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UMINHO CMEMS CENTER FOR MICROELECTROMECHANICAL SYSTEMS

Effect of Short Pulse Laser Patterning on Adhesion of Resin-Matrix Cements to Zirconia

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Centre for MicroElectroMechanical Systems(CMEMS)

Contents

1. Introduction

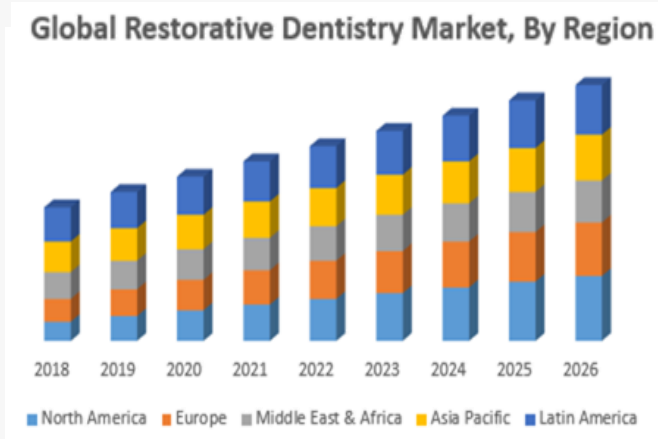
Motivation and Demand

Increasing all-ceramic dental restoration demand to avoid metallic alloys

All-ceramic adhesion problem with current interventions

(e.g., Sandblasting)

The global market still increasing, representing a billion industry



US$46 billion by 2026

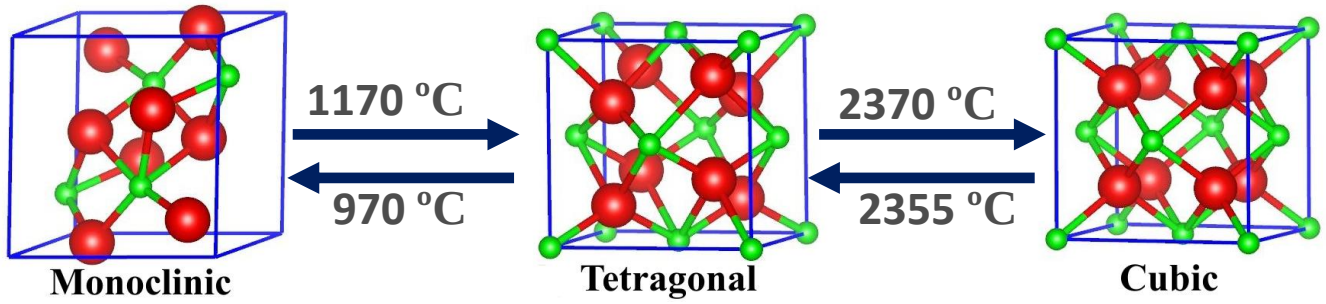
2.1 Zirconia in dentistry: Back ground

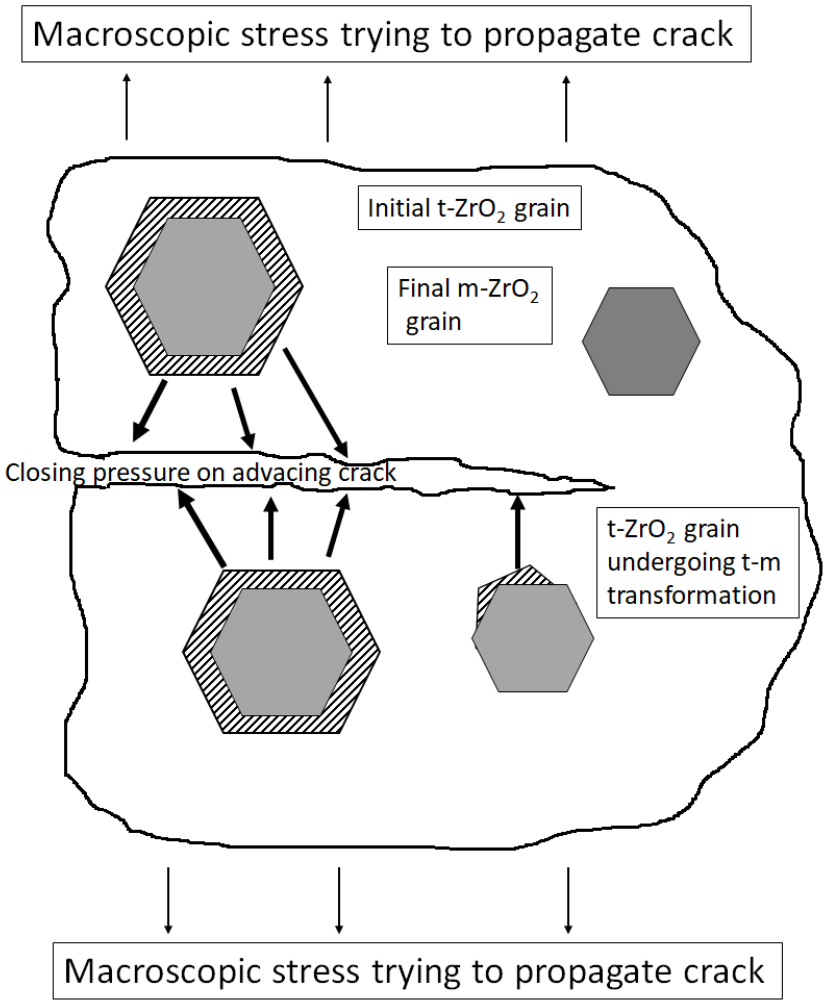
- Superior mechanical property

(density:6.05 gm/cm^3, Hardness:1350, Flexure strength:1000MPa, Compressive strength:2000MPa, Young's Modulus 205 Gpa)

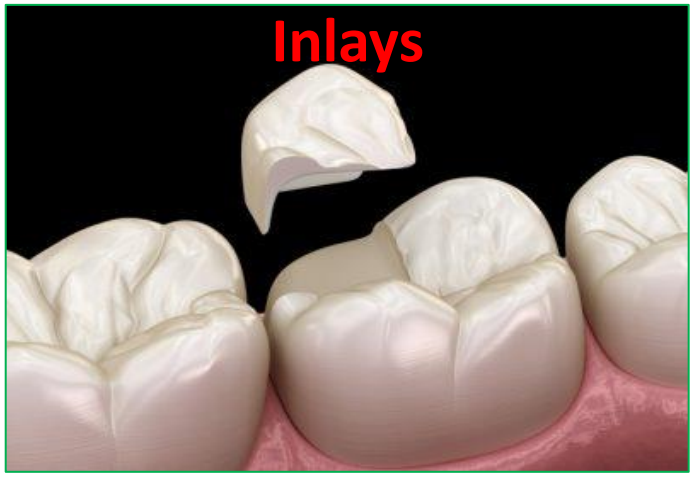
Ceramic Steel

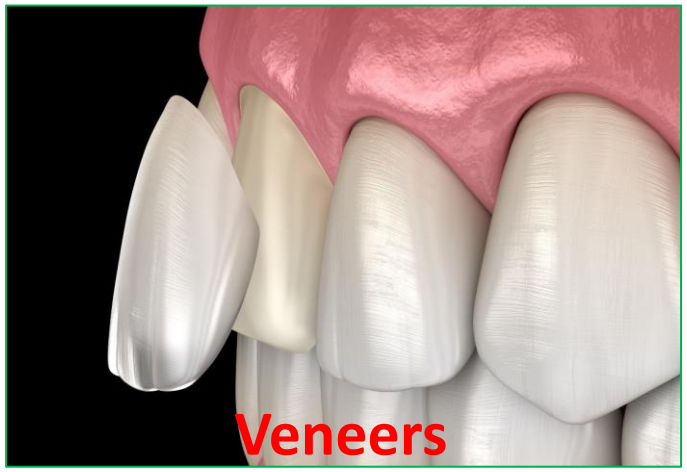
- Superior optical property
- Radiopacity (No radioactive concerns)
- Superior biocompatibility(no adverse reactions in human body)





2.2 ‘All-ceramic’ Secondary Restoration





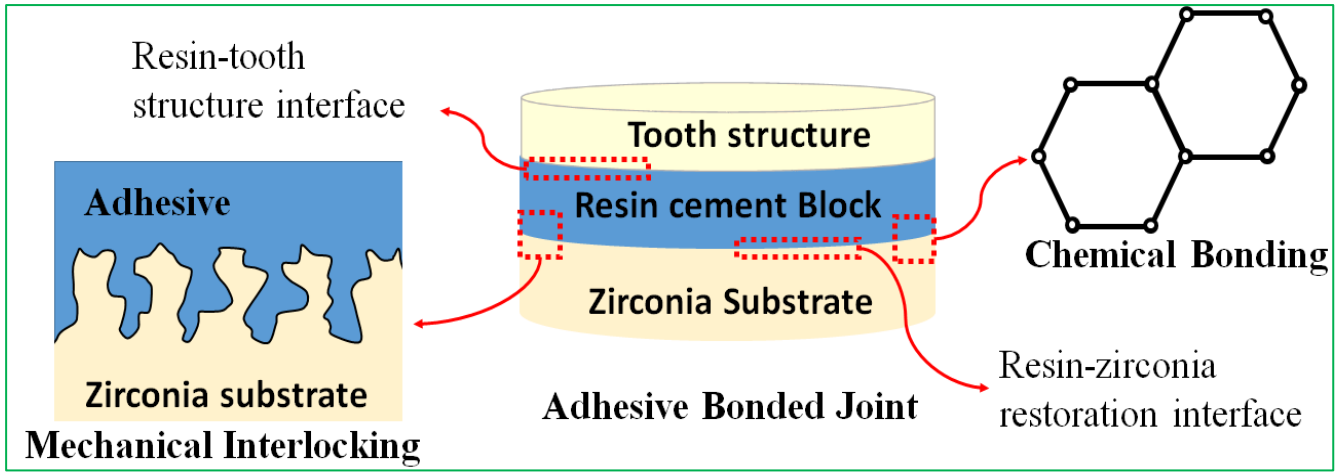
2.3 Adhesion in zirconia

- Adhesion between resin composite cement to indirect dental restorations is a vital factor for clinical success.

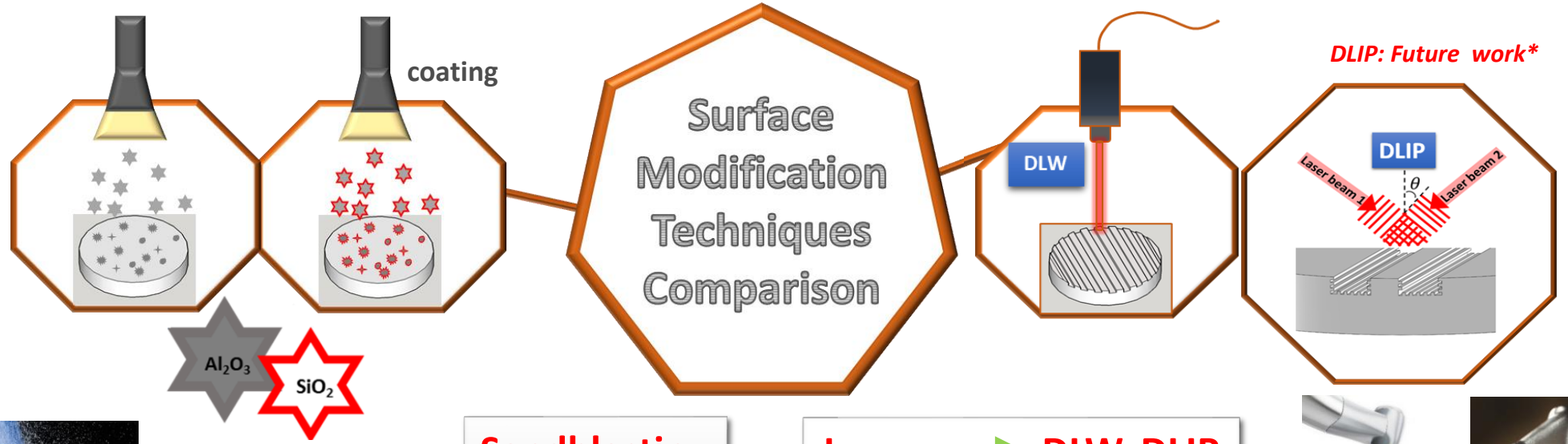
- The adhesion between dental ceramics and resin based composites is the result of a physicochemical interaction across the interface between the resin (adhesive) and the ceramic (substrate).

- The physical contribution to the adhesion process is dependent on the surface treatment and topography of the substrate and can be characterized by its surface energy.

- The chemical contribution to the adhesion is dependent on silane coupling agent, which promotes a chemical bond to any resin-based adhesive/cement system



3. Existing Challenges and Proposed Solution(Objective)



Sandblasting vs **Laser ▪▪▪▶ DLW, DLIP**

Current Problem: Sandblasting

Detrimental to the life span of the restoration

Damaged Surface | Damage in the internal structure of the material

Uncontrolled Microstructure | Unpredictable Surface Parameters

Prone to contamination | Random Topography | Phase Transformation

Can't be optimized | Operator can't control outcome

Solution: Laser(DLW, DLIP)

Controlled/Pre-designed surface Topography | Operator controlled Microstructure

Tunable Surface Parameters – wettability, roughness | Optimized adhesion Property

Can be Digitally Optimized | Ease of Automation | Multiscale Roughness Possible

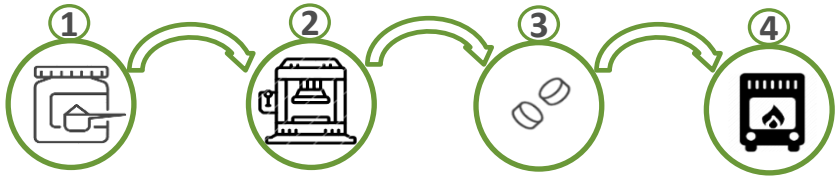
No Phase Transformation | Contact Less Technology-No Contamination | Flexible Process

Minimum Collateral damages | Operator sensitive | Fine and Precise cut Dimensions

Predictable Surface Parameters | Internal Structure Unaffected | Operator sensitive

4. Overall Summary of All Tasks of this work

MATERIALS



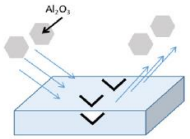
METHODS FOR SURFACE MODIFICATION


SAND BLASTING

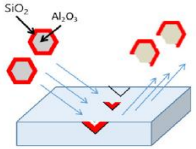

DLW


MICROMACHINING *

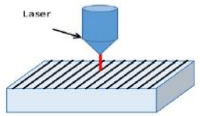

DLIP *



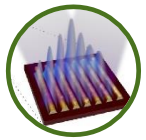
ALB



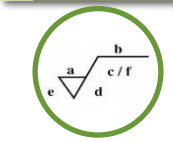
SIL *



DLW

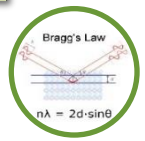

DLIP surface *

SURFACE CHARACTERIZATION



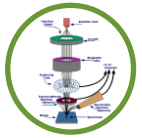
ROUGHNESS


WETTING ANGLE



XRD *


EDS *


SEM

MECHANICAL CHARACTERIZATION


BIAXIAL FLEXURAL STRENGTH *


TENSILE STRENGTH *

FATIGUE *


AGING

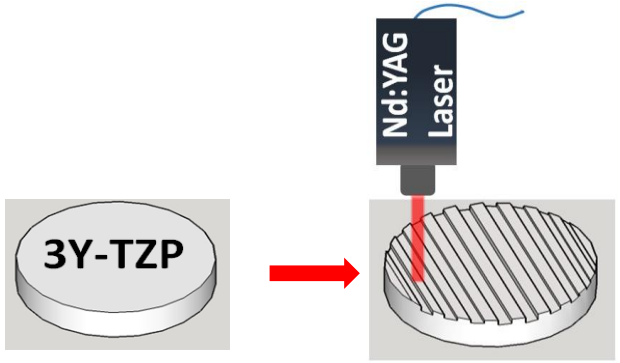

SHEAR STRENGTH

3Y-TZP: 3 mol% Yttria-stabilized tetragonal zirconia polycrystals
DLW: *Direct Laser writing*
DLIP:*Direct LASER Interference Patterning*
ALB: *Alumina Blasting*
SIL: *Tribochemical Silica Coating(Silica coated Alumina Blasting)*
XRD: *X-ray diffraction*
SEM*: Scanning Electron microscopy*
EDS: Energy-Dispersive X-Ray Spectroscopy

** Future work*

5. Laser-assisted texturizations(DLW) on zirconia surfaces

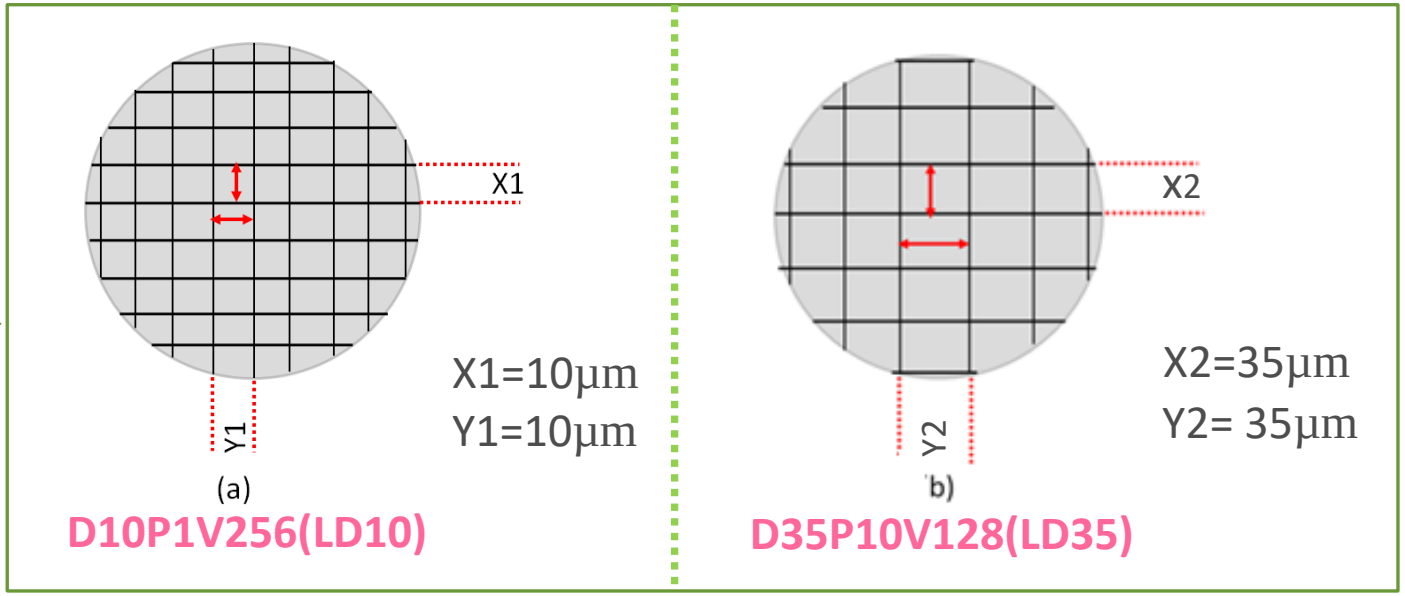
Direct Laser Writing (DLW)



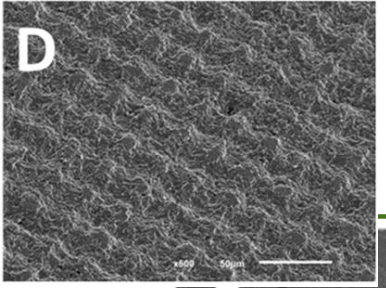
Laser parameters:

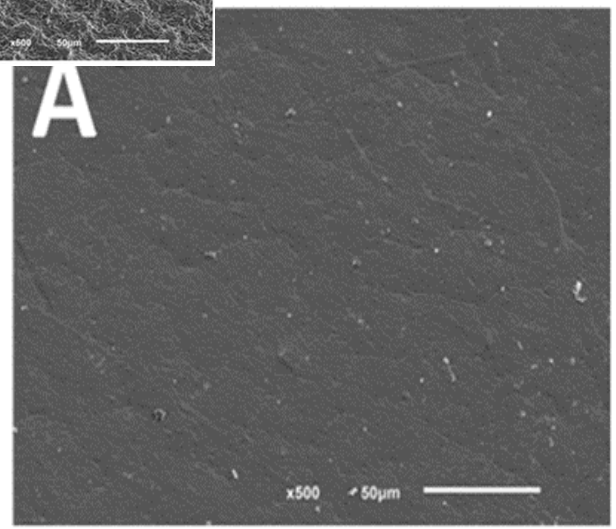
Experiment Group	Laser Power [W]	Scanning Speed [mm/sec]	Number of laser passages	Wobble Amplitude [mm]	Wobble frequency [Hz]
D10P1V256	0.06	256	1	0	0
D35P10V128	0.6	128	1	0	0

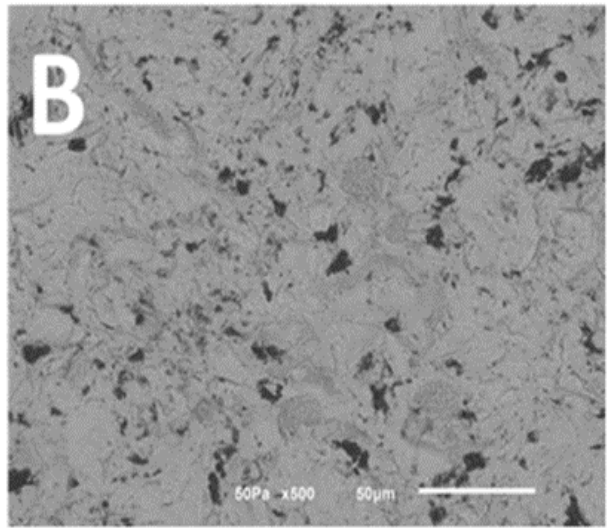
Laser Surface patterns:

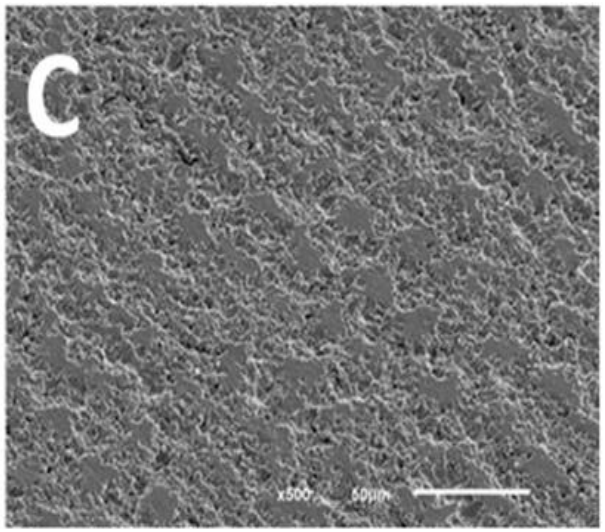


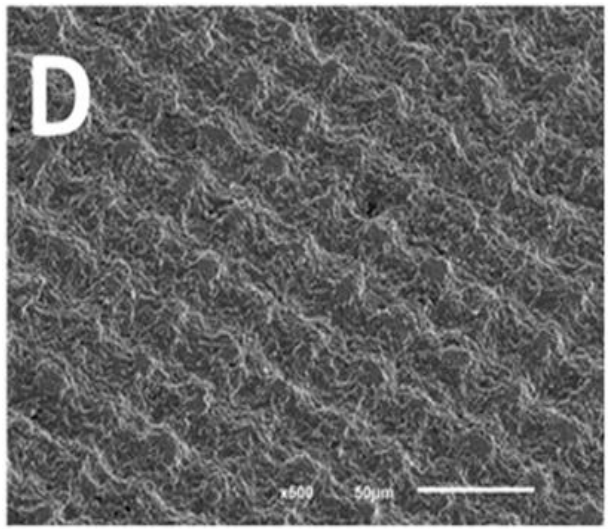
6.1 Microstructural characterization: SEM











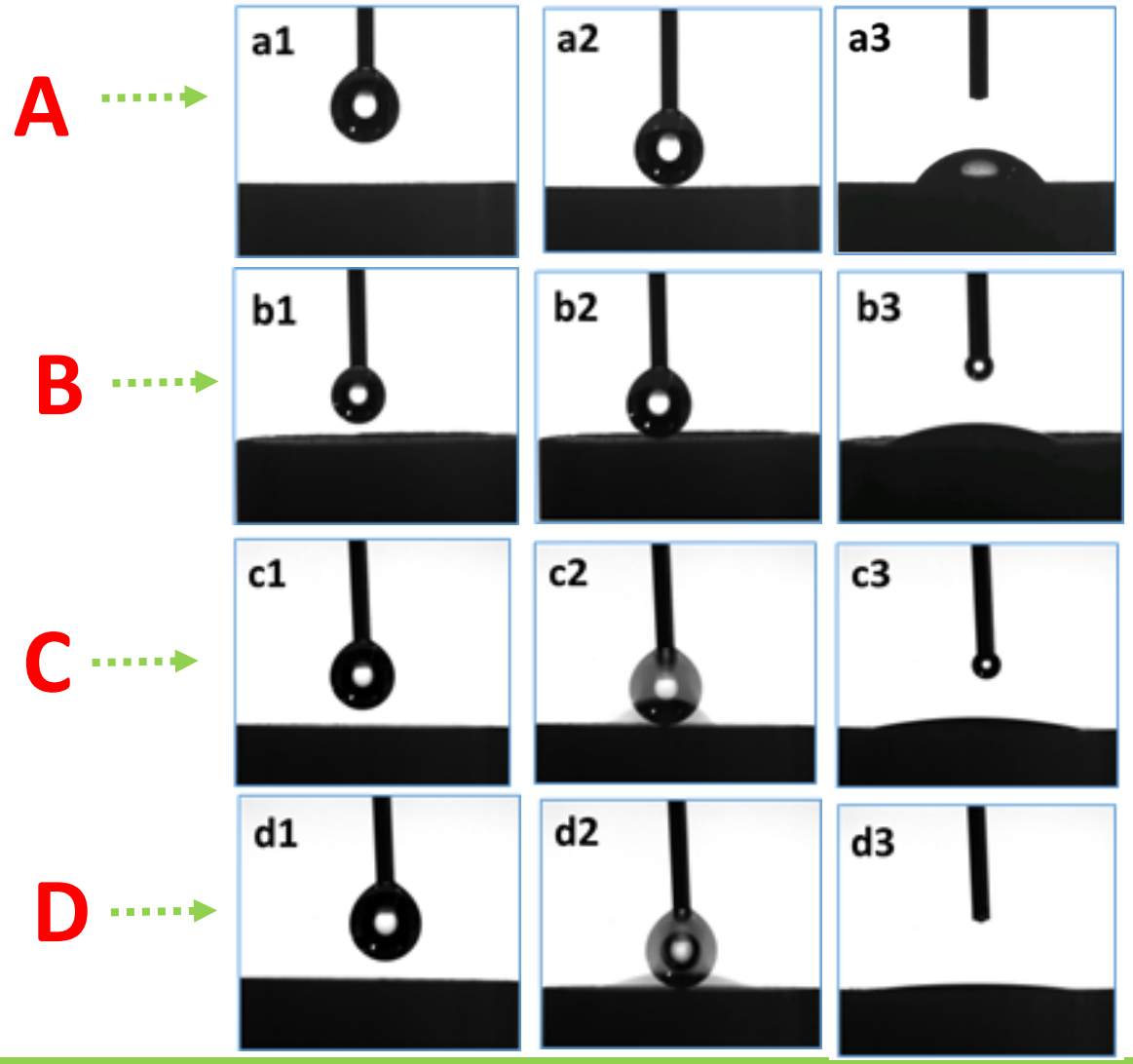
A: As Sintered
B: Alumina blasting
C: Laser Group:D10P1V256(LD10)
D: Laser group:D35P10V128(LD35)

6.2 Topographical characterization: Roughness parameters

Group Name	Average Roughness(Ra in µm) ± Std. Deviation
CTL	0.21 ± 0.01
ALB	2.75 ± 0.09
LD10	1.12 ± 0.03
LD35	2.09 ± 0.03

CTL: As Sintered
ALB: Alumina blasting
LD10: Laser(D10P1V256)
LD35: Laser(D35P10V128)

6.3 Wettability test: water contact angle

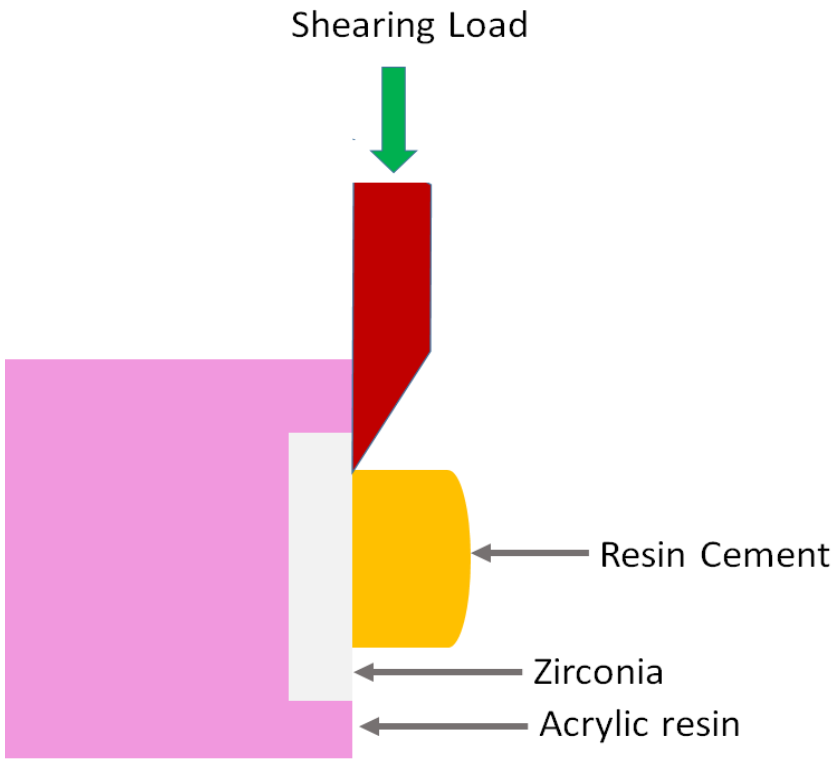


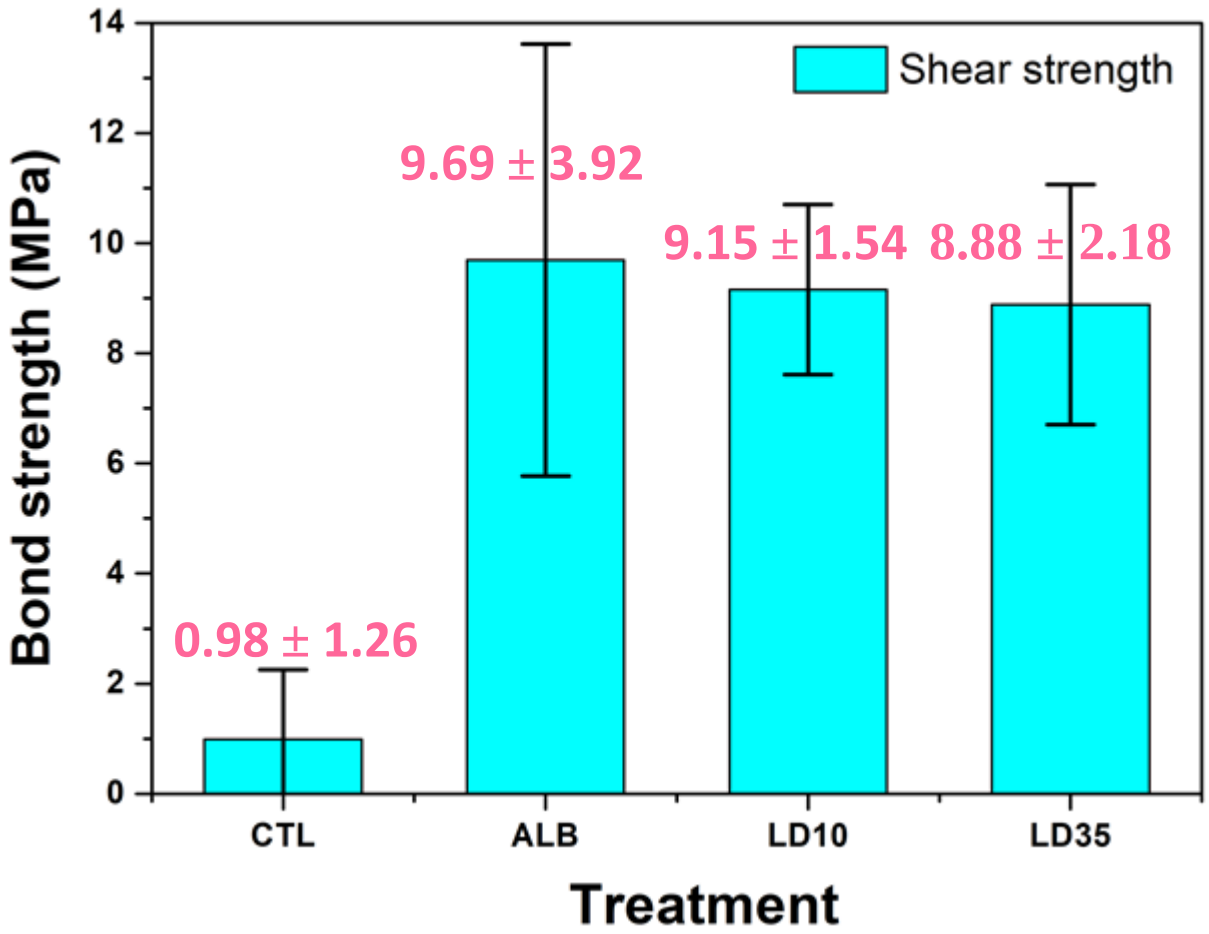
A: As Sintered(CTL)
B: Alumina blasting(ALB)
C: Laser:D10P1V256(LD10)
D: Laser:D35P10V128(LD35)

Group Name	Contact Angle ± Std. Deviation
CTL	46.32 ± 2.97°
ALB	24.8 ± 3°
LD10	19.1 ± 7.4°
LD35	9.2 ± 2.0°

7. Shear Bond Strength(SBS) Test

Shear bond strength test [ISO 29022:2013]





8. Conclusion

Under the limitation of this study it can be concluded that:

- Nd:YAG based short pulse laser patterning improved surface morphology, roughness and wettability.
- Laser textured zirconia surfaces yielded to higher shear bond strength of resin cement to zirconia without structural damage to the surface.
- Although highest SBS value was observed in ALB group, nevertheless the impact surface damage and its effect on the longevity of restoration needs to be studied,
- The standard deviation(Error) is highest for the ALB group.
- The SBS value under thermocycling condition also need to be analyzed in future study for all surface treatments groups.
- The XRD analysis of all treated surfaces will further unveil the resulting phase changes(t→m) of the respective groups.
- Nd:YAG laser can be employed as an effective alternative for surface modification for adhesion enhancement to zirconia.

Acknowledgments

This study was supported by FCT national funds, under the national support to R&D units grant, through the reference project UIDB/04436/2020 and UIDP/04436/2020. Additionally, this work was supported by POCI-01-0145-FEDER-031035_LaserMULTICER, CNPq-Brazil (CNPq/UNIVERSAL/421229/2018-7) and CAPES-HUMBOLDT Program (Grant number: 88881.197684/2018-01).

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Thank you for your attention.

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