Experimental tribo-chemical and silica-rich air-abrasion to enhance bonding to zirconia

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Objectives

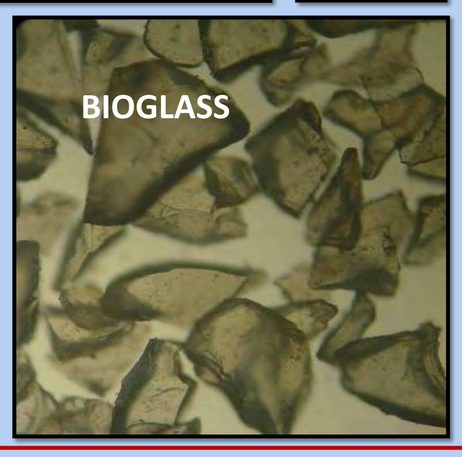
This study aimed at:

1. Assessing the micro-shear bond of an innovative simplified process to provide a reliable bonding of a resin cement to YTZP ceramics through indirect in-situ silica nanoparticle coating method (Tribo) using organic Si and Zr alkoxy R-Si(OR')$_3$ precursors

2. Assessing the effect of air-abrasion on the micro-shear bond when operated onto Tribo-treated and untreated YTZP using a silica-rich bioglass 45S5 (BAG) or aluminum trioxide (AlO).

3. Analysing the fractographic failure patters of the debonded specimens via optical microscopy.

Materials and Methods



SPECIMEN PREPARATION AND SEM-EDX ANALYSIS:

a. Pre-sintered blocks of Zr dental ceramic 10x9x9 mm.

b. Silica-coating method

c. Air-abrasion with AlO and Bioglass 45S5 Sylc

BONDING PROCEDURES:

a. Putty silicone was used to fabricate moulds

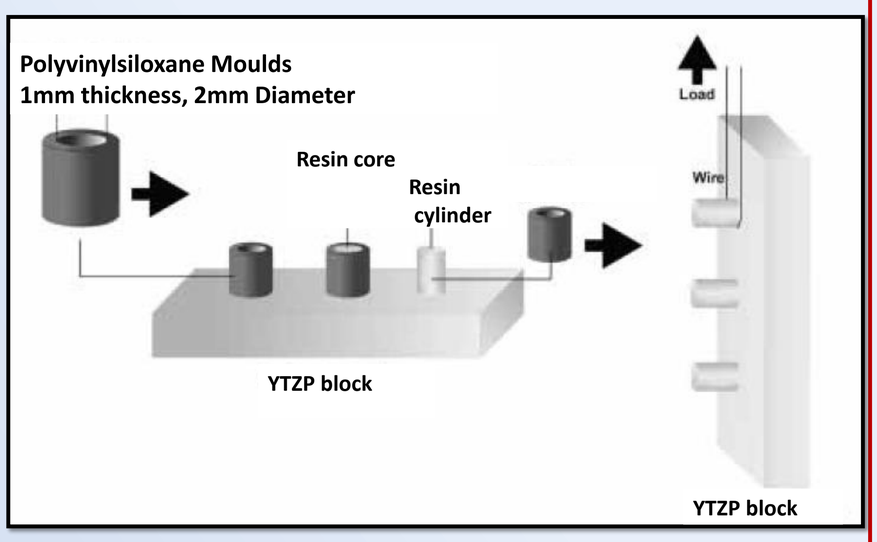
b. All groups received a layer of organo-silane

c. Moulds were placed on the surface of the zirconia blocks and filled with dual-cure resin cement

d. Cement was light-cured for 60 s

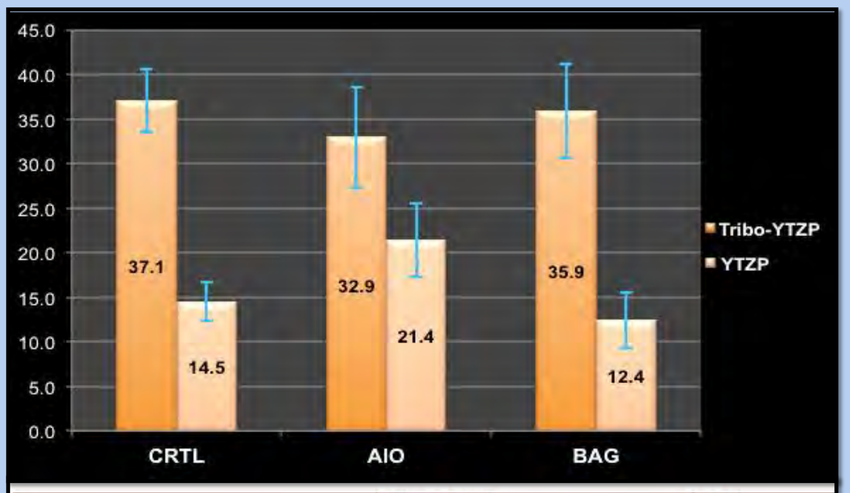
e. For each group, 10 resin cement cylinders were built up on differently treated/untreated ceramic surfaces.

f. Samples were stored in distilled water at 37ºC for 24 hr or 3 months



BOND STRENGTH TEST AND FAILURE ANALYSIS :

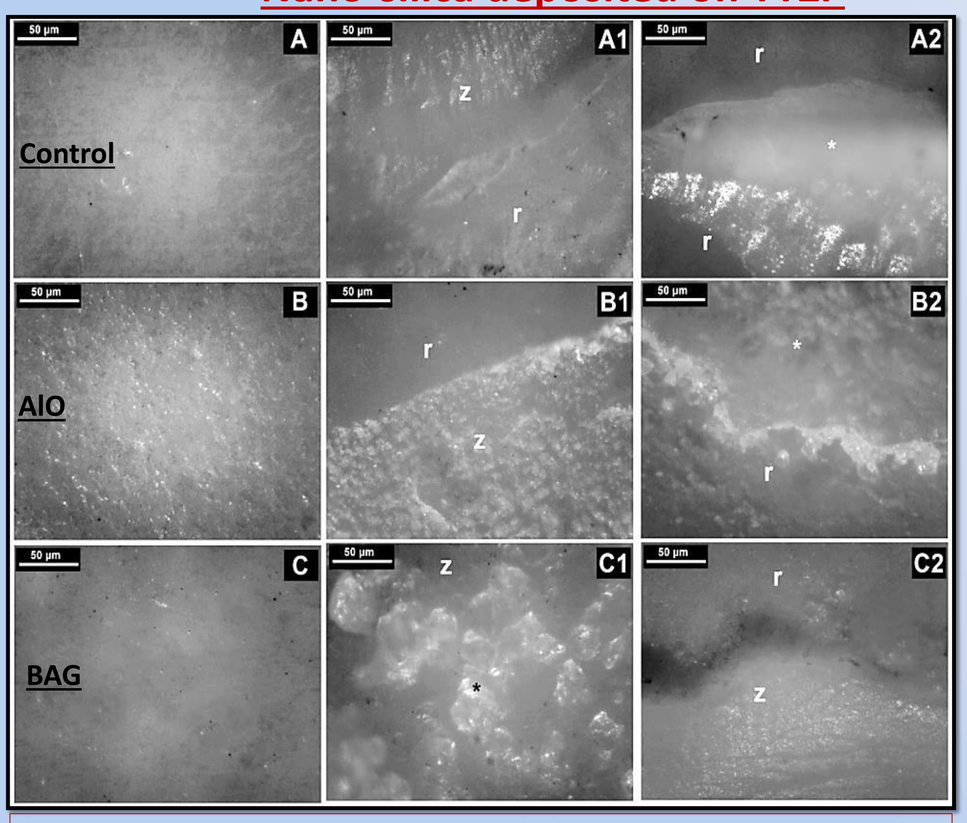
Micro-shear bond test and failure analysis high-resolution optical microscope



	Tribo-YTZP	YTZP
NO treatment (CTRL)	37.1 ± 3.5 ^{a1} [75/25/0]	14.5 ± 2.2 ^{a2} [0/15/85]
Aluminium oxide (AlO)	32.9 ± 5.6 ^{a1} [70/27/3]	21.4 ± 4.1 ^{b2} [0/55/45]
Bioglass (BAG)	35.9 ± 5.3 ^{a1} [70/30/0]	12.4 ± 3.1 ^{a2} [0/10/90]

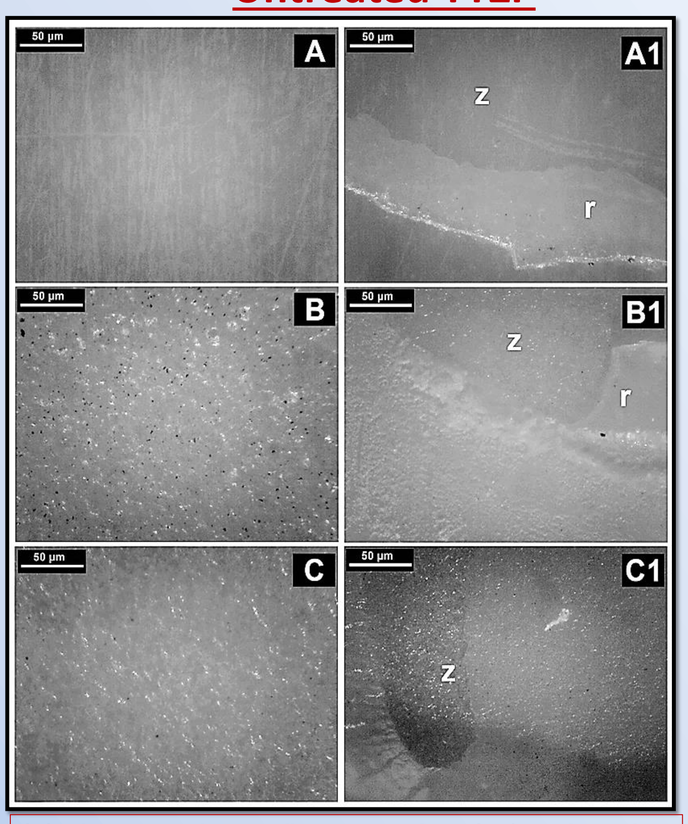
Same numbers in row indicate no statistical difference between Tribo- YTZP and untreated YTZP surface after air-abrasion treatment (AlO or BAG) or no treatment (CRTL).
Same letters in column indicate no statistical difference induced by each treatment (AlO; BAG; CTRL) on the same surface (Tribo-YTZP; YTZP; CTRL).
Numbers in parenthesis indicate the percentage of debonding failures obtained in each experimental group (cohesive/mixed/adhesive).

Nano-silica deposited on YTZP



(A): Presence of silica deposited superficially. (A1): Image after shear bond test, which debonded in mixed mode with remaining presence of resin (r) on zirconia surface (Z). (A2): Surface after shear bond test, which debonded in cohesive mode.
(B): Image of a rough surface created after air-abrasion application using aluminium oxide (B1): Surface after mirco-shear bond test which debonded in mixed mode with remaining presence of resin (r) on zirconia surface (Z). (B2): Image shows tribo-YTZP surface after micro-shear bond test, which debonded in cohesive mode.
(C): Image of tribo-YTZP surface specimens characterised after air-abrasion application using bioactive glass (BAG); note absence of clear roughness on surface which indicates silica tribo layer on surface is still present (C1): Image of remaining BAG particles on tribo-YTZP surface after mirco-shear bond test. (C2): Image of tribo-YTZP surface after mirco-shear bond test, which debonded in mixed mode with remaining resin (r) on zirconia surface (Z).

Untreated YTZP



(A): This image shows a flat YTZP surface. (A1): surface of YTZP after mirco-shear bond test which debonded in adhesive mode leaving a very little remaining presence of resin (r) on the zirconia surface (Z).
(B): Rough surface created after air-abrasion application using aluminium oxide. (B1): Surface of YTZP after shear bond test debonded in adhesive mode leaving a very little remaining presence of resin
(C): Surface after air-abrasion with BAG; note presence of a slight roughness on the surface created by air-abrasion
(C1) This image shows surface of YTZP after mirco-shear bond test, which debonded in mixed mode with no remaining presence of resin on zirconia surface (Z).

Conclusion:

1. This study introduces a novel, simple, safe, non-toxic and cost effective method to deposit nano-silica on the zirconia surface so providing reliable bond strength when using resin cements.
2. The application technique involves a sintering time and temperature similar to clinical and laboratory processing of oxide ceramics
3. Air-abrasion treatment with alumina is required to improve bond strength of untreated zirconia.
4. This innovative method could also be considered for bonding of other types of polymeric materials for varied applications of Y-TZP ceramics as biomaterials