

Impact of Surface Treatments on the Roughness Surface and Fracture Pattern of Zirconia Ceramic Restorations

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ABSTRACT

Purpose: The aim of this study was to assess the surface roughness, and fracture pattern of zirconia ceramic restorations after the application of different surface treatments.

Material and method: We conducted a systematic literature search on the electronic databases PubMed and Science direct using 12 key words via Boolean equations. We identified articles that met the eligibility criteria by checking the title and abstract. A full-text review was used to select articles based on the CASP grid. (The Critical Skills Appraisal Programme)

Results: 13 articles were selected after reading the full text. We noted a predominance of mixed failure in our study.

Conclusion: Sandblasting before sintering is a recommended method to increase surface roughness and improve the bond strength of the cosmetic ceramic. The mixed fracture mode is the most frequent mode in our study. Further clinical studies with standardization of protocols should be conducted.

Keywords: Fracture, surface roughness, surface treatments, zirconia.

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I. INTRODUCTION

Due to an increasing interest in esthetics and concerns about toxic and allergic reactions to certain alloys, the use of metal-free dental restorations was increased. Yttrium-reinforced polycrystalline tetragonal zirconia (Y-TZP) was introduced as a ceramic material to replace the metal framework. The mechanical, biological and aesthetic advantages of zirconia are very attractive. Thus, its use is part of a daily practice in the dental office. However, the adhesion between veneering ceramic and zirconia remains an element that compromises the longevity of these restorations. Indeed, many cases of fracture of the cosmetic ceramic along the interface with the framework have been reported [1], [2].

In order to overcome this problem, surface treatments have been developed and numerous scientific studies have been conducted on the influence of these treatments on the existing bond between the framework ceramic and the cosmetic ceramic [3].

The aim of our study is to investigate the surface roughness as well as the fracture pattern obtained after the application of surface treatments on zirconia ceramic restorations.

II. MATERIAL AND METHODS

Our study is a systematic review. A computerized literature search was conducted in pubmed and science direct using 12 anglo-Saxon keywords from several recent publications dealing with the subject: Zirconia -Y-TZP- Zirconium oxide-Zirconium dioxide-Veneering porcelain Surface treatment-Laser Nd:YAG- Laser CO₂ -Sol gel-Bonding strength Grinding and polishing treatments Plasma treatment-Fluorhydric acid-Airborne particle abrasion, roughness, fracture.

By reading the titles and abstracts followed by the full text of each reference, we selected articles that met the inclusion criteria listed below:

1- Studies published in English.

2- Articles evaluating the surface roughness and fracture pattern of zirconia ceramic restorations after the application of surface treatments

3- Articles published after 2010

4- Articles with sample sizes greater than or equal to 30.

A manual search using the bibliographic references of the selected articles was conducted to detect other possible articles. A critical reading of the content of the articles finally selected was performed. The quality assessment of the studies included in this review was carried out through "The Critical Skills Appraisal Programme" (CASP). The

reading and quality assessment of the publications was completed by 2 independent readers, with formal processes of discussion and consensus building in case of disagreement, in order to minimize subjectivity.

III. RESULTS AND DISCUSSION

In the first step we identified 277 studies. After this first selection and based on the reading of titles and abstracts we retained 33. By reading the full text we retained 13 articles (Fig. 1).

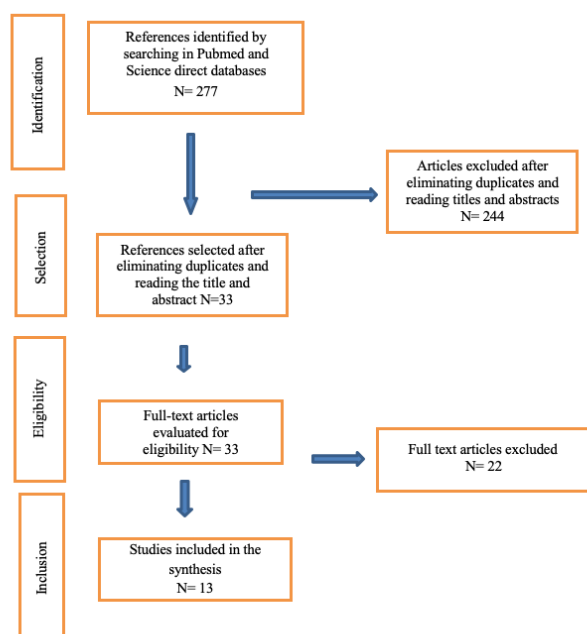


Fig. 1. Flow chart illustrating the study selection process.

All the studies found in our research were in vitro studies conducted by researchers from different countries and written in English. The selected references evaluated the influence of different surface treatments on roughness and fracture pattern.

A. Surface Roughness

Roughness was investigated in six studies (Table I):

Various zirconia surface treatments have been recommended to create surface roughness and improve the bond strength between the zirconia and the veneer ceramic (acid etching, grinding, abrasion with rotary instruments or air with alumina particles, acid etching or even the combination of all these techniques [3].

Because zirconia is acid resistant, mechanical abrasion methods are required to increase this roughness by creating micromechanical interlocking. However, these methods can create surface defects and reduce the strength of the material. Sandblasting, for example, can accelerate and accelerate the transformation of zirconia surface from tetragonal to monoclinic phase of the zirconia surfaces and cause microfractures [4], [5]. The studies found in our review conclude that sandblasting of zirconia before sintering is a useful method to increase the surface roughness and could improve the bond strength of the veneer porcelain. This may be due to the lower hardness of zirconia before sintering, resulting in a rougher zirconia

surface by sandblasting and thus a larger surface area available for mechanical interlocking without risking fracture. This can be explained by the low hardness of the zirconia prior to sintering, which resulted in a rougher zirconia surface by sandblasting and thus a larger surface available for mechanical interlocking without the risk of fracture [4]-[9].

TABLE I: VALUES OF SURFACE ROUGHNESS AFTER SURFACE TREATMENT

Authors	Surface treatment used	Results found
[4]	Group 1: no surface treatment Group 2: abrasion by alumina particles of 50 μm Group 3: abrasion by 125 μm alumina particles	Group 1: 0,120 μm Group2: 0,759 μm Group 3: 1,028 μm
[5]	-Control group -Group P: treated by Plasma at atmospheric pressure -Group A: abrasion by airborne particles 110 μm . -Group AP: treated by plasma at atmospheric pressure after abrasion by airborne particles 110 μm .	Control group: 218.1 \pm 14.1 nm, P: 259.5 \pm 55.5 nm, A: 380.5 \pm 34.8 nm, AP: 419.1 \pm 25.1 nm.
[6]	Group M: Milling without surface treatment Group APA: Abrasion by airborne particles Group LX1: Single laser treatment Group LX2: 2 laser treatments Group LX3: 3 laser treatments	M: 0.73 \pm 0.20 μm . APA: 0.79 \pm 0.21 μm . LX1: 1.15 \pm 0.21 μm . LX2: 1.18 \pm 0.23 μm . LX3: 1.21 \pm 0.22 μm .
[7]	As polished Group GB: Grit-blasting Group OP: Oxygen plasma Group AP: argon plasma Group CP: CF4 plasma	As polished: 0.065 \pm 0.007 μm GB 0.307 \pm 0.031 μm OP: 0.065 \pm 0.007 μm AP: 0.060 \pm 0.007 μm CP :0.058 \pm 0.007 μm
[8]	Group A: without treatment Group B: sandblasted under pressure of 0,2 MPa, then densely sintered Group C and D: sintered, then sandblasted under pressures of 0,2 MPa and 0,4MPa respectively	A: 0.63 \pm 0.42 μm B: 4.65 \pm 1.01 μm C: 0.89 \pm 0.35 μm D: 1.53 \pm 0.38 μm
[9]	Group C: grinding with diamond disc Group A: abrasion with Al2O3 particles in air suspension with 110 μm Group L: application of a coating Group AL: abrasion by airborne Al2O3 particles with 110 μm and application of a coating	A rough surface was observed in the specimens abraded by airborne particles (there was no distinct coating layer in the specimens applied by the coating)

B. Fracture Pattern

Ceramic fracture is described as:

- Adhesive: when it occurs between the zirconia and the cosmetic ceramic,
- Cohesive: when it occurs at the level of the cosmetic ceramic,
- Mixed: when there is a combination of both.

In our review, all three types of patterns were present, with a predominance of mixed failure.

8 studies performed thermocycling after the surface treatment, under a temperature varying between 5 and 55 $^{\circ}\text{C}$ with a difference in the number of cycles [3], [7], [10]-[15].

-20000 cycles for [3], [10]-[12].
-12000 for [7].
-10000 cycles for [13], [14].
-6000 cycles for [15].

For [13], regardless of thermocycling, there was no significant difference for bond value between the two primer and non-primer treated groups (Luxor Zirkonox-Primer). In contrast, thermocycling altered the fracture pattern: primer-coated zirconia samples showed predominantly cohesive and mixed fractures, whereas uncoated zirconia samples showed a higher number of adhesive fractures. Similarly, in the study by [10], even after 20,000 cycles, the zirconia was stable and the effect of the different surface treatments evaluated (sandblasting, IPS Emax Ceram Zirliner and PEVCD film) was durable.

In the studies of [7], [11] and [14], thermocycling resulted in a significant decrease in the bond strength between cosmetic ceramic and zirconia coated with (Hotbond Zirconnect) and Argon plasma, or sandblasted without subsequent heat treatment.

In the studies of [3], [12] and [13], all groups underwent heat treatment, which is why there was no comparison.

The most common mode of fracture in our study was the mixed mode encompassing both cohesive and adhesive fracture. Its origin is multifactorial: unsupported thickness of cosmetic ceramics [9], thermal expansion coefficient between zirconia and cosmetic ceramics and lack of thermal conductivity [14], ceramic surface finish, mounting technique of cosmetic ceramics, block fabrication technique [15], cooling rate [16], wettability of cosmetic ceramics [17], surface roughness of zirconia [18].

IV. CONCLUSION

The objective of our study was to investigate the effect of surface treatments on the roughness and fracture pattern of zirconia ceramic restorations. Based on the analysis of the studies found, sandblasting before sintering is recommended as an effective method to increase surface roughness and improve the bond strength of the cosmetic ceramic. For fracture, the mixed mode is the most frequently observed mode in our study with a multifactorial origin. Further clinical studies with standardization of protocols should be conducted.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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