy	32Ncm	32Ncm	Cast-to
III	Plastic ⊗	5	Titanium	10Ncm	32Ncm	Cast
IV	Plastic •	5	Gold alloy	10Ncm	32Ncm	Cast
V	CeraOne® *	5	Gold alloy		32Ncm	None
VI	Procera™ ♦	5	Gold alloy		32Ncm	None
Control	Gold *	1	Gold alloy		32Ncm	None

* Manufactured by Nobel Biocare, Inc., Westmont, IL
• Manufactured by Implant Innovations Inc., FL
⊗ Manufactured by Attachments International Inc., CA
♦ Manufactured by Nobel Biocare, Goteborg, Sweden

Casting Procedures

Each component was cast using an identical standardized technique. A 3 mm sprue former measured from abutment to reservoir (Williams Tri Wax Sprue, Amherst, NY) was attached to the coronal aspect of the wax pattern. Casting rings (Whip Mix Corp. St.Louis, MO) were lined with a Pre-cut non-asbestos oval liner (Belle de St.Claire®, Orange, CA). The wax patterns were placed on the crucible former and were invested using a high fusing investment material (Cera-Fina, Whip Mix corp. Louisville, KY). The casting rings were then placed within a pressurized unit for 15 minutes to eliminate air bubbles (Invest-Press, Lang Dental Mfg. Co, Wheeling, IL). The investment was allowed to set for 2 hours at room temperature as per manufacturer's recommendation. Using a two-stage procedure, the casting rings were placed in the wax elimination furnace (Jelrus, Two Stage Temp Master L, Long Island, NY) with an initial temperature of 70°F. The temperature was raised to 600°F at a rate of approximately 20°F/min and held for half-hour followed by a rise to the final temperature of 1100°F at the same rate. The investment cylinders were cast within half-hour. Four new pennyweights of a type IV gold alloy (Monogram 4, Leach and Dillon, San Diego, CA) were placed in the ceramic crucible of the casting machine (Kerr Casting Machine, Orange, CA) and liquefied using a natural gas and oxygen torch. The liquefied alloy was then injected into each casting ring using the casting centrifuge set at three complete turns. The rings were allowed to bench cool for one hour prior to devestment. After devestment, each casting was then cleaned in an ultrasonic bath using a cleansing solution (No-San, Triodent, Inc, Union, NJ) until all investment material was removed.

Statistical Analysis

Means and Standard Deviations were computed for each experimental group at each respectively measured time interval. Multiple comparisons were made among the experimental groups using the Student-Newman-Keuls test. Paired t-tests were used to evaluate differences within experimental groups at Precast, Postcast and Finish intervals. The null hypothesis was rejected at $p \leq 0.05$.

RESULTS

All castings were deemed technically successful following careful examination. No miscasts, incomplete burnouts or other investment or casting errors occurred during the course of this study. Repeated measures of the control abutment were done to identify measurement errors. They revealed a mean value of .017 mm with a standard deviation of .001 mm. The standard error for measurements was found to be .002 mm. Measurements of the control gold abutment before and after each measurement interval confirmed that no significant measurement apparatus distortion occurred during the course of experimentation. Mean control measurement was .017 mm. Values of the control measurements ranged between .015 mm and .018 mm at different measurement intervals with a standard deviation of .002 mm as shown in Table 3. The coefficient of variation was 11.8 %. Hence it could be suggested that most measurements were experimentally accurate and no distortion could be primarily attributed to the measurement apparatus-mating surface throughout the course of this study.

Representative Scanning Electron Microscopy pictures were made to show the marginal discrepancy of the different Groups at Finish stage and are shown in Figures 3-8.

Mean marginal discrepancies and standard deviations for each experimental Group are provided in Table 3.

Mean Group I measurements were .018 mm and .016 mm Pre and Postcast respectively. Mean Group II measurements were .010 mm Pre and Postcast. Mean Group III measurements were .006 mm, .037 mm, and .028 mm for Precast, Postcast and Finish respectively. Mean Group IV measurements were .008 mm, .039 mm, and .029 mm for Precast, Postcast and Finish respectively. Mean Group V measurement was .012 mm for Finish. Mean Group VI measurement was .008 mm for Finish.

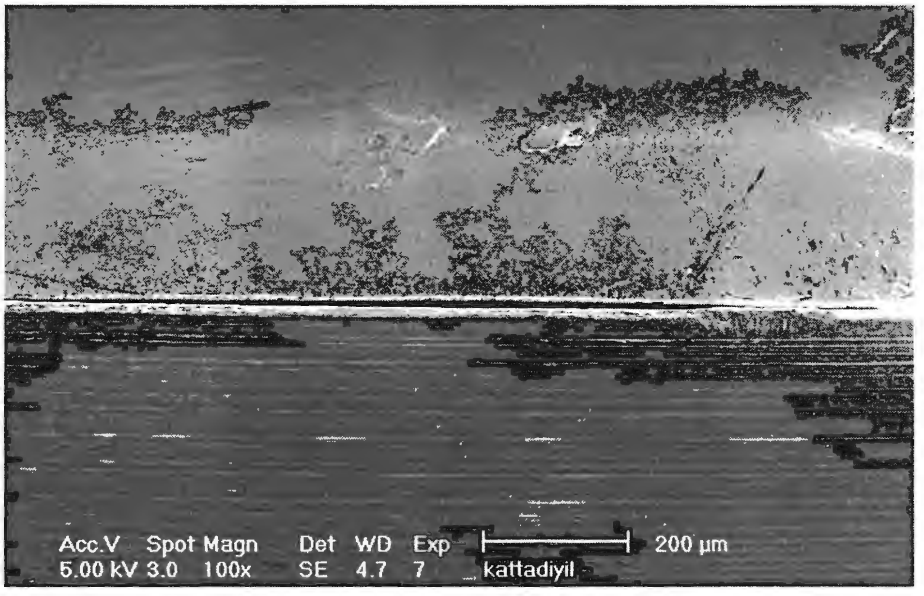

Figure 3: Scanning Electron Microscopic view of the Cast Gold Nobel Biocare Abutment-Implant body Interface

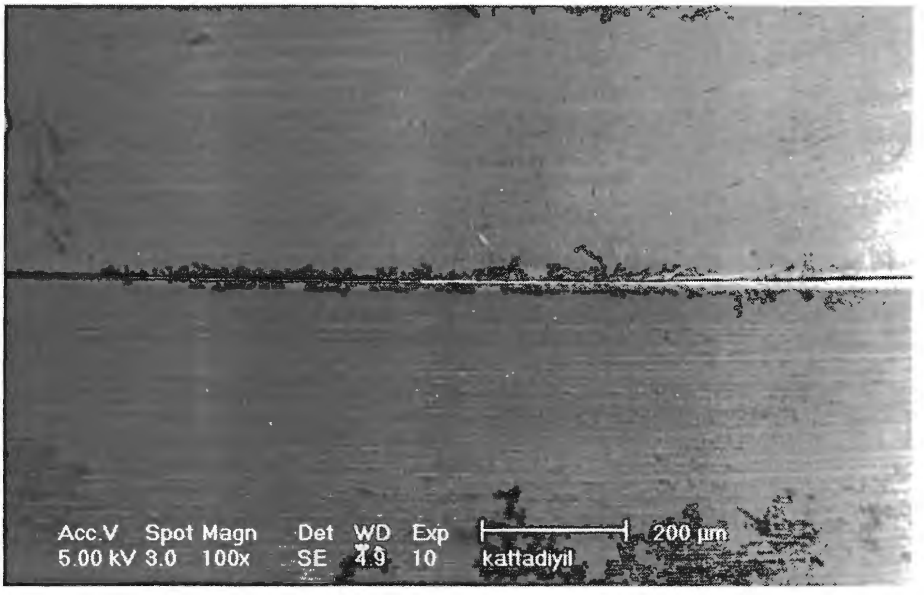

Figure 4: Scanning Electron Microscopic view of the Cast Gold Implant Innovations Abutment-Implant body Interface

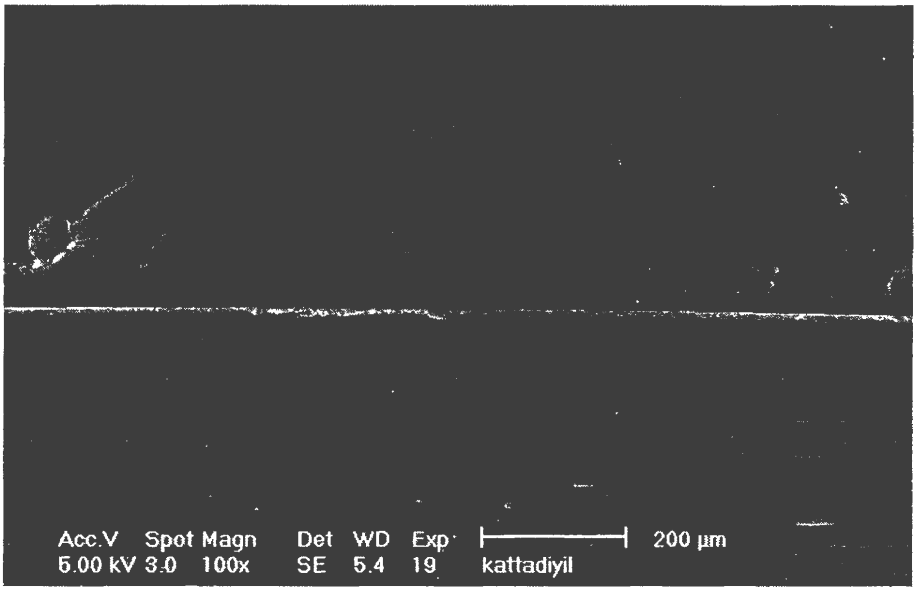

Figure 5: Scanning Electron Microscopic view of the Finished Cast Plastic Attachments International Abutment-Implant body Interface

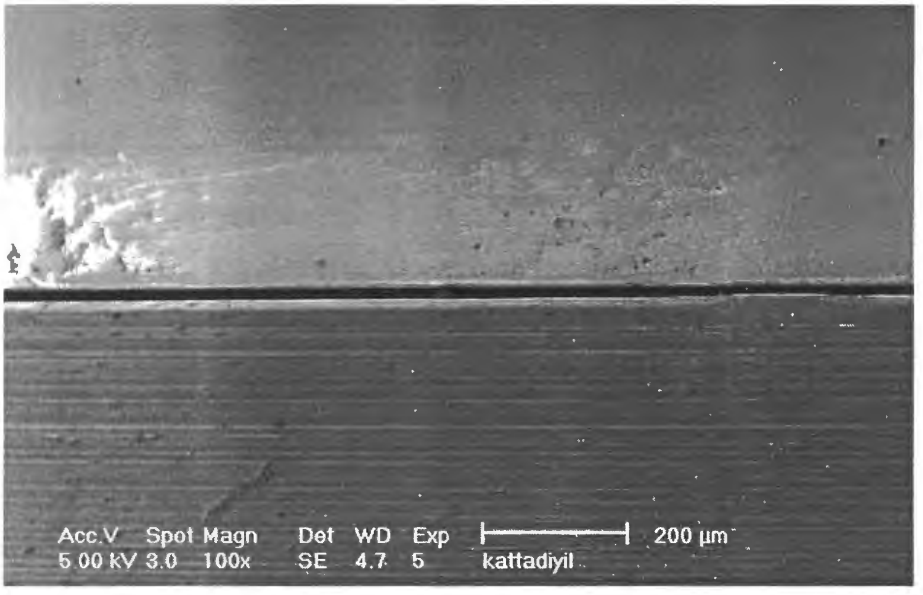

Figure 6: Scanning Electron Microscopic view of the Finished Cast Plastic Implant Innovations Abutment-Implant body Interface

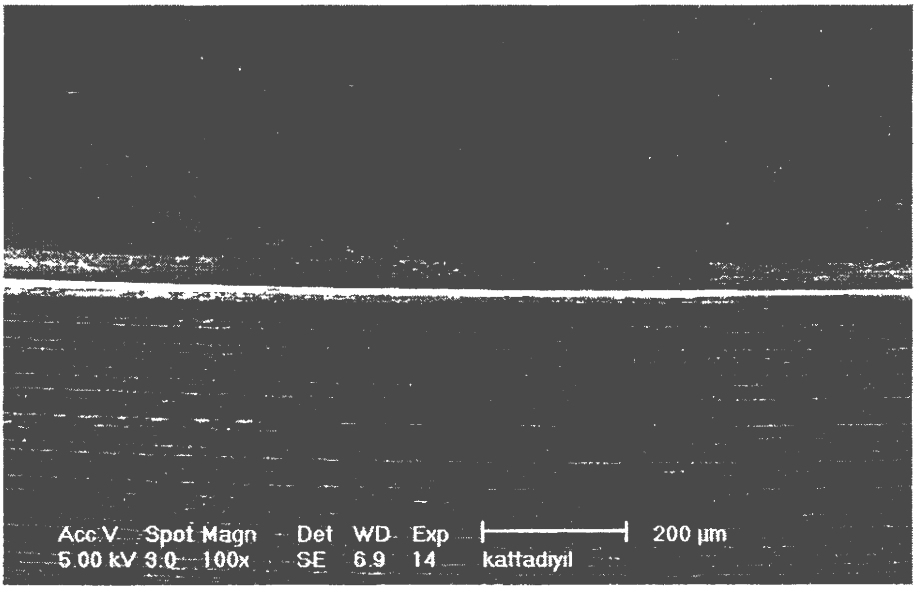

Figure 7: Scanning Electron Microscopic view of the CeraOne® Nobel Biocare Abutment-Implant body Interface

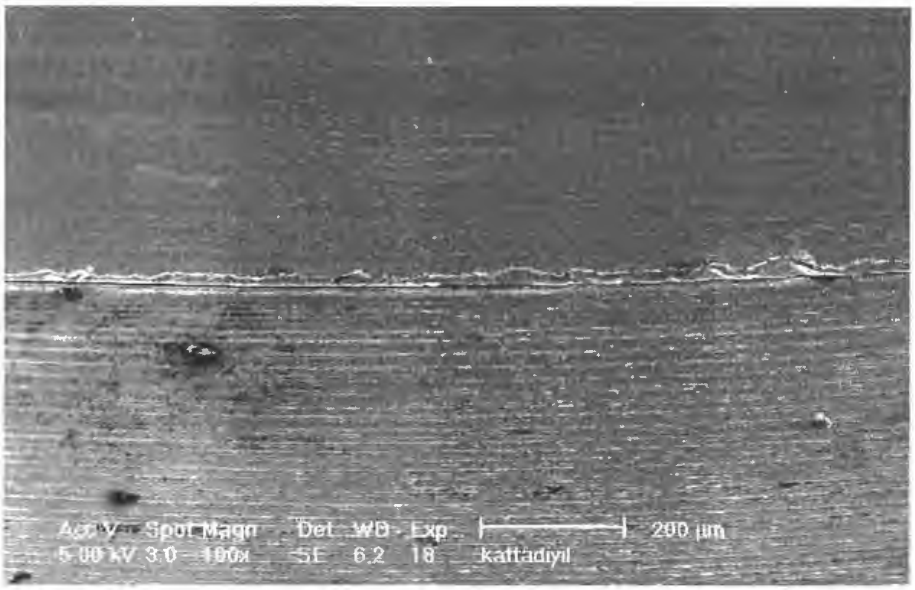

Figure 8: Scanning Electron Microscopic view of the Procera™ Nobel Biocare CAD-CAM Abutment-Implant body Interface

Table 3 : Means and Standard Deviations(SD) and Coefficient of Variation

Group No.	Measurement Interval	Mean(SD)	Coefficient of Variation (%)
Group I	Precast	.018(.001)	5.6
	Postcast	.016(.001)	6.3
Group II	Precast	.010(.001)	10.0
	Postcast	.010(.001)	10.0
Group III	Precast	.006(.002)	33.3
	Postcast	.037(.011)	29.7
	Finish	.028(.009)	32.1
Group IV	Precast	.008(.002)	25.0
	Postcast	.039(.011)	28.2
	Finish	.029(.012)	41.3
Group V	Finish	.012(.002)	16.7
Group VI	Finish	.008(.002)	25.0
Control		.017(.002)	11.8

Means and Standard Deviations are in millimeters

Intra Group Comparisons

Within Group comparisons with respect to Precast, Postcast and Finish measurement intervals were done using a paired t-test to compare the groups at significance level $\alpha = 0.05$ (Table 4).

♦ Group I: No significant difference between measurement values at Pre and Postcast intervals was seen ($p>0.05$).

♦ Group II: No significant difference between measurement values at Pre and Postcast intervals was seen ($p>0.05$).

♦ Group III: A significant difference between measurement values at Pre and Postcast intervals was seen. Values for Postcast measurements were significantly larger than those of Precast measurements ($p\leq 0.0001$). A significant difference between Postcast and Finish intervals was seen as well. Values for Postcast measurements were significantly larger than those of Finish measurements ($p\leq 0.0001$). A significant difference between Precast and Finish intervals was also seen. Values for Finish measurements were significantly larger than those of Precast measurements ($p\leq 0.0001$).

♦ Group IV: A significant difference between measurement values at Pre and Postcast intervals was seen. Values for Postcast measurements were significantly larger than those of Precast measurements ($p\leq 0.0001$). A significant difference between Postcast and Finish intervals was seen as well. Values for Postcast were significantly larger than those of Finish measurements ($p\leq 0.0001$). A significant difference between Precast and Finish intervals was also seen. Values for Finish were significantly larger than those of Precast measurements. ($p\leq 0.0001$)

♦ Group V and VI: Since only Finish measurements were made for Groups V and VI, intra group comparisons were not available.

Table 4 : Intra Group comparisons showing Means, Standard Deviations(SD) and Statistical Significance at different Measurement Intervals (MI).

MI	Group I	Group II	Group III	Group IV	Group V	Group VI
	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)
Precast	.018(.001)	.010(.001)	.006(.002)	.008(.002)		
Postcast	.016(.001)	.010(.001)	.037(.011)	.039(.011)		
Finish	.016(.001)	.010(.001)	.028(.009)	.029(.012)	.012(.002)	.008(.002)

Measurement Intervals connected by vertical lines are not statistically different ($p>0.05$)
Means and Standard Deviations are in millimeters

Inter Group Comparisons

Multiple Comparisons were done at Precast, Postcast and Finish intervals using the Student-Newman-Keuls method (Table 5).

Precast measurement comparison

♦ There were significant differences between Group I and Group II (Mean = .018 mm, SD = .001 mm and Mean = .010 mm, SD = .001 mm respectively). Group I and Group III (Mean = .018 mm, SD = .001 mm and Mean = .006 mm, S.D = .002 mm respectively), and Group I and Group IV (Mean = .018 mm, SD = .001 mm and Mean = .008 mm, SD = .002 mm respectively), and Group II and Group III (Mean = .010 mm, SD = .001 mm and Mean = .006 mm, SD = .002 mm respectively).

♦ There were no significant differences between Group II and Group IV (Mean = .010 mm, SD = .001 mm and Mean = .008 mm, SD = .002 mm respectively) and between Group III and Group IV (Mean = .006 mm, SD = .002 mm and Mean = .008 mm, SD = .002 mm respectively).

Postcast measurement comparison

♦ There were significant differences between Group IV (Mean = .039 mm and SD = .011 mm) and Group I (Mean = .016 mm and SD = .001 mm) and between Group IV and Group II (Mean = .039 mm, SD = .011 mm and Mean = .010 mm, SD = .001 mm respectively).

♦ There were significant differences between Group III (Mean = .037 mm and SD = .011 mm) and Group I (Mean = .016 mm and SD = .001 mm) and between Group III and Group II (Mean = .037 mm, SD = .011 mm and Mean = .010 mm, SD = .001 mm respectively).

♦ There were no significant differences between Group I and Group II (Mean = .016 mm, SD = .001 mm and Mean = .010 mm, SD = .001 mm respectively) and between Group III and Group IV (Mean = .037 mm, SD = .011 mm and Mean = .039 mm, SD = .011 mm respectively).

Table 5 : Inter Group comparisons showing Means, Standard Deviations(SD) and Statistical Significance at different Measurement Intervals

Group No.	Precast	Postcast	Finish
	Mean(SD)	Mean(SD)	Mean(SD)
Group I	.018(.001)	.016(.001)	.016(.001)
Group II	.010(.001)	.010(.001)	.010(.001)
Group III	.006(.002)	.037(.011)	.028(.009)
Group IV	.008(.002)	.039(.011)	.029(.012)
Group V			.012(.002)
Group VI			.008(.002)

Groups connected by vertical lines are not statistically different ($p>0.05$)
Means and Standard Deviations are in millimeters

Finish measurement comparison:

♦ Group IV (Mean = .029 mm and SD = .012 mm) showed a marginal discrepancy that was statistically higher than Group I (Mean = .016 mm and SD = .001 mm), Group V (Mean = .012 mm and SD = .002 mm), Group II (Mean = .010 mm and SD = .001 mm) and Group VI (Mean = .008 mm and SD = .002 mm).

♦ Group III (Mean = .028 mm and SD = .009 mm) showed a marginal discrepancy that was statistically higher than Group I (Mean = .016 mm and SD = .001 mm), Group V (Mean = .012 mm and SD = .002 mm), Group II (Mean = .010 mm and SD = .001 mm) and Group VI (Mean = .008 mm and SD = .002 mm).

♦ There were no significant differences between any of the premachined components of Group I (Mean = .016 mm and SD = .001 mm), Group V (Mean = .012 mm and SD = .002 mm), Group II (Mean = .010 mm and SD = .001 mm) and Group VI (Mean = .008 mm and SD = .002 mm).

♦ There were no significant differences between either of the castable plastic components of Groups III and IV (Mean = .028 mm, SD = .009 mm and Mean = .029 mm, SD = .012 mm respectively).

♦ Group I (Mean = .016 mm and SD = .001 mm), Group V (Mean = .012 mm and SD = .002 mm), Group II (Mean = .010 mm and SD = .001 mm) and Group VI (Mean = .008 mm and SD = .002 mm) showed significantly lower marginal discrepancies compared to Group III and IV (Mean = .028 mm, SD = .009 mm and Mean = .029 mm, SD = .012 mm respectively).

Graph with measurement comparisons of all the Groups at Precast, Postcast and Finish time intervals is shown in Figure 9.

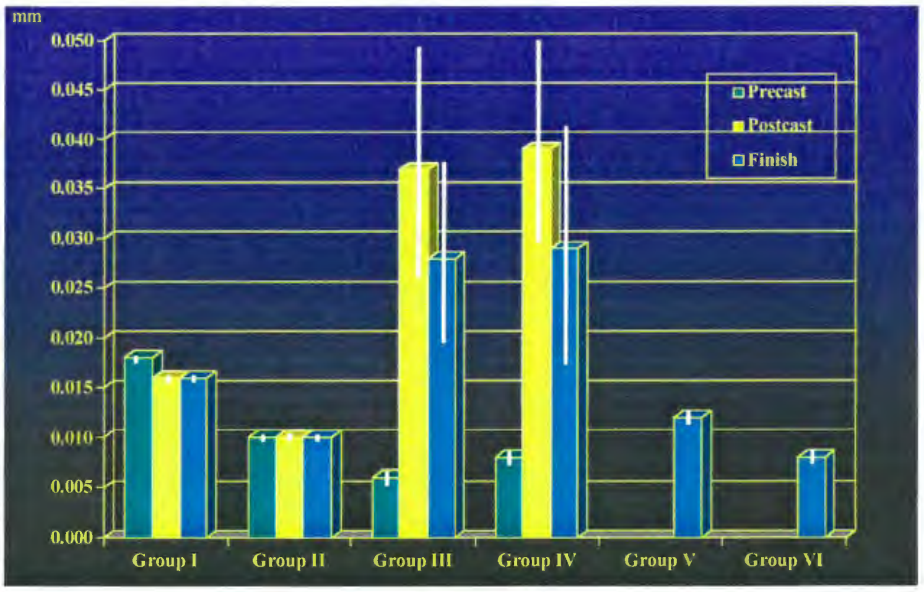

Figure 9: Measurement Comparisons at Precast, Postcast and Finish intervals.

DISCUSSION

The study was carefully designed to limit measurement bias and inaccuracy. A control premachined gold cylinder was used for measurements before and after each group measurement at each interval. This was done to detect any distortion of the measurement apparatus throughout the course of experimentation. The means for the control measurements ranged between .015 mm and .018 mm with a standard deviation of .002 mm at various measurement period intervals and supports the contention that the measurement apparatus mating surface was not altered during the course of experimentation. Repeated measures of the control abutment revealed a mean marginal discrepancy of .017 mm with a standard deviation of .001 mm and a standard error of .002 mm. Measurements were performed by a single blinded principal investigator to limit measurement bias, and control for measurement variability.

Plastic components revealed superior marginal fit compared to premachined abutments at only the Precast measurement interval. At the Postcast and Finish measurement intervals, the cast plastic components of both Groups III and IV showed a marginal fit discrepancy which was statistically inferior to the measurements for premachined cast-to gold abutments of Groups I and II as well as the premachined titanium abutments of Groups V and VI. Improved clinical biomechanics as well as decreased bacterial contamination and/or leakage of the abutment-implant body interface may be provided by premachined components.

Improved marginal fit of the plastic patterns at the Precast stage is most likely due to minor distortion of the plastic components when affixed to the implant body. A standardized compressive tightening force of 10 Ncm was applied with a torque wrench which may have masked plastic component marginal discrepancies if any. However, 10 Ncm is a reasonable representation of forces normally applied to these components through firm finger tightening during laboratory construction procedures. This statement is further supported by the report of

Cheshire and Hobkirk[42] who found that hand tightening produced decreased vertical discrepancy compared to a tightening force of 10 Ncm at the abutment-cylinder interface. This suggests that hand tightening could produce a higher torque value. However for the purpose of standardization and to avoid human errors as much as possible it was decided to use 10 Ncm to tighten the plastic abutments.

Changes in marginal discrepancy after casting and finishing plastic castable components can be attributed to inherent errors in the casting and finishing process and/or during tightening of the plastic components itself and not to pre-existing distortion of the Precast plastic pattern. This is supported by our findings since the changes after casting and finishing are of equal magnitude for both groups of components even though they were procured from different manufacturers and would most likely differ with respect to plastic pattern Precast distortion.

All Postcast measurements of plastic components revealed greater marginal discrepancies when compared to Precast. As mentioned earlier this is probably due to the inherent errors associated with the casting process. Also, a larger existing marginal discrepancy could have been masked due to the flexibility of the plastic pattern on being subjected to compressive tightening forces at the Precast stage.

At the Precast measurement interval, a significant difference is seen between the marginal discrepancy for premachined gold abutments belonging to Group I and Group II as compared to no significant difference between the same groups at the Postcast measurement interval. This finding is difficult to explain but is most likely due to measurement error.

Measurements made after finishing both groups of cast plastic components showed a significant improvement in marginal discrepancy as compared to their measurements at the Postcast stage. This indicates that despite higher marginal discrepancy of the cast plastic components, meticulous attention to finishing of the mating surface did significantly improve the

marginal fit between the abutment-implant interface of these components. However, even with this improvement the interface was still statistically inferior to the cast premachined gold (Groups I and II), premachined titanium (Group V) and CAD-CAM custom premachined titanium (Group VI) abutments. It is important to mention that most commercial laboratories would not have spent as much time lapping and finishing these components under the microscope to ensure an accurate mating surface as was done in this study.

The values obtained from this study for the mean marginal discrepancy of the CeraOne® premachined titanium abutment and the cast plastic component groups are lower than those reported by Byrne.[29] They reported mean measurements of 86 micrometers at the Nobel Biocare implant-CeraOne® abutment interface and 84 micrometers at the Nobel Biocare implant-Implant Innovations finished postcast plastic abutment interface. However, this could be attributed to the differences in study methodology as well as to the greater care and standardization of the casting and finishing procedures used in the present study to minimize errors.

Binon et al[43] reported a mean marginal interface error of 49 micrometers for the Branemark implant components. In their study they included the rounded edge of the abutment in their measurements. This could explain the larger marginal discrepancy reported in the Binon study compared to the lesser marginal discrepancy measured for the Branemark components in the present study. Jansen et al[23] clearly indicate in their Scanning Electron Microscopy analysis that the rounded edge does not influence the interface between implant and abutment. In the present study measurements were taken from the implant body to the abutment interface excluding the rounded edge.

Dellow et al[30] reported the mean interface discrepancy of Branemark implant-abutment components to be about 7 micrometers. However, minimal information is available as to the type

of abutment and the torque forces used that would permit a comparison of their results with this study.

The selection of torque applied to the components was based on study standardization rather than manufacturer recommendations. One manufacturer (Implant Innovations) recommends 20 Ncm for abutment fixation rather than the 32 Ncm as was applied in this study. The decision to use a higher and standard torque (32 Ncm) in this study seems justified from the conclusions of Byrne et al.[29] They claimed that the lesser torque (20 Ncm) they used could have contributed to the overall inferior adaptation found for Implant Innovations components in their study.

Carr et al[31] evaluated the effects of fabrication, finishing and polishing procedures on preload in prostheses using conventional gold and plastic components. They concluded that after finishing and polishing of cast plastic frameworks there was an increase in preload compared to no such manipulations. Also, if maximum preload is desired, the use of premade metal components offer an advantage over plastic patterns in both preload magnitude and precision. In the present study it was found that premachined abutments offered a superior marginal fit over cast plastic components. It was also observed that finishing and polishing of the mating surface of the cast plastic components improved the marginal fit significantly. Hence combining the results of the Carr study and the present study it could be inferred that a superior marginal fit could result in an increased preload. An increased preload may help minimize screw-loosening and improve implant biomechanics.

The premachined abutments of Groups I and II, which were cast-to, did not reveal any significant changes after casting. This finding is not surprising since the mating surfaces of these components are not directly manipulated or altered during the casting process. Similar marginal discrepancies were noted for all of the premachined components. CAD-CAM (Group VI)

components seem to exhibit superior marginal integrity when compared to both premachined gold abutments (Group I and II) as well as the titanium CeraOne® abutments (Group V). The mean marginal discrepancy of CAD-CAM components were only 8 micrometers compared to 16, 10 and 12 micrometers for Groups I, II and V respectively. The differences, however, were not significant. CAD-CAM technology (Procera™) appears to be extremely promising with respect to marginal integrity.

The results of this study are supported by Byrne et al[29] who evaluated marginal discrepancy of castable patterns, premachined and laboratory modified premachined abutments to dental implants at the abutment-implant interface as well as the screw to screw seat of the abutment. The authors reported that no significant distortion occurred to premachined abutments which were waxed and cast. They also stated that premachined abutments, including those that are cast-to and are subjected to porcelain firing, are superior in adaptation to those cast from burnout patterns and laboratory finished. These findings are in agreement with the present study.

The data suggests that once refined, implant abutments manufactured through CAD-CAM technology (Procera™), may emerge as an excellent clinical treatment option for dental implant restorations. They exhibit the potential for excellent marginal integrity and possess the ability to correct for compromised implant angulations. They would be beneficial in highly esthetic implant restorative situations and would further be useful in more challenging restorative situations due to their versatility. Since these abutments are manufactured from titanium, the controversy regarding the use of non-titanium metals onto dental implants would also be put to rest. Jemt[39, 33] and Rubenstein[37] found favorable clinical responses to the use of custom made abutments. Further, Balshi et al[44] point out that using angulated custom abutments will not necessarily promote peri-implant problems. The angulated and/or custom made abutment is a

treatment adjunct that provides flexibility for ensuring successful results when a variety of reconstruction problems are encountered. However, further clinical data need to be collected before recommending these abutments as a solution to the inherent problems posed by both premachined and custom made castable abutments.

Clinical Relevance

The degree of accuracy of marginal fit between implant and implant framework components has been a topic of prolonged discussion. Jemt et al[18] have published that clinically, this debate was meaningless. The authors attempted to correlate in vivo measurements of prosthesis misfit and change in marginal bone level, in implants placed in the edentulous maxilla. They concluded that even though none of the measured prostheses showed a completely passive fit, negative bone changes could not be demonstrated over a period of up to five years. However, the authors of this study themselves state that this finding does not preclude bone loss in other clinical situations where certain patients could react more sensitively to bone strain due to misfit and where the prosthesis precision would be worse than found in their study. They found correlation, though weak, between misfit and some of the distortion parameters used in the study. They also report that since implants are ankylosed and hence do not measurably move in the bone in clinical situations it must be anticipated that stress introduced into the implant system as a result of prosthesis misfit maybe present many years after placement and could result in failure. Carr et al[45] and Michaels et al[46] using different animal models failed to distinguish a difference in bone response between different levels of prosthetic fit. However, the main drawbacks of the Carr study and Michaels study were that they did not load the prostheses with different levels of misfit and hence were not able to duplicate a clinical situation and also the short duration of both the studies (4 and 12 weeks respectively).

Component misfit may have greater implications with respect to bacterial contamination leading to peri-implant bone loss. Jansen et al[23] evaluated microbial leakage and marginal fit of the implant-abutment interface and concluded that a certain degree of microbial leakage existed in all the evaluated systems that could, ultimately lead to peri-implantitis. It is logical to assume that a decreased marginal discrepancy would favor reduced marginal leakage.

Persson et al[19] examined bacterial colonization on internal surfaces of Branemark system® implant components and revealed that after varying periods of function in the oral cavity, the components harbored a heterogeneous and primarily anaerobic bacteria. Most of the species identified in this study could also be found in deep periodontal pockets.

In a study by Hermann et al[20] the authors concluded that bacterial contamination of the microgap between implant and abutment is directly responsible for peri-implant bone loss and may be the reason behind the phenomenon of early peri-implant bone loss as discussed by Adell.[9]

Numerous experimental and clinical studies in both animals as well as in humans have shown that bacterial plaque accumulation can cause progressive bone loss around implants and may lead to implant failure.[47, 48] The evidence in support of the detrimental effect of bacteria on the bone implant interface is overwhelming.[49, 26] Saito et al[50] reports that although long term plaque accumulation did not cause marked periodontal destruction, the peri-implant tissue may be more susceptible to plaque accumulation than the periodontal tissue. Also, teeth may serve as a reservoir for the bacterial contamination of the implant sulcus. Therefore, the reduction or elimination of the abutment-implant interface microgap would most likely benefit the long-term success of the implant restoration through improved peri-implant health by reducing bacterial contamination of implant components.

Isidor[2] concluded from his study that occlusal overload can result in loss of osseointegration and that plaque accumulation on oral implants can result in a loss in

marginal bone height. Even though in their study occlusal overload was applied through supra-occlusal contacts resulting in lateral forces, it could be argued that a certain degree of misfit of the components could produce a similar effect.

It is clear that there is no consensus among various authors regarding acceptable levels of framework misfit and the exact relationship between misfit, biomechanical stress, bacterial contamination and dental implant failure. It seems logical however, that techniques or components which can produce frameworks with reduced marginal discrepancy may enhance long-term implant survival through the reduction of biomechanical stress on the implants and microbial leakage of the peri-implant environment.

In the present study component fit was best with Procera™ CAD-CAM custom premachined titanium abutments followed by premachined CeraOne® titanium abutments, premachined gold abutments and lastly by castable plastic components. Significant differences were shown between marginal discrepancy observed with premachined components and castable plastic components. Mean marginal discrepancies for all groups however were relatively small ranging between 8 and 29 micrometers. Each measurement of marginal discrepancy of implant components obtained in this study meets and in fact exceeds what is considered an acceptable standard value of measurement at the tooth to crown margin. Further studies are necessary to determine the clinical relevance of these marginal discrepancies.

CONCLUSIONS

Within the limitations of this study the following conclusions can be made :

♦ Significantly better fit was provided by premachined gold and titanium abutments (Gold abutments, CeraOne® and Procera™ CAD-CAM abutments) when compared to castable plastic components at the Postcast and Finish stages.

♦ Laboratory finishing and polishing of the cast plastic abutment mating surface provides for significantly improved marginal integrity.

♦ There is no significant alteration of the premachined gold abutment mating surface fit following casting.

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