Fracture resistance of different integral ceramic restorations

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Abstract: -In recent years new ceramic materials and new technologies have been developed, for more-and-more popular integral-ceramic dental restorations. Clinical decision on which material, design, technology is more suited for patient becomes harder, with every new introduced material and technique. Ceramic materials are known to be brittle, prone to fracture materials, when they are used to restore posterior teeth. The aim of this study was to determine fracture resistance of different integral ceramic crowns: hot-pressed ceramic and bilayered all-ceramic crowns with different core designs. Monolithic hot-pressed ceramic crowns show lowest stress resistance than bilayered zirconia-hot-pressed ceramic with anatomic core design. Within the limitations of this study can concluded that most indicated restorations for posterior area are bilayer crowns with anatomic framework design, and uniform thickness porcelain veneer.

Key-Words: -All-ceramic crowns, Fracture load, Zirconia, CAD/CAM, porcelain-veneered zirconia, hot pressed ceramic

1 Introduction

All-ceramic restorations become more and more popular among patients and clinicians due to their high aesthetic properties and biocompatibility. Ceramics where used for the first time in dentistry for more than two centuries ago, first successful all-porcelain "jacket" crown being produced in 1889, by Charles H. Land. To prevent internal micro-cracking produced during cooling time, after 1950 ceramic-fused to metal crowns where developed. Another improvement was to introduce various fillings to improve mechanical properties, like various forms of mica. Other ceramics were developed adding leucite or by glass-infiltration of alumina cores, for improving both mechanical and esthetical properties. [1] Conventionally, ceramics are classified by their microstructure in four categories: glass-based systems (mainly silica), glass-based systems (mainly silica) with fillers, usually crystalline (leucite, lithium disilicate), Crystalline based systems with glass fillers (alumina) and polycrystalline solids (alumina and zirconia) [2]. Feldspathic porcelains failed in producing integral ceramic restorations, due to their low flexural strength and high marginal discrepancies caused by firing shrinkage. Aluminous porcelain development offered new possibilities for core fabrication, replacing metal framework. Because its low flexural strength, this type of ceramic can be used only for anterior teeth [3]. Ceramic properties as low tensile strength, brittleness and crack propagation are the reasons for extended use, even today, of ceramic fused to metal restorations [4,5,6]. However, metal frameworks have some shortcomings, as being non aesthetic, teeth and gum discoloration, potential to provoke allergic reactions, bimetallism phenomena.[7] Use of all-ceramic restorations extended to posterior area, even for fixed partial prostheses, with the development of new, higher strength materials [8]. Nowadays, technologies used to obtain all-ceramic fixed prosthesis are: powder/liquid, glass-based systems; machinable or pressable blocks of glass-based systems and CAD/CAM processing of alumina or zirconia [2,3]. Because of materials variety, with different properties, and the large number of available technologies, practitioners may feel lost when they have to choose the optimal clinical solution. This is why, in the last three decades, CAD/CAM technologies and in consequence, materials used with these have spread. Using CAD/CAM systems veneers, inlays, onlays, crowns, implant abutments, and even extended fixed partial dentures can be produced [6]. One of the major advantages of CAD/CAM technologies is that many laboratory steps are no longer necessary, potential sources of inaccuracy being eliminated.

Also, CAD/CAM milling technology is the most used method to obtain zirconia-based ceramics. Zirconia frameworks are good alternatives to replace metallic frameworks due to their mechanical properties [9]. This particularity consists in structural features of zirconium, which is found in three different crystal structures: monoclinic at room temperature, tetragonal at 1200° C and cubic at 2370° C. In stabilized zirconia tetragonal form is "metastable" at room temperature, suffering a toughening mechanism. According to this, material under mechanical or thermal stress eliminates the trapped energy by transforming tetragonal into monoclinic phase, associated with a volume increase, producing localized compressive stress around the tip of the crack which prevents its propagation [2].

Zirconia used in dental field is available as pre-sintered blanks. Intraoral scanning and computer-aided milling minimize the potential human errors, producing better restorations, with a better adaptation and less structural defects [3,10]. These properties make zirconia the ideal material for frameworks for almost any fixed partial restoration [11].

However, bilayered integral ceramic restorations showed a tendency to mechanical failure, thru delamination or "chipping" of the veneering ceramic phenomena [12]. Different studies and reviews show that integral ceramic crowns with zirconia infrastructure are more prone to chipping, compared to metal-ceramic fixed prosthetics [13,14].

2 Problem Formulation

Integral ceramic crowns are extremely popular because they're aesthetic and biocompatibility, but these types of restorations are known as brittle and more prone to fracture. Clinicians can become confuse in the variety of ceramic materials and design possibilities.

3 Purpose

The aim of the study was to compare the fracture load of different types of integral ceramic restorations, with or without zirconia core and with different core designs.

4 Materials and method

For this study a first resin maxillary molar (Frasaco GmbH, Tettnang, Germany) was chosen to be covered with different types of all-ceramic restorations. This was prepared with a wide chamfer finishing line, a 6° occlusal convergence angle, 1.5 mm anatomic reduction of occlusal surface, and two planes palatal reduction of functional cusps, according recommendations for teeth preparations for integral-ceramic crowns. Tooth was replicated with silicone impression material (Fegurasil Ad Special, Feguramed GmbH, Buchen, Germany) and a stone model was obtained (GC Fuji Rock, GC, Japan). The plaster die was scanned using the Cercon Eye scanner (Degudent, Hanau, Germany). Scanned data were computed and then three designs were developed using Cercon Art software (Degudent, Hanau, Germany): one for a resin pattern for hot-pressed ceramic, one for uniform thickness coping with 0.5 mm thickness, and one cutback design, to obtain uniform thickness for veneering ceramics.

Resin patterns were invested in a specific phosphate-bonded investment mass. After burning the patterns, a glass-ceramic (Cergo Kiss, DeguDent, Hanau, Germany) was pressed in the pre-heated mold at 980° C, 4.5 bar, for 20 min. After the cooling, mold is divested, the crown is adapted, finished and glazed. Zirconia frameworks, both with uniform thickness and anatomically-reduced, were milled from pre-sintered zirconia blocks, 25% larger than the original size, automatically calculated by CAD system, for compensate firing shrinkage. After milling, copings were sintered at 1350°C for 7 hours in a specific furnace. After sintering and adaptation, frameworks had been sandblasted with alumina (110-125UM, at 3 bar, 45 angle) and cleaned with a steam cleaner. A wax-pattern was shaped using a mold over the copings, in order to keep the same morphology and dimensions for the final crowns (Fig.1)

Fig. 1. Wax pattern over zirconia core prepared to be invested.

This ensemble was invested, and the glass-ceramic (Vita PM 9, Vita-Zahnfabrik, Bad Säckingen, Germany) was over-pressed at 1000°C, 3.0 bar, 29 min. Ten specimens for each design were made. A metallic replica of prepared molar was casted. Each specimen was cemented on the Ni-Cr alloy (Nicor, Schutz Dental GmbH, Rosbach, Germany) molar using a phosphate zinc oxide cement, under finger pressure for 5 minutes. All samples were fabricated by the same operator. Loading tests were conducted after twenty-four hours after cementation, with a universal testing machine (Instron 3366, Instron Corp, Norwood, MA, USA).
Probes were attached at 0 degrees to the long axis of the crown. The force was expressed throw a stainless steel, 15 cm long with a round end of 6 mm diameter stylus. To prevent the load dispersion a 0.2 mm rubber dam was applied between tip of the stylus and ceramic surface. The force was applied on the occlusal surface, the load was increased from 0 to the fracture point, with 2 mm/min crosshead speed.(Fig.2)

Fig. 2. Probe under loading

5 Results and discussions

All specimens used in this study had the same morphology and thickness. The load was applied in same spot (central fossa).The load at failure was registered as fracture resistance.
Significantly lower fracture resistance was observed in the first group of specimens - hot-pressed ceramics, with a mean of 1683 N (Fig. 3).

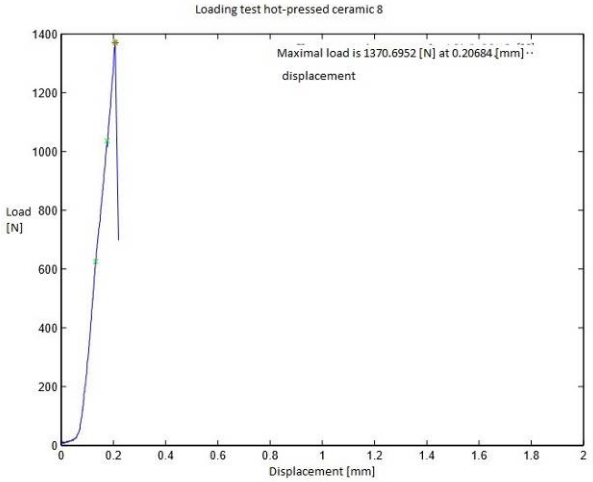

Fig. 3.Load test hot-pressed ceramic

Group of integral ceramic crowns with an uniform thickness infrastructure shown an increased resistance, with a mean fracture force of 3820 N (Fig.4).

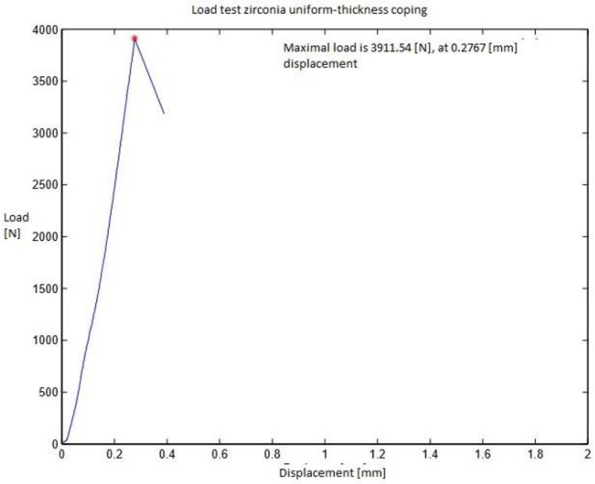

Fig. 4. Load test uniform thickness zirconia framework

Best results were obtained for zirconia anatomic-design core group and uniform thickness veneer porcelain, with a mean value of the braking-force of 4659 N (Fig.5).

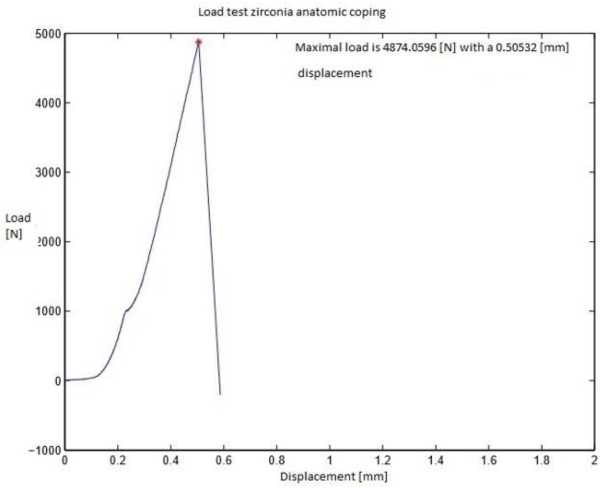

Fig. 5. Load test anatomic-reduced zirconia framework.

The fracture initiation point was at the load-application point, and extended to the axial walls. (Fig.6)

Fig. 6. Fracture initiation point and extension.

6 Conclusion

Besides material properties which have a significant influence on functional behavior of all-ceramic crowns, a very important factor is the particular geometry of these restorations [14]. This can produce stress accumulation, with initiation and further fracture propagation of glass-ceramics.

Within the limitations of this in vitro study, the anatomic framework designs of bilayer all-ceramic crowns, which ensure an uniform thickness for veneering porcelain, significantly reduce fracture risk of integral-ceramic restorations.

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