Metal Ceramic and Porcelain-veneered Lithium Disilicate Dental Crowns: A Comparative Study using VFEA

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Background

Metal ceramic (MC) systems are one of the oldest bilayer dental restorative systems that are in use since 1960s. Owing to their wide grown popularity and high survival rates, these material systems are studied extensively. However, with the focus on aesthetics rising, MC systems are slowly being replaced by all ceramic systems. One of such all ceramic systems is porcelain-veneered lithium disilicate (PVLD) system. This is a new system that has not been studied much, both clinically and computationally.

Fig. 1: Metal ceramic crowns

Aim

Both MC and PVLD systems fail due to chipping of the porcelain veneer layer, which is caused by the tensile residual stresses. This study compares the effects **cooling rates** (slow and fast) and **veneer-core thickness ratios** on the amount of residual and transient stresses produced in MC and PVLD restorations using viscoelastic finite element analysis (VFEA).

Materials and Methods

a) Thermomechanical properties

In this study, MC system had PoM/Metal and PVLD system had emax.Ceram/emax.CAD as veneer and core layers for the bilayer dental restoration. Thermal conductivity, density, specific heat, coefficient of thermal contraction (CTC), Young's modulus of each of these materials were measured at different temperatures (Fig. 2a-d).

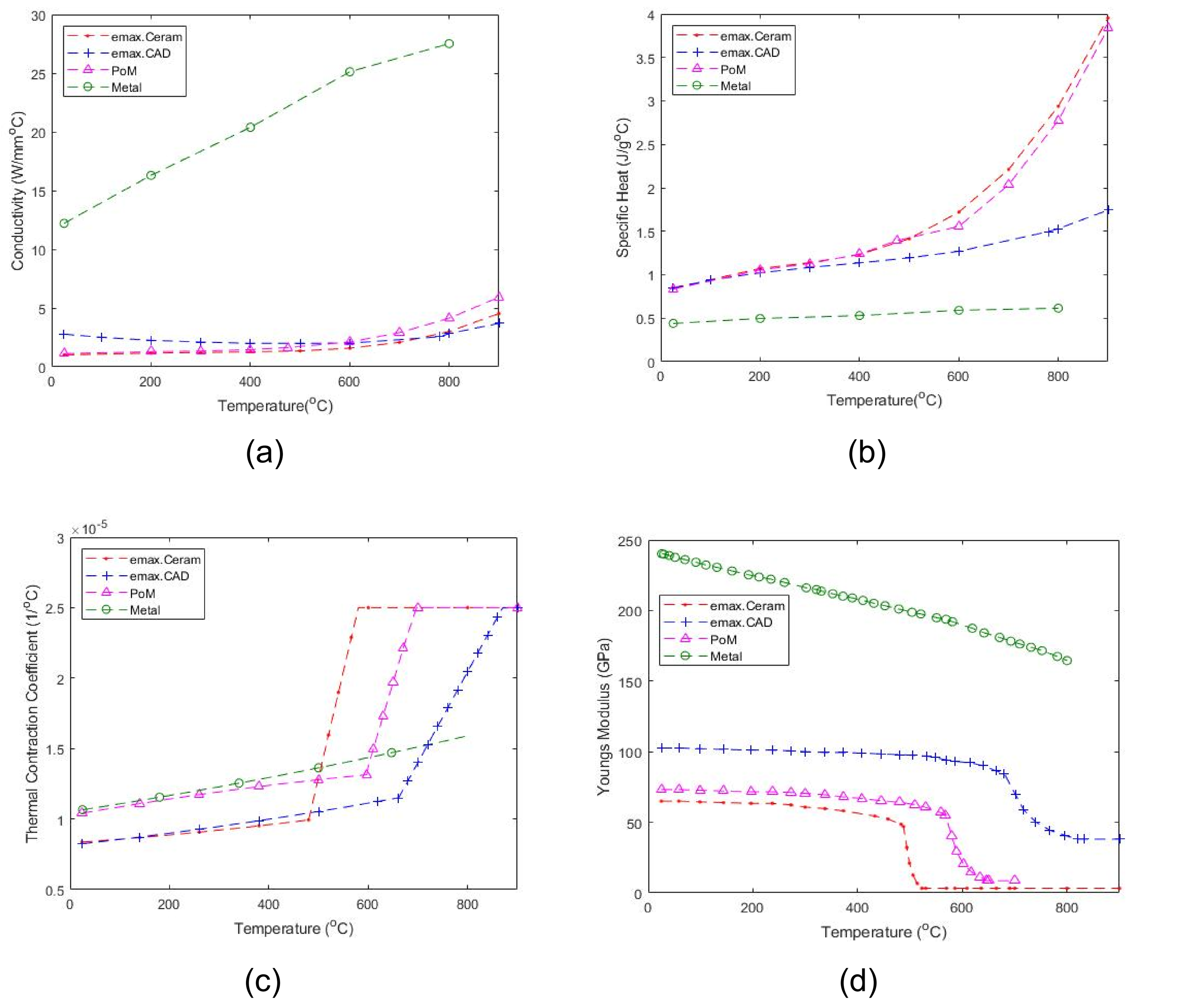

Fig. 2: Temperature dependent material properties: (a) Conductivity; (b) Specific heat; (c) Thermal contraction coefficient and (d) Modulus

b) Validation of VFEA

Bilayer plates of PVLD material system were fabricated and residual stresses in the emax.Ceram layer were measured by the Vickers indentation method (4.9 N for 5 s). Similar plates were then modeled in ABAQUS and VFEA was carried out. Simulated results were then compared with experimental data that showed an excellent match.

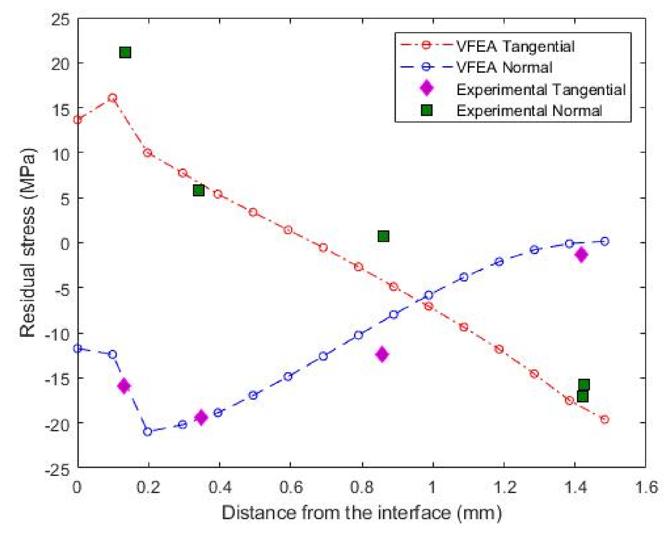

Fig. 3: VFEA experimental verification plot

c) Viscoelastic finite element analysis of axisymmetric crowns

1/4th of the 3D axisymmetric bilayer crown models were run in ABAQUS, for different veneer to core ratios and cooling rates, for each material system.

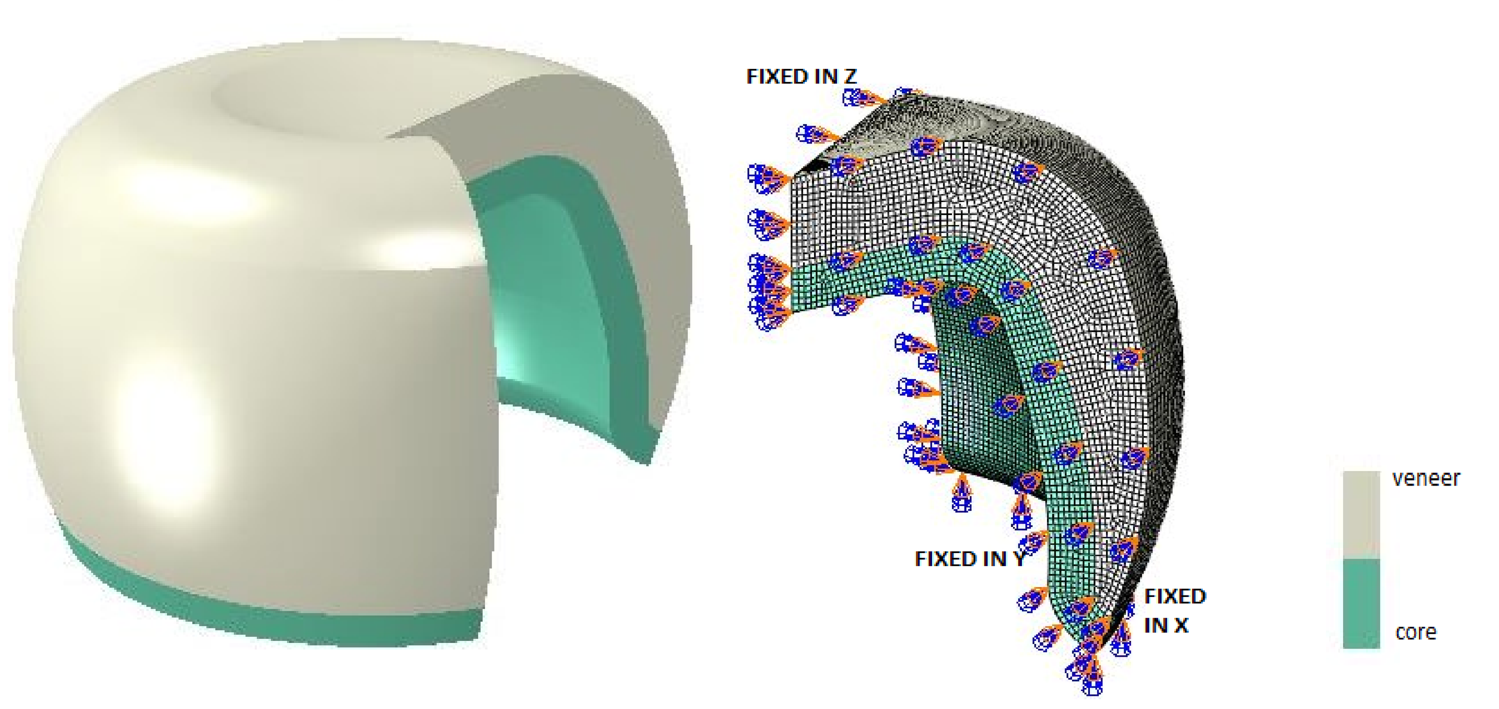

Fig. 4: Finite element model of full dental crown and 1/4th simulated model, with appropriate boundary conditions

Results

Table 1: Material Combination

Model	Veneer: Core	Bilayer System
Model 1	2:1	MC
Model 2	1:1	MC
Model 3	1:2	MC
Model 4	2:1	PVLD
Model 5	1:1	PVLD
Model 6	1:2	PVLD

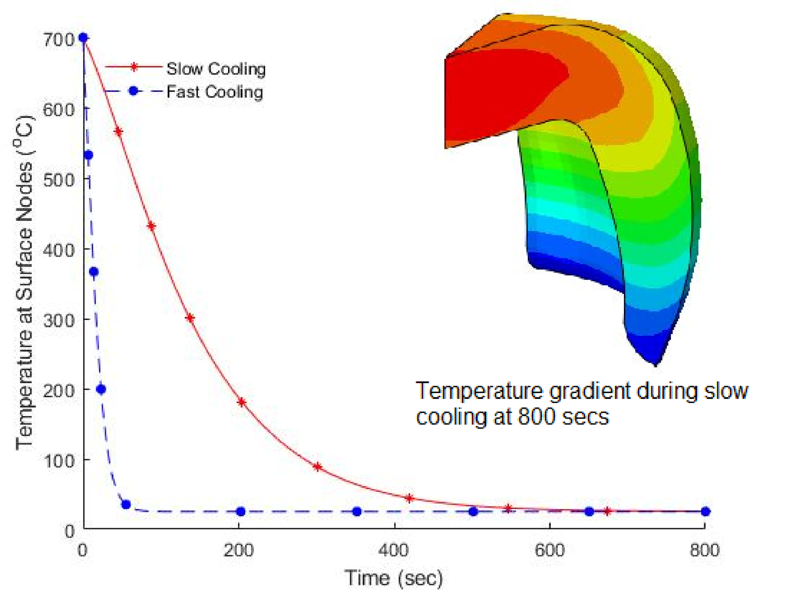

Fig. 5: Slow cooling (~30°C/min) and fast cooling (~300°C/min) temperature profile

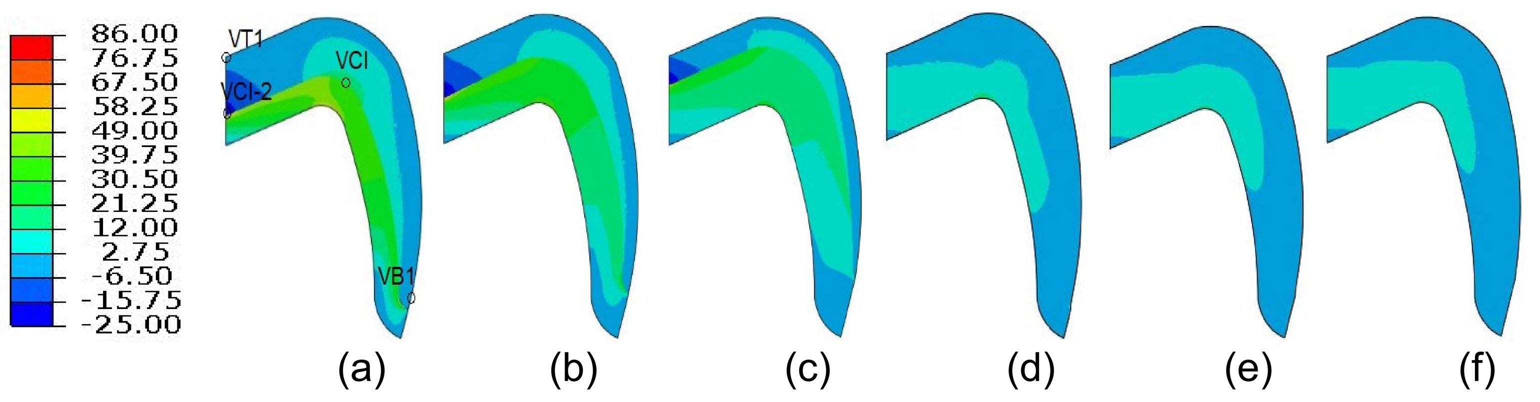

Fig. 6: Stress Contour for slow cooling in MC system: (a) Model 1 (V: 17.56/C: 82.36); (b) Model 2 (V: 13.62/C: 68.18); (c) Model 3 (V: 10.06/C: 56.69), and PVLD system: (d) Model 4 (V: 10.38/ C: 16.06); (e) Model 5 (V: 10.17/ C: 14.24); (f) Model 6 (V: 8.99/C: 12.70)

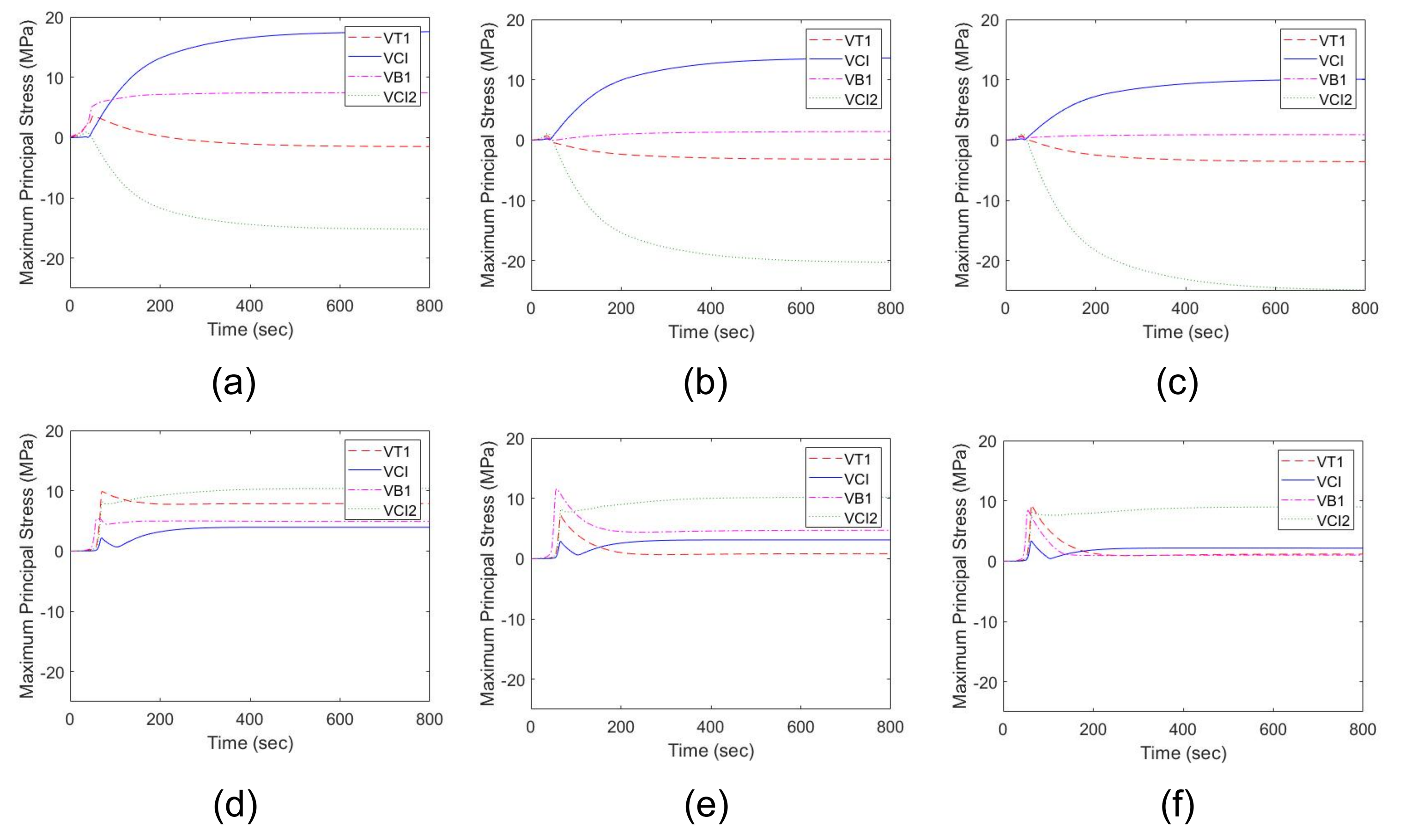

Fig. 7: Transient stress for slow cooling in MC system: (a) Model 1; (b) Model 2; (c) Model 3 and PVLD system: (d) Model 4; (e) Model 5; (f) Model 6

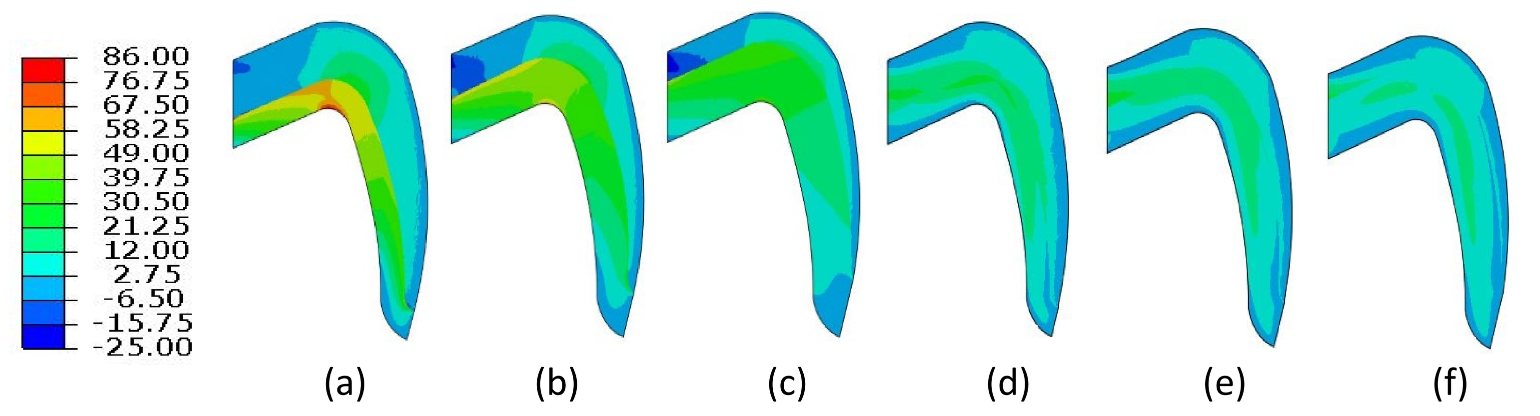

Fig. 8: Stress Contour for fast cooling in MC system: (a) Model 1 (V: 27.18/C: 85.73); (b) Model 2 (V: 23.52/C: 75.02); (c) Model 3 (V: 17.55/C: 62.85), and PVLD system: (d) Model 4 (V: 23.76 /C: 27.59); (e) Model 5 (V: 26.13/C: 18.43); (f) Model 6 (V: 26.53/C: 14.07)

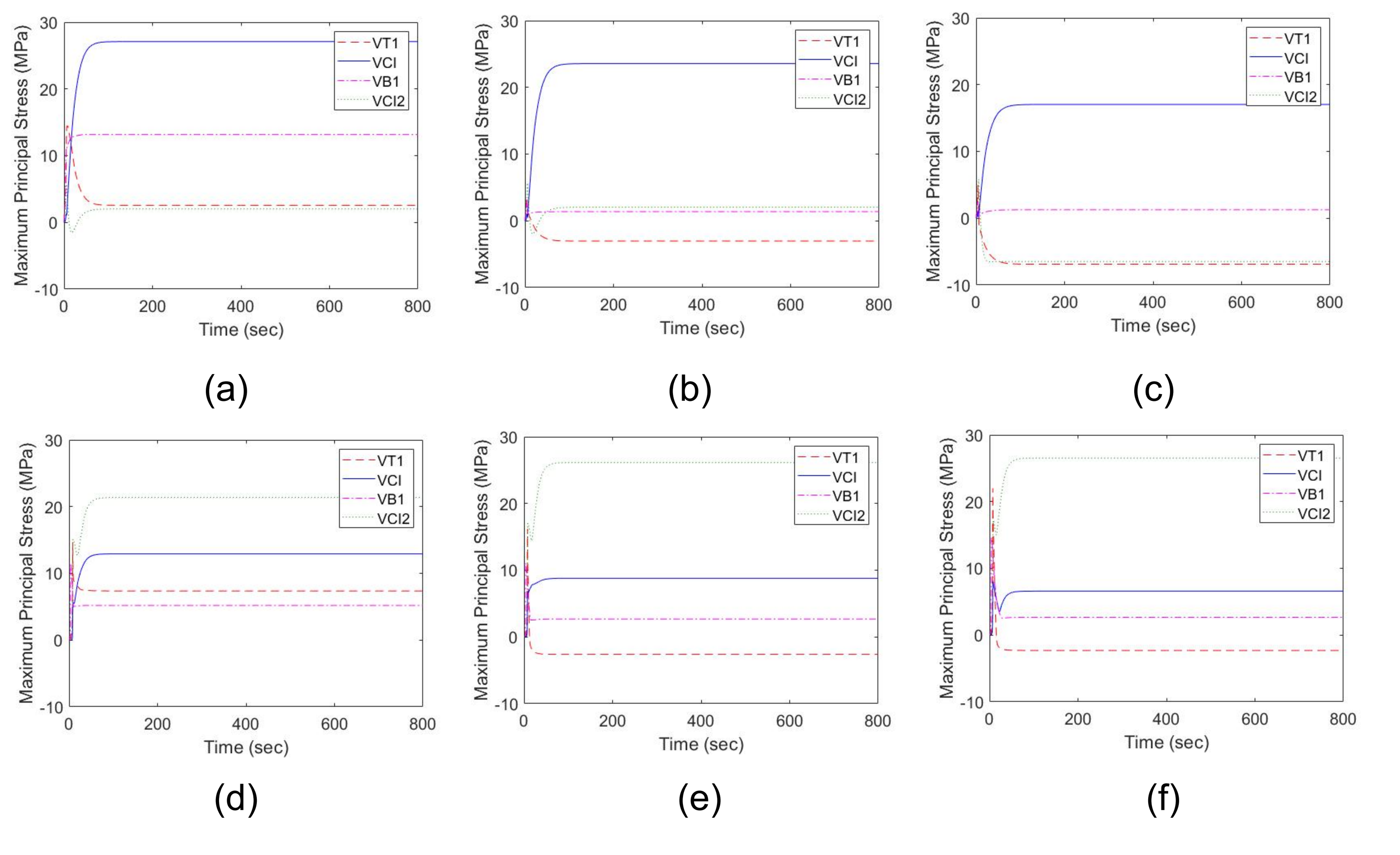

Fig. 9: Transient stress for fast cooling in MC system: (a) Model 1; (b) Model 2; (c) Model 3 and PVLD system: (d) Model 4; (e) Model 5; (f) Model 6

Conclusion

- PVLD system showed lower stress than MC in both veneer and core layers in all conditions simulated.
- Slow cooling resulted in lower stresses.
- Decrease in veneer thickness decreased amount of stress in MC, but not in PVLD system.
- Maximum residual stress located at central fossa for PVLD and in the cusp area for MC crowns, affecting final failure mode.
- Longer clinical follow-ups of PVLD crowns are needed to validate all these conclusions.

Acknowledgement

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