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# The substitution of the implant and abutment for their analogs in mechanical studies: In vitro and in silico analysis

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ABSTRACT

The use of analogs could reduce the cost of mechanical tests involving implant-supported crowns, but it is unclear if it would negatively affect the data accuracy. This study evaluated the substitution of the implant by implants analogs or abutment analogs as a support for crowns in mechanical tests, taking into account stress distribution and fracture load of monolithic lithium disilicate crowns. Thirty lithium disilicate monolithic crowns were randomized into three groups according to the set: Implant + abutment (IA); implant analog + abutment (IAA); abutment analog (AA). The specimens were subjected to mechanical fatigue ($10^6$ cycles, 200 N, 2 Hz) and thermal fatigue ($10^4$ cycles, 5°–55 °C). A final compression load was applied and the maximum fracture load was recorded. Data were analyzed using one-way ANOVA ($\alpha = 0.05$). The experiment was validated by finite element analysis and the maximum principal stress was recorded. No statistically significant difference was observed in the mean fracture load among groups ($P > 0.05$). The failure mode was similar for all groups with the origin of crack propagation located at the load point application. Finite element analysis showed similar stress distribution and stress peak values for all groups. The use of implant's or abutment's analog does not influence the fracture load and stress distribution for cemented implant-supported crowns.



## 1. Introduction

The continuous improvement of dental ceramics and growing demand for cosmetic work have proposed the substitution of metal ceramic crowns for all-ceramic ones [1]. Metal free restorations have the aesthetics advantage of blending with the underlying tooth structure as well as strength that allows a wide range of its indication [2]. The monolithic form of ceramic has allowed a major mechanical improvement of ceramic restorations when compared to the conventional bilayer ones [3–6]. Also, the use of CAD/CAM technology and prefabricated blocks provide less porosities, adequate fit and increased reliability [7, 8]. This technology has been used with success not only for teeth fabrication, but also in several areas of tissue engineering as in scaffold design [9].

The clinical success of these materials can be relied on many factors, such as fracture load and fatigue resistance that must be equivalent to the dynamic masticatory forces, which might lead failures [10–12]. Static compression test is a traditional mechanical methodology that evaluates materials behavior. Although it does not represent a clinical condition, provides basic materials strength data [13,14].

The high costs concerning the need of special devices to approach the masticatory dynamic and the reproduction of implant supported restorations have stimulated the search for alternatives for in vitro studies without compromise data accuracy [11,15–17]. The use of analogs instead of their respective components (i.e. abutment or implant) for mechanical tests on implant-supported crowns might significantly reduce the costs; however it is unclear if it would negatively affect the data since they have different mechanical properties [18]. A previous study has shown that the core material's properties are able to influence the mechanical performance [19] so that, future studies are warranted.

Taking into account the absence of the scientific data, this study sought to evaluate the stress distribution and fracture load of monolithic lithium disilicate crowns supported by prosthetic components vs. their analogs. The postulated null hypothesis was that the use of analogs does not affect stress distribution and fracture load of monolithic lithium disilicate crowns.

## 2. Materials and methods

### 2.1. In vitro analysis

Thirty monolithic lithium disilicate crowns (IPS e-max, Ivoclar Vivadent) were CAD/CAM milled (Ceramill Mind, Amann Girrbach). After the milling procedure, the crowns were crystalized and glazed according to the manufacturer's instructions (IPS Ivocolor, Ivoclar Vivadent).

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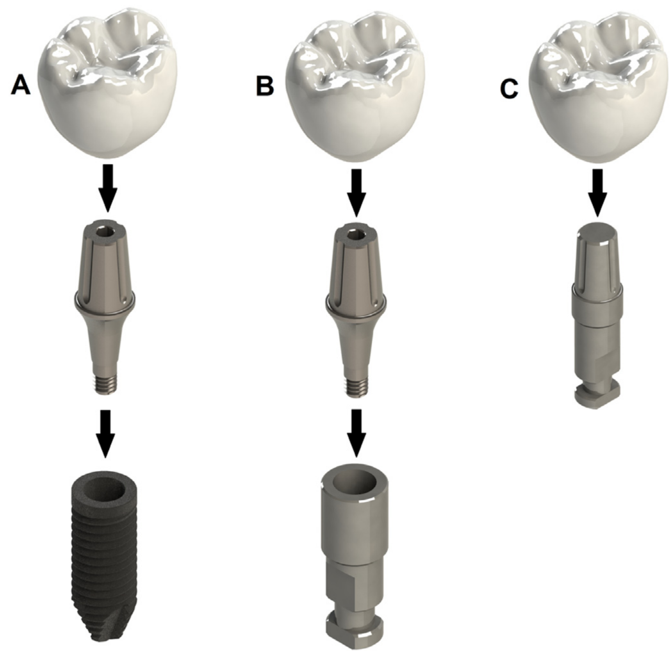


**Fig. 1.** Schematic view showing the experimental design: (A) Implant + abutment (IA), (B) Implant analog + abutment (IAA), (C). Abutment analog.

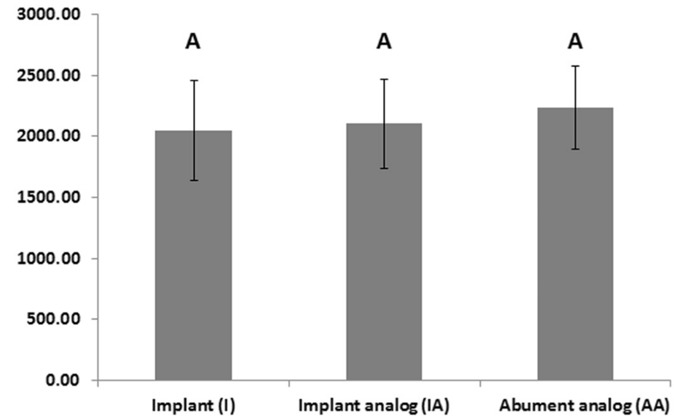


**Fig. 3.** Mean fracture loads of lithium disilicate crowns cemented in different sets: IA, IAA and AA.

The crowns were randomly divided into three groups according to the set in which they were cemented: 1. Implant + abutment (IA), 2. Implant analog + abutment (IAA), and 3. Abutment analog (AA) (Fig. 1).

A morse taper implant (4.0 × 11 mm) and a universal monolithic abutment (4.5 × 2.5 × 6 mm) (Titaoss Max CM, Intraoss) were used to reproduce a single restoration; both pieces were made of titanium alloy (Ti6Al4V) while the implant's analog and the abutment's analog were composed of stainless steel. All abutments were tightened with 32 N·cm using a digital torque meter with precision of 0.1 N·cm (TQ8800, Lutron).

Samples were vertically embedded into acrylic resin (Clássico, Dencôr) using polyvinyl chloride tubes (15 × 15 mm) with the implant's platform positioned at the same level of acrylic resin. For cementation procedure, crowns were ultrasonically cleaned with ethanol for 1 min. The internal surface of the crown was acid-etched with 10% hydrofluoric acid (Condac porcelana, FGM) for 20 s. The crowns were rinsed with water and gently air-dried with oil-free air.

A thin layer of silane coupling agent (Prosil, FGM) was applied to the internal surface for 60 s; the excess of silane was volatilized with an air-spray. The ED primer II (Kuraray Noritake) was applied on the abutment/abutment analog for 30 s.

The crowns were cemented using a dual cure resin composite cement (Panavia F 2.0, Kuraray Noritake). A 10N-load was applied over the crown to remove cement excess. The margin was light-cured for 20 s on each surface using an LED source of 1200 mW/cm$^2$ light intensity (Radii-cal, SDI). After cementation, the specimens were stored in deionized water at 37 °C for 24 h prior to test to allow complete hydration and avoid any dimensional expansion effect due to water absorption [20].

For mechanical fatigue, the samples were tilted at 30° in a metal matrix and undergone to $10^6$ mechanical cycles. A load of 200 N was applied on the internal slope of the mesiobuccal cusp using a stainless-steel indenter at 2 Hz (ER-1100, ERIOS).

Samples were thermal fatigued through 10,000 thermal cycles (MSCT-3e, Elquip, São Carlos, São Paulo, Brazil) in alternating water baths with temperatures of 5 °C and 55 °C (30 s each with a 5 s interval).

After mechanical and thermal fatigue, samples were fractured on a single-load compression test. A vertical load was applied on the center of occlusal surface of the crown using a stainless-steel hemispherical indenter (5 mm diameter) (Instron 4411, Instron) at a crosshead speed of

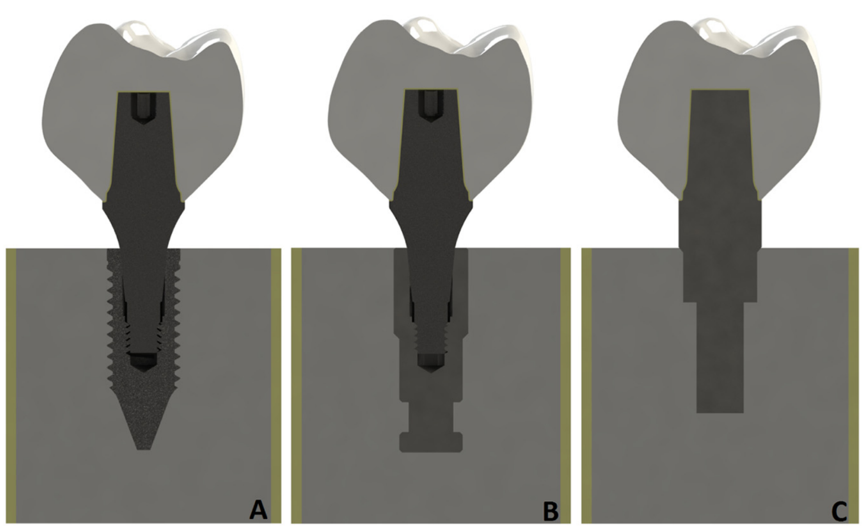


**Fig. 2.** Sectional view of the groups IA (A), IAA (B), and AA (C).