The influence of veneering porcelain thickness of all-ceramic and metal ceramic crowns on failure resistance after cyclic loading

Akihiko Shirakura, RDT, DDS, a Heeje Lee, DDS, b Alessandro Geminiani, DDS, c Carlo Ercoli, DDS, d and Changyong Feng, PhD e

Statement of problem. In some clinical situations, the length of either a prepared tooth or an implant abutment is shorter than ideal, and the thickness of a porcelain crown must be increased. Thickness of the coping and the veneer- ing porcelain should be considered to prevent mechanical failure of the crown.

Purpose. The purpose of this study was to investigate the influence of veneering porcelain thickness for all-ceramic and metal ceramic crowns on failure resistance after cyclic loading.

Material and methods. All-ceramic and metal ceramic crowns (n=20) were fabricated on an implant abutment (RN Solid Abutment) for the study. Two different framework designs with 2 different incisal thicknesses of veneering porcelain should be considered to prevent mechanical failure of the crown.

Results. According to the Fisher's exact test, the all-ceramic group showed significantly higher success (P=0.03) and survival rates (P=0.001) than the metal ceramic group. For the failure load, the 2-way ANOVA showed significant effects for material (P<0.001) and thickness (P=0.004), but not a significant interaction effect (P=0.186). For the metal ceramic groups, crowns with a 2-mm porcelain thickness showed a significantly higher failure load than crowns with a 4-mm porcelain thickness (P=0.004). However, all-ceramic groups did not show a significant difference between 2 different thicknesses of veneering porcelain (P=0.198).

Conclusions. The influence of veneering porcelain thickness of all-ceramic and metal ceramic crowns on failure resistance after cyclic loading is a significant topic in dental research.
There are various restorative materials commercially available for the replacement of single and multiple teeth. While metal ceramic systems have a longer track record,\(^2\) various types of all-ceramic crown systems are also available.\(^1\) Several methods and products, including conventional powder-sluurry techniques, and castable, machinable, pressable, and infiltrated ceramics, are used to fabricate all-ceramic crowns.\(^1\) These systems can be broadly divided into the following categories with respect to the presence of a ceramic core: (1) core systems which use a ceramic core, characterized by high fracture toughness,\(^6,7\) veneered with feldspathic porcelain to simulate the esthetics of a natural tooth, and (2) coreless systems which are fabricated completely of a specific ceramic material. These systems achieve a toothlike appearance with the selection of an appropriately colored ceramic and the application of surface-coloring techniques. The ceramic core is produced by either slip casting or machine milling, commonly combined with a sintering process. The ceramic core is produced by either slip casting or machine milling, commonly combined with a sintering process.

### Conclusions

The all-ceramic crowns showed significantly higher success and survival rates after cyclic loading, but lower failure loads than metal ceramic crowns. The thickness of the veneering porcelain affected the failure load of the metal ceramic crowns, but not that of the all-ceramic crowns. (J Prosthett Dent 2009;101:119-127)

### Clinical Implications

Procura AllCeram crowns may allow up to approximately 4 mm of feldspathic porcelain on the incisal area without increasing the failure rate or decreasing the failure load.

### MATERIAL AND METHODS

Two different coping designs based on the thickness of the incisal veneering porcelain were used (Figs. 1 and 2, Table I). Each design was used for the 2 different systems (metal ceramic and all-ceramic), resulting in 4 experimental groups (n=10). The sample size was determined from a pilot study based on 2-way ANOVA (metal versus ceramic framework; long framework versus short framework), and a sample size of 6 in each combination (24 total) was deemed sufficient to have 90% power to detect differences for the comparison of interest. For the long ceramic coping group (CL), an implant abutment (RN Solid Abutment; Institut Straumann AG, Waldenburg, Switzerland), 5.5 mm in height, was connected to an implant analog (RN synOcta analog; Institut Straumann AG) with 35 Ncm torque using a torque control device (ratchet and torque control device, Institut Straumann AG). A plastic coping (048.245, Institut Straumann AG) was placed on the abutment, and the length of the plastic coping was adjusted to accommodate fabrication of a full contour waxing. The full contour waxing possessed the dimensions shown in Figure 1. An index of the full contour waxing was made using polydimethylsiloxane putty impression material (Sil-Tech; Iovivo Vivadent, Amherst, NY) (index A). The index consisted of buccal and lingual halves that could be separated and re-assembled for fabrication of the wax patterns. The waxing was cut back to provide the space for the veneering porcelain to be placed over the wax pattern after the coping was cemented in place.

### Table I. Materials used for coping and veneering porcelain

<table>
<thead>
<tr>
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*Composition (wt%): Au, 45.0; Pd, 41.0; Ag, 6.0; Sn, 2.2; In, 3.4; Ga, 1.8; Ru, <1.0; Re, <1.0; Li, <1.0
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CLINICAL IMPLICATIONS

Procura AllCeram crowns may allow up to approximately 4 mm of feldspathic porcelain on the incisal area without increasing the failure rate or decreasing the failure load.

There are various restorative materials commercially available for the replacement of single and multiple teeth. While metal ceramic systems have a longer track record,1,2 various types of all-ceramic crown systems are also available.3-14 Several methods and products, including conventional powder-sultry techniques, and castable, machinable, pressable, and infiltrated ceramics, are used to fabricate all-ceramic crowns.3 These systems can be broadly divided into the following categories with respect to the presence of a ceramic core: (1) core systems which use a ceramic core characterized by high fracture toughness,6,7 veneered with feldspathic porcelain to simulate the esthetics of a natural tooth, and (2) coreless systems which are fabricated completely of a specific ceramic material. These systems achieve a toothlike appearance with the selection of an appropriately colored ceramic and the application of surface-coloring techniques. The ceramic core is produced by either slip casting or machine milling, commonly combined with a computer-aided design/computer-aided manufacturing (CAD/CAM) method.1

The simplest shape of any core or framework, both for all-ceramic and metal ceramic systems, covers all of the surfaces of the prepared abutment teeth, including the margins, with an even thickness of the material, which is then veneered with feldspathic porcelain to achieve the desired tooth shape. For metal ceramic systems, the longevity of the restoration specifically, the integrity of the veneering porcelain layer, is thought to be dependent on framework design.4,10-12 Two principles have been suggested to increase the long-term prognosis of the veneering porcelain of a metal ceramic system: (1) the porcelain is veneered with the minimum thickness compatible with good esthetics, and (2) the porcelain is supported by the coping so that tensile or shear fractures can be minimized.11 The assumption is that an excessively thick layer of veneering porcelain may be more prone to shear and tensile force-induced fractures under occlusal loading. A survey of crown and fixed partial denture failures indicated that the incidence of porcelain fractures is the second most common cause for metal ceramic prosthesis replacement,13 while other studies showed porcelain fracture to occur only in 2.5% to 4.5% of single metal ceramic crowns14-16 and 2% of partial fixed dentures.17 Kelly17 reported that the structural problems of metal ceramic prostheses can be as low as 3% to 4% at 10 years of service. Libby18 showed a prevalence of 8% of porcelain failures with 5-unit fixed partial dentures (FPDs) over 14.4 years of service.

For the all-ceramic prosthesis which uses a ceramic framework, it has been reported that, similarly to metal ceramic restorations, veneering porcelain fracture remains one of the primary complications affecting longevity.18,19 While a certain number of fractures are expected as a consequence of fatigue after long-term service, it is assumed that an improperly designed core/framework requires the application of an excessively thick layer of veneering porcelain which may result in a higher incidence of failure, not only for metal ceramic systems but also for all-ceramic prostheses.7

The restoration of anterior teeth with crowns and FPDs 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 can be particularly challenging for anterior restorations for which 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 necessary to provide mechanical resistance to fracture, it may be detrimental to esthetics, and specifically, to achieving translucency. In these situations, to satisfy esthetic demands, a clinician may seek a framework that does not properly extend into the incisal third to support the veneering porcelain. What remains unclear is the effect that such a framework design would have on the longevity of metal ceramic and all-ceramic anterior crowns.

Two studies, published in the same group, investigated the mean load at fracture of alumina all-ceramic crowns (Procura AllCeram; Nobel Biocare AB, Goteborg, Sweden) with different thicknesses of veneering porcelain, and found different results with 2 similar experimental designs.15,19 The authors used a brass die simulating a posterior tooth, with the veneering porcelain thicknesses ranging from 0 (alumina coping only) to 1.4 mm, and the specimens were tested with a single load-to-failure application. The authors reported that increasing the thickness of the veneering porcelain increased the compressive load at fracture in one study,20 and reported no relation between the thickness and the compressive load in the second.21 The purpose of the present study was to investigate the influence of incisal veneering porcelain thickness of all-ceramic and metal ceramic crowns on failure resistance after thermal cycling, cyclic mechanical loading, and load-to-failure testing. The null hypothesis was that there would be no significant differences in the failure resistance between 2 different thicknesses of veneering porcelain for the individual crown systems. Also, it was hypothesized that there would be no significant difference in the failure resistance between the tested metal ceramic and all-ceramic crown systems. Moreover, this study sought to investigate the effects of thermal cycling and cyclic loading on the occurrence of cracks in the veneering porcelain of the tested systems. The null hypothesis was that there would be no difference in the crack occurrence between the metal ceramic and all-ceramic systems, and no difference between the 2 different thicknesses of veneering porcelain in each system.

MATERIAL AND METHODS

Two different coping designs based on the thickness of the incisal veneering porcelain were used (Figs 1 and 2; Table I). Each design was used for the 2 different systems (metal ceramic and all-ceramic), resulting in 4 experimental groups (n=10). The sample size was determined from a pilot study based on 2-way ANOVA (metal versus ceramic framework; long framework versus short framework), and a sample size of 6 in each combination (24 total) was deemed sufficient to have 90% power to detect differences for the comparison of interest.

Long coping design.

The long coping design was fabricated on a die simulating a maxillary central incisor tooth, with a 35-N cm torque using a torque control device (ratchet and torque control device, Institut Straumann AG). A plastic coping (048.245, Institut Straumann AG) was placed on the abutment, and the length of the plastic coping was adjusted to accommodate fabrication of a full contour waxing. The full contour waxing possessed the dimensions shown in Figure 1. An index of the full contour waxing was made using polydimethylsiloxane putty impression material (Sil-Tech; Ivoclar Vivadent, Amherst, NY) (index A). The index consisted of buccal and lingual halves that could be separated and reassembled for fabrication of the wax patterns. The waxing was cut back to provide the space for the veneering porcelain.

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1 Long coping design.
2 Short coping design.
porcelain following the coping design in Figure 1. Another index (index B) was made of the cut-back wax pattern using the same material and the same method as for index A. The cut-back wax pattern and the abutment were both scanned (in-and-out scanning) by a touch-probe scanner (Procura Scanner Mod 40; Nobel Biocare AB), and the electronic file was sent to the manufacturer’s processing center (Procura manufacturing facility; Nobel Biocare AB) with the dimensions illustrated in Figure 1.

Veneering porcelain was applied with the aid of index A as follows: 2 layers of shade base porcelain (Cerabien; Noritake Dental Supply Co Ltd, Aichi, Japan) were applied and fired in a porcelain furnace (Prografat P100; Ivoclar Vivadent), followed by 2 layers of dentin and enamel porcelain. All of the specimens were glazed according to the manufacturer’s instructions. For the short ceramic coping group (CS), only the abutment was scanned using the Procura system described above, to obtain 10 alumina copings with an even thickness of 0.4 mm (Fig. 2). The veneering porcelain was applied using index A, as in the CL group.

For the long metal coping group (ML), the abutment was connected to the implant analog and the plastic coping was placed. Index B was used to duplicate a wax pattern of the index A. A shape and dimensions identical to the coping, as for the CL group. Index B was replaced on the implant analog assembly, and the molten wax was poured into the space between index B and the plastic coping. Ten wax patterns were fabricated, invested (Ceram 3; Cerec; Noritake, Nihon) and cast as in the ML group. All of the crowns were cemented onto the corresponding abutments using resin cement (Panavia F; Ivoclar Vivadent). The cementation and cementing procedures were performed at room temperature by a single investigator. After cementation, the crown-abutment-analog assemblies were stored in saline solution at 37°C for 1 week. They were then subjected to 1000 cycles of thermal cycling. Each 70-second-long cycle consisted of 5 seconds of dwell time in 2 baths of 5°C and 55°C, with 2 transport times (30 seconds each) between the 2 baths.

Each specimen was mechanically tested with a custom-designed cyclic loading apparatus (Fig. 3). The apparatus delivered simultaneous unidirectional cyclic loading at an angle of 135 degrees to the long axis of the tooth to simulate the force application to a maxillary incisor, as an average rpm of 250, with a load of 49 N. The load was applied to the lingual aspect of the specimens at 2.5 mm below the incisal edge, using a round stainless steel indenter with a diameter of 6 mm. The frequency was monitored at least once each day during each testing with a contact tachometer (Model 461891, rpm range of 0.5-15,000, accuracy ±0.5%, Extech Instruments Corp, Waltham, Mass). Each specimen was kept continuously wet by applying saline solution with a custom-made delivery system and was loaded for 1.2 x 10^6 cycles, simulating 5 years of clinical service, or until it failed.5,6

The specimens were thoroughly evaluated for the presence of cracks with an optical stereomicroscope at x10 magnification (LM; Meiji Tech America, Santa Clara, Calif). The specimen was considered as “success” if there was neither bulk fracture nor cracks. The specimen was considered “failure” if there was bulk fracture or if the crack occurred on the facial aspect of the crown. If these complications occur in a clinical situation, the crown will likely be replaced. The specimen that was not categorized as “failure” was categorized as “survival.” It included the “success” specimens, and the specimens that had cracks not involving the facial surface. The specimens did not show bulk fracture were further tested. They were loaded on the incisal edge along the long axis of the tooth with an 8-mm-diameter flat stainless steel piston until fracture, using a universal testing machine (MTS Alliance; MTS, Eden Prairie, Minn) at a crosshead speed of 1.5 mm/min. To decrease the possibility that a localized stress concentration would cause fracture of the porcelain, a 1-mm layer of tin was interposed between the crown and the loading apparatus.

Since the sample size was relatively small, and for some cells, the counts were less than 5, the Pearson’s chi-square test was inappropriate. Therefore, Fisher’s exact test was used to compare the success and survival rate between the 2 different systems (x2 test). When ANOVA was used to assess the significances of material, porcelain thickness, and interaction effect. Also a 2-sample t-test was performed to compare between the 2 porcelain thicknesses within the same material.

**RESULTS**

Success, survival, and failure of the specimens under cyclic loading are summarized in Table II. Five specimens from the CL and CS groups were not considered a success, whereas only 1 from ML and none from MS were considered a success. According to the Fisher’s exact test, the all-ceramic group showed significantly higher success (P<.003) and survival rates (P<.001) than those of the metal ceramic group after cyclic loading. The CL and CS groups had 3 and 1 failures, respectively, due to the presence of cracks on the facial surfaces of the specimens. None of the specimens from either CL or CS showed a bulk fracture after the cyclic loading. The ML group had 7 failures, which concern a bulk fracture including the incisal edge and 6 crack occurrences on the facial surfaces of the specimens. The ML group had 7 failures, which concern a bulk fracture including the incisal edge and 6 crack occurrences on the facial surfaces of the specimens. The ML group had 7 failures, which concern a bulk fracture including the incisal edge and 6 crack occurrences on the facial surfaces of the specimens. The ML group had 7 failures, which concern a bulk fracture including the incisal edge and 6 crack occurrences on the facial surfaces of the specimens. The ML group had 7 failures, which concern a bulk fracture including the incisal edge and 6 crack occurrences on the facial surfaces of the specimens. The MS group had 1 fracture of the solid abutment and 7 failures, which resulted in 8 failures in total, although only 7 were considered as crown failures, for the purpose of comparison. The metal ceramic group had 18 crack occurrences in the all-ceramic group demonstrated core and veneering porcelain fracture under the load failure (Fig. 6). The 2-way ANOVA was significant for the factors material (P<.001) and porcelain thickness effect (P<.004), but not for interaction effect (P=.198) (Table IV). Within the same material group, ML showed significantly greater failure loads than MS (P=.004) while, for the all-ceramic system, CL and CS were not significantly different (P=.198).
porcelain following the coping design in Figure 1. Another index (index B) was made of the cut-back wax pattern using the same material and the same method as for index A. The cut-back wax pattern and the abutment were both scanned (in-and-out scanning) by a touch-probe scanner (Procera Scanning Mod 40, Nobel Biocare AB), and the electronic file was sent to the manufacturer’s processing center (Procera manufacturing facility, Nobel Biocare, Mahwah, NJ) to obtain 10 identical aluminia copings (Procera AllCeram; Nobel Biocare AB) with the dimensions illustrated in Figure 1.

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The specimens were thoroughly cleaned, air dried, and then stored in saline solution for 1 week prior to testing. For each specimen from either CL or CS, a load of 49 N was applied to the incisal edge, at an average speed of 1.5 mm/min. To decrease the rate between the 2 different systems (rs 0.5), 2-way ANOVA was used to assess the significance of material, porcelain thickness, and interaction effect. Also a 2-sample t test was performed to compare between the 2 porcelain thicknesses within the same material.

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![Custom-designed cyclic loading apparatus.](Image)

![Cracks of metal ceramic crowns occurring at cyclic loading site.](Image)

![Crack observed on cervical area for all-ceramic crown.](Image)
TABLE III. Mean and SD of failure load

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean (N)</th>
<th>SD</th>
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<tr>
<td>CL</td>
<td>10</td>
<td>1619.82</td>
<td>414.97</td>
</tr>
<tr>
<td>CS</td>
<td>10</td>
<td>1339.80</td>
<td>212.82</td>
</tr>
<tr>
<td>ML</td>
<td>9*</td>
<td>3116.42</td>
<td>628.65</td>
</tr>
<tr>
<td>MS</td>
<td>9*</td>
<td>2429.62</td>
<td>572.90</td>
</tr>
</tbody>
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CL - ceramic core, long; CS - ceramic core, short; ML - metal core, long; MS - metal core, short.
*One specimen was excluded due to considerable chipping during cyclic loading.
**One specimen was excluded due to abutment fracture during cyclic loading.

DISCUSSION

For the present study, 2 null hypotheses were addressed for the testing of the ultimate failure load: (1) there would be no significant differences in the failure resistance between 2 different thicknesses of veneering porcelain in the individual crown systems, and (2) there would be no significant difference in the failure resistance between 2 different crown systems. The first null hypothesis was rejected for the metal ceramic system, but it was accepted for the all-ceramic system, which showed no significantly different failure load between 2 different veneering porcelain thicknesses. The results support rejection of the second hypothesis.

For the occurrence of cracks after thermal and mechanical cyclic loading, 2 null hypotheses were addressed: (1) 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) there would be no significant difference in the occurrence of cracks between 2 different crown systems. The first null hypothesis was accepted, while the significant difference in the occurrence of cracks after cyclic loading between the 2 different crown systems indicated that the second hypothesis should be rejected.

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 the results must be interpreted with caution. For example, the present unidirectional cyclic loading design reproduces only 1 (vertical) vector of forces generally found in the masticatory cycle, 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 frequently used in other studies to simulate cyclic occlusal contact, it has also been argued that this type of loading might cause the level of stress in the ceramic to exceed what is found intraorally.

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For the occurrence of cracks after thermal and mechanical cyclic loading, 2 null hypotheses were addressed: (1) 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) there would be no significant difference in the occurrence of cracks between 2 different crown systems. The first null hypothesis was accepted, while the significant difference in the occurrence of cracks after cyclic loading between the 2 different crown systems indicated that the second hypothesis should be rejected.

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 the results must be interpreted with caution. For example, the present unidirectional cyclic loading design reproduced only 1 (vertical) vector of forces generally found in the masticatory cycle, 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 frequently used in other studies to simulate cyclic occlusal contact, it has also been argued that this type of loading might cause the level of stress in the ceramic to exceed what is found intraorally.

In this regard, however, it is interesting to note some fundamental differences in the behavior of the tested metal ceramic specimens when compared to alumina framework/ceramic ones. The same cyclic loading regimens produced distinctly different crack locations for the 2 groups. Ten specimens from the Procera AllCeram groups resisted the cyclic loading without any crack development (“success”), as opposed to the metal ceramic groups that had only a single specimen with a score of “success.” For the all-ceramic groups, cracks occurred on 10 specimens (6 metal ceramic crowns scored as “survival” and 4 as “failure”), whereas for the metal ceramic cracks, cracks occurred on 18 specimens (4 were assigned a score of “survival” and 14 were categorized as “failure”). The “failure” scores primarily resulted from the occurrence of cracks that compromised the esthetics, essentially extending onto the facial aspect of the crowns. This classification was arbitrarily designated by the authors based on clinical criteria. A crown would certainly be replaced if the loading conditions resulted in a bulk fracture, and it could be argued that a visible fracture affecting the buccal surface would also not be considered acceptable by most patients, therefore requiring replacement. While 14 cracks of the metal ceramic crowns involved the buccal surface, it is noteworthy to mention that all of the cracks in this group also originated in the cervical area of the crowns (Fig. 3), and only 1 at the loading site. For the metal ceramic crowns, it could be argued that the loading of porcelain specimens with a spherical indenter resulted in an excessive level of stress concentration at the loading site, initiating the crack in this area with a subsequent extension on the buccal surface. However, the same loading conditions in the Procera AllCeram crowns did not result in the same pattern of cracks. Only 1 crack was observed at the loading site, and 90% of the cracks involved only the cervical areas of the crowns. The authors speculated that this different behavior in the oral biomechanical environment, such as that of mastication, was partially due to the specific short-term occlusal loading regimen of the Procera copings noted along the junction between the solid abutment and the prosthetic platform of the implant analog (junction A). When the solid abutment was screwed into the implant analog, it created an obtuse angle at the junction A (Fig. 6). Since the tip of the touch probe of the Procera scanner is round, this angular joint was not completely captured by the scanner, with a resulting rounded internal angle of the coping. Therefore, the alumina coping was fabricated with greater cement space at the junction A area than at any other internal aspect of the crown. Figure 6 also showed the catastrophic fracture of the Procera AllCeram crown under the load-to-failure test, and the thick cement layer was observed along junction A. It is possible that the greater thickness of the cement layer might have caused tipping of the all-ceramic crown during cyclic loading, possibly producing excessive hoop stresses at the cervical margin of the crowns and resulting in the occurrence of cracks. A study investigating the thickness of the cement layer of the Procera AllCeram crowns found an increased cement layer on the round slope of the chamfer margin, and it was caused by the same reason explained above.

It also should be noted that, while a higher number of crowns in the metal ceramic group showed the presence of cracks after the cyclic loading testing, their mean ultimate failure load was significantly greater than that of the all-ceramic crowns. While the direction of loading during this test was...
The thickness of the incisal porcelain was inversely related to the failure load in metal-ceramic crowns, while it did not significantly affect that of Procera AllCeram crowns. This leads one to believe, sim- ilarly, that Procera AllCeram crowns have a dominant effect on the occurrence of failure under cyclic loading.

Within the limitations of this study, the following conclusions were drawn:

1. All-ceramic crowns tested showed significantly higher survival rates after the cyclic load testing than did metal ceramic crowns.

2. Metal ceramic crowns showed significantly greater fracture toughness and survival rates after the cyclic load testing than metal ceramic crowns following cyc- lic loading.

3. The thickness of the incisal veneering porcelain affected the failure load, and metal-ceramic crowns showed significantly more incidence of failure than all-ceramic crowns.

CONCLUSIONS


28. Morita T, Morita H, Morita M, Morita E. Characteristic and the resultant great- er cement thickness of the porcelain to the abutment and the prosthes- tically typical of the implant analog could have caused the cervical cracks observed in these crowns. These fac- tors were not controlled for in the cur- rent study and should be included in future studies.

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Purpose: The purpose of this study was to determine dynamic changes in bone metabolism around osseointegrated titanium implants under mechanical stress.

Materials and Methods: Two titanium implants were inserted parallel to each other in the tibia of rats and perpendicu- lar to the bone surface with the superior aspect of the implant exposed. Eight weeks after insertion, closed, coated springs with 0.5, 1.0, 2.0, and 4.0 N were applied to the exposed superior portion of the implant for 7 weeks to apply a continuous mechanical stress. Bone scintigrams were performed using a gamma camera with a modified high-res- olution pinnhole collimator. Images were made at 1, 4, 7, 10, 14, 21, 28, 49, and 56 days after insertion and at 3 days and at weekly intervals until 7 weeks after load application. The ratio of the metabolic activity around the implants to that around a reference site (uptake ratio) was established. The Friedman, Steel, and Tukey tests (P < .05) were used to assess statistical significance.

Results: In the process of osseointegration, the uptake ratio increased during the first week after implant insertion and then gradually decreased. During the initial 3 weeks the uptake ratio was significantly higher than at 1 day after insertion. In the process of load application, the uptake ratio increased with 2.0- and 4.0-N loads; it was significantly higher until 6 weeks than it had been before load application.

Conclusion: Bone metabolism around the implants increases with load and depends on the magnitude and period of the loading.

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Bone metabolic activity around dental implants under loading observed using bone scintigraphy


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along the axis of the tooth, it could be speculated that the presence of cracks in metal ceramic crowns, at least as per adjudicated by implant testing with resiliency conditions used in this study, is of secondary importance in determining the ultimate resistance to fracture, and that the intrinsic characteristics of the material, as well as in all-ceramic crowns, have a dominant effect on the occurrence of failure under single load-to-failure testing. It could be speculated that, since most of the metal-ceramic specimens that were loaded to failure had already shown the occurrence of cracks during cyclic testing and, therefore, stresses high enough to produce tensile failure had already occurred, the loading conditions in the load-to-failure test may have actually stressed the crowns that were deemed “success” or “survival” in different manners. Although this is experimentally possible, it is none-the-less surprising to see that the raw values of the load-to-failure test did not show a separation or clear identification between the specimens that were initially classified as success from those classified as survival.

In addition, the thickness of the incisal porcelain was inversely related to the failure load in metal ceramic crowns, while it did not significantly affect that of Procera AllCeram crowns. This leads one to believe, similar to the ideas mentioned previously with respect to the metal-ceramic porcelain, that this type of crown may have somewhat different behavior under loading. From a clinical perspective, the fact that a 4-mm incisal extension in metal-ceramic crowns is not more prone to develop cracks under cyclic and single-load-to-failure testing in Procera AllCeram crowns may indicate that, if higher incisal transverse forces are transmitted, it might be achieved by shortening the core thickness and adding more incisal feldspathic porcelain. The present study investigated only limited conditions of materials for the core and veneering ceramic, and the results cannot be generalized to other systems. Moreover, the results might only apply to situations in which the crowns were cemented on the implant abutments with resiliency, which provides a dry environment, and the core-abutment inter-face. The results might be different if the crowns were cemented on sound dentin, which might keep the inter-face wet with tubular fluid. Future studies should concentrate on testing whether the current results are applicable to other metal ceramic all-ceramic systems. If the results are confirmed with other metal and ceramic frameworks, it would then be interesting to assess, with appropriately designed in vitro studies, the behavior of these observed differences in behavior. Moreover, it was speculated by the authors that the geometric characteristics and the resultant greater cement thickness of the proximal to the abutment and the prothetic platform of the implant analog could have caused the cervical cracks observed in these crowns. These factors were not controlled for in the current study and should be included in future studies.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. All-ceramic crowns tested showed significantly higher survival rates and survival criteria after the cyclic loading test than did metal ceramic crowns.

2. Metal ceramic crowns showed significantly greater higher survival rates in metal ceramic crowns than the all-ceramic crowns following cyclic loading.

3. The thickness of the incisal veneering porcelain affected the failure load during the metal ceramic crowns but not that of the all-ceramic crowns. The metal ceramic crowns with 2-mm porcelain demonstrated significantly higher failure loads than crowns with 4-mm porcelain.

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