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Compressive Strength Evaluation between Metal Ceramic and Zirconia Crowns. An in-Vitro Study

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Abstract

The aim of this study is to evaluate the compressive strength of metal and zirconia cores and also the point of chipping of the veneered porcelain to both the core materials. For the present study, full coverage crowns were fabricated for mandibular molar. The crowns were divided into two groups. First group is five samples of metal ceramic crowns and second group is five samples of zirconia ceramic crowns. These crowns were subjected to static compression loading in a universal testing machine until the fracture of the veneering porcelain. The compressive load was recorded in newton. Data were subjected to student t test analysis. Mean compressive strength for group 1 metal ceramic crowns was 2587.80N and the mean compressive strength for group 2 zirconia ceramic crowns was 1361.00N. The compressive strength of metal when being used as a core material is significantly higher than zirconia. Under static compressive loading, the point of fracture of the veneered porcelains occurred at significantly lower values for the zirconia based restorations when compared to that of metal ceramic restorations.

Keywords: *zirconia, metal ceramic, compressive strength, chipping.*

Introduction

Fixed prosthodontic treatment involves the replacement and restoration of teeth by artificial substitutes that are not readily removed from the mouth. Its focus is to restore function, esthetics and comfort[1]. For the past 40 years the porcelain-fused-to-metal systems have been extensively used in fixed partial dentures (FPDs) and still represents the gold standard. The advantages of the PFM systems are to combine the fracture resistance of the metal substructure with the esthetic property of the porcelain[2]. The drawbacks of these restorations are that the bulk of the natural tooth may need to be sacrificed to provide adequate space to ensure adequate fracture resistance and aesthetics[3]. However, recently the increasing demand for esthetic restorations as well as the questionable biocompatibility of some dental metal alloys has accelerated the development and improvement of metal-free restorations.[4]

All ceramic restorations have become more widely distributed due to their high esthetic potential and their excellent biocompatible properties[5]. Zirconia (ZrO2) is a ceramic material with adequate mechanical properties for manufacturing of medical devices[7]. Since it was introduced in Dentistry, the polycrystalline zirconium dioxide (zirconia) resulted particularly attractive in prosthodontics, due to its excellent mechanical properties and improved natural-looking appearance compared to metal–ceramics. Zirconia stabilized with $Y_2 O_3$ has the best properties for these applications. Zirconia is a crystalline dioxide of zirconium[10].

The first proposal of the use of zirconium oxide for medical purposes was made in 1969[12]. Zirconia exhibits a phenomenon called "transformation toughening," which disables the progress of crack growth and increases toughness against fractures[14]. The tetragonal crystals of zirconium oxide are metastable and the stress applied to cracks or flaws can transform them into larger monoclinic crystals[15]. Yttrium partially stabilized tetragonal zirconia poly crystal (3Y-TZP) is made of transformable t-shaped grains stabilized by the addition of 3mol% yttrium-oxide (Y2O3). Such a polycrystalline material exhibits low porosity and high density; at the moment it is the most popular and frequently used form of zirconia commercially available for dental applications[20].

COMPRESSIVE STRENGTH

In the study of strength of materials, the compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine[21]. Some material fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load.[2] Compressive strength is often measured on a universal testing machine[23].

Dental ceramic materials exhibit many desirable material properties, including biocompatibility, esthetics, diminished plaque accumulation, low thermal conductivity, abrasion resistance, and color stability[24]. However, brittleness and low tensile strength are weak points of ceramic materials. Therefore, the clinical success of all-ceramic fixed partial dentures (FPD) has been disappointing, especially for posterior FPDs when compared with metal-ceramic restorations. Although metal frameworks have inherent disadvantages, studies reveal that the resistance to fatigue failure is comparatively more for metal ceramic restorations when compared to all ceramic restorations.[25]

Porcelain materials present two problems associated with occlusal forces: fracture of the porcelain, which is dependent upon the size and direction of the force (e.g., normal chewing versus bruxing), the type of porcelain (e.g., feldpathic, versus lithium disilicate, versus zirconia), and the time of force application; and wear of the material and its antagonist, whether natural enamel or other restorative materials. This is dependent upon the type of porcelain, quantity and timing of force, glazed versus polished porcelain, and the nature of the antagonist.[27]

Method

For the present study, full coverage crowns fabricated for mandibular first molar were tested for compressive strength. Materials used subjected to testing include:

1) Metal ceramic

2) Zirconia ceramic *(Table 1)*.

In order to standardize the crowns, a conventional tooth preparation was done on a mandibular first molar typhodont tooth model (Nissin)[29]. A full arch mandibular impression tray was used to make impression of the prepared tooth model using Aquasil soft putty/ regular set (DENTSPLY) and Aquasil ultra LV, type 3: light bodied consistency (DENTSPLY) using the double mix technique (fig 1) . The impression was poured using type IV dental stone. The dies were casted in cobalt chromium alloy[32] (fig 2).

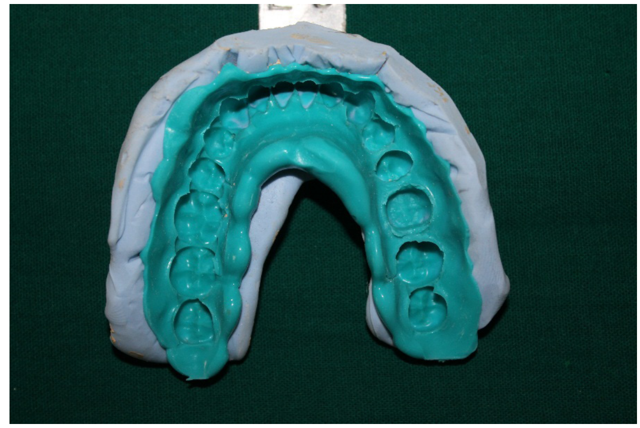

Fig. 1 - Impression of prepared Typhodont tooth model

Fig. 2 - Cobalt chromium dies

Fig. 3 - Fabricated crowns on the dies

Bonding Casts To The Crowns

Once fabricated, the crowns were bonded onto the metal dies (fig 4) using dual polymerization composite resin cement (Rely X U 200,3M.) and light cured for a period of 20 seconds for initial setting of the material (fig 5).

A force of 10 N was applied for 5 minutes to ensure even distribution of the bond material and seat the crowns properly[34]. After the cement had set the excess cement were removed from the margins of the restoration .

Fig. 4 - Crowns cemented on the stabilized dies

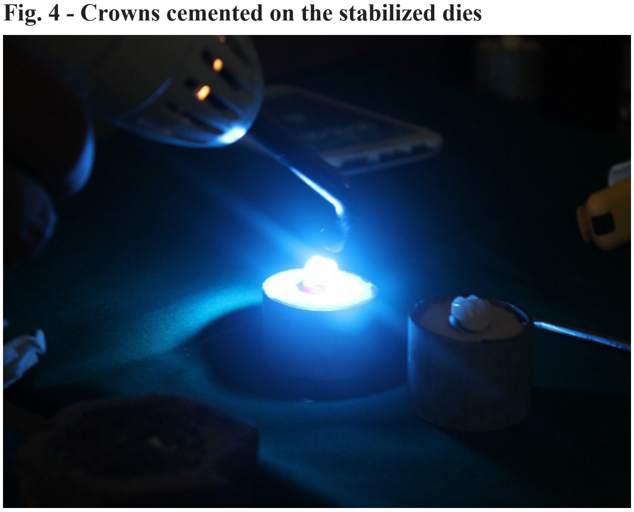

Fig. 5 - Light curing done for initial setting of the cement

Compression Testing

The compression testing was carried out using a universal testing machine (Instron model: WDW-100). The load applicator (4mm metal ball) descended onto the samples (fig 6) exercising a continuous force with a vertical cross head speed of 1mm/min, moving vertically downward perpendicular to the occlusal zone.

The load force applicator's ball established three point contact with the slopes of the vestibular cusps. Static compression loading was carried out until chipping or fracture took place of the veneered porcelain to the corresponding core material. This value was recorded in Newton (N). The data obtained was tabulated and analyzed using student t-test analysis.

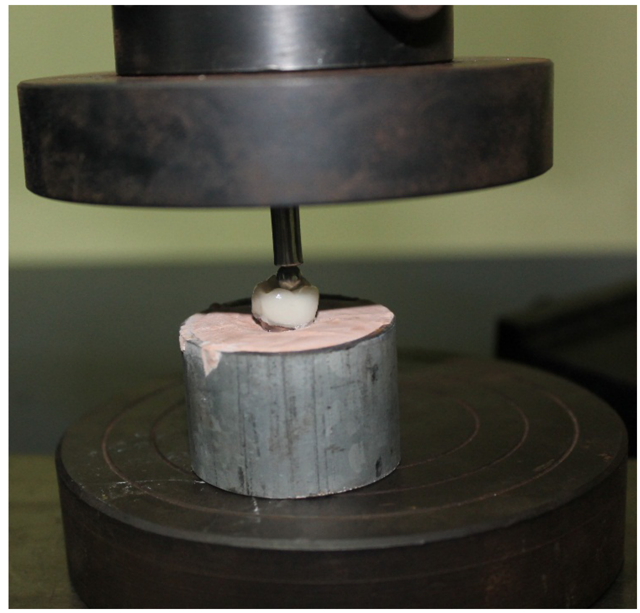

Fig. 6 - Static compression loading done on the samples

Results

Five samples were tested for compressive strength of metal ceramic in which chipping of veneering porcelain was at maximum of 2908N and minimum of 2300N.

Five samples were tested for compressive strength of zirconia ceramic in which chipping of veneering porcelain was at a maximum of 1500N and minimum of 1000N.

Mean values of compressive strength for metal ceramic and zirconia crowns were 2587.80 and 1361.0 N respectively (Table 1). These values were subjected to independent student t-test analysis (Table 2). The t-value obtained was 7.880 with degree of freedom (df) being 7.589 (Table 2). There was a statistically significant difference between the compressive strength of metal ceramic and zirconia crowns (p=0.000) (Table 3).

Discussion

With regard to biting forces in the oral cavity, compressive strength of materials used in fixed restorations plays a significant role in the durability and longevity of the prosthesis. Normal chewing cycle starts with opening movement from centric occlusion, lateral movement and closure on to working side. Then finally shear movement against slopes of the upper teeth to grind the food particles and bring the jaw back to centric occlusion. The para functional habits like clenching includes sustained amount of compressive forces in centric occlusion, whereas bruxing include sustained compressive and shearing forces.

The choice of compressive test type and its specific design used in this study is best suited to study the resistance of ceramic materials. These have been substantiated by numerous authors (Snyder et al, Panadero et al). The compressive testing would therefore appears to be a validated method for evaluating fracture resistance of crowns or fixed partial dentures. Furthermore the cross head speed (1mm/min) and static compressive load were established in light of a literature review dealing these variables.

Despite the many disadvantages of in vitro study it is important to evaluate isolated mechanical properties under standardized conditions and limited influencing parameters. Although compressive strength does not reproduce conditions in the oral environment as faithfully as in vitro cyclic studies, the results of this type of test provide valid information, which can then be extrapolated in clinical practice.

All-ceramic crowns are subject to fracture during function. To minimize this common clinical complication, zirconium oxide is the material of choice used for the framework of all-ceramic crowns**. Kelly** suggested several recommendations for a clinically relevant *in vitro* load-to-failure test for all-ceramic restorations: use of a die material with elastic modulus similar to dentin, failure test under wet cyclic loading, preparation of the teeth or dies according to clinical guidelines and use of all-ceramic crowns with clinically relevant dimensions.

In the current study, some experimental conditions were different from Kelly's recommendations. The elastic modulus of the die material in this study is higher than that of dentin. However, natural teeth are hard to be standardized in size, mineralization, internal cracks, pulpal chamber dimension, and mechanical properties and would have fractured under the high compressive loads exerted during the test. Clinically, restorations are subjected to dynamic complex loading in saliva, which contains both organic and inorganic components. These conditions are quite different from the conditions used in this study; thus, further investigation should be carried out using stress corrosion or corrosion fatigue methodology so that the long term performance of restorations can be predicted.

The typical failure pattern of a veneering material in the daily clinical practice is known as ceramic chipping. For metal ceramics restorations, the linear coefficient of thermal expansion for metal and ceramic must closely match to achieve a strong interfacial bond. A small mismatch between these two factors results in an unknown amount of residual stress at the interface. This stress is usually confined to the veneered porcelain only.

The bond between veneering ceramic and zirconia framework is currently the subject of comprehensive investigation, when compared to that of metal ceramic restorations and this forms the basis of this study. The results of the present study show that the point of chipping or fracture of the veneering porcelain for the metal ceramic restorations ranges from 2000 to 3000N. Subsequently the chipping for the zirconia based restorations ranges from 1000 to 1500N. There is a statistically significant difference between the two groups.

From the present in vitro study, it may be confirmed that porcelain veneers with the same characteristics behave in response to static loading differently depending on the type of core they cover. Zirconia restorations fracture at lower static load values. Porcelain veneer over a metal ceramic core resisted higher static loading.

Conflict of Interest: Nil

Source of Funding: Self

Ethical Clearance: Not required as it is an in-vitro study

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