

Original Article

Effect of curing method and thermocycling on flexural strength and microhardness of a new composite resin with alkaline filler

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ABSTRACT

Background: Cention N has been introduced as an alternative material for amalgam. The purpose was to investigate the flexural strength and microhardness of this material in self-cure and dual-cure modes before and after thermocycling.

Materials and Methods: In this experimental study, 40 samples of Cention N were prepared in order to determine and compare the microhardness. Half of the samples were set by self-cure method and the other half with dual-cure method. The Vickers microhardness test was performed once after 24 h and again after 10000 thermocyclings. Three-point flexural test was used to determine and compare the flexural strength of 52 rod-shaped samples. Half of the samples were set by self-cure method and the other half with dual-cure method. Among 26 samples in each group, 13 samples were randomly selected and three-point flexural test was performed after 24 h and for another 13 samples after 10,000 thermocyclings. Data were analyzed using two-way ANOVA and paired samples *t*-test ($P < 0.05$).

Results: There was a statistically significant difference between the mean of microhardness values in two curing methods ($P < 0.001$) and in two storage conditions ($P < 0.001$). The mean of dual-cure microhardness (100.99 ± 7.22) was higher than that of self-cure (64.61 ± 12.51) and the mean value associated with pre-thermocycling (89.75 ± 15.84) was higher than that of the post-thermocycling (76.44 ± 23.56). There was no statistically significant difference between the mean flexural strength in the two curing methods (self-cure [72.85 ± 16.26], dual cure [79.87 ± 23.07]; [$P > 0.05$]). However, the mean flexural strength without thermocycling (85.98 ± 21.74) was higher than that of the thermocycled group (64.24 ± 6.40) ($P < 0.001$).

Conclusion: The microhardness of Cention N in dual-cure mode was higher than that of self-cure mode, but the flexural strength of dual-cure was not significantly different from that of self-cure. Thermocycling had a significant effect on the microhardness and flexural strength.

Key Words: Aging, composite resins, flexural strength, hardness, self-curing of dental resins

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INTRODUCTION

Amalgam has been used as a restorative material for more than 100 years due to its good mechanical

properties. However, its use in recent years has declined in some advanced countries due to the

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toxicity of mercury and more importantly the increasing demand for esthetic treatments.^[1,2]

The composite resin was introduced in 1960 and has been in use for more than 50 years. New composite resins, called bulk-fill, have good abrasion resistance and low polymerization shrinkage and have a greater depth of cure. Therefore, it is possible to fill the posterior cavity in bulk form that reduces the restoration time and reduces the bubble in the restoration. However, failure of posterior composite restorations with composite resins is highly observed which is due to high abrasion, polymerization shrinkage, open contact, postoperative sensitivity, secondary caries, irreversible pulpitis, and restoration fracture.^[3-6]

Cention N is an alkasite restorative material and refers to a group of restorative materials that resemble a compomer or Ormocer and is a subgroup of composite resin materials. This new material contains alkaline filler and is capable of releasing acid neutralizing ions. This tooth-colored material is used for direct restorations as a self-cure, which can be combined with optional light curing. Cention N has been recommended for primary tooth restoration and Class I, II, and V restorations of permanent tooth. This is a radiopaque material and releases fluoride, calcium, and hydroxide ions, that this release is more in an acidic medium than in a neutral medium.^[7] Donly *et al.* investigated the prevention of demineralization in the margin of restorations performed with Cention N and concluded that Cention N could well prevent secondary caries in restoration margins.^[8]

The monomeric portion of this material contains 4 different dimethacrylates, a combination of urethane dimethacrylate (UDMA), tricyclodecandimethanol dimethacrylate (DCP), aromatic aliphatic-UDMA, and polyethylene glycol 400 dimethacrylate (PEG-400 DMA) cross-linked during polymerization which make up 21.6 percent by weight of the final mixed material. This results in strong mechanical properties such as high flexural strength and high compressive strength (flexural strength of 110 Mpa and compressive strength of 302 Mpa), which are more than the flexural and compressive strength of the two types of Fuji LX GP and Ketac molar easymix glass ionomers. In addition, the hydrophilic properties of this material make it able to better moisten the tooth structure and adipose smear layer. On the other hand, the density of the polymer lattice

is high and polymerization is performed at all depths of restoration. The isofillers in Cention N also keep the contractile stress at low level. As important as the monomer composition is, the ratio of organic to inorganic components of material is also responsible for the low volumetric shrinkage. Therefore, volumetric shrinkage and contractile stress in Cention N decrease during polymerization and it allows us to use this material on a bulk basis. Therefore, Cention N can be a suitable alternative material for posterior teeth restoration.^[7,9] Recently, Chowdhury *et al.* demonstrated that teeth restored with Cention N have higher fracture resistance than teeth restored with Z350 composite resin and amalgam and significantly strengthened teeth after Class II cavity restoration.^[10]

When we discuss about choosing the right restorative material, the mechanical properties are important because it strongly affects the durability of the restorative material. One of the most important features is the hardness of the restorative material, which has a good relationship with compressive strength, resistance to intraoral conditions and its degree of conversion. Another laboratory test used to evaluate mechanical properties is flexural strength testing. This test simulates the set of forces, which are extended in stress-stricken areas and applies tensile and compressive forces simultaneously in or near the point of pressure.^[11,12] Panpisut and toneluck demonstrated that Cention N exhibited higher biaxial flexural strength than RMGIs but lower than Z350 composite resin. They also pointed out that monomer conversion of Cention N was higher than that of Z350 but lower than RMGIs.^[13]

Despite the confirmation of biocompatibility and nonmutagenicity of this material,^[9] there is insufficient information regarding its mechanical properties and efficacy in clinical settings and after the accelerated aging process in the laboratory. Thus, the purpose of this study was to determine and compare the microhardness and flexural strength of Cention N in both self-cure and dual-cure conditions and to evaluate the effect of repeated thermocyclings on these properties.

MATERIALS AND METHODS

Microhardness test

In this experimental study, 40 samples of Cention N (Ivoclar Vivadent AG., Schaan, Liechtenstein) were prepared in 8 mm in diameter and 2 mm in

thickness. Twenty samples set with self-cure method and the other 20 samples were set by dual-cure method. Curing was done for 20 s after about 2 min of mixing the material using LED light curing unit (Demetron A2, Ker, Scaffati, Italy) with an intensity of 1000 mW/cm² according to manufacturer's instructions. The surface of all samples was smoothed with 1200 Grit silicon carbide sheets for 20 s. Then, the polishing and finishing was done by Sof-Lex discs (3M ESPE, St. Paul, MN, USA).

Vickers test was used to perform the microhardness test. The Vickers hardness test was performed once 24 h later and again after 10000 thermocyclings using the Struers Duramin-5 microhardness tester (Struers corp, Tokyo, Japan). The indenter was applied 3 times on the surface of each sample under 300 g pressure for 15 s and the mean hardness was recorded for each sample.

Flexural strength test

Fifty-two rod-shaped samples of Cention N material with the dimensions of 2 mm × 2 mm × 25 mm were prepared. Twenty-six samples were set with self-cure method, and other 26 samples were set with dual-cure method. Curing was done for 20 s after about 2 min of mixing the material using LED light curing unit (Demetron A2, Ker, Scaffati, Italy) with an intensity of 1000 mW/cm² according to manufacturer's instructions. The samples were manually smoothed with 1200 Grit carbide silicon sheets. In each group, 13 samples were stored in distilled water at 37°C for 24 h and the other 13 were subjected to 10000 thermocyclings. Three-point bending flexural test was performed using Universal Testing Machine (Hounsfield Test Equipment, Model H5KS, Surrey, UK) at the cross-head speed of 1 mm/min to determine the flexural strength (MPa).

It should be noted that the temperature range in thermocycling was 55 ± 5 and 5 ± 5°C. The immersion time in the hot and cold water tank was 30 s and the transfer time from one tank to another was 5 s.

Statistical analysis

Two-way ANOVA was used for statistical analysis in order to compare the effect of curing type and thermocycling on flexural strength. Repeated measures ANOVA was used to compare the effect of these variables on the microhardness. The *t*-test was also used for pairwise comparisons. Significance level was set at $P < 0.05$.

RESULTS

Microhardness

The mean and standard deviation of the microhardness values are presented in Table 1. Repeated measures ANOVA showed that there was a statistically significant difference between the mean of microhardness values in the two curing methods ($P < 0.001$), and in the case of dual-cure (103.46 ± 7.60), it was more than the self-cure mode (75.31 ± 6.32). There was also a statistically significant difference between the mean of microhardness values before and after thermocycling ($P < 0.001$) and the mean of microhardness values in pre-thermocycling stage (89.75 ± 15.84) was higher than that in post-thermocycling stage (76.44 ± 23.56). Furthermore, There was an interaction between the curing method and the evaluation stage ($P < 0.001$), in other words, the effect of thermocycling on the mean of microhardness is not the same in both curing methods. Paired samples *t*-test to investigate the effect of thermocycling on the mean of microhardness values in each of the two curing methods showed that there was a statistically significant difference between the mean of microhardness values in the self-cure method before and after thermocycling ($P < 0.001$) and the mean of microhardness in pre-thermocycling stage (75.31 ± 6.32) was higher than that in post-thermocycling stage (53.20 ± 4.68). There was no statistically significant difference between the mean of the microhardness values before (103.46 ± 7.60) and after thermocycling (98.52 ± 6.03) in dual-cure method ($P > 0.05$).

Flexural strength test

The mean and standard deviation of the flexural strength values (MPa) have been presented in Table 2. Two-way ANOVA showed that there was no significant difference between the mean flexural strength in

Table 1: Mean and standard deviation of microhardness values

Storage condition	Curing method	Mean±SD
Without thermocycling	Self-cure	75.31±6.32
	Dual-cure	103.46±7.60
	Total	89.75±15.84
With thermocycling	Self-cure	53.20±4.68
	Dual-cure	98.52±6.03
	Total	76.44±23.56
Total	Self-cure	64.61±12.51
	Dual-cure	100.99±7.22

SD: Standard deviation

Table 2: Mean and standard deviation of flexural strength (MPa) values

Curing method	Storage condition	Mean (MPa)±SD
Self-cure	Without thermocycling	84.55±15.46
	With thermocycling	62.05±6.81
	Total	72.85±16.26
Dual-cure	Without thermocycling	87.30±26.87
	With thermocycling	67.81±3.72
	Total	79.87±23.07
Total	Without thermocycling	85.98±21.74
	With thermocycling	64.24±6.400

SD: Standard deviation

the two curing methods (self-cure [72.85 ± 16.26], dual cure [79.87 ± 23.07]; [$P > 0.05$]). However, there was a statistically significant difference between the mean flexural strength in the two storage conditions ($P < 0.001$) and the mean flexural strength in the distilled water storage (85.98 ± 21.74) was higher than that in the thermocycling group (64.24 ± 6.40). There was also no interaction between the storage method and the curing method, in other words, the effect of the storage method on the mean flexural strength variable in both curing methods was identical ($P > 0.05$).

DISCUSSION

Cention N is a new restorative material belonging to composite resin materials with alkaline filler. The presence of alkaline fillers in this material increases the release of hydroxide ions, which regulates the pH value during acidic attacks. As a result, it can prevent demineralization. In addition, the release of large amounts of fluoride and calcium ions provides the basis for enamel remineralization. UDMA is the main component of the monomer matrix. It has a medium viscosity and has strong mechanical properties. The cross-linked polymer structure is the reason for the high flexural strength of this material.^[8,14,15]

Curing this material is performed through self-cure method that dual-cure method can be also used. The self-cure mechanism is that the liquid part of Cention N contains hydroperoxide and the standard filler in the powder has been covered with other initiator components. Hydroperoxide is more resistant to temperature than conventional benzoyl peroxide, which is an important factor in stability. Thiocarbamide, instead of amine, also enhances the color stability of the product. As the amine content increases, the color stability of a material decreases. The dual-cure mechanism is that Cention N has

an ivocerin optical initiator and a phosphine oxide initiator for light curing. Ivocerin is a dibenzoyl germanium derivative of the free amine initiator.^[16]

Aging of samples using thermocycling is a common protocol for assessing dental material degradation over time. Immersion of the restorative materials in water with or without thermocycling also results in crack growth, which can weaken flexural strength.^[17] The thermal protocol used in this study is consistent with the protocol used in previous studies, where the temperature used is 5°C–55°C. The 10,000 thermocyclings can also be correspond to heat exchange cycles which have occurred in the mouth for almost 1 year. Even if the thermal protocol does not simulate real conditions like the oral environment, at least it can be used to evaluate the behavior of such substances subjected to heat stresses.^[18,19]

The selection of restorative material must include an understanding of the properties of the material and no material can be ideal and be able to replace all the features of the missing tooth structure. To achieve the best clinical outcome, dentists must have a clear knowledge of the mechanical properties of these materials. Therefore, when the selection of the appropriate restorative material is discussed, the mechanical properties are important, because it strongly affects the durability and survival of the restorative material.^[11,20] The aim of this study was to investigate the flexural strength and microhardness of a new composite resin with alkaline filler (Cention N) in both self-cure and dual-cure modes and the effect of thermal cycles on it.

In a study conducted by Tuncer *et al.*, which aimed to investigate the effects of thermocycling on the mechanical properties of several composite resins, they concluded that the 10,000 times of thermocycling process had a significant effect on the composite resin microhardness.^[21] In the present study, there was a significant effect of thermocycling on microhardness of Cention N in the self-cure mode, but it was not significant in dual-cure mode.

According to the study of Ilie *et al.*, who investigated the effect of curing method on polymerization and mechanical properties of Cention N, it was concluded that the use of blue light to accelerate curing of Cention N would increase the microhardness of this material, which is consistent with our study.^[22] In the present study, the microhardness of this material in the dual-cure mode was significantly higher than in

the self-cure mode. According to a study conducted by Mazumdar *et al.*, Cention N had the highest microhardness among the nano-hybrid composite resin, amalgam, GC type II and amalgam which has been used in posterior restorations for over hundred years, was in second place.

Fractures occurred in the mass of restorations and in margins are one of the most important problems associated with failure of posterior composite resin restorations. Flexural strength testing evaluates fracture-related properties of restorative materials, especially when used in Class I, II and IV restorations. In other words, flexural strength test can be used as an indicator of survival of the restoration under chewing conditions. Various studies have shown that the filler volume and weight percent of composite resins are directly related to the strength of the material.^[23] The filler in Cention N is responsible for the strength and resistance against the stress and strain forces inside the mouth and causes the durability of material over time. The filler is selected to have both the required strength and the wettability with the liquid and to be combined with the matrix. Also, barium aluminum silicate glass and calcium fluorosilicate glass particles between 0.1-35 μm are responsible for the strength of this material. Therefore, this material is expected to have appropriate flexural strength and microhardness.^[9]

Studies on the effect of monomer components on the mechanical properties of composite resins have also shown that flexural strength increases when Bis GMA or TEGDMA is replaced with UDMA. The monomeric portion of Cention N is present in its liquid contains 4 different dimethacrylates, which make up 21.6% of the final weight of the material after mixing. A combination of UDMA, DCP, aromatic aliphatic UDMA and PEG_400 DMA are cross-linked during polymerization, results in strong mechanical properties and long term stability of material.^[23]

Test methods for the evaluation of dental restorative materials (luting and resin-based filling materials) have been described by ISO 4049 standards. According to the new recommendations, only flexural strength and modulus of elasticity are considered as criteria, because the materials are subject to occlusal forces. ISO 4049 has used flexural strength to classify two types of light-cure direct restorative resins. The group with flexural strength above 80 MPa is used for occlusal restorations and the group with flexural strength above 50 MPa is used for other areas.^[24]

In the present study, flexural strength of Cention N was above 80 MPa in both self-cure and dual-cure conditions. Therefore, according to ISO 4049 standards it can be used for occlusal area restorations. Chole *et al.* investigated the flexural strength of Cention N, bulk fill composite resin, nanocomposite, and RMGI cement. They concluded that Cention N had the highest flexural strength among the four materials.^[23] Furthermore, according to Panpisut and Tuneluck, the flexural strength of Cention N was equal to Z350 composite resin but higher than RMGIs.

Souza *et al.* conducted a study to evaluate the effect of thermocycling on the physical properties of indirect composite resin. They concluded that the effect of thermocycling on the flexural strength of the composite resin was significant and decreased it, but it was not significant in the microhardness results.^[25] In our study, thermocycling also had a significant effect on flexural strength in both self-cure and dual-cure groups, and on microhardness in self-cure mode.

In the study conducted by Kutuk *et al.*, the mechanical properties and water absorption was investigated by two types of GICs with different formulations. In this study, 3 groups of GIC were prepared, each by 3 different methods. The first method was prepared according to manufacturer's instructions. In the second group, coating material (EQUIA-coat, GC) was used and the third group was cured with blue light. Flexural strength and microhardness tests were performed in all groups. According to the results, the use of blue light did not have a significant effect on flexural strength but had a significant effect on microhardness, which is consistent with our study.^[26]

CONCLUSION

This study showed that the mean microhardness of Cention N in dual-cure method was higher than the self-cure method. In addition, the mean microhardness in prethermocycling stage was higher than that of postthermocycling stage. There was no statistically significant difference between the mean flexural strength in the two curing methods but the mean flexural strength in the water storage group was higher than that of the thermocycling group.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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