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Evaluating The Mechanical Properties of Restorative Materials Alternative to Amalgam

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INTRODUCTION

Interest in developing new materials to replace amalgam in stress-bearing Class II restorations remains high following the introduction of the Minimata Convention. This study compared the flexural strength and fracture toughness of three commercial restorative materials suggested as amalgam alternatives and an in-house produced conventional resin composite. Materials included Fill-Up (Coltene), Cention N (Ivoclar-Vivadent) as dual-cure resin composites and EQUIA Forte (GC America), a glass hybrid restorative (EQUIA Forte Fil glass-ionomer and EQUIA Forte Coat).

MATERIALS AND METHODS

Materials (n =10) used are detailed in the below table.

Material	Filler/Powder	Resin/liquid
Composite Control	Total Filler: 80%wt (63%vol) Silanised barium aluminium silicate glass Filler size: D_{50}= 0.7 µm	Resin: BisGMA, TEGDMA BisEMA
Cention N	Total Filler : 78%wt (57%vol) Barium aluminium silicate glass, ytterbium trifluoride, Isofiller, calcium barium aluminium fluorosilicate glass filler and calcium fluorosilicate (alkaline) Filler size: 0.1 µm to 35 µm	UDMA DCP Aromatic-Aliphatic UDMA PEG-400DMA
Fill-Up	Total Filler: 65%wt (49%vol) Amorphous Silica and Zinc Oxide Filler size: 0.1-5.5 µm	TMPTMA, UDMA, bis-GMA, TEGDMA
EQUIA Forte	Fluoro-alumino-silicate glass and Polyacrylic acid powder	Polyacrylic acid, Distilled water, Polybasic carboxylic acid
EQUIA Forte Coat	5-10%wt silicon dioxide	Methyl methacrylate

A conventional light-curable composite was formulated as the control group. Cention N samples were prepared according to manufacturer's instructions by mixing the powder/liquid at 1:1 ratio, the mixture was then incrementally placed into the mould and light cured for 20s using BluePhase Style LED (1200mW/cm^2).

EQUIA Forte samples were prepared by mixing each capsule for 10s, material was then placed incrementally into the mould followed by application of EQUIA Forte coat which was light cured for 20s.

Flexural strength (FS) and fracture toughness were determined using a universal testing machine (Instron 3365,USA) equipped with a three-point bending apparatus at 0.5 mm/min cross head speed. Specimens were loaded on a support span with knife edge geometry, Figure (1). Fracture toughness (K_{1C}) was evaluated using the sharp single edge notch beam method [(1)], specimen configuration shown in Figure (2).

Fractographic analysis was conducted using SEM.

Statistical analysis was conducted using ONE-WAY ANOVA and post-hoc Tukey tests.

Figure (1)

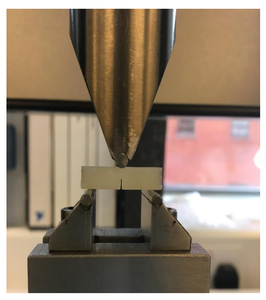
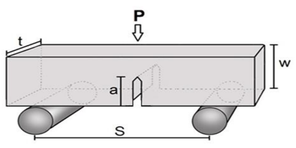
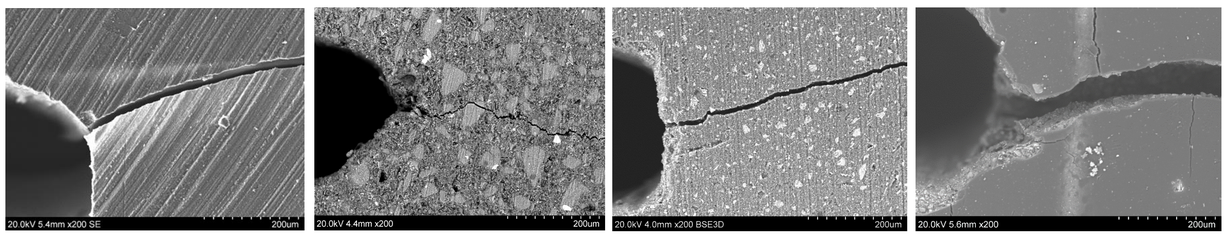


Figure (2)



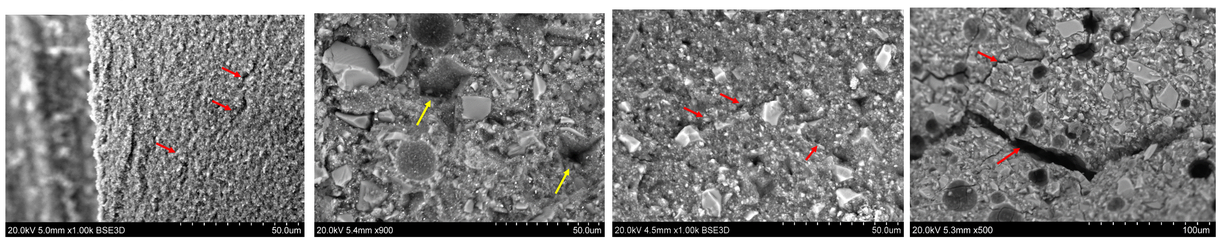
SEM analysis of broken fracture toughness specimens showed clear cracks extending exclusively from the pre-inserted notch into each specimen resulting in two distinctive fractured surfaces, examples below.

Composite control *Cention N* *Fill-Up* *EQUIA Forte*

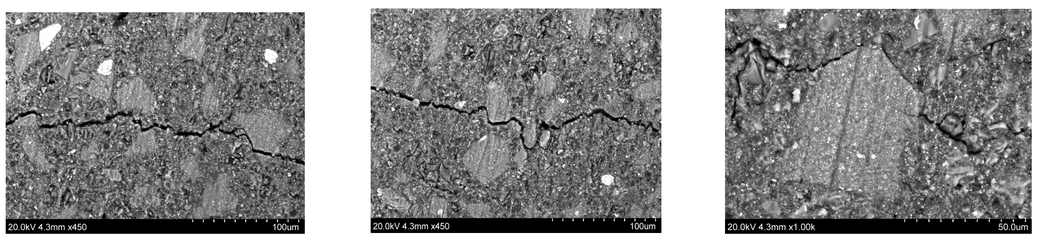


Two distinct fracture phenomena were identified: (1) The presence of major and micro crack lines running through the matrix (red arrows) and (2) The detachment of fillers from the resin matrix leaving spaces corresponding to their shape (yellow arrows). Additionally, voids were predominantly present in both Cention N and EQUIA Forte which could be attributed to the mixing of the powder and liquid components. Examples shown below.

Composite control *Cention N* *Fill-Up* *EQUIA Forte*

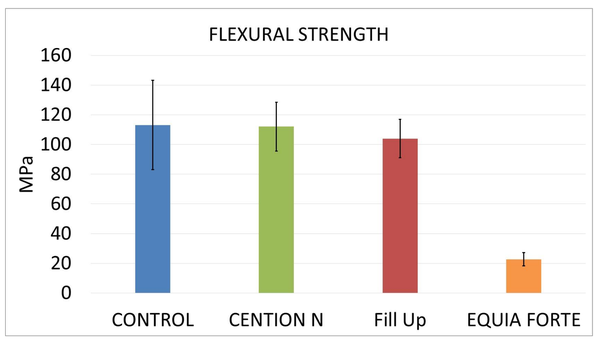


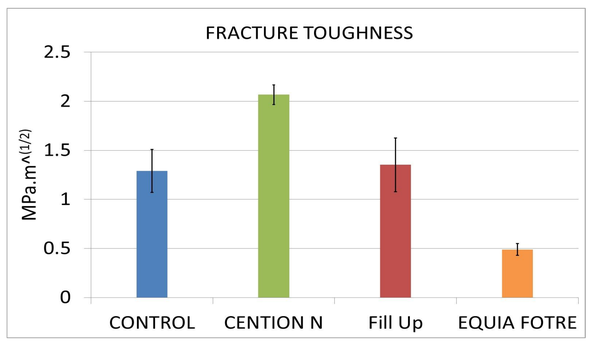
Interestingly fractured Cention N specimens showed a distinctive fracture toughening phenomenon of "crack deflection" when the tip of the crack encountered larger filler particles, examples shown below.



RESULTS AND DISCUSSION

Fill-Up and Cention N showed similar FS compared to the control (p>0.05). Fill-Up also showed similar K_{1C} to the control (p>0.05). Cention N showed increased K_{1C} compared to both the control and Fill-Up. However EQUIA Forte showed the lowest K_{1C} compared to Fill-Up, Cention N and the composite control (p<0.05).





CONCLUSION

Fill-Up and Cention N exhibited similar/enhanced mechanical properties compared to a highly filled conventional resin composite and significantly higher values compared to a glass hybrid material. This shows promising results considering that K_{1C} and FS directly correlate to the clinical performance and longevity of restorations [(2)].

REFERENCES

(1) ASTM E399-12-e2. Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials.

(2) HEINTZE, S. D., ILIE, N., HICKEL, R., REIS, A., LOGUERCIO, A. & ROUSSON, V. 2017. Laboratory mechanical parameters of composite resins and their relation to fractures and wear in clinical trials—A systematic review. Dental Materials