The influence of incisal veneering porcelain thickness of two metal ceramic crown systems on failure resistance after cyclic loading

Abstract

Statement of problem. In some clinical situations, the length of either a prepared tooth or an implant abutment is shorter than ideal, and the occlusal clearance to be restored by a porcelain crown is large. Incisal thickness of the coping and the veneering porcelain should be considered to prevent mechanical failure of the crown.

Purpose. The purpose of this study was to investigate the influence of incisal veneering porcelain thickness of metal ceramic systems on failure resistance after cyclic loading.

Material and methods. With a standardized technique, 60 metal ceramic anterior crowns with 2 different incisal thicknesses of porcelain veneer (2.0 and 4.0 mm) and 2 different metal alloys (Pisces Plus (B), base metal, and Leo (N), high noble metal) were fabricated to fit a custom abutment and divided into 4 groups (B20, B40, N20, N40) (n=15). The crowns were then cemented using resin cement (PANAVIA 21) and thermal cycled and mechanically cycle loaded (49-N load) for 2,000,000 cycles. The specimens were evaluated for cracks and/or bulk fracture with an optical stereomicroscope (x10) and assigned a score of success, survival, or failure. The specimens without bulk fracture after cyclic loading were loaded along the long axis of the tooth, on the incisal edge, in a universal testing machine at a crosshead speed of 1.5 mm/min until fracture. The fracture strength value (N) was recorded. The exact logistic regression and Fisher's exact test were used to study the effect of different alloys and porcelain incisal thicknesses on the success and survival rates after cycle loading. The forces at failure (fracture) of different groups were compared using the rank transform-based nonparametric 2-way ANOVA (〈=.05).

Results. According to exact logistic regression, crowns of the high noble alloy group showed significantly higher success rates (P=.002) than those of the base metal group after cyclic loading. The success rate of the crowns with 2 mm of incisal veneering porcelain was significantly higher (P<.001) than that of the crowns with 4 mm of incisal veneering porcelain. For crowns with a 4-mm incisal thickness, N40 showed a significantly higher success rate than B40 (P=.04, Fisher's exact test). As for survival rate, the exact logistic regression indicated that neither metal type (P=.11) nor thickness (P=.60) had a significant effect. The 2-way ANOVA showed a significant effect of thickness (P=.001) and no significant effect of metal type (P=.08) on the failure load.

Conclusions. The high noble metal ceramic crowns demonstrated a significantly higher success rate after cyclic loading than the base metal ceramic crowns. Crowns with a porcelain incisal thickness of 2 mm showed, for both metal ceramic systems, a greater success rate than those with a 4-mm incisal thickness.

INTRODUCTION

Longevity of metal ceramic (MC) complete coverage crowns, both in vivo and in vitro, has been reported.[1-3] Veneering porcelain fracture remains a primary complication occurring in 5% to 10% of single-unit prostheses[4] and represents the second most common cause of MC prosthesis replacement.[3] Kelly,[5] in a review article, stated that structural problems of MC prostheses can be as low as 3%to4%at10years of service, while Libby et al[2] showed a prevalence of 8% of porcelain failures with 5-unit fixed dental prostheses (FDP) over 14.4 years of service. According to Christensen,[1] MC restorations have an average of 10 years of esthetic longevity and about 20 years of functional longevity. However, the failure of MC crowns may be encountered after only a few years (mean length of 6.5 years of service) because of porcelain fracture or inadequate esthetics.[6]

After long-term service, fatigue is likely the most common cause of fracture, but it is generally assumed that an improperly designed framework might also result in a higher incidence of veneering porcelain fractures.[7,8] It has therefore been suggested that porcelain should be kept to a minimum thickness compatible with esthetics and that relatively thin porcelain, of uniform thickness and supported by a rigid substructure, is “strongest.”[9,10] It has been recommended that a properly designed MC crown should not have in excess of 1.5 to 2 mm of veneering porcelain, to reduce the likelihood of fracture.[11]

Unfortunately, only a limited number of reports in the literature examine the importance of framework design on the fracture strength of porcelain.[12] Clinical evidence has also indicated that ceramic restoration fractures are rarely related to an episode of single load application, for example, trauma or clenching, but rather result from cyclic loading and fatigue failure. In vitro simulated impact[13] and load-to-failure tests[14] are less time consuming and costly than in vivo studies. Even though in vitro studies are limited because they do not completely mimic the clinical environment and distribution of force,[13,15-17] such tests do provide criteria for further clinical evaluation.

Cyclic mechanical loading and thermal cycling represent the ideal in vitro design for a study reproducing physiological function.[18-20] White et al[21] reported that cyclic mechanical loading of porcelain results in the propagation of small cracks and a higher propensity for the porcelain to fracture at a lower magnitude of stress. Thermal variations (0 to 67°C) can also affect crack propagation and the longevity of restorations.[22]

The restoration of anterior teeth with crowns and FDPs that have a framework for porcelain support is further complicated by the requirement, generally placed on the veneering porcelain, to simulate a lifelike tooth appearance. This is particularly challenging for anterior restorations where a high level of translucency, generally in the incisal and middle third of the tooth, is required. While the presence of the framework in these areas is thought to be necessary to provide mechanical resistance to fracture, it may be detrimental for esthetics and, specifically, for creating translucency. In these situations, to satisfy the esthetic demands, a clinician may seek a framework that does not properly extend in the incisal third to support the veneering porcelain. A previous study[23] has shown that high noble metal ceramic crowns made with an incisal porcelain thickness of 2 mm showed higher load-to-failure values than crowns with 4 mm of porcelain thickness, but there was no difference in the occurrence of cracks after cyclic and thermal loading. Alumina framework crowns (Procera All- Ceram; Nobel Biocare AB, Göteborg, Sweden) showed no difference in the occurrence of cracks after thermal and cyclic loading and demonstrated no difference in the load-to-failure values between crowns with 2 or 4 mm of incisal porcelain thickness.

The choice of the alloy for the metal framework also seems to be an important factor for the longevity of MC crowns. The use of base metal alloys has the advantage of a lower cost, but it has also been associated with variable (sometimes lower[24-26] and sometimes higher[27]) outcomes in the porcelain bond strength compared to high noble alloys. The bond strength between base metal and porcelain varies depending on the specific metal and porcelain combination, and is affected by the treatment technique.[24-28] It is, therefore, unknown whether crowns made with base metal alloys with different incisal porcelain thicknesses behave differently than similarly designed crowns made with high noble alloys under thermal and mechanical cyclic loading and ultimate load-to-failure tests. Therefore, the purpose of this study was to assess the effect of incisal porcelain thickness of MC crowns made with 2 different alloys when subjected to thermal cycling, cyclic mechanical loading, and ultimate load-to-failure testing.

It was hypothesized that there would be no significant difference in the load-to-failure resistance between 2 different thicknesses of veneering porcelain. It was further hypothesized that there would be no significant difference in the load-to-failure resistance between the high noble and base metal alloy crown systems. Moreover, this study sought to investigate the effect of a thermal cycling and cyclic loading protocol on the occurrence of cracks in the veneering porcelain of the tested systems. Therefore, the null hypotheses were that there would be no difference in the crack occurrence between the high noble and base metal alloy crown systems and no difference between the 2 different thicknesses of veneering porcelain in each system.

MATERIAL AND METHODS

For this study, 10 uniform-sized replicas of a regular neck implant/ solid abutment assembly (RN Solid abutment analog; Straumann USA, Andover, Mass) were machined, as a 1-piece structure, using grade-2 titanium bars (Ti, 99.2%; O, 0.25%; N, 0.03%; H, 0.015%; Fe, 0.3%; C, 0.1%) with an apicocoronal dimension of 5.5 mm. A 1.5-mm modified shoulder was placed at the finish line with a 130-degree inclination to the long axis of the die. Two different designs of metal framework, based on the thickness of the incisal veneering porcelain (2 and 4 mm), were used for the present study, as shown in Figures 1 and 2.

In contrast with the previous study,[23] no preformed plastic pattern was used to fabricate the framework. A full contour waxing (ProArt; Ivoclar Vivadent AG, Schaan, Liechtenstein) was performed on one of the previously described replicas based on a central incisor average apicocoronal dimension of 9.9 mm.[29] A vinyl polysiloxane (VPS) (Virtual; Ivoclar Vivadent AG) impression was made to record this waxing (INDEX #1) and sectioned along the long axis to recover the waxed die. The waxing was cut back to provide for a uniform 1.5 mm and 2.0 mm of porcelain thickness on the axial and incisal surfaces, respectively. Another impression was made with the same VPS (INDEX #2) and again sectioned along the long axis. The INDEX #2 was used to fabricate 30 wax patterns for groups N20 and B20, according to the following protocol. The titanium replica was coated with 2 layers of die spacer (Die Spacer; Degussa-Ney, Bloomfield, Conn) and lubricated (Die Lube; Degussa-Ney). Molten wax was injected into the space between INDEX #2 and the die. The wax was cooled to room temperature, the INDEX #2 halves were separated, and the wax pattern was inspected for integrity. A second waxing was made by injecting molten wax into INDEX #1. This waxing was cut back to provide for a uniform 2.5 mm and 4.0 mm of porcelain thickness on the axial and incisal surfaces, respectively. A VPS impression of this pattern was made (INDEX #3) and sectioned along the long axis. INDEX #3 was used to fabricate 30 wax patterns for subgroups N40 and B40, as previously described for subgroups N20 and B20. Patterns were invested (an equal number of specimens from each subgroup were placed in each ring) with phosphate-bonded investment (Cera-Fina; Whip Mix Corp, Louisville, Ky).

Thirty MC crowns were cast with each of the following 2 alloys: Leo (Ivoclar Vivadent AG) (Au, 45%; Pd, 41%; Ag, 6%; In, 3.4%; Sn, 2.2%; Ga, 1.8%; Ru <1%; Li <1%, Rc <1%) and Pisces Plus (Ivoclar Vivadent AG) (Ni, 61.5%; Cr, 22.0%; W, 11.2%; Si, 2.6%; Al, 2.3%; other <1.0%), and divided into 2 equal subgroups for each of the alloys (n=15).

The feldspathic veneering porcelain (IPS Classic; Ivoclar Vivadent AG) was then applied with the aid of INDEX #1 and according to a previously developed technique.[23] Briefly, 2 layers of opaquer (IPS Classic Opaquer; Ivoclar Vivadent AG) were applied and fired in a porcelain furnace (Programat P100; Ivoclar Vivadent AG), followed by 2 layers of dentin and enamel porcelain, according to the manufacturer's instructions. The thickness of the veneering porcelain was standardized with the INDEX #1 and condensed using an electric vibrator (Model 10650; Whip Mix Corp) for 5 seconds. Excess water was absorbed from an opening in the index using tissue paper kept in contact with the veneering porcelain during the condensation procedure. All specimens were glazed with a definitive firing cycle and glazing liquid, according to the manufacturer's instructions (IPS Classic; Ivoclar Vivadent AG).

The first subgroup of specimens had a framework cast with the high noble alloy Leo (Ivoclar Vivadent AG) and were designed to have 2 mm of incisal porcelain (N20), while the crowns of the second subgroup were designed to have 4 mm of incisal porcelain (N40). The third (B20) and fourth (B40) subgroups had incisal thicknesses of veneering porcelain equal to groups N20 and N40, but were cast with the base metal alloy Pisces Plus (Ivoclar Vivadent AG).

The sample size for each subgroup (n=15) was calculated based on a 1-way ANOVA. From a previous pilot study, the failure load after cyclic loading of the N20 subgroup was 2211 N (SD, 1671 N) while for subgroup N40, it was 2124 N (SD, 1200 N). Using a 1-way ANOVA, the mean failure loads of the 4 groups were compared. The total sample of 60 specimens (n=15) achieves 82% power (〈=.05) to detect differences among the means with an effect size of 0.45.

Ten crowns at a time were then cemented onto the dies with resin cement (PANAVIA 21; Kuraray Medical, Inc, New York, NY) according to the manufacturer's instructions. The abutment was thoroughly cleaned with a 70% isopropyl alcohol-impregnated pad (Alcohol Prep Pads; Triad Pharmaceuticals, Hartland, Wis) and air dried. Cement was mixed, applied on the intaglio surface of the crown, and the crown was fully seated with finger pressure. The crown/die assembly was placed under a 5-Kg load; after 60 seconds, excess cement was removed, and a glycerol gel (Oxyguard; Kuraray Medical, Inc) was placed around the margin, as recommended by the manufacturer. After 10 minutes, the crown/die assembly was thoroughly rinsed under an air-water spray for 30 seconds, and the glycerol gel and any residual excess cement were carefully removed with a curette (4R/4L Columbia University Curette; Hu-Friedy, Chicago, Ill).

After cementation, the crown/die assemblies were stored in saline solution at 37°C for 1 week. Thermal cycling (5°C to 55°C) for 1000 cycles (5-second dwell time and 30-second transport time) and cyclic mechanical testing were accomplished,[23] but differently from the previous study; in the present study, cyclic loading was extended to 2,000,000 cycles or until failure.

After thermal and mechanical cycling, the crowns were scored according to the following criteria.[23] The specimen was considered a "success" if, during a visual examination performed by the naked eye, the surface appeared unaltered and there was neither bulk fracture nor cracks. The specimen was considered as "survival" if, during a visual examination performed by the naked eye, a crack was present and confined to the lingual aspect of the crown. The specimen was considered a "failure" if, during a visual examination by the naked eye, a crack occurred on the facial aspect of the crown or the specimen presented a bulk fracture. If these complications were to occur in a clinical situation, the crown would likely be replaced. All visual examinations where performed by the same operator under natural light conditions.

The specimens that did not show bulk fracture were further tested. Specimens were loaded on the incisal edge along the long axis of the tooth with an 8-mm-diameter flat stainless steel piston until fracture in a universal testing machine (Alliance RT/50; MTS Systems Corp, Eden Prairie, Minn) at a crosshead speed of 1.5 mm/min. To accomplish a homogeneous stress distribution, a 1-mm-thick piece of tinfoil was placed between the crown and the stainless steel loading insert.[30,31] After loading in the universal testing machine, the location and mode of failure for each test specimen were examined using incident light.

After testing was completed, the crown and cement residues were removed from the abutments with the following procedure.[32] Each crown/ die assembly was heated to a temperature of 600°C for 1.5 hours and then allowed to bench cool at room temperature. The crown/die assembly was placed in an ultrasonic cleaner (Quantrex; L&R Manufacturing Co, Kearny, NJ) for 30 minutes with a cement-removal solution (Removalon-I; Premier Dental Products, Inc, Norristown, Pa).[33] After this procedure, it was possible to remove the crown from the die with gentle finger pressure. Dies were cleaned in distilled water in an ultrasonic cleaner for 30 minutes and then wiped with cotton gauze. Before the first cementation, all dies were heated to a temperature of 600°C for 1.5 hours, then allowed to bench cool at room temperature and cleaned in the manner previously described, for uniformity of method.[34] Then, 10 other crowns were cemented on the abutments according to the previously described protocol and subjected to the same testing.

Exact logistic regression[35] was used to study the joint effects of metal type and incisal thickness on the success and survival rates. Fisher's exact test was used to study the marginal effect of different alloys and porcelain incisal thicknesses on the success and survival rates. The joint effects of metal type and incisal thickness on the forces at failure (fracture) of different groups were studied by the rank transform-based nonparametric 2-way ANOVA.[36,37] The overall load of each crown was calculated based on the linear combination of failure load ranks developed by Feng et al.[38] All significance levels were set at 〈=.05 (2 sided). The Simes-Hochberg correction procedure was used to control the type I error in the event of multiple comparison.[39,40] Statistical analyses were performed with statistical software (SAS 9.1; SAS Institute, Inc, Cary, NC).

RESULTS

Success, survival, and failure of the specimens under cyclic loading are summarized in Tables I through III. Fifteen specimens from the N20 group and 5 from the N40 group were considered a success, whereas only 11 from the B20 group and none from the B40 group were considered a success. No specimens from the N20 group and 10 specimens from the N40 group were rated as surviving, whereas 3 from the B20 group and 11 from the B40 group were rated as surviving. Neither specimens from the N20 nor the N40 group were considered failures, whereas 1 from the B20 group and 4 from the B40 group were considered failures.

For the study of the specimens in the "success" category, the exact logistic regression with metal type and incisal thickness as the covariate and the success indicator as the dependent variable showed that the crowns of the high noble alloy group demonstrated a significantly higher success rate (P=.002) than those of the base metal group after cyclic loading. The success rate of the crowns with 2 mm of incisal veneering porcelain was significantly higher (P<.001) than that of the crowns with 4 mm of incisal veneering porcelain (Table II).

For further study of the specimens classified as "success," the marginal effect of metal type was evaluated by combining crowns with different thicknesses (N20 + N40 vs. B20 + B40). The Fisher's exact test showed a significant effect of metal type (P=.04). When the marginal effect of veneering porcelain thickness was studied by combining crowns cast with different alloys (N20 + B20 vs. N40 + B40), the Fisher's exact test also showed a significant effect of veneering porcelain thickness (P<.001) (Table II).

Examining these same specimens (those in the "success" category), the effect of metal type with the same thickness and the effect of thickness with the same metal type were evaluated using the Fisher's exact test. The N40 group showed a significantly higher success rate compared to the B40 group (P=.04). However, the effect of metal type was not significant for crowns with a 2-mm incisal thickness (N20 vs. B20, P=.10). According to the Fisher's exact test, the N20 group showed a significantly higher success rate compared to the N40 group (P<.001), and the B20 showed a significantly higher success rate compared to the B40 group (P<.001).

For the study of the specimens categorized as "survival," the exact logistic regression with metal type and incisal thickness as the covariates and the success indicator as the dependent variable demonstrated that neither metal type (P=.11) nor thickness (P=.60) had a significant effect on survival rate. None of the other correlations studied showed a statistically significant difference (Table III).

The results of the load-to-failure test were the following: the mean failure loads were 4881.9 ±1829.7 N, 4067 ±1296.5 N, 4682.8 ±1910.2 N, and 2436.9 ±1926.5 N for groups N20, N40, B20, and B40, respectively. The rank transform-based nonparametric 2-way ANOVA showed a significant effect of thickness (P=.001) and no significant effect of metal type (P=.08) on the failure load.

DISCUSSION

For the occurrence of cracks after thermal and mechanical cyclic loading, 2 null hypotheses were investigated: (1) that there would be no significant differences in the occurrence of cracks between 2 different thicknesses of veneering porcelain in the individual crown systems, and (2) that there would be no significant difference in the occurrence of cracks between 2 different crown systems with the same porcelain thicknesses. The first null hypothesis was rejected for both alloys. The significant differ-ence in the occurrence of cracks after cyclic loading between the base metal alloy crowns with different porcelain incisal thicknesses supported rejection of the second hypothesis, while the same hypothesis failed to be rejected for the high noble alloy crowns.

It is important to recognize that any in vitro study design that aims to reproduce a complex biomechanical environment such as that of mastication has certain limitations, and results must be interpreted with caution. The unidirectional cyclic loading design adopted in this study reproduced only a single (vertical) vector of force of the masticatory cycle[17] and, therefore, does not entirely simulate the complexity of the oral biomechanical environment. In addition, although the loading of ceramic restorations by a round indenter has been used in other studies to simulate cyclic occlusal contact,[23,30,31] it has also been argued that this type of loading might cause a level of stress in the ceramic material in excess of what would be found in the oral cavity.[5]

However, it is interesting to note some fundamental differences in the behavior of the tested high noble alloy MC specimens when compared to base metal alloy MC specimens. Twenty specimens from the high noble MC groups resisted the cyclic load-ing without any crack development ("success"), as opposed to the base MC groups, from which only 11 specimens were given a score of "success." For the high noble MC groups, cracks occurred in 10 specimens ("survival"), whereas for the base MC groups, cracks occurred in 14 specimens. No specimens from the high noble alloy MC group showed cracks involving the facial aspect of the crown, nor bulk fracture or "failure," whereas for the base metal ceramic groups, facial cracks and bulk fractures occurred in 5 specimens.

The “failure” scores mostly resulted from the occurrence of cracks that compromised the esthetics, essentially extending to the buccal aspect of the crowns. This classification was arbitrarily designated by the authors based on clinical criteria.[23] Indeed, a crown would be replaced if the loading conditions resulted in a bulk fracture, and it can be argued that a visible fracture affecting the facial surface would also not be deemed acceptable by most patients, therefore requiring replacement. Most of the cracks in the “failure” category were found in the base metal alloy groups (n=4 in B40; n=1 in B20) compared to the noble alloy group (n=0 in N40; n=0 in N20). Such cracks typically involved the facial surface and the area of the cingulum. Therefore, it could be speculated that the loading of porcelain specimens by a spherical indenter results in an excessive level of stress concentration at the loading site,[14] initiating the crack in this area with a subsequent extension on the facial surface (Fig. 3). The thickness of the incisal porcelain was inversely related to the failure load, while the different alloy type did not significantly affect the failure load.

From a clinical perspective, the fact that a 4-mm incisal extension of the veneering feldspathic porcelain is more prone to develop cracks under cyclic and single load-to-failure testing indicates that this crown design is questionable, especially when fabricated with base metal alloys. When the esthetic requirements, for example, high translucency of the incisal third of the crown, dictate the presence of feldspathic porcelain and the fabrication of a shorter framework, other treatment choices, such as ceramic crowns, should be considered.[23]

It is also of interest to note several differences from the previous study.[23] In the current study, the presence of cracks after thermal and cyclic loading correlated, for the base alloy crowns, with the ultimate load-to-failure values. Indeed, B20 showed significantly higher success rates and load-to-failure values than B40. Similarly, N40 showed significantly higher success rates and load-to-failure values than B40. The same correlation was not evident in the high noble alloy groups; although different success rates were seen for the 2 incisal porcelain thicknesses, no significant differences were found in the load-to-failure values.

Although the results of this study do not completely agree with those of Shirakura et al,[23] several differences in the experimental designs are worth noting. The implant-abutment assembly was machined in a single piece, rather than assembled with commercially available implant components. This was done in an attempt to avoid abutment fracture, as was seen in one instance in the Shirakura et al[22] study. Since the abutments were custom made, it was also determined that preformed plastic components (048.245; Institut Straumann AG) would not be used to aid in the pattern fabrication, but, rather, after the application of 2 layers of die spacer, the pattern would be waxed directly on the die. Moreover, the cyclic loading regimen was extended from 1,200,000 to 2,000,000 cycles. It is possible that these experimental differences are somehow responsible for the differences seen between the present study and that of Shirakura et al[23] with respect to the behavior of the high noble alloy MC crowns. The present study investigated only limited combinations of materials for the framework and veneering porcelain, and the results cannot be generalized to other systems. Moreover, the results may apply only to situa-tions involving MC crowns cemented on implant abutments with resin cement, and may not pertain to crowns cemented to dentin. In addition, the same results may not be relevant for MC crowns cemented on dentin or with different types of cement. Further studies are necessary to evaluate the behavior of other metal ceramic or ceramic materials undergoing a similar test. If these results are confirmed with other metal and ceramic frameworks, then further research should be conducted, with appropriately designed in vitro studies, to investigate the reasons for this difference in behavior. The behavior of different metal ceramic systems was not evaluated in this study and should be investigated in the future.

CONCLUSIONS

Within the limitation of this study, the following conclusions were drawn: 1. Crowns with 2 mm of incisal veneering porcelain showed significantly higher success rates compared to crowns with 4 mm of incisal veneering

porcelain. 2. High noble alloy crowns showed

significantly higher success rates than base metal alloy crowns.

3. High noble alloy MC crowns with 4 mm of veneering porcelain showed a significantly higher success rate than base metal alloy MC crowns with 4 mm of veneering porcelain.

4. High noble alloy MC crowns with 2 mm of veneering porcelain did not show significantly higher success rates than base metal alloy MC crowns with 2 mm of veneering porcelain.

5. The thickness of the incisal veneering porcelain significantly affected the failure load.

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Figure 1. Schematic drawing of framework design adopted for group with 2 mm of veneering porcelain.

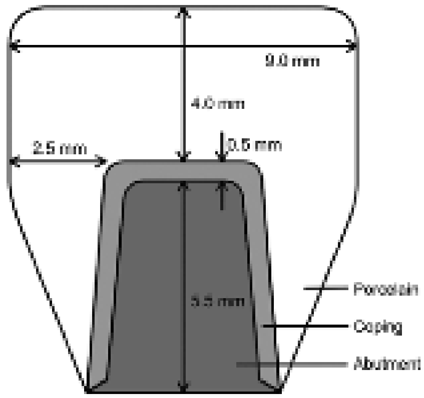

Figure 2. Schematic drawing of framework design adopted for group with 4 mm of veneering porcelain.

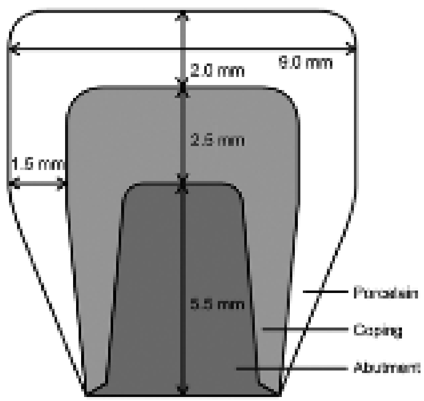

Figure 3.Cracks in metal ceramic crowns occurred at cyclic loading site.

Table 1. Frequency of occurrence for success, survival, and failure (n=15)

Group	Metal Type and Porcelain Thickness	Success Frequency	Survival Frequency	Failure Frequency
N20	noble metal 2 mm of porcelain	15	0	0
N40	noble metal 4 mm of porcelain	5	10	0
B20	base metal 2 mm of porcelain	11	3	1
B40	base metal 4 mm of porcelain	0	11	4

Table II. Comparisons of success data using exact logistic regression

Comparison		*P*	
		Metal	Thickness
Overall		.002	<.001
Combined thickness	(N20 + N40 vs. B20 + B40)	.04	
Combined metal	(N20 + B20 vs. N40 + B40)		<.001
Within thickness	20 (N20 vs. B20) 40 (N40 vs. B40)	.10 .04	
Within metal	L (N20 vs. N40) P (B20 vs. B40)		<.001 <.001

L: Leo, high noble metal; P: Pisces Plus, base metal

Table III. Comparisons of survival data using exact logistic regression

Comparison		P	
		Metal	Thickness
Overall		.11	.60
Combined thickness	(N20 + N40 vs. B20 + B40)	.11	
Combined metal	(N20 + B20 vs. N40 + B40)		.61
Within thickness	20 (N20 vs. B20)	1.00	
	40 (N40 vs. B40)	.24	
Within metal	L (N20 vs. N40)		.10
	P (B20 vs. B40)		.60

L: Leo, high noble metal; P: Pisces Plus, base metal