



Mechanical Properties of Milled vs Printed Ceramic Reinforced Composite Resins

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Introduction

Advantages of digital workflows using CAD-CAM systems over the conventional analog method, for single units, include eliminating the provisional restoration phase, reducing chair time, and increasing patient satisfaction rates¹.

CAM systems are generally classified into subtractive and additive manufacturing techniques². While subtractive manufacturing methods have been tried and tested, they still pose their own set of disadvantages and limitations such as:

- Significant amount of material wastage approaching 30% of the size of the initial ingot³.
- Possible incorporation of microscopic imperfections and potential surface cracks during the milling procedure, which can compromise the restoration's longevity^{4,5}.

The use of additive manufacturing techniques, also known as 3D printing, emerged recently as an alternative manufacturing workflow to address some of the aforementioned challenges of milling, and to offer flexibility in designing and fabricating intricate shapes. However, their mechanical properties have not been studied sufficiently which is what we intended to investigate.

Materials and Methods

Two types of milled materials TetricCAD (Ivoclar) and Cerasmart (GC America), and one printed material Ceramic Crown (Sprintray) were evaluated for their (1) Flexural Strength, (2) Fracture Toughness, and (3) Shear Bond Strength, according to their ISO standards.

Sample Testing

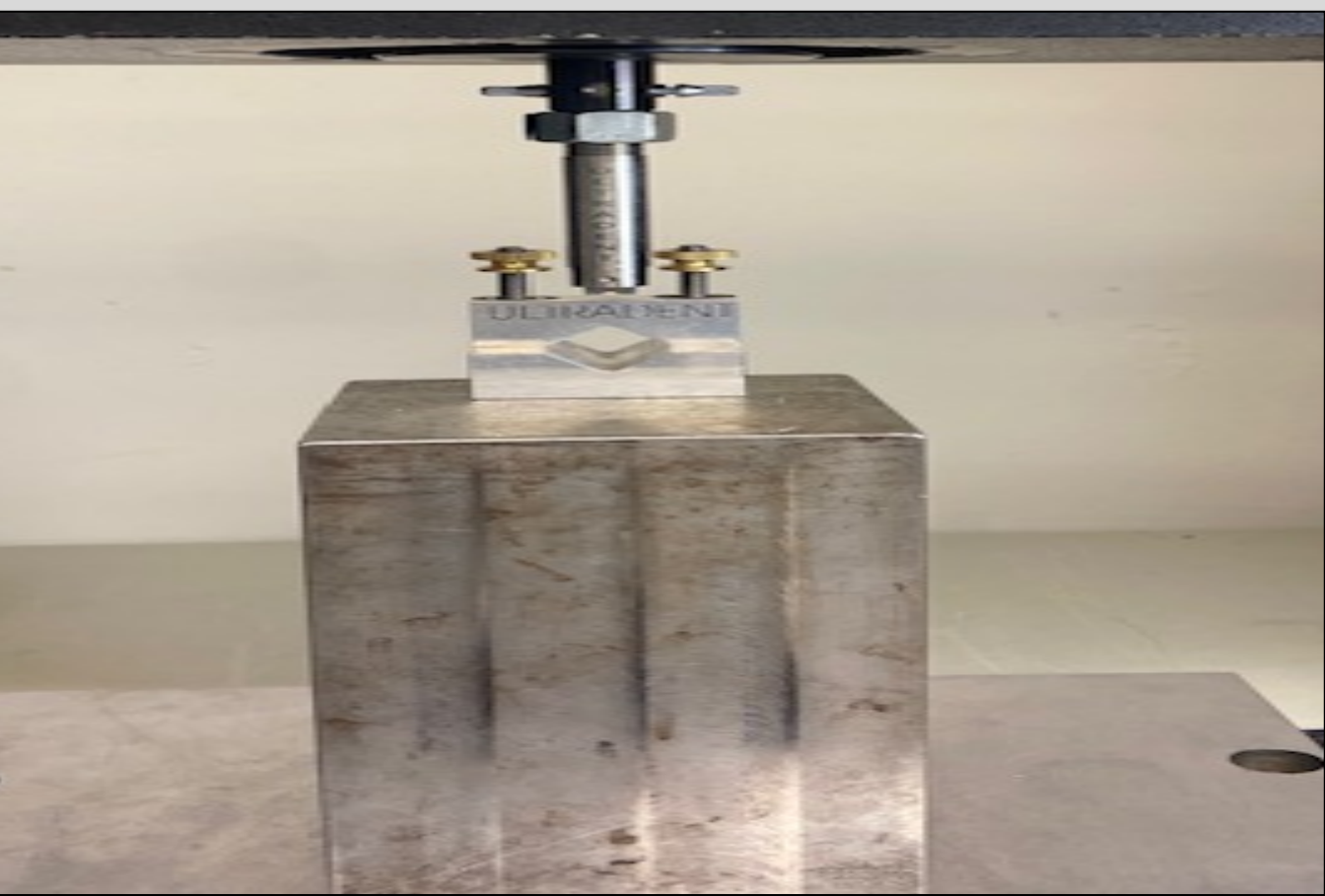
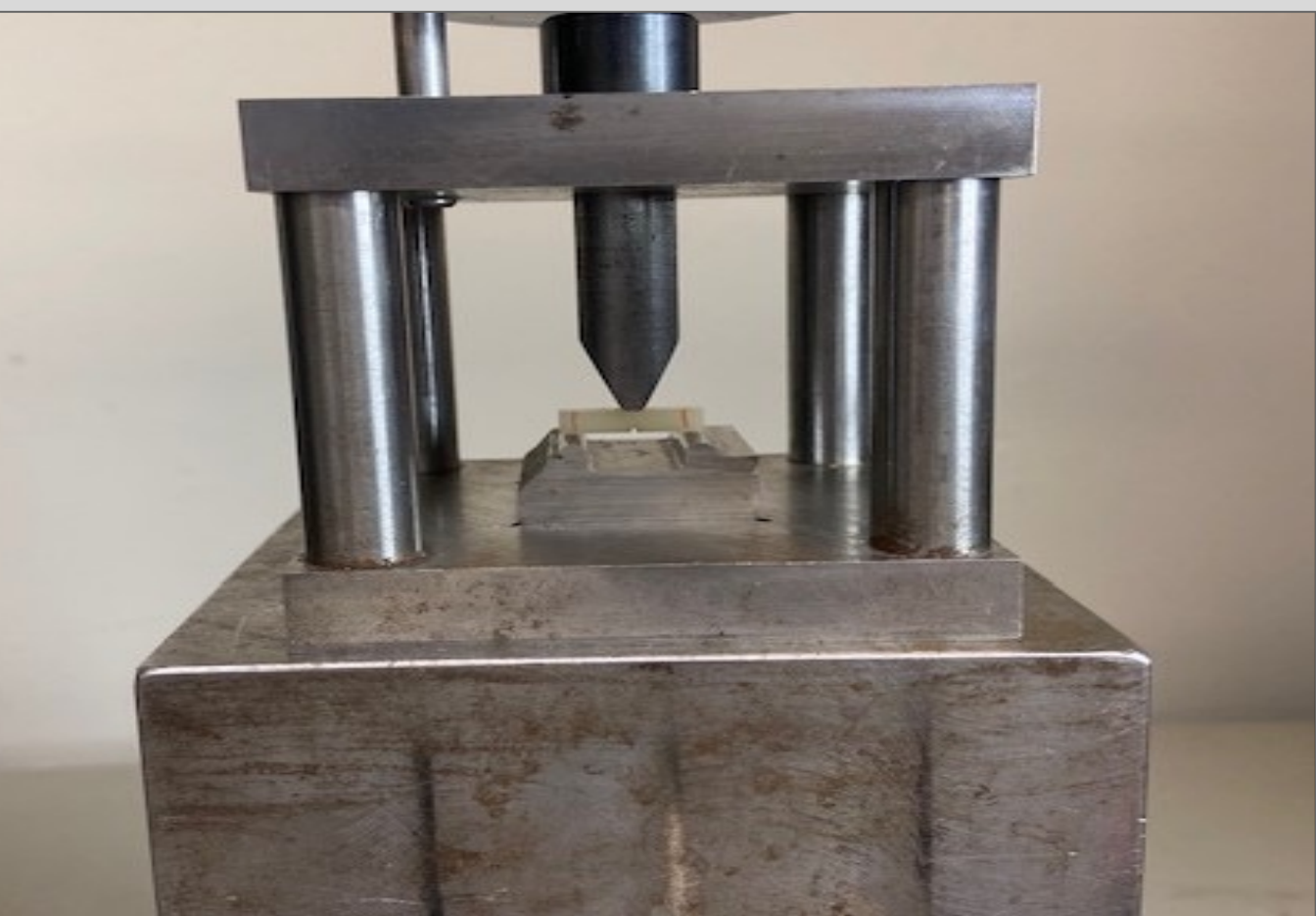
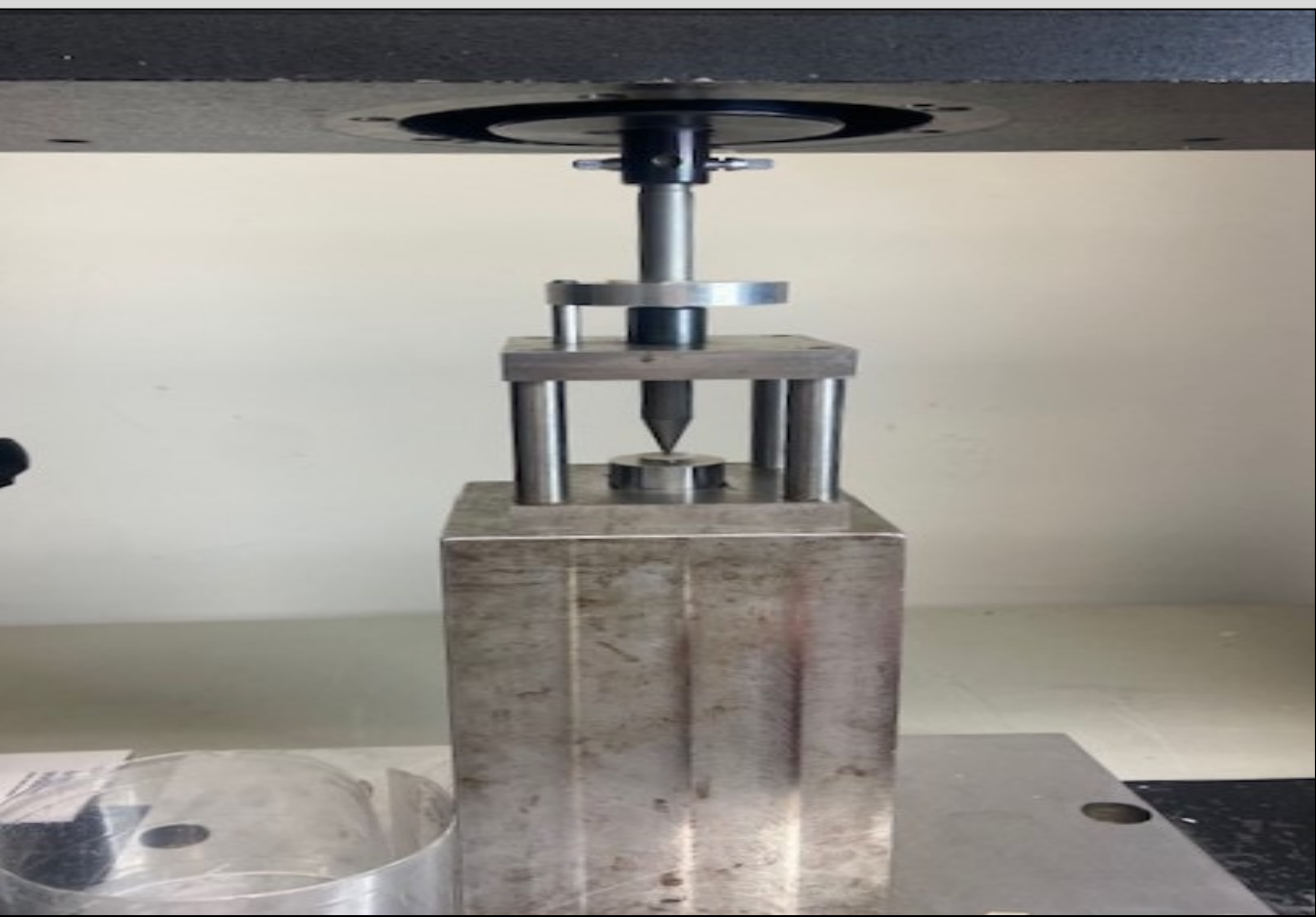
45 ceramic discs total (n=15) were fabricated in each material. Testing was completed on a Piston-on-three ball jig (Universal Testing Machine). Flexural Strength was derived utilizing the formula as outlined in ISO 6872 Standard.

A total of 32 sample rods were made: 8 TetricCAD (Ivoclar), 8 Cerasmart (GC America) and 16 Ceramic Crown (Sprintray) [8 in the vertical and 8 in the horizontal direction] were fabricated.

Single Edge V Notch Beam Test was used according to ISO 23146.

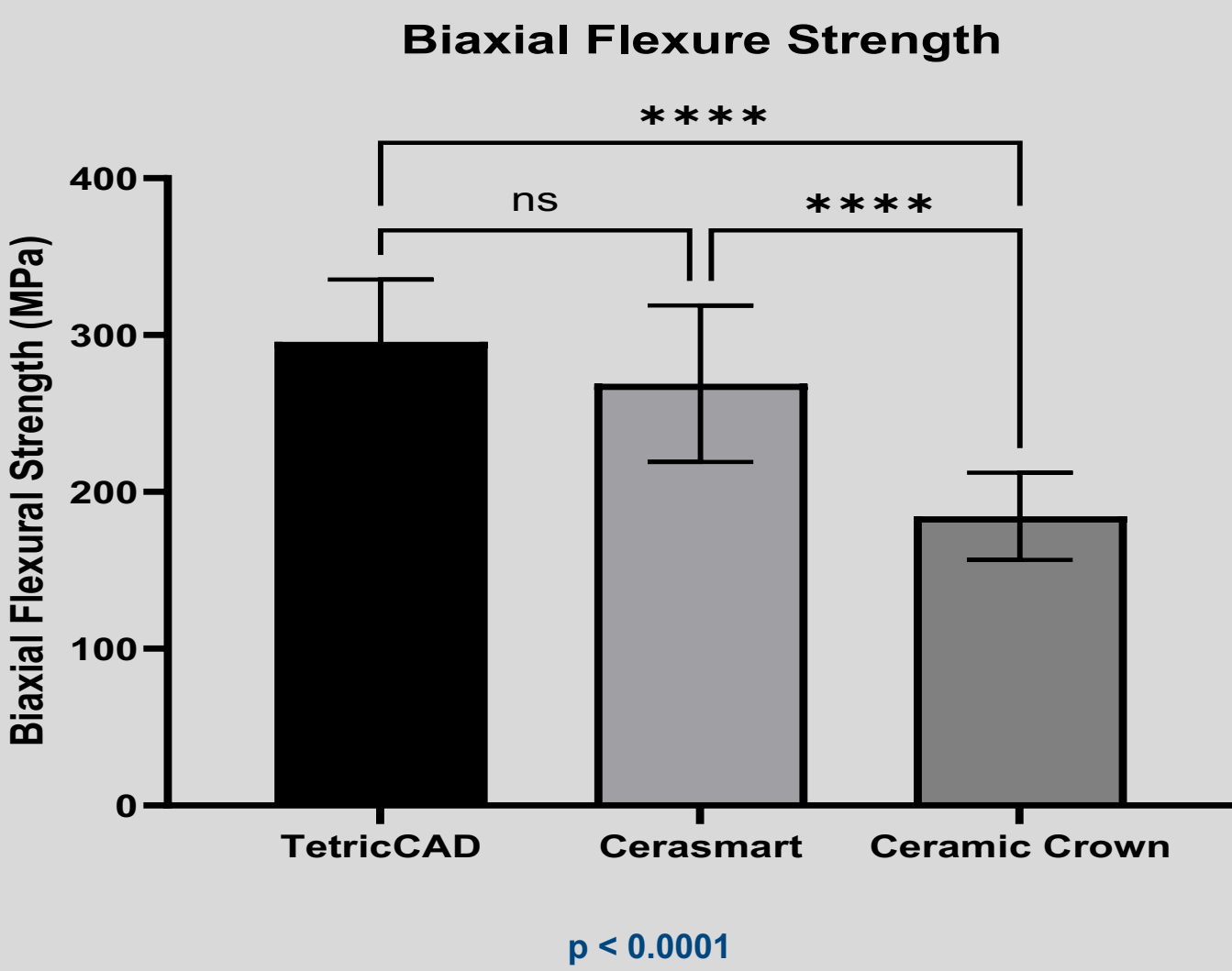
30 resin specimens were mounted in an Ultradent mold.

Application: Adhese Universal (Ivoclar) and Panavia V5 (Kuraray)
Testing: 1KN load cell at 1mm/min crosshead speed. Resin cement bond to tooth structure is well studied; We decided to investigate bond strength between substrate material and resin cement.



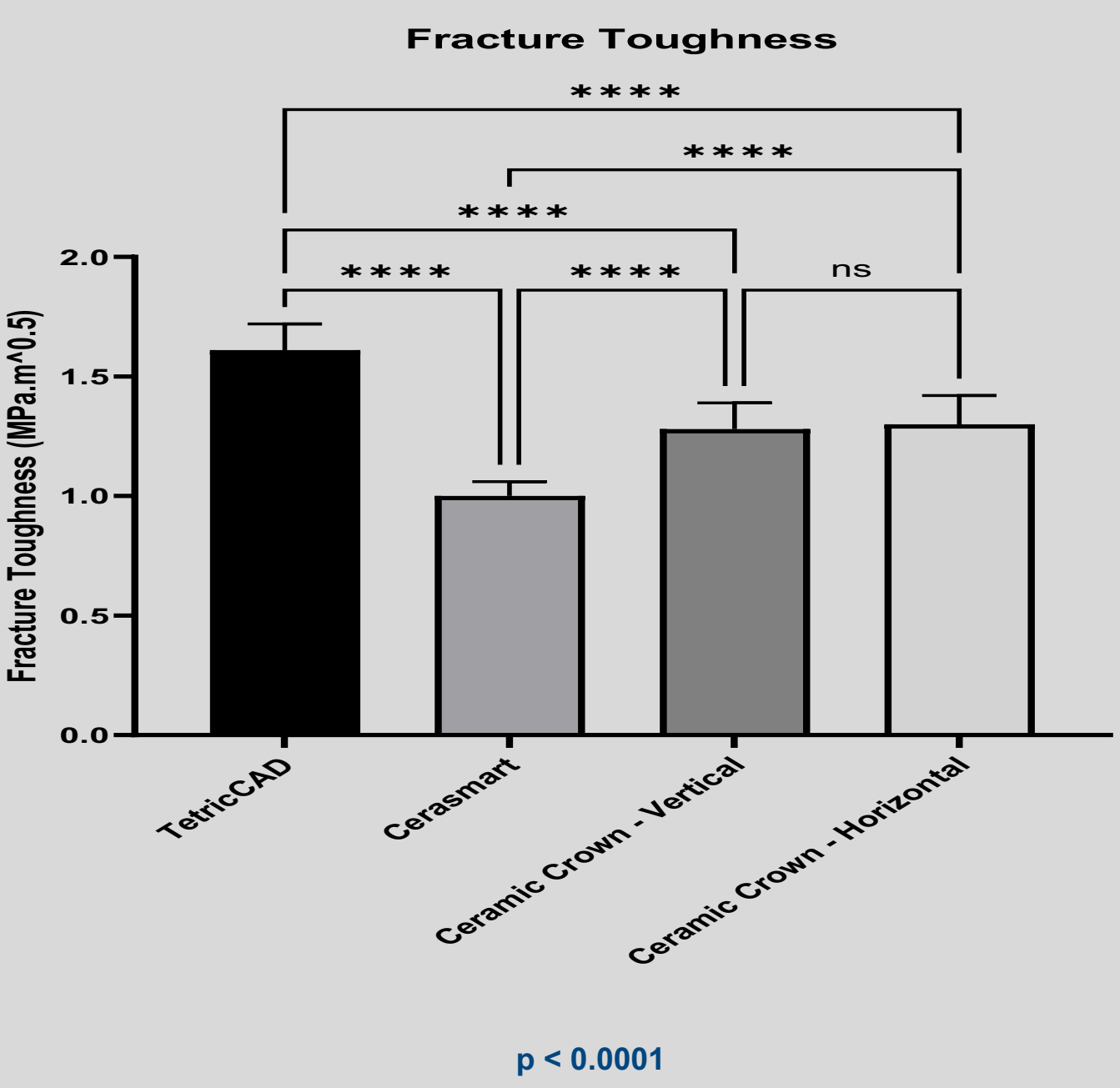
Biaxial Flexure Strength

The biaxial flexural strength results ranged from 295.71 ± 39.83 MPa to 184.39 ± 27.86 MPa ($p < 0.0001$). In general, TetricCAD (Ivoclar) and Cerasmart (GC America) exhibited the highest values, while Ceramic Crown (Sprintray) showed the lowest



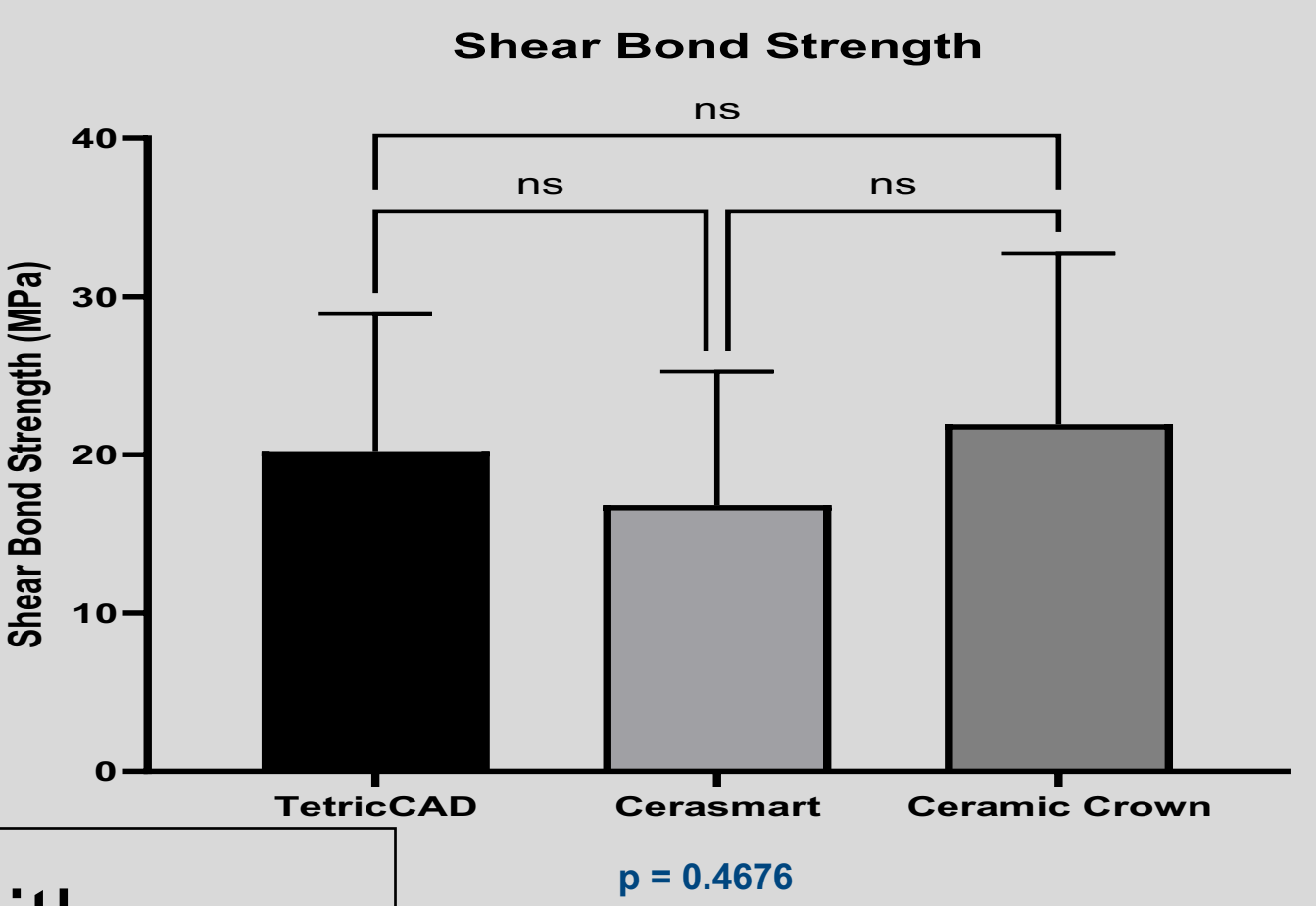
Fracture Toughness

The fracture toughness results ranged from 1.61 ± 0.11 MPa·m^{0.5} to 1.00 ± 0.06 MPa·m^{0.5} ($p < 0.0001$). In general, TetricCAD (Ivoclar) presented the highest values, followed by Ceramic Crown (Sprintray). Cerasmart (GC America) exhibited the lowest values. There was no statistically significant difference between the vertical and horizontal printing directions of Ceramic Crown (Sprintray) ($p > 0.05$).



Shear Bond Strength

The shear bond strength results varied from 21.93 ± 10.82 MPa to 16.79 ± 10.82 MPa. There was no statistically significant difference among the three tested materials ($p = 0.4676$).



Discussion/Conclusions

Although the 3D printed material has been approved for use with a D2740 Code, it behaves more like a ceramic reinforced composite with some slightly inferior properties as compared with its milled counterparts.