FRACTURE RESISTANCE OF THREE MONOLITHIC CAD/CAM MANUFACTURED IMPLANT SUPPORTED CROWNS CEMENTED TO A TI-BASE CONNECTOR

A manuscript

Presented to the Faculty of the Advanced Education in General Dentistry, Two-Year Program,

United States Army Dental Health Activity, Schofield Barracks, HI

And the Uniformed Services University of the Health Sciences – Post Graduate Dental College

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Oral Biology

By

Michael A. Hoffman, MAJ, DC, USA

May 2019

DENTAL

Uniformed Services University

DISCLAIMER

Distribution Statement

Distribution A: Public Release.

DEPARTMENT OF THE ARMY
ADVANCED EDUCATION IN GENERAL DENTISTRY 2-YEAR PROGRAM
SCHOFIELD BARRACKS DENTAL CLINIC
BUILDING 660 McCORNACK ROAD
SCHOFIELD BARRACKS, HI 96857

THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: Fracture Resistance of Three Monolithic CAD/CAM Manufactured Implant Supported Crowns Cemented to a Ti-Base Connector

Name of Candidate: MAJ Michael A. Hoffman
Master of Science Degree
June 12, 2019

All work has been completed to the satisfaction of the research committee.

THESIS/MANUSCRIPT APPROVED: DATE:

[redacted] 31 May 19

Lisa N. Yarbrough, COL, DC
Program Director, AEGD-2 Hawaii
Committee Chairperson

[redacted] 31 May 19

Brandon M. Gage, LTC, DC
Assistant Program Director, AEGD-2 Hawaii
Committee Member

[redacted] 3 June 19

Catherine F. Uyehara, PhD
Chief, Department of Clinical Investigation, TAMC
Committee Member

By
MICHAEL A HOFFMAN, MAJ, DC, USA
D.D.S, University of Michigan-School of Dentistry 2008
B.S., Grand Valley State University 2004

Mentor Staffing By
BRANDON M GAGE, MAJ, DC, USA
M.S., Uniformed Services University of the Health Sciences – Post Graduate Dental College
D.D.S., Creighton University – School of Dentistry 2006
B.A., Brigham Young University 2002

And

JEE KIM, MAJ, DC, USA
Certificate in Prosthodontics, U.S. Army Prosthodontic Program FT Gordon, GA 2015
D.D.S., University of Southern California-Herman Ostrow School of Dentistry2011
M.S., University of California Irvine 2005
B.A., Cornell University 2003

And

LISA N YARBROUGH, COL, DC, USA
Certificate, Advance Education in General Dentistry-Two Year, Fort Bragg, N.C. 2005
D.M.D., University of Florida 1998
B.S., Florida State University 1994

Schofield Barracks, HI
May 2019

ACKNOWLEDGMENTS

I would like to thank Drs. Lisa Yarbrough, Brandon Gage, Jee Kim, and Martin Smallidge for their insight and guidance throughout this project. Mr. Michael Lustik for your assistance with statistical analysis. Mr. Wayne Ichimura for your help with design and fabrication of test materials, troubleshooting during testing, and running the actual experiment.

DEDICATION

To my wife, Danielle, thanks for your encouragement, support, and love throughout the past two years. I couldn’t have done it without you.

The author hereby certifies that the use of any copyrighted material in the thesis manuscript entitled:

"FRACTURE RESISTANCE OF THREE MONOLITHIC CAD/CAM MANUFACTURED IMPLANT SUPPORTED CROWNS CEMENTED TO A TI-BASE CONNECTOR

"

Is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

[redacted]

Michael A. Hoffman
Comprehensive Dentistry Residency
Uniformed Services University
Date: **05/31/2019**

Abstract

FRACTURE RESISTANCE OF THREE MONOLITHIC CAD/CAM MANUFACTURED IMPLANT SUPPORTED CROWNS CEMENTED TO A TI-BASE CONNECTOR

Presented by: Michael A. Hoffman, MAJ, DC

Hoffman, MA[1], Kim, J[1], Gage, B[1], Lustik, M[2], Yarbrough, L[1]
[1]AEGD-2, Schofield Barracks Dental Clinic [2]Dept Clinical Investigation, Tripler Army Medical Center

Introduction: Dental implants are a popular treatment modality for restoring edentulous areas. After osseointegration, the implant must be restored with an implant abutment and crown. Traditionally, a dental lab fabricated these components. The introduction of the Tibase connector allows clinicians to utilize CAD/CAM technology to design and manufacture these components themselves. To date, few studies considered the ability of these restorations to sustain forces encountered in the posterior dentition.

Objective: To evaluate the forces required to fracture monolithic implant crowns fabricated from three different ceramics cemented to a Tibase connector and to determine if there is a difference in failure force and failure mode between materials.

Methods: Three groups of 20 monolithic ceramic crowns were fabricated from Enamic (Vitazahnfabrik), Emax (Ivoclar) or InCoris Zirconia (Dentsply-Sirona) ceramics. These crowns were cemented to a Tibase connector (Dentsply-Sirona) and attached to a dental implant (3i) embedded in acrylic to simulate an osseointegrated implant. These crowns were subjected to a constant force at a 45° angle on an MTS universal testing machine to simulate forces in the posterior dentition. Force at failure and failure type were recorded.

Results: Mean failure force for the three samples were 1,995 N for Enamic, 2,277 N for Emax, and 2,265 N for InCoris. The majority of Emax and InCoris failures were over 2500N ($p=0.065$). There was no significant difference in failure between the three groups ($p= 0.089$). The majority of failures were due to fracture of the ceramic crown (58%, n=34) The second most common failure was fracture of the abutment screw connecting the crown to the implant (25%. N=15). No Tibase connectors failed during the experiment.

Conclusion: Crowns fabricated with a Tibase withstood forces exceeding those normally encountered in the human dentition. Failure of the crown or the abutment screw typically is a favorable failure mode. Crowns fabricated with a Tibase connector appear to be a viable treatment option regardless of ceramic type.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Background

Dental implants are a popular treatment modality for restoring edentulous areas. When planning for an implant restoration, a clinician must take into consideration the materials he is using. Custom abutments are often fabricated from titanium, which allows for a restoration with excellent strength, an intimate fit with the internal components of the implant, and biocompatibility with the surrounding tissues. There are some limitations to these restorations. The dark color and inherent opacity of the titanium can lead to esthetic issues in some situations. If titanium abutments are utilized with a traditionally cemented crown the clinician runs the risk of extruding cement in the gingival tissues.
A dental lab must fabricate these abutments, which can be costly and time consuming. The introduction of titanium inserts to manufacture hybrid implant abutments offers solutions to several of these issues. Hybrid abutments utilize a titanium insert designed to fit into the implant that is luted to a ceramic abutment or crown. Tibase is one such titanium insert.

In terms of implant restoration esthetics, metal abutment show through can cause an unaesthetic gray appearance in ceramic restorations and gingiva[1,2]. This is especially true in patients who exhibit a thin gingival phenotype [1]. An initial solution to this problem was to fabricate abutments from zirconia. Zirconia exhibits good strength, esthetics, and biocompatibility, but can fracture when used with an internal implant connection [1, 2, 3, 12]. This is because the zirconia tends to be more brittle than titanium. Zirconia is especially brittle when subjected to tensile forces within the implant connection. These forces are better handled by a titanium connection[3]. Zirconia abutments also have a less intimate connection with implants when compared to a titanium abutment. This is because zirconia cannot be milled as accurately as titanium. This poor fit can contribute to screw loosening and wear on the zirconia abutment via micromovement. [13] The Tibase is a titanium insert that fits intimately into the internal surface of an implant. The clinician can then design a veneering ceramic coping that is cemented to the Tibase to create a hybrid ceramic/titanium custom abutment. The clinician can also design a monolithic ceramic crown that is cemented to the Tibase. The Tibase thus allows for an intimate titanium-to-titanium connection while solving the esthetic issues inherent in an all-metal abutment.

When restored with a cemented crown, implant restorations pose a potential risk to the periodontal tissues. Crowns that are cemented to a titanium abutment run the risk of cement extrusion into the implant sulcus which can result in periimplantitis. The cement is difficult to clean up and is not always apparent clinically or radiographically. It can serve as a source of chronic inflammation in the tissue surrounding the implant and lead to bone loss, periimplantitis, and implant failure[21]. The Tibase addresses this issue in two ways. Cementation of the abutment occurs extraorally, thus eliminating cement extrusion [12,16] The Tibase also gives the clinician control over restoration design parameters that can influence gingival health. The clinician can design a monolithic screw retained restoration to completely remove the risk of cement extrusion. Or if the clinician needs to design a cement retained prosthesis, he can ensure the margin of the restoration is gingival or supragingival to ensure complete cleanup of cement.

A dental laboratory must fabricate a titanium custom abutment and abutment supported crown. This adds time and cost to the restoration. The clinician has little control over parameters such as margin location, emergence profile, abutment height, and thickness of crown restorative materials. These are all parameters that contribute to the esthetic and functional success of the implant restoration. The patient must also return for a second visit, which can increase cost of the restoration for the patient and clinician. It also subjects the implant to multiple instances of implant components, such as healing abutments, being placed and removed. This can subject the implant to micromovement which could affect its long-term success[6]. With the Tibase, the clinician uses chair side optical scanning to create a digital model of the patient's case reducing time to restore the case[6]. Emergence profile, material thickness, and other design parameters are now in the hands of the clinician[14]. The need to send the case to a lab and bring the patient back for a second appointment is virtually eliminated.

Several ceramics are available in abutment blocks for use in the manufacture of CAD/CAM restorations. These abutment blocks are designed with a screw access channel that fits intimately with the Tibase . This channel aids in orientation and retention. Some of the materials available in abutment blocks include lithium disilicate (Emax, Ivoclar Vivadent), hybrid polymer-infilitrated ceramic called Enamic (Vita Zahnfabrik), and zirconia (InCoris Sirona). Emax is a well-studied material that exhibits excellent strength and esthetics. It comes in a monosilicate block that can be milled and then fired to convert it to lithium disilicate. It is indicated for anterior as well as posterior restorations and can be used as a monolithic or hybrid restoration. Enamic is a polymer-infiltrated ceramic that offers the advantage of not requiring a firing cycle. Its lower modulus of elasticity may also help it to act as a shock absorber for implant restorations[6]. Zirconia is a well-studied polycrystalline material that is milled in a weaker monoclinic form. After sintering, the restoration exists in the tetragonal form and possesses excellent fracture resistance. All three of these materials can be utilized with the Tibase to fabricate monolithic crown restorations or hybrid abutments.

While the clinician is given more control over restorative aspects, the addition of the Tibase introduces a potential area of failure in the implant-supported prosthesis. There are several different areas where the restoration can fail. First, the bonding interface between the titanium and ceramic can fail leading to debonding. The ceramic material can fail due to reduced material thickness from the addition of the Tibase. Ceramic failure can also occur in the cervical region as the Tibase creates tensile forces where the abutment meets the implant platform. Finally, the abutment screw can become loose or break. [10, 11, 14, 15, 16]
As the dental profession embraces CAD/CAM technology, more practitioners will attempt to maximize its utilization. This increased use could lead to prescribing Tibase restorations in situations where there is limited evidence to support its use. One such area is the use of Tibase to restore posterior teeth. Posterior teeth are subject to massive forces

from 200-900 Newtons.[11] Studies simulating the restoration of anterior teeth show that Tibase restorations are a viable solution in the anterior region where forces range from 100-300 Newtons[10,12] To date, no in vitro studies exist that test fracture resistance of Tibase restorations in the posterior region.

The purpose of this study was to evaluate the use of Tibase restorations in the posterior dentition. We sought to determine the fracture force and mode of fracture for statically loaded molar implant supported crowns fabricated from three commercially available ceramics luted to a Tibase.

Methods and Materials

To simulate a clinical situation, a 5mm platform 3i Nanotite tapered Certain implant analog (3i Biomet, Carlsbad, CA) was placed in the #19 edentulous site of a mandibular model. A titanium insert (Tibase, Dentsply Sirona, Bensheim Germany) was placed in the implant platform analog and hand tightened. A scan body was placed on the Tibase and utilizing a chairside CAD/CAM unit (CEREC Omnicam, Dentsply Sirona) a digital scan of the Tibase was taken. Utilizing the CEREC software, an ideal monolithic screw retained implant crown was designed to replace a mandibular first molar.

Three groups of twenty monolithic ceramic implant restorations were fabricated utilizing a Sirona MCLX lab mill (Dentsply Sirona) from either lithium disilicate (Emax Abutment blocks, Ivoclar Vivadent LOT X20995, X25997, X21168, W11446); a hybrid ceramic (Enamic, Vita Zahnfabrik, Bad Sackingen, Germany LOT 82260, 66000, 75630, 82260) and zirconia (Incoris ZI Dentsply-Sirona York PA LOT 2018054874, 2018236040). Emax crowns underwent crystallization in a Programat Oven (Ivoclar Vivadent) per manufacturer specifications. Zirconia specimens were sintered in a Sirona HTC inFire Speed Sintering Lab furnace (Dentsply Sirona) per manufacturer guidelines. Enamic crowns did not require any further processing.

The intaglio of the Emax crowns was etched for 20 second with 5% hydrofluoric acid (IPS Ceramic Etching gel, Ivoclar Vivadent, Schaan Lichtenstein), steam cleaned, air dried, and treated with a silane coupling agent (Monobond Plus, Ivoclar Vivadent) for 30 seconds. Enamic Crowns were internally etched for one minute with 5% HF acid, steam cleaned, air dried, and treated with Monobond Plus for 30 seconds. Zirconia crowns were lightly air abraded with 50 micron aluminum oxide, steam cleaned, air dried, and treated with Monobond plus

To simulate osseointegrated implants, sixty Nanotite Tapered Certain 5.0 X 10mm implants (3i Biomet, Carslbad, CA) were imbedded in acrylic material with 2mm of collar exposed to simulate clinical bone loss (ISO 14801). Orthodontic Acrylic (Dentsply-Sirona) was mixed according to manufacture directions. Implants were held in place by a jig and placed in a standardized mold with unset acrylic. Samples were cured under pressure at 40 psi to ensure adequate cure. Sixty Sirona Tibase titanium inserts were inserted into the implants and secured with the included abutment screw. (See Figure 1) All abutment screws were torqued to 20NCM with an implant driver. After ten minutes all abutment screws were torqued a second time to compensate for screw relaxation. All Tibase samples were then air abraded with 50 micron aluminum oxide.

Samples were then steam cleaned to remove debris. Prior to cementation, all Tibase were treated with Monobond Plus for 30 seconds.

All restorations were cemented to the Tibase utilizing a resin cement (Multilink Hybrid abutment cement, Ivolcar Vivadent) per the manufacturer's instructions.

To simulate the sealing of the access hole, teflon tape was placed in each screw channel; bonding agent was applied (Optibond Plus, Kerr, Orange, CA) and cured for 20 second with a dental curing light (Kerr Demi, Kavo Kerr, Bioggio Switzerland). The screw access was filled with composite (Filtek Supreme, 3M, Minneapolis, MN) and cured for 40 seconds. All restorations were stored in distilled water for 72 hours at 37° prior to being subjected to loading.

Samples were randomized for testing. Each sample was secured in an acrylic jig that placed the sample at a 45° angle to a spherical loading device to simulate off angle loads in the posterior mandible. (See Figure 3) A universal testing machine (MTS 858 Bionix II Mini, MTS Eden Prairie, MN) applied a constant force with a crosshead speed of 2mm/min until the specimen failed. The force in Newtons at which the specimen failed and the type of failure were recorded. A nonparametric Kruskal-Wallis test was performed to determine difference in failure force and mode.

Figure 1. Tibase secured to implant embedded in acrylic

Figure 2. Enamic, Emax, and InCoris samples

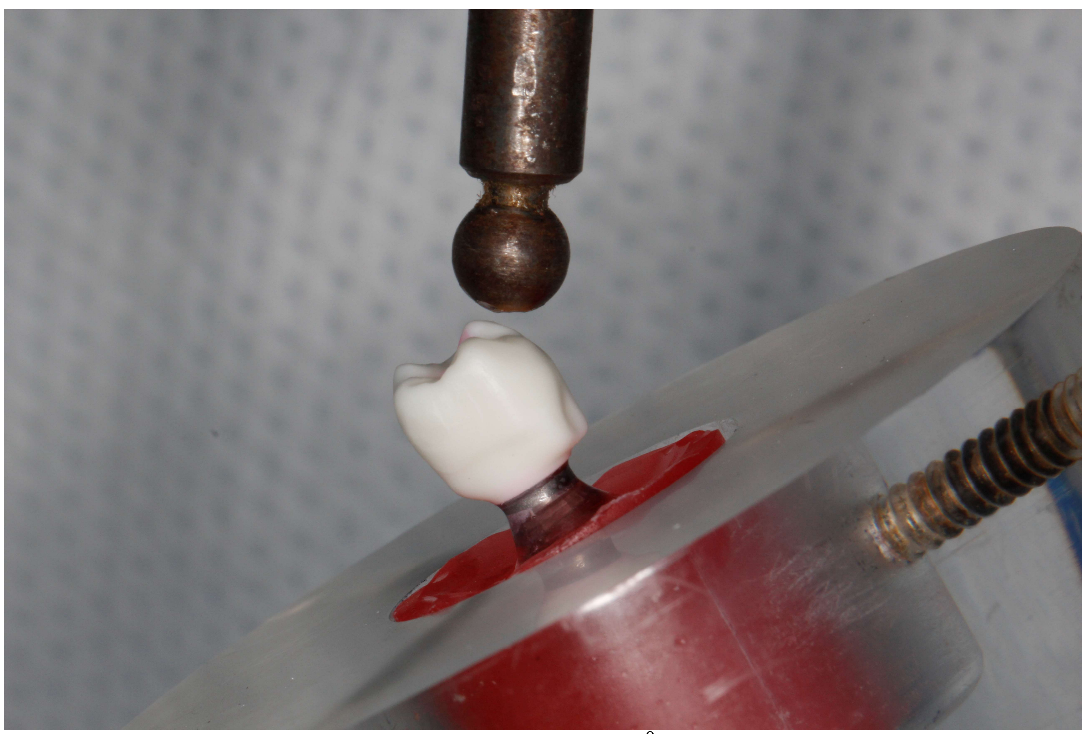
Figure 3. Sample secured in jig at 45^0 angle to crosshead.

Results

A total of 59 specimens were included in the final analysis of failure mode and fracture strength. One zirconia specimen was damaged while determining failure mode and was excluded from the study. Three modes of failure were noted during the experiment. Specimens either suffered catastrophic fracture of ceramic with the Tibase intact (FCTI), fracture of the abutment screw (FAS), or failure of the acrylic base with the restoration intact (Restoration intact, Base Broken RIBB). Enamic had zero fractured abutment screws, 19 FCTI (95%) and 1 RIBB (5%), Emax had 4 FAS (20%), 15 FCTI (75%) and 1 RIBB (5%). Zirconia had zero ceramic failures, 11 FAS (58%), and 8 RIBB (42%). (*See Figure 4*)

For all specimens, 25% (n=15) failed due to FAS, 58% (n=34) failed due to FCTI, and 17% (n=10) failed due to RIBB. (p<0.0001) (*See Table 1*)

When evaluating force at failure, Enamic showed a mean failure force of 1995N with a minimum failure force of 708N and maximum failure force 2647N. Emax showed a mean failure force of 2227N with minimum failure force of 564N and maximum force of 2,647N. Zirconia showed a mean failure force of 2,265N. Minimum force was 656N and maximum force was 2646N. There was a marginal difference in mean fracture force (p< 0.089) (*See Figure 2*)

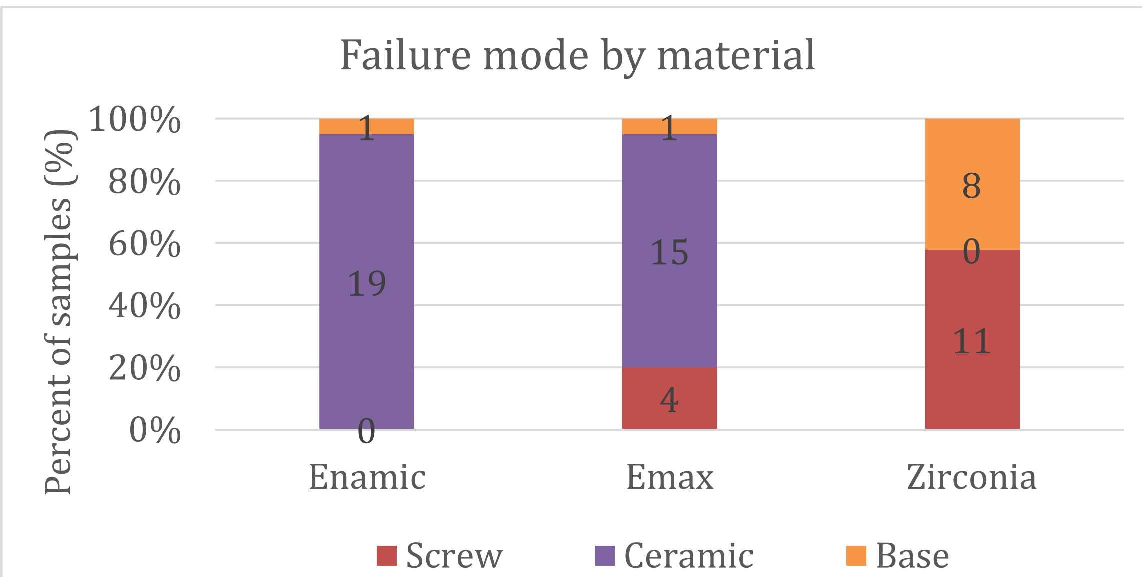

Figure 4. Failure mode by material.

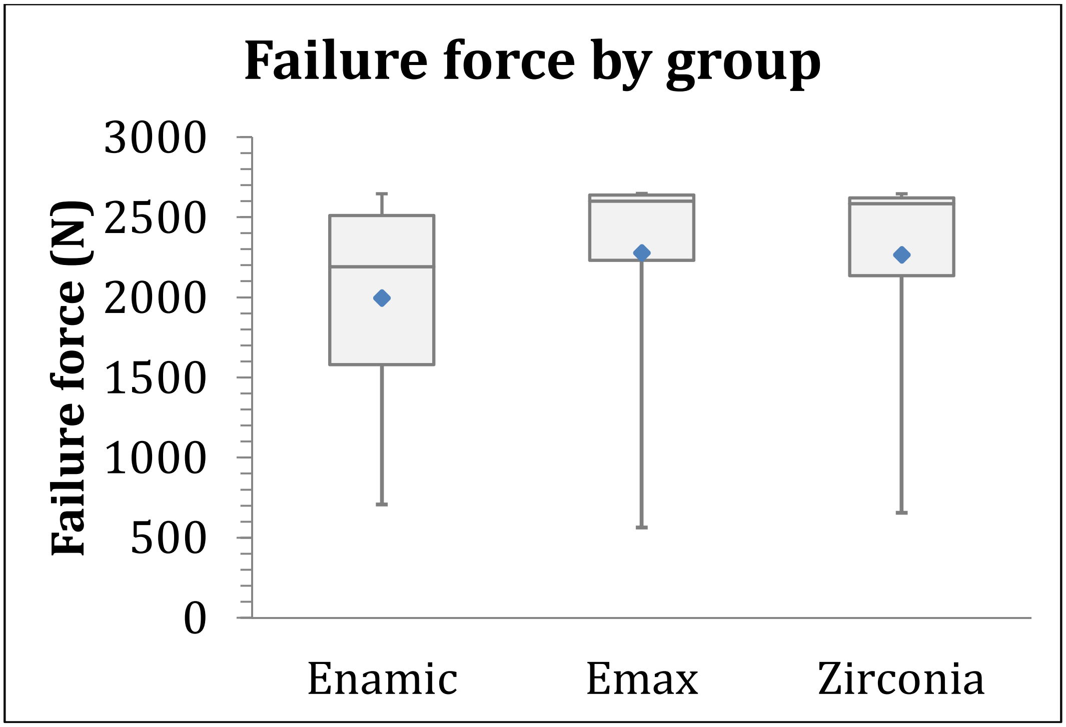

Figure 5. Failure force by group.

	Failure mode						
	Screw		Ceramic		Base		
	n	%	n	%	n	%	p-value
Material							<0.001
Enamic	0	0	19	95	1	5	
Emax	4	20	15	75	1	5	
Zirconia	11	58	0	0	8	42	
All	15	25	34	58	10	17	

Table 1. Percentage of failures by mode of failure

Failure force							
	n	mean	std	median	min	max	p-value
All	59	2178	588	2464	564	2647	
Material							0.089
Enamic	20	1995	615	2192	708	2647	
Emax	20	2277	596	2601	564	2647	
Zirconia	19	2265	533	2585	656	2646	
Failure mode							0.629
FAS	15	2235	628	2607	564	2646	
FCTI	34	2170	575	2472	708	2647	
RIBB	10	2117	626	2240	656	2636	

Table 2. This table depicts the mean, median, minimum, and maximum failure forces for each material. It also depicts the mean, median, minimum, and maximum failure forces for each failure mode.

Discussion

There were zero Tibase failures in this experiment. The addition of the Tibase to the restorative system did not affect the survival of these restorations. Nor was the Tibase the point of failure. On average, these restorations survived forces well outside the range a human can produce.

There are questions in the literature as to whether adding a titanium insert could introduce bending moments in the ceramic intaglio leading to failure[12]. We did not find this to be an area of failure in this experiment. Another area of concern with the Tibase is debonding of the restoration either due to failure in the bond between the Tibase and the ceramic or inadequate retention due to the height of the Tibase. While we did not look at this particular problem, current research appears to refute this[21].

The majority of specimens survived forces exceeding those produced in a clinical situation. Humans have recorded values of upward of 900 Newtons. Most of these samples withstood loads far outside those parameters. Within the limits of this study, it can be assumed that all three of these restorative materials can be used in the posterior dentition with little reservation.

There was only a small statistical difference in mean failure force between Emax and InCoris. Based on our research, a clinician looking for strength in a restorative material could feel safe prescribing either of these materials in the posterior dentition. Enamic failed at much lower forces than Emax and InCoris, but still withstood forces much higher than those found in the human dentition. It is still a viable treatment option in the posterior dentition. In fact, its's lower fracture strength may be beneficial. There is a school of thought that stronger or harder may not be a better quality for an implant restoration. Kurbad notes that Enamic's lower modulus of elasticity might allow it to act as a "shock absorber"[12]. Because implants lack proprioception, a softer restoration could absorb some of the forces imparted on the implant. Future studies could investigate this matter further.

None of the failures in this study resulted in damage to the implant. The loss of a surgically placed implant could be costly to the patient in terms of discomfort, recovery, and finances. If the ceramic restoration fails with the Tibase intact, then the Tibase and abutment screw can be recovered.
Failure of abutment screw was the second most common failure. This is a more favorable failure because this is where the restoration should fail. Removal of a fractured screw and replacement with a new one is potentially easier on the provider and the patient. It is also more economical to only replace a screw versus an abutment and crown.

Future studies, could investigate the role of cyclic fatigue after thermocycling. This type of testing can better simulate how this type of restoration would fare over a lifetime of service. Combining different ceramic materials to fabricate crowns and mesostructures is another area that warrants further investigation. Fabricating a mesostructure from one type of ceramic and a crown from another adds complexity and may introduce areas of potential failure into the restorative system. Finally, there is a need for clinical studies to definitively support the use of Tibase restorations on a regular basis.

Conclusion

Based on the findings of this research, implant supported restorations fabricated with a Tibase can withstand forces well outside those created in the human masticatory system. Implant supported monolithic ceramic crowns fabricated from Tibase connected to either Emax, Enamic, or InCoris are all viable treatment options in the posterior dentition.

References

1. Martinez-Rus,F, Preito M, Salido M, Madrigal CA. Clinical study Assessing the Influence of Anodized Titanium and Zirconium Dioxide Abutments and Preri-implant Soft Tissue Thickness on the Optical Outcomes of Implant-Supported Lithium Disilicate Single Crowns. Int Journ. Oral and Maxillofacial Implants 2017 32.156-163
2. Sailer I, Sailer T, Stawarczyk B, Jung, R., Hammerle C, In Vitro Study of the Influence of the Type of Connection on the Fracture Load of Zirconia Abutments with Internal and External Implant-Abutment Connections. Int. Journ. Oral and Maxillofacial Implants 2009; Vol 24.850-858
3. Guilerhme N, Wadhwani C, Zheng C, and Chung K. Effect of surface treatments on titanium alloy bonding to lithium disilicate glass-ceramics. J. Prosthet Dent 2016 116 (5).797-802
4. Mobilio N, Catapano S. The use of monolithic lithium disilicate for posterior screw-retained implant crowns. J. Prosthet Dent 2017 (In press)
5. Shenava A, Failure Mode of Implant Abutment Connections-An Overview, IOSR-JDMS Dec 2013 11.32-35
6. Kurbad A. Final restoration of implants with a hybrid ceramic superstructure. Int. J. Computerized Dent 2016 19(3).257-279
7. Rauscher O. Impressionless Implant-supported Restoration with CEREC 4.2. Int. J. Computerized Dent 2014 17.159-168
8. Lin W, Harris B, Zandinejad A, Martin W, and Morton D. Use of Prefabricated Titanium Abutments and customized anatomic lithium disilicate structures for cement-retained implant restoration in the esthetic zone. J. Prosthet. Dent March 2014 111.181-185
9. Kammermeier A, Rosentritt M, Behr M, Schneider-Feyrer S, Preis V. In vitro performance of one-and two –piece zirconia implant systems for anterior application. J. Dent 2016 53. 94-101
10. Kapos, T, Evans, C.CAD/CAM Technology for Implant Abutments, Crowns, and Superstructures, Int. J. Oral and Maxillofac. Implants 2014 29.117-136
11. Preis V, Kammermeier A, Handel G, Rosentritt M. In vitro performance of two-piece zirconia implant systems for anterior application. Dental Materials 2016 32. 765-774
12. Elsayed A, Wille, S, Al-Akhali M, and Kern M. Comparison of Fracture Strength and failure mode of different ceramic implant abutments. J. Prosthet. Dent. April 2017 117 (4).499-505
13. Mehl C, Gassling V, Schultz-Langerhans S, Acil Y, Bahr T, Wiltfang J, Kern M. Influence of Four Different Abutment Materials and the Adhesive Joint of Two-Piece Abutments on Cervical Implant Bone and Soft Tissue. Int, J. Oral and Maxillofac. Implant 2016 31.1264-1272
14. Gehrke P, Johannson D, Fischer C,Stawarczyk B, Florian Beuer F. In Vitro

Fatigue and Fracture Resistance of One- and Two-Piece CAD/CAM Zirconia Implant Abutments. Int. J. Oral and Maxillofac. Implant 2015 30.546-554

15. Rosentritt M, Rembs A, Behr M, Hahnel S, Preis V. In Vitro Performance of implant-supported monolithic zirconia crowns: Influence of patient-specific tooth-coloured abutments with titanium adhesive bases. J. Dent 2015 43.839-845
16. Preis V, Hahnel S, Behr M, Bein L, Rosentritt M. In-vitro fatigue and fracture testing of CAD/CAM-materials in implant-supported molar crowns. Dental Materials 2017 33.427-433
17. Guilherme N. et al. Assessment of reliability of CAD-CAM tooth-colored implant custom abutments J Prosthet Dent 2016 116 (2).206-213
18. International Organization for Standardization. ISO 14801:2003. Dentistry fatigue test for endosseous dental implants. Geneva: International Organization for Standardization 2003.
19. Roberts E, Bailey C, Ashcrat-Olscheid D, Vandewalle K. Fracture Resistance of Titanium-Based Lithium Disilicate and Zirconia Implant Restorations. J. Prosth 2018 27.644-650
20. Arce C, Lawon N, Liu P, Lin P, Givan D. Retentive Force of Zirconia Implant Crowns on Titanium Bases Following Different Surface Treatments. Int. J. Oral and Maxillofacial Implants 2018 33.530-535
21. Staubli N, Walter C, Schmidt C, Wiger R, Zitzman NU. Excess cement and Risk of Peri-Implant Disease-a Systematic Review. Clin. Oral Implant Res 2017 28.1278-1290