

The influence of "C-factor" and light activation technique on polymerization contraction forces of resin composite

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ABSTRACT

Objectives: This study evaluated the influence of the cavity configuration factor ("C-Factor") and light activation technique on polymerization contraction forces of a Bis-GMA-based composite resin (Charisma, Heraeus Kulzer). **Material and Methods:** Three different pairs of steel moving bases were connected to a universal testing machine (Emic DL 500): groups A and B – 2x2 mm (CF=0.33), groups C and D – 3x2 mm (CF=0.66), groups E and F – 6x2 mm (CF=1.5). After adjustment of the height between the pair of bases so that the resin had a volume of 12 mm³ in all groups, the material was inserted and polymerized by two different methods: pulse delay (100 mW/cm² for 5 s, 40 s interval, 600 mW/cm² for 20 s) and continuous pulse (600 mW/cm² for 20 s). Each configuration was light cured with both techniques. Tensions generated during polymerization were recorded by 120 s. The values were expressed in curves (Force(N) x Time(s)) and averages compared by statistical analysis (ANOVA and Tukey's test, $p < 0.05$). **Results:** For the 2x2 and 3x2 bases, with a reduced C-Factor, significant differences were found between the light curing methods. For 6x2 base, with high C-Factor, the light curing method did not influence the contraction forces of the composite resin. **Conclusions:** Pulse delay technique can determine less stress on tooth/restoration interface of adhesive restorations only when a reduced C-Factor is present.

Key words: Composite resins. Physical properties. Bis-GMA

INTRODUCTION

The development of adhesive restorative materials is the main characteristic of current Dentistry. Despite all technology applied in the development of composites, the presence of a polymeric matrix as a basic component of this type of material causes shrinkage during the light curing polymerization⁸. The shrinkage of a composite resin is a natural molecular phenomenon and a consequence of monomer approximation during the polymeric chain formation¹⁹. The contraction forces

originated inside the material are transmitted, in part, to the adhesive interface between the tooth and restoration, which may result in cusp deflexion^{15,21} and gap formation¹¹. These gaps allow oral fluids and bacterial penetration that are the main factors producing clinical problems like marginal percolation, secondary caries and postoperative sensitivity^{2,19}. To minimize the tensions of contraction forces during and after the polymerization process, it is important to know and to use the technical resources.

An important factor to reduce polymerization

tensions is the cavity configuration factor. Some authors⁸ observed that the contraction tension in some chemically activated resins is related to the ratio of the adhesion area to the free area (called cavity configuration factor or "C-Factor"). The quantity of free area is directly proportional to the flow (or elastic deformation) of the material, relieving, in part, the stresses generated by the volumetric contraction. However, doubts still persist on the real importance of this factor over the contraction tensions of a light curing composite resin that has a shorter period to relieve the stresses.

Another important factor to control the stresses from polymerization contraction is the light intensity. A low light intensity increases the period that the resin remains with a low elasticity modulus (pre-gel phase), allowing molecular accommodation and relieving contraction tension^{10,13,17}. In this way, techniques that modulate the polymerization process were developed to minimize contraction problems. One technique that has been recognized is the pulse delay: polymerization starts with a low light intensity during a short period, followed by a non-light interval and then conventional activation allowing reasonable conversion rates. The non-light interval gives some time for the pre-gel phase to be prorogated allowing the material to flow during the beginning of the polymerization reaction and relieving part of the tension generated by the resin contraction^{12,14}. Some authors^{9,13,21} have emphasized that this technique reduces the polymerization contraction forces when compared to the single pulse technique, enhancing the adhesive forces and does not reduce the superficial hardness²⁴.

However these factors are interdependent and studies to determine the contribution of both factors combined on the adhesive interface tension are still required. The aim of the present study was to evaluate the forces generated during the polymerization contraction of a Bis-GMA based composite resin with an association of different cavity configurations (C-Factor) and light activation techniques, with constant volume.

MATERIAL AND METHODS

Experimental design

This *in vitro* study was performed involving 2 factors: C-Factor (in 3 levels) and light activation technique (in 2 levels). The quantitative response variable was the force (N) generated during the composite resin polymerization.

The contraction forces of a hybrid composite resin (Charisma-Heraeus Kulzer- Headquarter - Germany) during polymerization were recorded on a universal testing machine (EMIC DL500; EMIC, São José dos Pinhais, PR, Brazil). One pair of stainless

steel bases 50 mm high x 2 mm long x 2 mm wide was used for groups A and B (C-Factor=0.33); another pair of bases 50 mm high x 3 mm long x 2 mm wide for groups C and D (C-Factor=0.66); and a pair of bases 50 mm high X 6 mm long X 2 mm wide was used for groups E and F (C-Factor=1.5) (Figure 1). Each pair of bases was connected parallel to each other and the upper base was connected to a 50 Kg load cell that was then connected to the moving arm of the testing machine. The lower base was connected to the fixed arm of the machine⁵.

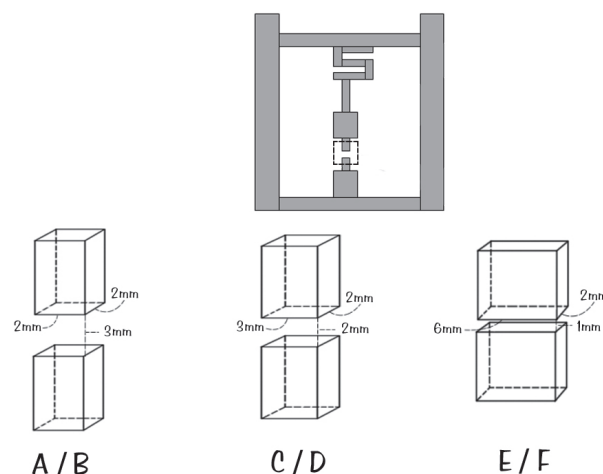


Figure 1- Schematic aspect of steel bases dimensions of all groups

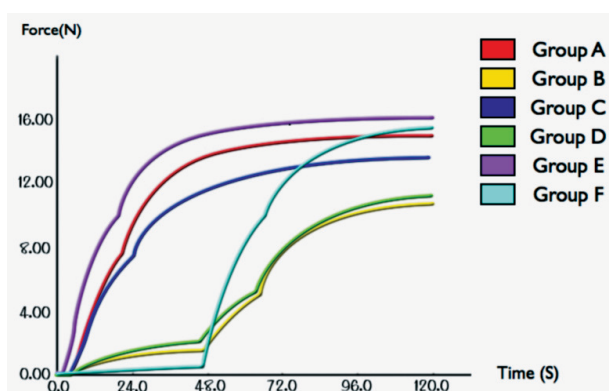
After the distance adjustments were made between the bases to achieve a standardized volume of 12 mm³ for all samples, the composite resin was inserted in a single increment. A halogen light source with different periods and intensities (VIP; Bisco, California, USA) was used. Two polymerization techniques were used: 1) pulse delay (groups B, D, F): light activation for 5 s with 100 mW/cm² at 40 s intervals and light activation for 20 s with 600 mW/cm²; 2) continuous pulse (groups A, C, E): light activation for 20 s with 600 mW/cm². For each pair of bases, the composite resin was activated with the two light activation techniques and the experiment was carried out at 23°C±2°.

Six specimens were obtained for each group, a total of 12 specimens for each pair of bases. During testing, the load cell recorded the forces generated by the polymerization contraction and data was recorded continuously during 120 s [graph Force (N) x Time(s)]. The maximum values were statistically analyzed with two-way ANOVA (C-Factor and light activation technique) and individual differences were analyzed with Tukey test at 5% significance level.

Table 1- Study groups, size of the bases, C-Factor, contraction forces (N), light activation mode and statistical analysis

Groups	Bases	C- Factor	contraction forces (N)	light activation technique	statistical analysis
A	2x2	0.33	14.98±0.24	continuous	C
B	2x2	0.33	11.06±0.69	pulse delay	A
C	3x2	0.6	13.71±0.71	continuous	B
D	3x2	0.6	11.19±0.42	pulse delay	A
E	6x2	1.5	15.88±0.85	continuous	C
F	6x2	1.5	15.53±0.75	pulse delay	C

Different letters indicates statistically significant differences between groups ($p < 0.05$).

**Figure 2-** Shrinkage strain resulting from polymerization contraction of the experimental groups

RESULTS

The lowest stress values were recorded in groups B and D, with bases 2x2 (C-Factor 0.33) and 3x2 (C-Factor 0.6). No statistically significant differences could be found for 6x2 (C-Factor 1.5) bases with any activation techniques (Table 1). The details of the results are presented (Figure 2), which shows the coefficient of near linear fit of contraction force/time, resulting in a plateau at the end of which the maximum shrinkage stress was recorded.

DISCUSSION

The C-Factor is related to the flow capacity of the composite resin based materials, which is an important phenomenon to relieve contraction tensions at tooth/restoration interface⁸. It has been observed that the higher the configuration factor, the higher the tension at the adhesive interface, independent of the volume increments in chemically activated resins^{8,22}. To relieve these tensions there must be a considerably free area (low C-Factor) and a longer pre-gel phase allowing better resin flow and tension relief.

In the present study a constant volume of the composite resin and the pulse delay technique were used in groups B and D, with bases 2x2 (C-Factor 0.33) and 3x2 (C-Factor 0.6), and it was observed

that the free surfaces allowed the flow of the composite resin, relieving part of polymerization tension with less contraction force (Table 1). These results are in accordance with other authors^{4,16,20,23}. However, for groups E and F, with higher C-Factors (1.5), which means larger areas of adhesive surfaces in relation to free surfaces, the contraction values were higher, regardless of the activation technique that was used. These results demonstrate the importance of C-Factors and similar observations have been reported⁶. It is important to highlight that the composite resin was inserted in one single increment, and for cavities with high C-Factor, it is recommended to use the incremental technique and light activation modulation to reduce the C-factor⁶.

In addition to the C-Factor, the light intensity can also influence the polymerization tension of the composite resin. For light activated composites, it is possible to reduce the velocity of the reaction without compromising the final polymerization by using lower intensity for longer periods of time^{19,23}. This is possible because the polymerization conversion rate is related to the energy density absorbed by the composite ($\text{mW}/\text{cm}^2 \times \text{s} = \text{mJ}/\text{cm}^2$), while the reaction velocity is related to the light intensity or power³.

There are different techniques for light activation of composite resins. Some authors have proposed an alternative technique, using low light intensity at the beginning to diminish the polymerization velocity, with better monomer accommodation and less tension, followed by the conventional technique to allow an adequate conversion rate¹². The pulse delay allows a slow initial reaction, reducing the contraction forces¹⁴ and optimizing the marginal sealing, since less stress results in less gap formation¹.

In the present study, the combination of pulse delay technique and low C-Factor resulted in lower contraction forces probably due to a better flow of the material during the pre-gel phase and a rearrangement of the polymeric chains²¹. For groups A, B, C and D with reduced C-Factors (0.33 and 0.6, respectively), significant differences were found between the two light activation techniques,

demonstrating that the polymerization technique is also important to relieve stresses resulting from the polymerization contraction when a sufficient free area is available. Authors that have compared the conventional and gradual light activation techniques found similar results that the gradual light activation did not compromise the bonding between tooth and restoration¹². However, for 6x2 bases with higher C-Factor (1.5), the activation technique was not significant, thus demonstrating that the small free area that is present in this cavity configuration was not able to relieve the tensions.

Therefore, according to the results obtained in this study, the use of pulse delay technique for composite resin polymerization can result in restorations with less stress at the tooth/restoration adhesive interface. Furthermore, a free surface is required to allow the composite resin flow and consequent relief of the tension forces originated from the polymerization contraction. When small amounts of free surfaces are present to relieve these tensions (high C-Factor), even the pulse delay technique is not able to diminish the intensity of the contraction forces.

CONCLUSION

According to the results obtained in this study, it may be concluded that:

The pulse delay technique has positively influenced the relief and the magnitude of the contraction forces of the composite resin, only when a low C-Factor was present;

For a high C-Factor, the light activation technique was not capable of diminishing the contraction forces of the polymerization process.

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