

# Influence of Different Ceramic Systems on Marginal Misfit

## ABSTRACT

*Objective:* the aim of this study was to evaluate the marginal misfit at the interface between a ceramic coping and its abutment. *Methods:* Twenty-four specimens were made with solid abutments. The specimens were divided into 3 groups according to the ceramic system (n = 8): Lava (zirconia), IPS e.max Press (lithium disilicate), and IPS Empress Esthetic (leucite). All copings were cemented with resin luting agent (RelyX U200) and the marginal misfit were evaluated at 3 different times: initial, after cementation, and after mechanical cycling using a linear measuring microscope (Measuring Microscope STM-Olympus) at a magnification of 40x. All specimens were subjected to mechanical cycling (1 million cycles) by an universal testing machine (Instron 8800). The results were statistically analyzed using Analysis of Variance and Student's t-test ( $\alpha = 0.05$ ). *Results:* all groups showed an increase in the marginal misfit after cementation. The lithium disilicate group demonstrated the lowest interfacial gap values at each evaluation ( $p = 0.001$ ). The zirconia and leucite groups showed similar interfacial gap values (initial,  $p = 0.244$ ; and post cementation,  $p = 0.751$ ). *Conclusions:* the cementation increase the marginal misfit, but the mechanical cycling did not influence the marginal misfit of the ceramics systems evaluated.

## INTRODUCTION

An increasing demand for better aesthetics, combined with advancements in the science of dental implantology, has led to improvements of ceramic implants.<sup>1-2</sup> Traditional porcelain-fused-to-metal crowns (PFM) consisted of a ceramic over a metal infrastructure, which limited their translucency and, in some cases, compromised the aesthetics of the restoration.<sup>3</sup> Metal-free restorations have been developed in order to improve aesthetics of oral rehabilitation procedures.<sup>4</sup> One of the most significant challenges associated with metal-free restorations is the development of ceramics with physicochemical properties similar to, or better, than those of PFM restorations. Thus, ceramic compositions have been steadily improved, leading to the current reinforced ceramics with an increased crystalline content, such as zirconia, lithium disilicate, alumina, and leucite.<sup>5</sup> Among these materials, zirconia is known for its superior mechanical properties when compared to other ceramic systems as resistance to fracture (9–10MPa of fracture toughness) and flexural strength (900-1200MPa).<sup>6,7</sup> In addition, the properties of these materials, notably their mechanical strength, have allowed their use to be extended to rehabilitative treatments of posterior teeth.<sup>8,9</sup>

The marginal adaptation of the crown to the abutment should be as perfect as possible, in order to preserve gingival and periodontal health, prevent bio-film and food accumulation, reduce the solubility of luting materials and allow adequate biomechanical behavior.<sup>6</sup> Thus, the use of fast and accurate methods,

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## Authors

Dr Sebastião Pires Vargas \*  
(DDS, MSc)

Prof. Ana Christina Claro Neves \*  
(DDS, MSc, PhD)

Prof. Rafael Vitti \*  
(DDS, MSc, PhD)

Prof. Marina Amaral \*  
(DDS, MSc, PhD)

Dr Mirelle Nery Henrique \*  
(DDS, MSc, PhD)

Prof. Laís Regiane Silva-Concílio \*  
(DDS, MSc, PhD)

## Address for Correspondence

Prof. Rafael Vitti \*

Email: rafapvitti@gmail.com

\* Department of Dentistry, University of Taubaté,  
Taubaté, Brazil.

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including computer-aided-design (CAD) and computer-assisted-manufacturing (CAM) for milling prosthetic components has increased as a result of the fast development of digital computer technology. CAD/CAM may be a good alternative in Dentistry to reduce chairside and the fabrication time of high strength ceramics as yttria-stabilized zirconia.<sup>10,11</sup> Many studies have demonstrated that a marginal misfit of 120 µm is clinically acceptable in terms of longevity of a crown.<sup>12-15</sup>

The most common finishing line of a preparation for implant supported metal-free restorations is, usually, a “shoulder”.<sup>14,15</sup> Knowing that the marginal misfit correlates with the design of the implant platform and considering that most of the implants have a shoulder platform, metal-free crowns generally meet these requirements.<sup>16</sup>

Thus, the aim for this study was to evaluate the marginal misfit of different all-ceramic system on an abutment platform with 45° subjected to mechanical cycling. The hypothesis tested was that the different ceramic system used with abutment platform (45°) would not influence the marginal misfit.

## MATERIALS AND METHODS

### ANALOGS INCLUSION AND PREPARATION FOR TESTING

For this study, 24 regular neck (RN) synOcta (ITI, Straumann, Basel, Switzerland) implant analogs and 24 RN solid 6 (ITI, Straumann) abutments were used (Figure 1). The implant analogs were attached to a cast surveyor (Bio Art, São Carlos, São Paulo, Brazil) using an implant screw driver (ITI-Straumann - InstitutStraumann AG 4002) and then inserted into an epoxy resin-glass fiber composite in a polyvinyl chloride (PVC) tube (½ inch × 19 mm).

The outer surfaces of the PVC were flattened in order to ensure that the samples would be at the same position for interface evaluations. Replicas were placed on the abutments with a long key for RN solid abutments and fixed using 15 Ncm torque. To standardize the readings, 4 marks were made in the analog base of each sample with both pen and high-speed handpiece equipped with a spherical carbide bur (0.5 mm).



Figure 1: Implant analogs and abutments used

### MANUFACTURING AND CEMENTATION PROCEDURES OF THE CERAMIC COPINGS

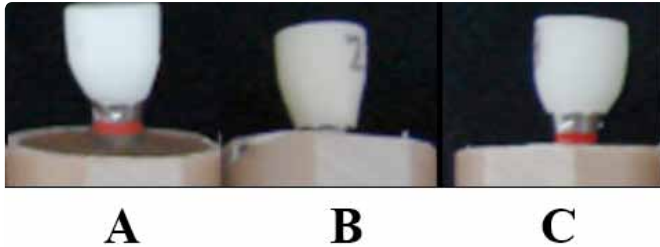
Three ceramic systems were evaluated in this study (n = 8): Lava (3M ESPE, St. Paul, MN, USA), IPS e.max Press (Ivoclar Vivadent, Amherst, NY, USA), and the IPS Empress Esthetic (Ivoclar Vivadent) (Table 1). Three patterns with dimensions of 8.0 x 8.0 mm were fabricated in acrylic resin (GC Pattern Resin America, Alsip, IL, USA) to standardize the manufacturing of the ceramic copings. Copings were fabricated over the solid abutment implant analogs.

Lava system consisted of an optical scanner associated to a software (for generating three-dimensional models), milling unit and a furnace for sintering. For both IPS e.max Press and IPS Empress Esthetic systems, pressed technique (similar to the lost wax technique) was used. Infrastructures were sculpted in wax in order to form a mold that was eliminated in a furnace (Edgcon 5P, EDG, São Carlos, SP, Brazil). The ceramic material was then injected into the mold. The surface treatment of each ceramic system was performed according to the manufacturer’s: Lava - sandblasting with aluminum oxide at 30 psi; IPS e.max Press and IPS Empress Esthetic - etching with 5% hydrofluoric acid for 60s and silane.

Table 1. Groups according to ceramic type, manufacturer, crystals, and manufacturing method.

Commercial Name	Manufacturer	Crystals	Method
Lava	3M ESPE, St. Paul, MN, USA	Yttria-stabilized zirconia	CAD/CAM
IPS e.max Press	Ivoclar Vivadent, Schaan, Liechtenstein	Lithium disilicate	Pressed
IPS Empress Esthetic	Ivoclar Vivadent, Schaan, Liechtenstein	Leucite	Pressed

A self-adhesive resin cement (RelyX U200, 3M ESPE) was handled according to the manufacturer's recommendations for cementing all ceramic copings to the abutments (Figure 2). Both catalyst and base pastes were mixing (1:1 ratio) for 20 s on mixing pad. A metallic apparatus was used to apply a constant pressure (3 kg) during the cementation. The resin cement was light cured for 20 s with a light-emitting-diode curing unit (Radii Cal, SDI, Australia) with 1,200 mW/cm<sup>2</sup>. Samples were kept in a dark environment, with 100% humidity, at 37° C, for 24 hours.



**Figure 2:** Ceramic cemented to the abutments. A - Lava; B - IPS e.max Press; C - Empress Esthetic

## MARGINAL MISFIT AND MECHANICAL CYCLING

Marginal misfit measurements were obtained at 3 different periods during the process: [1] initial, [2] after cementation and [3] after cycling. Measurements (with a precision of 0.5 µm) were taken using a linear measuring microscope (Measuring Microscope STM-Olympus, Tokyo, Japan), at a magnification of 40x, performed by one single investigator. Each previously identified region was evaluated 3 times and a mean value was calculated for that region. The vertical misfit was defined as the vertical gap between the zero point on a line passing through the most external point of the analog implant and the same area of the coping. Samples were subjected to 1 million cyclical loads using an universal testing machine (Model 8800, Instron, Canton, MA, USA), with a load of 400 N and frequency of 8 HZ, simulating 1 year of functional use. The number of cycles was recorded by software connected to the universal testing machine. Following, samples marginal misfit were evaluated again, following the previously described procedure.

Mean values were subjected to statistical analysis. Kolmogorov-Smirnov test was performed to confirm that mean values were normally distributed. For intra- and inter-group comparisons, mean values were analyzed by two-way analysis of variance (ANOVA) and Student's t-test, at a pre-set alpha of 0.05.

## RESULTS

Lowest misfit values were found for IPS e.max Press group, at all evaluation periods, when compared to other groups ( $p = 0.001$ ). Similar marginal misfit values were found for Lava and Empress Esthetic groups, with no significant differences at different evaluation periods (initial,  $p = 0.244$ , and after cementation,  $p = 0.751$ ).

Intragroup analyses showed statistical differences in the values of marginal misfit initial and after cementation for all groups. Mechanical cycling (1 million cycles) did not influence the width of the gap for any of the evaluated groups.

## DISCUSSION

The hypothesis of this study was rejected, since the observed interface values for all groups (different ceramic system) showed different marginal misfit. However, these values were lower than the maximum clinically acceptable gap (120 µm)<sup>12-15</sup>, at all evaluation periods. The use of an implant platform with a 45° probably contributed to the observed marginal misfit values since many studies unanimously concluded that the angle has a great influence on the marginal misfit.<sup>14,17-19</sup> The IPS e.max Press demonstrated the lowest marginal misfit, among the 3 evaluated groups, at all evaluated periods (Table 2). This ceramic system contains reinforcing ceramic particles of, approximately, 70% in volume of lithium disilicate crystals.

**Table 2.** Mean values (µm) and standard deviations of marginal misfit at the different periods.

Group	Initial	After Cementation	After Cycling
Lava	13.90 (1.09) Ab	16.19 (1.39) Aa	16.22 (0.99) Aa
IPS e.max Press	5.84 (0.71) Bb	7.81 (0.95) Ba	7.67 (0.82) Ba
IPS Empress Esthetic	13.34 (1.39) Ab	16.04 (1.23) Aa	15.18 (0.95) Aa

Different lowercase letters in rows and capital letters in columns are statistically different ( $p < 0.05$ )

The composition of the Empress Esthetic implant system is different compared to the previous material commercially known as Empress I. The leucite crystals of the Empress Esthetic system are smaller (1 to 5 µm), providing a more compact and homogeneous crystalline distribution. Lava system contains yttria-stabilized zirconia particles. This stabilization occurs by the incorporation of yttrium oxide into pure zirconia, thereby stabilizing the crystal in tetragonal phase, resulting in a poly-phase material with a polycrystalline microstructure. Such a microstructure leads to increased fracture toughness and flexural strength, when compared to other ceramic systems. For that reason, the application of this material has now been extended to the use as restorative material for posterior teeth.<sup>7,9</sup>

In addition to the different reinforcing crystals for each ceramic system, there are also differences in the methods used to obtain the ceramic copings. For IPS e.max Press and Esthetic systems, a similar methods of preparation, which are based on the lost wax technique, was used. For this technique, a wax pattern is invested and heated, in order to remove the wax, creating a mold in which the ceramic is injected (pressed) at high temperatures. For the leucite system (Esthetic), the temperatures range from 1150 to 1180°C and for lithium disilicate (IPS e.max Press), the temperatures range from 890 to 920°C. This process of injection at high temperatures reduces the bias inherent to the ceramic shrinkage during firing process, commonly observed for feldspathic ceramics.<sup>20</sup> On other hand, Lava system uses CAD/CAM technology that enables scanning and manufacturing of prosthetic structures.

Model scanning and overall machining process might also impact the final accuracy of the procedure. For this process, the ceramic is milled with a dimension 20% larger than that of final dimensions, since the sintering process results in a 20% volumetric shrinkage. These factors may have contributed to the increased values observed for Lava group, when compared to IPS e.max Press.

There was a statistical increase in the size of the marginal misfit after cementation procedures, when compared to initial values, which suggests that this process might lead to an increase in interfacial gap dimension.<sup>5,21</sup> To minimize the variation of one of the factors that may contribute to the thickness of the cement, the manufacturers' recommendations regarding the handling and preparation techniques. During the cementing process, the cement was applied to the axial walls of the copings, and with the support of a device, the cemented piece was maintained under a pressure of 3 kg in order to facilitate the flow of the cement and to produce a uniform line of cement.

All groups were subjected to 1 million cycles that simulated the behavior of an implanted prosthesis for one year in masticatory function.<sup>22</sup> For all groups evaluated in this study, mechanical cycling did not significantly influence the marginal misfit (Table 2), when compared to values observed after cementation. These results suggest that the evaluated ceramics cemented with self-adhesive resin cement performed adequately, once subjected to the simulation of masticatory forces.<sup>13,22</sup>

## CONCLUSIONS

The cementation procedures significantly increased the marginal misfit for all evaluated ceramic systems, but all groups showed clinically acceptable gap. Mechanical cycling did not influence the interfacial gap.

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