Influence of preheating of composites on voids, internal adaptation and post-gel shrinkage strain using Nano CT analysis

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Monomer Conversion

Aim: The purpose of the present study was to compare the degree of conversion of a preheated composite ($68^{O}C$ – light cured for 5 seconds) and room temperature composite ($25^{o}C$– light cured for 20 seconds).

Material and Methodology:

Filtek Supreme XT (3M) composite specimens (Discs of diameter 5 mm and depth 2mm) were divided into two groups based on their temperature and duration of exposure to curing light.

The groups were as follows:

- Pre-heated composite discs photocured for 5 seconds.
- Room temperature composite discs photocured for 20 seconds.

In order to monitor the conversion at the bottom surface of a 2-mm height specimen, brass rings (5 mm diameter, 2 mm depth) were filled with uncured composite and placed on a temperature-controlled stage of a diamond-attenuated total reflectance unit. The top surface of the composite was compressed using a mylar strip to compact it to ring dimensions after which the specimens were light cured (Valo, Ultra dent) according to the predetermined durations.

Infrared spectra were collected between 1550 and 1680 cm^{-1} at a rate of one-per-second at 2 cm^{-1} resolution. Uncured composite resin was also analyzed using the FTIR to later compare with the conversion values of the composite specimens in different groups as a control. Five specimens were tested in each group and the monomer conversion was calculated by standard methods that utilize changes in the ratios of aliphatic-to-aromatic C-C absorption peaks in the uncured and cured states.

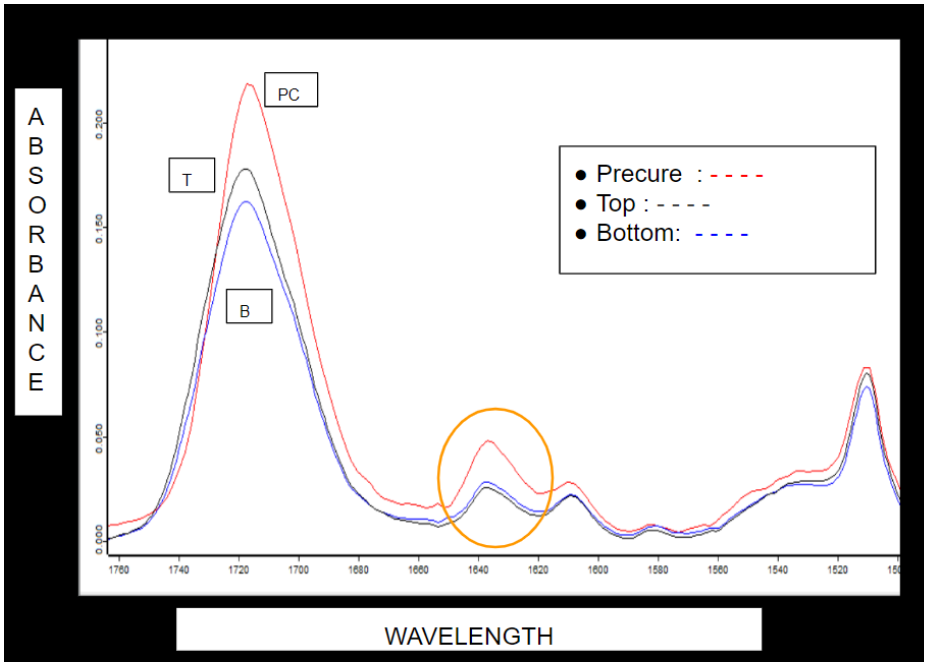

Figure 1: Graphical representation of the absorbance of preheated composite (68°C) before and after polymerization

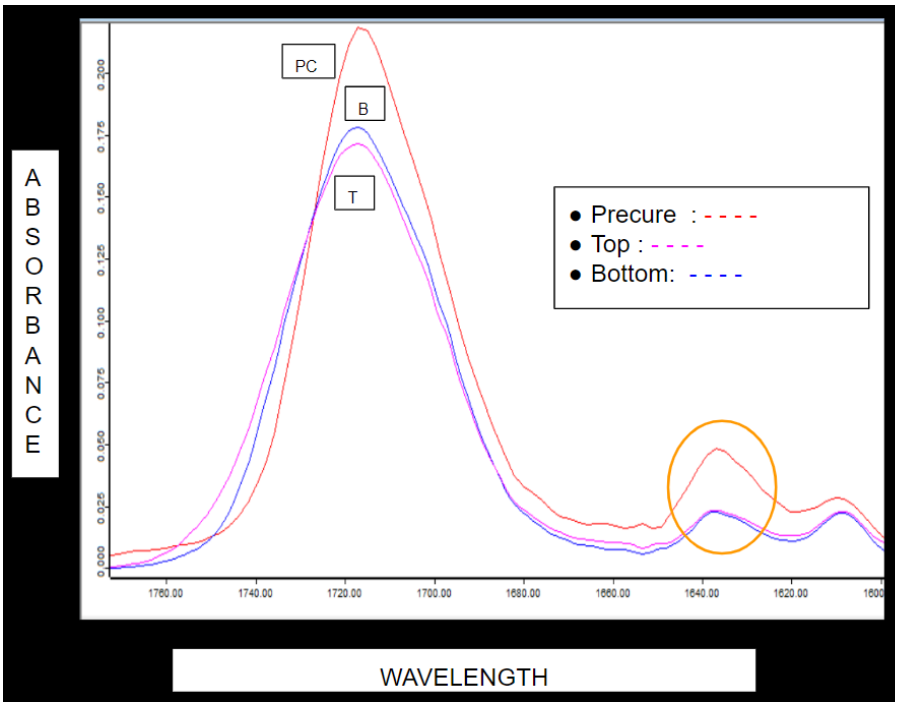

Figure 2: Graphical representation of the absorbance of composite resin cured at room temperature before and after polymerization

Comparison of the data obtained from the FTIR analysis to determine degree of conversion at top surface

Precure Data	Room temperature Top	Pre heated top
1715 - 0.21453	1715 - 0.17176	1715 - 0.17242
1638 - 0.04327	1638 - 0.02294	1638 - 0.03046
1608 - 0.02598	1608 - 0.02329	1608 - 0.02810
	DC - 59%	DC - 65 - 68%

$$\text{Calculation of DC} : \frac{(1638/\ 1608)^{\text{After}}}{(1638/\ 1608)^{\text{Before}}} \times 100$$

Chrószcz MW, Barszczewska-Rybarek IM, Wori P. The Relationship between the Degree of Conversion in Dental Dimethacrylate Polymers Determined by Infrared Spectroscopy and Polymerization Shrinkage. *Engineering Proceedings*. 2021; 11(1):52.

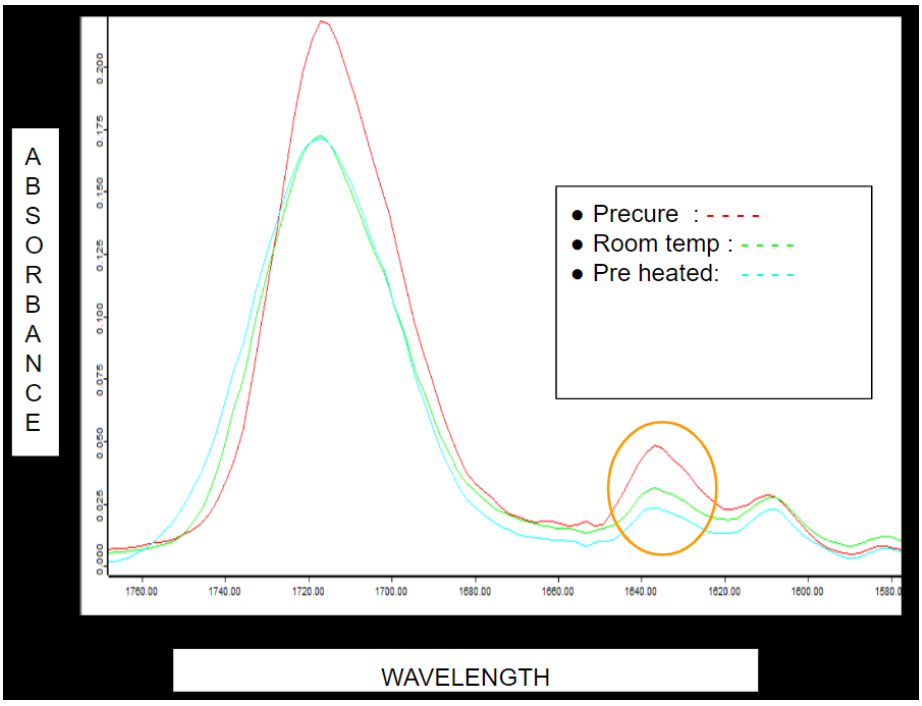

Figure 3: Comparison of the absorbance of Preheated composite cured for 5 seconds and room temperature composite cured to 20 seconds.

Results:

Preheating of resin composites had a significant influence on the final degree of conversion. The mean conversion values were 59% for room temperature (25°C) and 67% at 68°C.

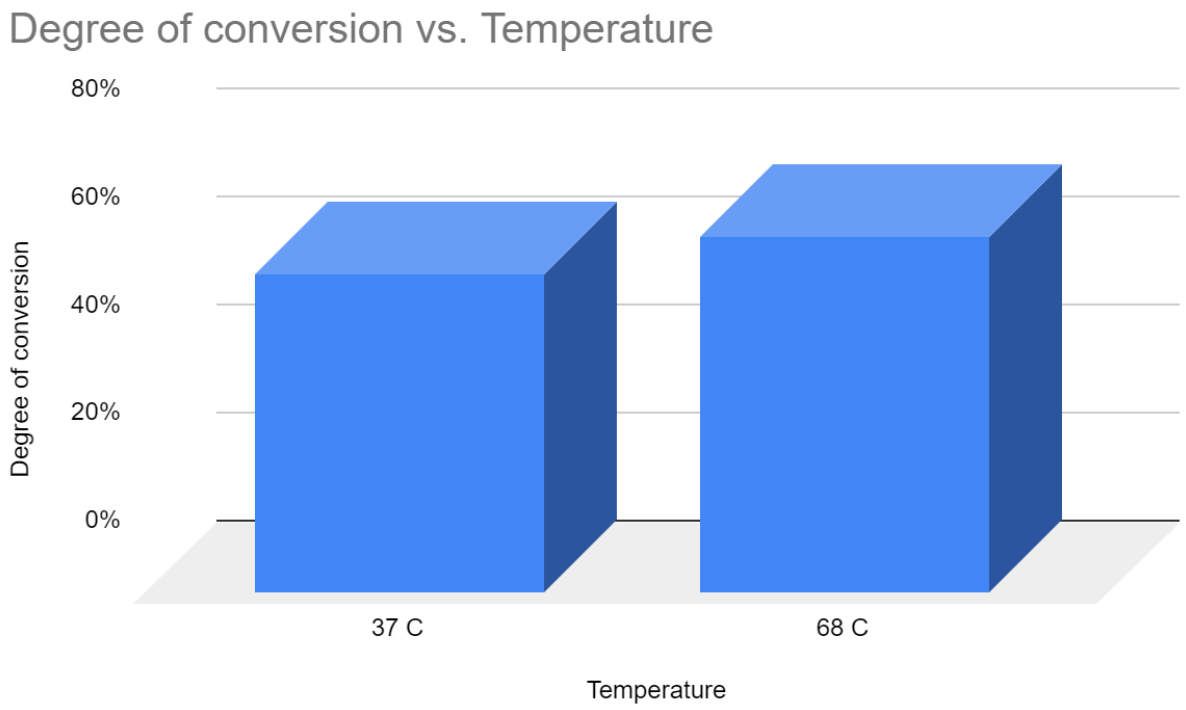

Figure 4: Influence of preheating of resin composite on the degree of conversion

Inference:

Preheating of the resin composites (68°C) resulted in a significant increase in the degree of conversion despite reduced light curing time (5 seconds) when compared to composite cured at room temperature for 20 seconds. The mean conversion values for the preheated composites and room temperature composites were 67% and 59% respectively.

Degree of Conversion - Part II

Aim : The purpose of the second part of the study was to compare the degree of conversion of a preheated composite ($68^{O}C$ – light cured for 5 seconds) and room temperature composite ($25^{o}C$– light cured for 20 seconds) immediately and 5 minutes after curing.

Materials and methodology :

The resin composite used for the second part of the study is the same as used in the first part. In order to evaluate the conversion of the bottom surface of a 2-mm height composite specimen, brass rings (5 mm diameter, 2 mm depth) were filled with uncured composite and placed on a temperature-controlled stage of a diamond-attenuated total reflectance unit. The top surface of the composite was compressed using a mylar strip to compact it to ring dimensions after which the specimens were light cured (Valo, Ultradent) according to the predetermined curing time.

Infrared spectra were collected between 1550 and 1680 cm^{-1} at a rate of one-per-second at 2 cm^{-1} resolution. Uncured composite resin was also analyzed using the FTIR to later compare with the conversion values of the composite specimens in different groups as a control. Five specimens were tested in each group and the monomer conversion was calculated by standard methods that utilize changes in the ratios of aliphatic-to-aromatic C-C absorption peaks in the uncured and cured states.

The bottom surface of the composite specimens were evaluated at two time intervals :

- Immediately after curing
- 5 minutes after curing

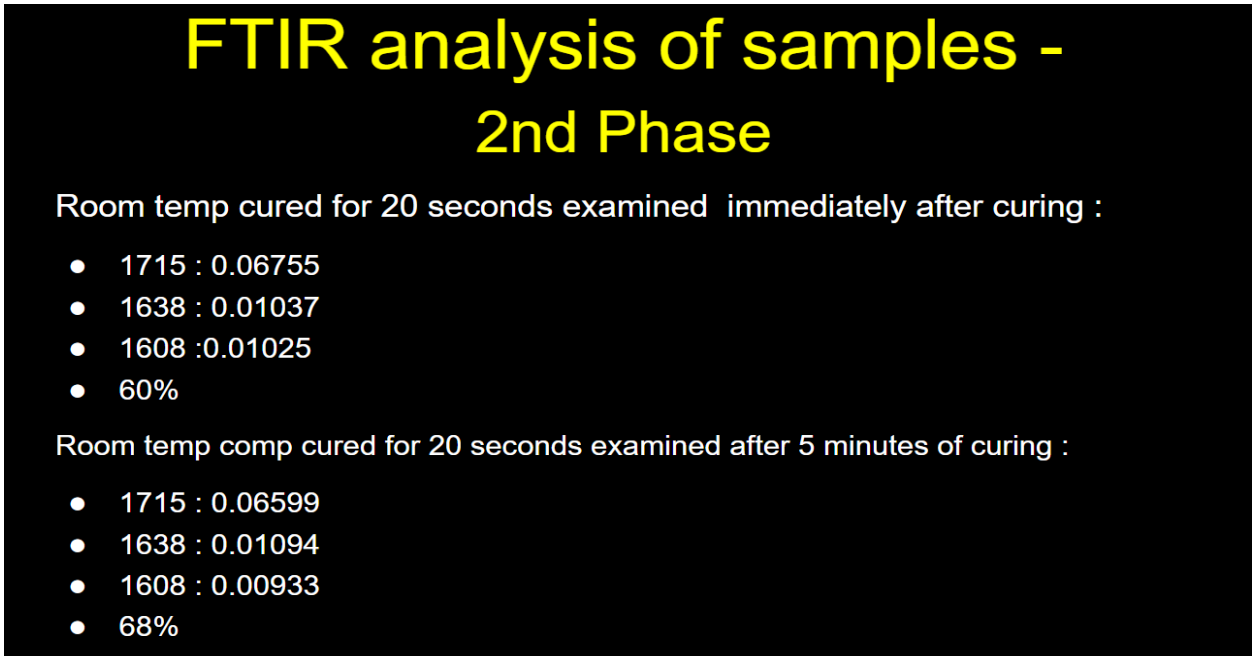

Fig 5 : Absorption spectra of the bottom surface of room temperature resin composites cured for 20 seconds immediately and 5 minutes after curing.

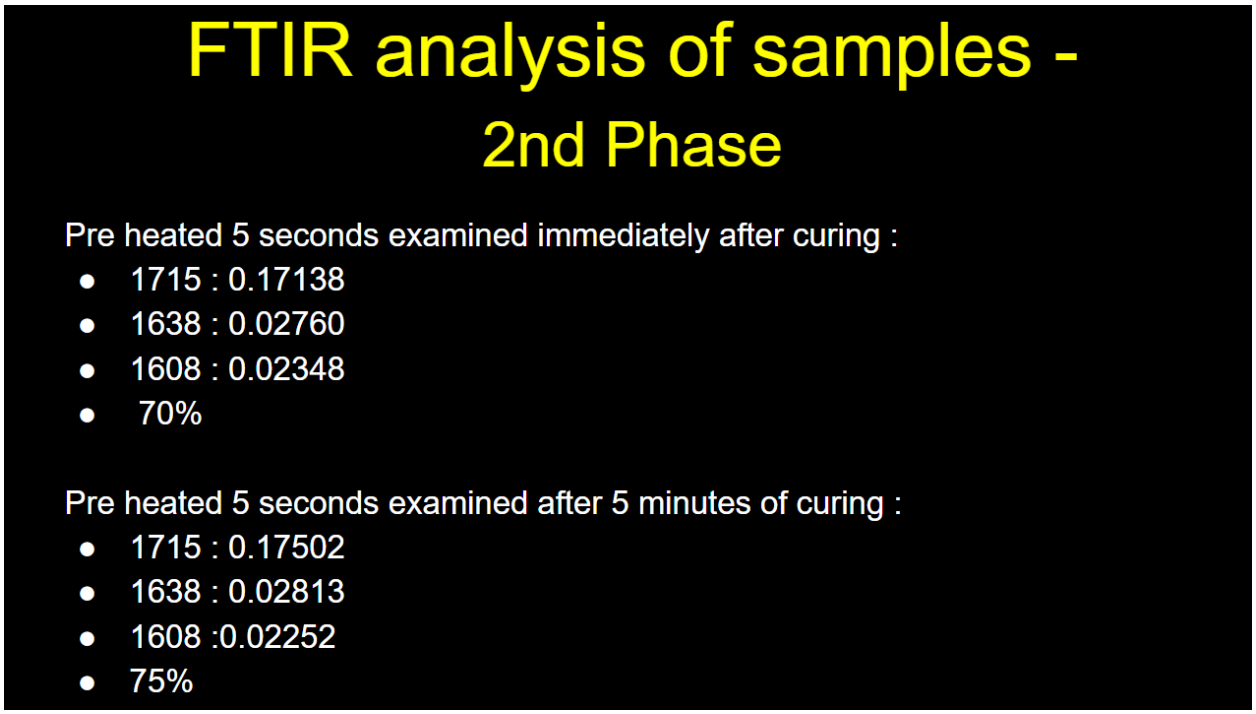

Fig 6 : Absorption spectra of the bottom surface of pre heated resin composites cured for 5 seconds immediately and 5 minutes after curing.

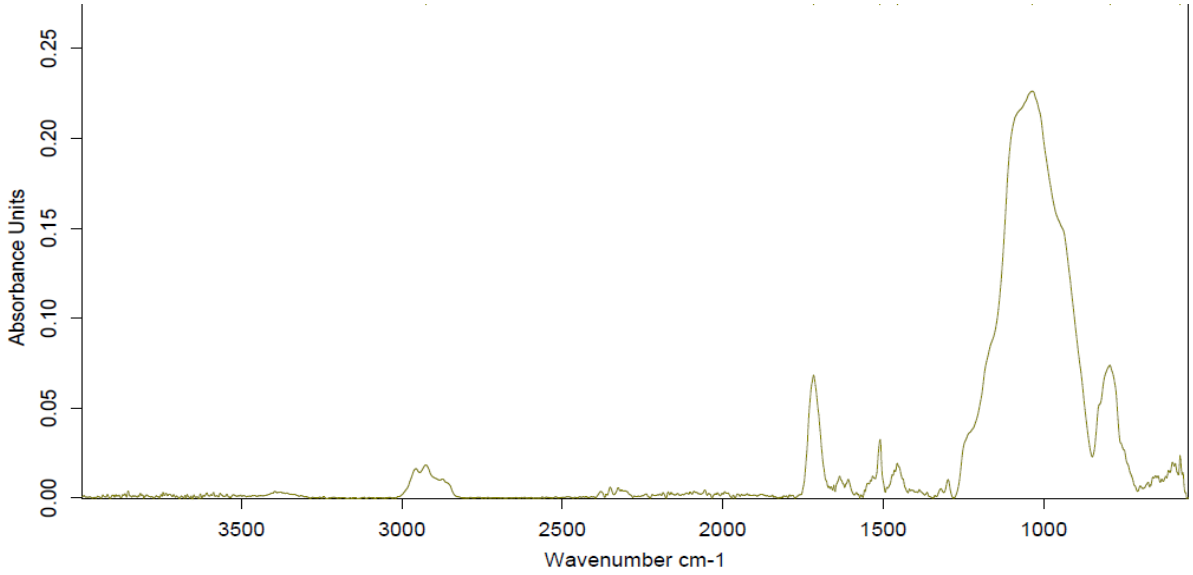

Fig 7 : Bottom surface of room temperature composite resins cured for 20 seconds after 5 minutes of curing.

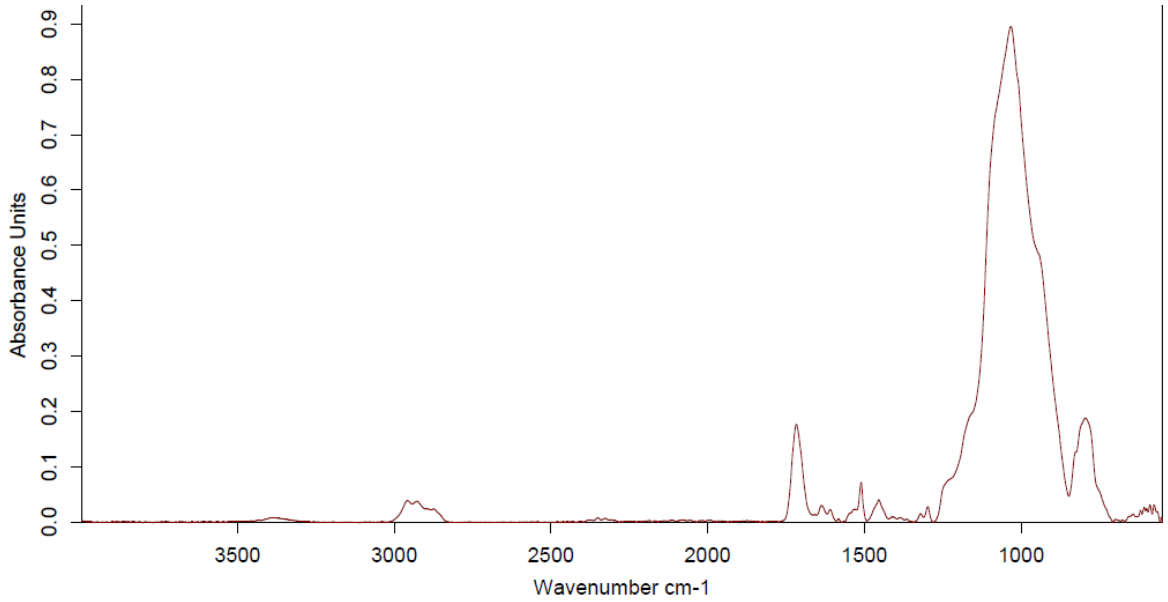

Fig 8 : Bottom surface of preheated composite resins cured for seconds after 5 minutes of curing.

Interpretations of 2nd phase :

- Preheated composite specimens report improved degree of conversion immediately and 5 minutes after curing for 5 seconds than room temperature composite specimens cured for 20 seconds both immediately after curing and after 5 minutes after curing.

- The increased degree of conversion does not result in increased polymerisation shrinkage in the composite specimens as the shrinkage is compensated by the improved flow of the preheated composites.

Summary and Conclusion :

Pre heated composites report increased degree of conversion when cured for a shorter duration of time when compared to room temperature composites cured for 20 seconds.

Nano CT Analysis

Aim: Nano CT evaluation of voids, internal adaptation and post-gel shrinkage strain (PGSS) of pre heated and room temperature class II composite restorations.

Material and Methodology:

10 Intact human premolars extracted for orthodontic reasons were selected for the study. Class II preparations of standardized dimensions were made on the mesial and distal proximal surfaces using high speed fine diamond.

Class II preparation dimensions :

- 3mm mesiodistal
- 3mm buccolingual
- One mm above the cementoenamel junction

The teeth were randomly divided into two groups based on the temperature of resin composites and the duration of photocuring as follows :

- Group - 1 : Pre-heated resin composites photocured for 5 seconds
- Group -2 : Room temperature resin composites photocured for 20 seconds

The internal surfaces of the preparations were treated with All Bond Universal (Bisco Inc., Schaumburg, IL, USA) following manufacturer's instructions and photocured using Valo LED curing light (Ultradent, Utah, USA) for 20 seconds.

Group 1 samples were restored with Filtek Supreme XTE (3 M ESPE, St. Paul, MN, USA) at 68^0C using Compex HD (Addent, USA) and photocured for a duration of 5 seconds.

Group 2 samples were restored with Filtek Supreme XTE (3 M ESPE, St. Paul, MN, USA) composite at room temperature and photocured for a duration of 20 seconds.

The tooth samples were subjected to Bruker Skyscan Nano CT scanner for evaluation of voids, internal adaptation and PostGel Shrinkage Strain (PGSS). The Nano CT slices obtained were analyzed at three different locations - pulpal floor, axiopulpal line angle and gingival floor. Internal adaptation was evaluated using the Image J software. The data obtained was analyzed to evaluate the area of marginal gaps in the restorations when compared to the total surface area of the prepared cavities to derive the Post-gel Shrinkage Strain.

The Post-gel shrinkage strain (PGSS) was calculated using the following formula :

$$\text{Post gel shrinkage strain (PGSS)} = \frac{\text{Area of marginal gap}}{\text{Area of preparation}} \times 100$$

All the samples were also quantitatively evaluated for the presence of internal voids.

Results :

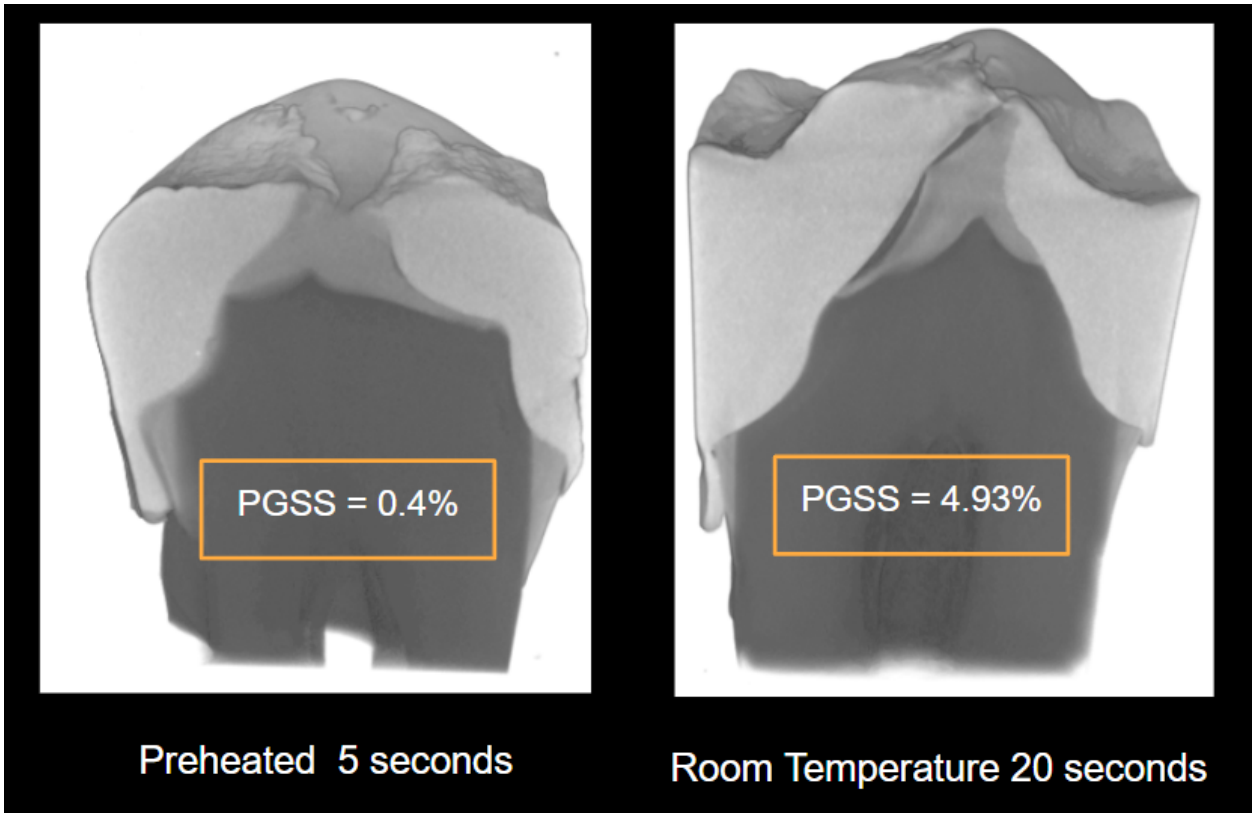

Figure 1 : Nano CT axial slices reveal increased PostGel Shrinkage Strain in sagittal slices (Mesiodistal) in room temperature resin composites in comparison to preheated resin composites.

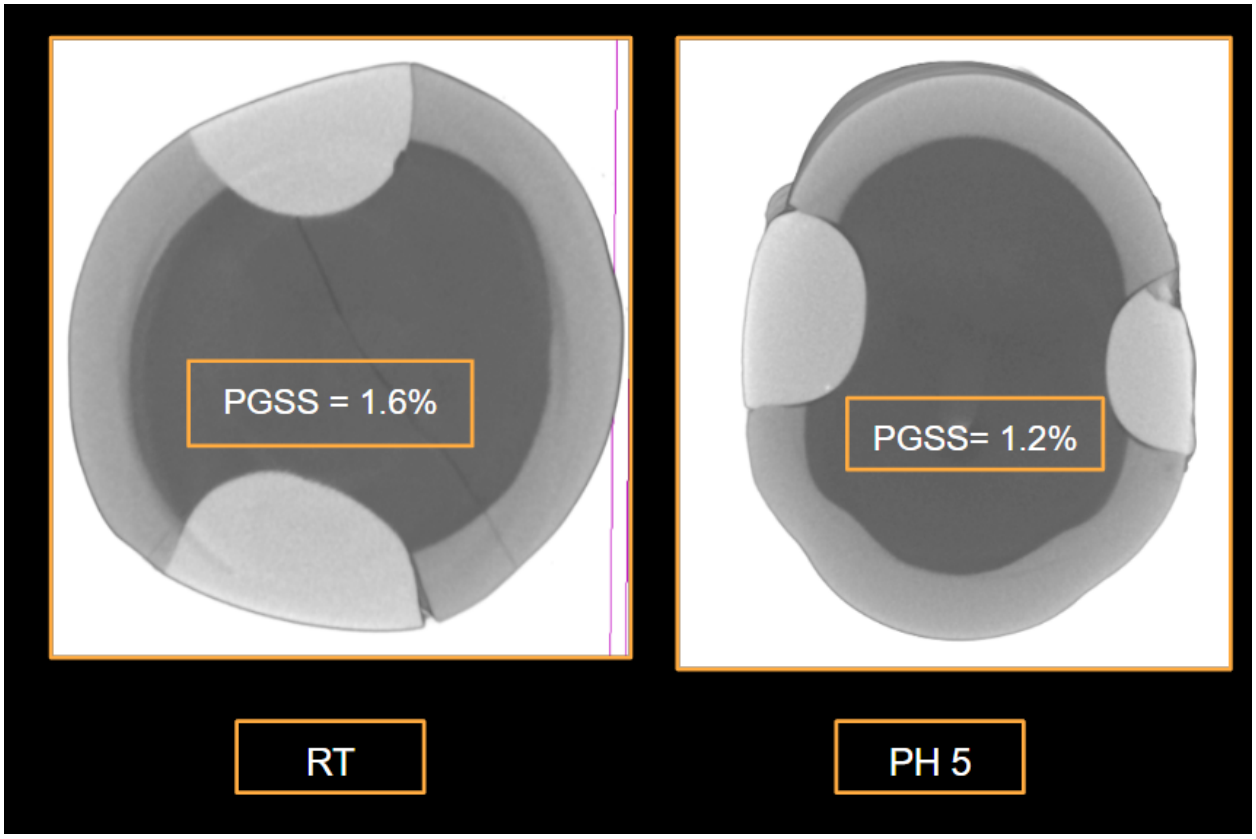

Figure 2 : Nano CT axial slices reveal increased PostGel Shrinkage Strain at axiopulpal line angle in room temperature resin composites in comparison to preheated resin composites.

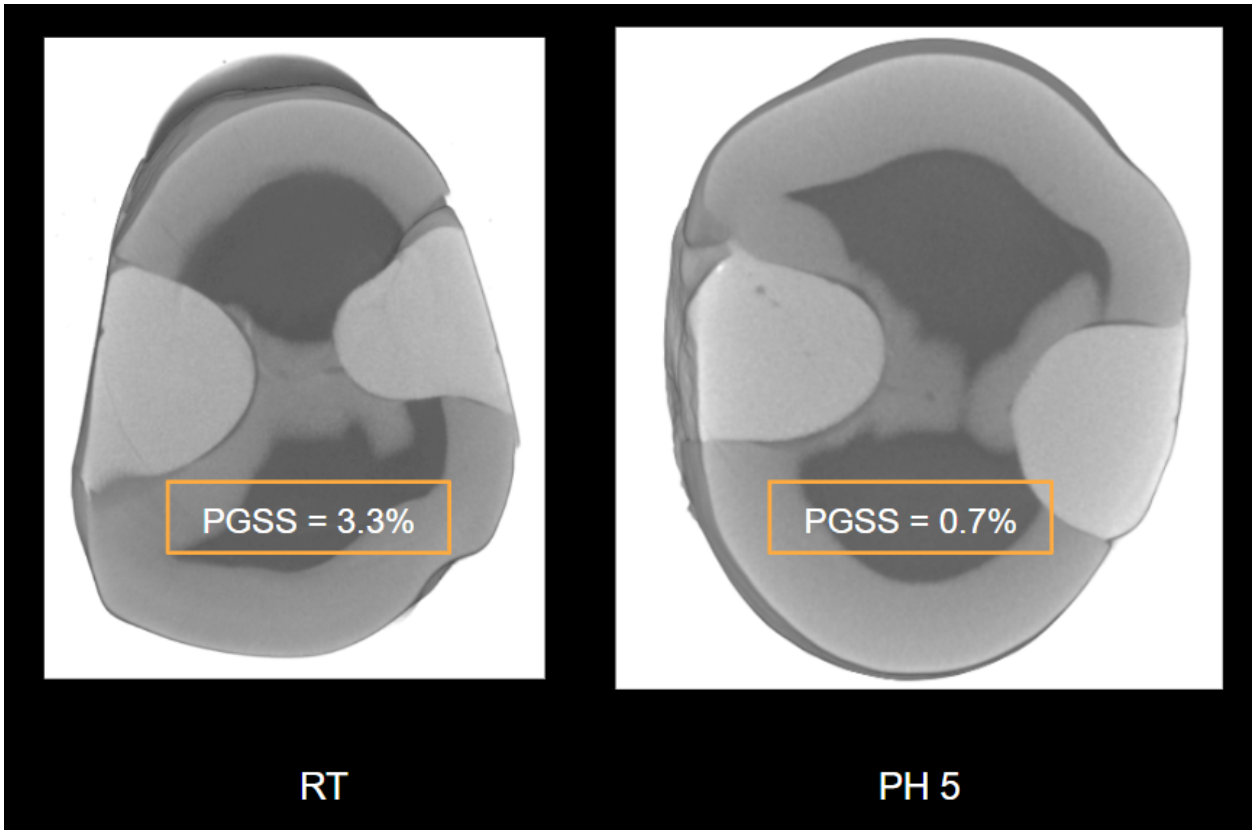

Figure 3 : Nano CT axial slices reveal increased PostGel Shrinkage Strain at pulpal floor in room temperature resin composites in comparison to preheated resin composites.

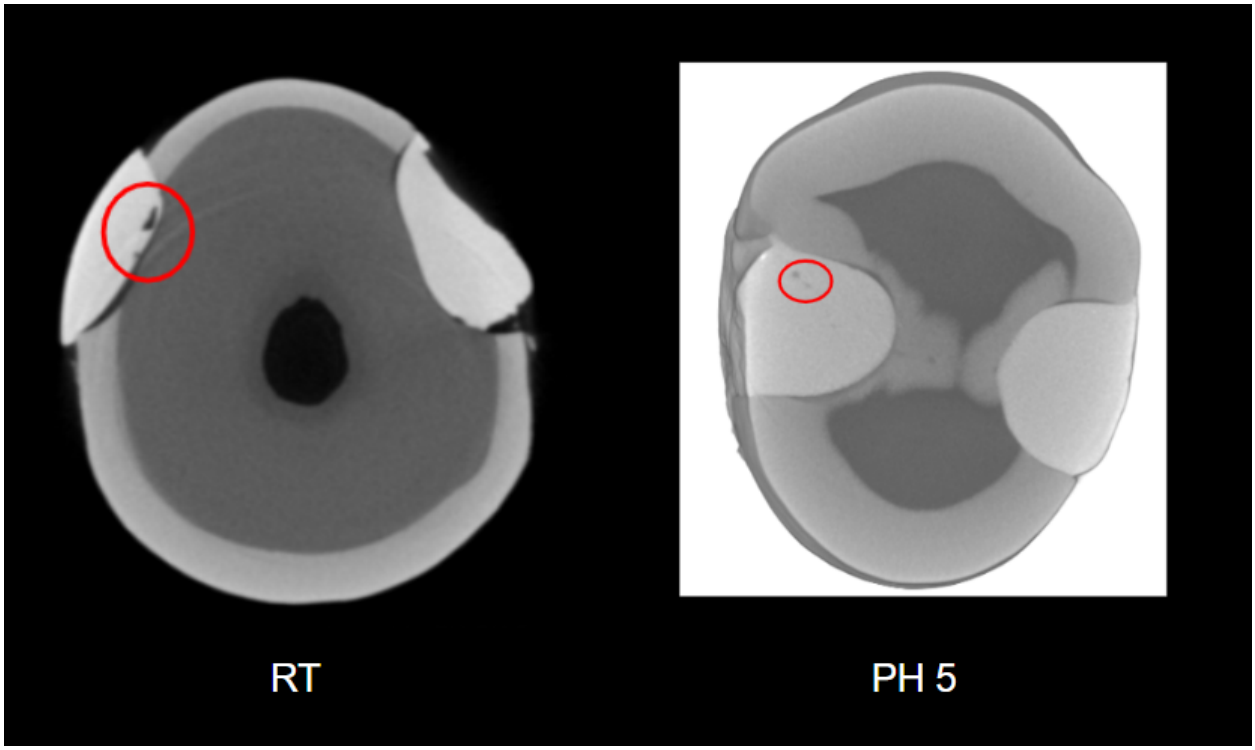

Figure 4 : Nano CT axial slices reveal presence of more voids in room temperature resin composites in comparison to preheated resin composites.

Interpretation of the Nano CT slices

- Post gel shrinkage strain of room temperature resin composites at 20 seconds was significantly higher when compared to the preheated resin composites at 5 seconds.

- The number of internal voids within resin composites photocured at room temperature for 20 seconds was higher when compared to the preheated resin composite restorations photocured for 5 seconds.

Summary and Conclusions

- The PostGel Shrinkage Stress of preheated resin composites was found to be significantly less as compared to composites cured at room temperature. This can be attributed to shorter duration of photocuring and improved flow of preheated composites.

- Preheated composites cured for 5 seconds have better marginal adaptation than room temperature resin composites cured for 20 seconds.

- Preheated composites cured for 5 seconds showed reduced incidence of voids when compared to room temperature composites cured for 20 seconds.

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