International Journal of Scientific Research in Dental and Medical Sciences

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Comparative Evaluation of Microhardness and Degree of Polymerization of Dual-cure Resin Cement on Luting Composite Resin Endocrowns of 5.5mm and 7.5mm Thicknesses: An in-vitro Study

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ARTICLE INFO

Article history:
Received 30 September 2024
Received in revised form 10 November 2024
Accepted 21 November 2024
Available online 26 November 2024

Keywords:
Fourier Transform Infrared
Polymerization
Resin Cements

ABSTRACT

Background and aim: The aim of this in vitro study was to assess and compare the microhardness and degree of polymerization of dual-cure resin cement used for luting composite resin Endocrowns using the Vickers microhardness test and Fourier Transform Infrared (FTIR) spectroscopy.

Material and methods: The study comprises two test groups and one control group. The test groups comprised composite resin endocrowns of 5.5mm and 7.5mm thickness. The dual-cured resin cement was used to lute the endocrowns. As a control group, 2 mm-thick cured resin cement was used. The cured resin cement was subjected to testing using Vickers microhardness and FTIR spectroscopy.

Results: The mean microhardness across all groups was 7.4663, with an overall standard deviation of 0.30963 and a standard error of 0.05653. The ANOVA test results revealed a significant difference in microhardness values ($F = 180.665$, $p < 0.001$). The mean degree of polymerization across all groups was 7.8723, with an overall standard deviation of 0.35528 and a standard error of 0.06487. The ANOVA test results revealed a significant difference in the degree of polymerization between the groups ($F = 144.873$, $p < 0.001$).

Conclusions: The study's statistical analysis was evident through ANOVA and post hoc Tukey's tests. The sufficient sample size for each group enhanced the statistical power and allowed for a more accurate variability assessment.

1. Introduction

Optimum restoration of endodontically treated teeth has been extensively discussed in the literature. Preserving and protecting the current tooth structure is a key aspect of post-endodontic restoration and restoring satisfactory esthetics, form, and function. Managing mutilated teeth requires a comprehensive treatment plan, depending on the availability of coronal structure. The successful survival of endodontically treated patients is accompanied by the integration of coronal restorations.[1] Endodontically treated teeth usually present with considerable loss of tooth structure due to trauma, caries, or central destruction created by the endodontic access preparation. Such teeth are more prone to fracture during mastication. Hence reinforcement of the weakened tooth structure. As there is an evolution in restorative dentistry from mechanical retention to chemical bonding, the advent of adhesives plays a crucial role. Adhesive dentistry is based on developing materials that effectively bond the tooth tissues. The use of resin cement has a pivotal role in clinical practice for luting indirect restorations.[2] Since adhesive technologies have improved, post and core treatment has become less necessary. Based on this adhesive concept in 1995, a novel technique that utilized a porcelain core/crown unit as a single unit called the monobloc technique was later developed and renamed as an Endocrown technique. Endocrown is an adhesive crown characterized as full crown of tooth colored restorative material that presents a central extension into the pulp chamber to increase the surface area of bonding, fixed to posterior endodontically treated teeth with a supragingival butt joint retaining as much as possible enamel for improved adhesion.[3] Its endodontic extension is limited to pulp chamber and is minimally invasive of root canals. Endocrowns present several advantages over posts, cores, and crowns, as they are easier to prepare with increased fracture resistance, require lesser clinical time, and visits with superior esthetic properties. Besides, adhesive restorations minimize the infiltration of microorganisms from the coronal to the apical part, thus improving the clinical success of endodontic treatment.[4] Moreover, they provide significant advantages in cases where posts are contraindicated due to short or narrow canals and prevent root perforation, which is encountered in post-space preparation. In particular, the clinical failure of an

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https://doi.org/10.30485/IJSRDMS.2025.490011.1621

endocrown is debonding, which is an important consideration in restorative dentistry. The success of endocrowns also relies heavily on the correct application of adhesive techniques. Among the luting agents, resin-based cements are considered the optimal choice for endocrowns due to their superior bonding strength and durability. Dual-cure resin cement, in particular, is favored for its versatility and reliable performance, making it highly suitable for bonding endocrowns. Their broad acceptance among clinical use is rooted in their ability to cure through light and chemical means. However, the polymerization behavior of dual-cure resin cement in endocrown restorations remains questionable. Increased thickness of endocrowns compared to conventional crowns compromises the penetration of light into the dual-cure resin cement, which may lead to concerns regarding the efficiency of photopolymerization.[6] The present study throws light on the effectiveness of the polymerization of dual-curing luting resins under indirect composite resin endocrowns of varying thicknesses. Vickers microhardness measurements obtained indirectly assess the relative depth of polymerization of the resin cement, which is determined using a Fourier Transform Infrared (FTIR) spectroscope with an attenuated total reflectance (ATR) unit.

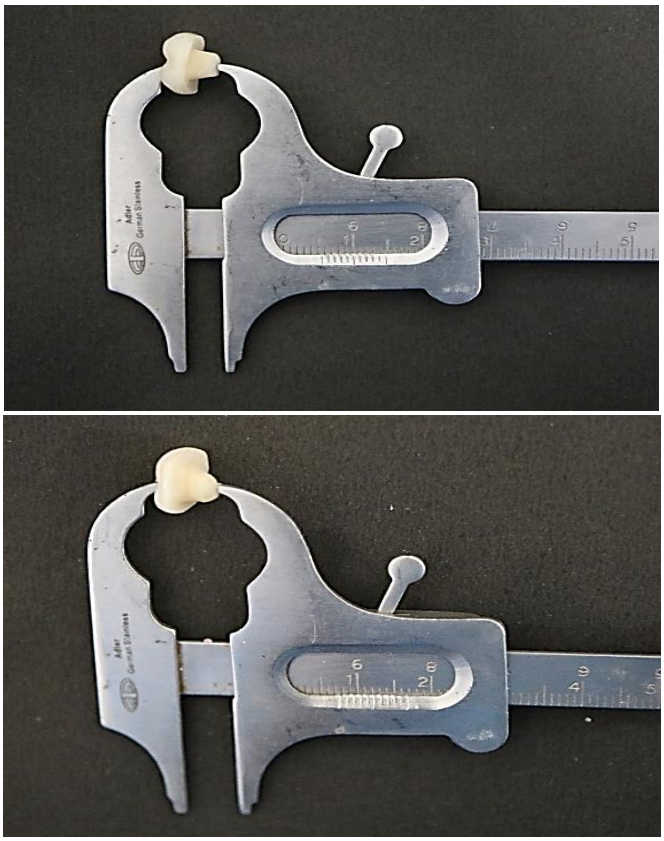
2. Material and methods

Fabrication of sample groups

A mold was prepared from an extracted human lower third molar mounted onto the gypsum type IV die stone (Fig. 1).

Fig. 1. Endocrown preparation on extracted teeth mounted using gypsum type IV dental stone.

At about 1.0 mm above the cementoenamel junction of the clinical crown was removed using wheel-shaped diamond endpoints, and using a short flat tapered diamond point, a cavity of 4mm deep was obtained as space for a 2mm endocrown extension and 2mm for the luting material to be tested, such that the central cavity measured – 3 X 2 X 2 mm. In order to facilitate the later stages of the removal of the luting material specimens after polymerization without altering the surfaces of the mold, an ejection tunnel was created at the bottom of the cavity. A 1.5mm cylindrical tunnel is drilled in the centre going through to the furcation of the tooth that would allow the insertion of a thin instrument to push out the cured specimens. A removable plug uses an additional silicone to avoid excess luting material through that tunnel. A standardized Endocrown composite resin material was generated with the Cerec 3D CAD/CAM (EXOCAD Dental Systems) software, using CERASMART composite resin material of 5.5mm and 7.5mm thicknesses (Figs. 2 and 3).



Figs. 2 and 3. Boleys gauge caliper showing Endocrown thickness of 5.5mm and 7.5mm, respectively.

Fabrication of specimen

A dual polymerizable luting resin cement VA (variolink II A3; Ivoclar Vivadent) was used to simulate the luting procedure. A mylar strip separated the inner surface of the composite endocrown from the luting agent. The Endocrown was inserted into the mold cavity over the mylar strip, and the underlying resin was polymerized with an LED unit (Woodpecker LED curing unit) (Figs. 4 and 5). irradiation is performed from 3 locations (occlusal, buccal, lingual) around the restoration to minimize the distance between the light source and the luting cement(Fig. 6).

Fig. 4. Application of rubber dam on the extracted tooth mold to mimic clinical conditions.

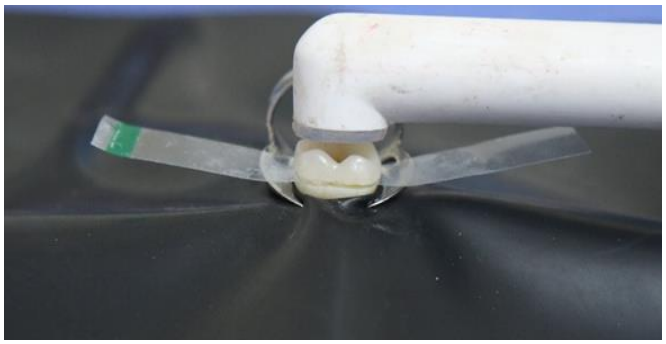


Fig. 5. Placement of mylar strip over the extracted tooth and endocrown is placed on it with the curing unit in position.

The lamp was first placed perpendicular to the occlusal surface and in contact with the restoration (irradiation time, 90 seconds). It was then positioned at an angle of approximately 45 degrees to the buccal and lingual surfaces in contact with the cementoenamel junction (2 X 90 seconds). Irradiation time was set at 90 seconds per side to compensate for the energy loss through a 5.5mm thick indirect restoration. It was cooled with compressed air during polymerization to prevent the restoration from overheating.

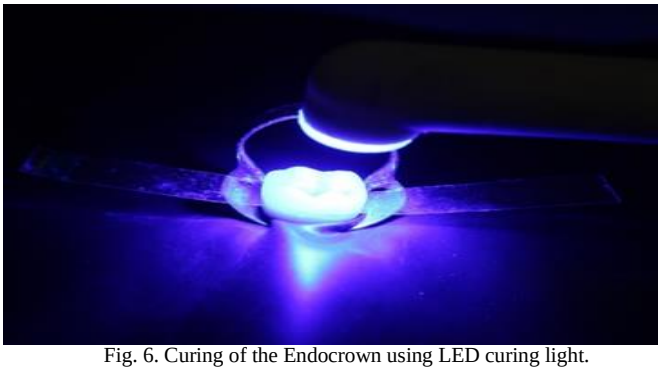


Fig. 6. Curing of the Endocrown using LED curing light.

The Endocrown was then removed, and the polymerized luting material was gently extracted from the mold cavity through the tunnel. A permanent marker was used to identify the occlusal surface of the resin specimen. The same procedure was repeated for the 7.5mm thick Endocrown.

Fabrication of control group

The cement thickness of 2mm is obtained by placing a glass slide at a 2mm distance. The maximum surface conversion of the Variolink II specimen was obtained by direct irradiation (40 seconds) under a Mylar strip (Figs. 7 and 8).

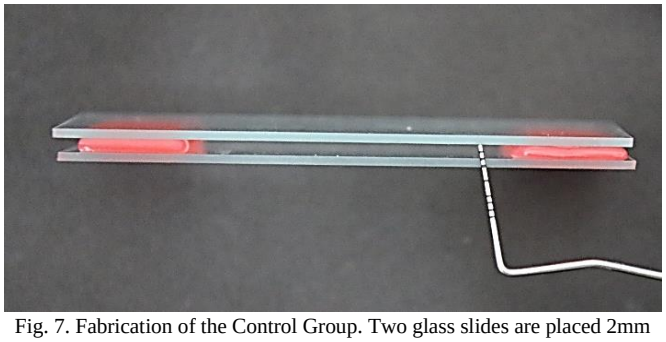


Fig. 7. Fabrication of the Control Group. Two glass slides are placed 2mm apart, with wax stoppers on either end.

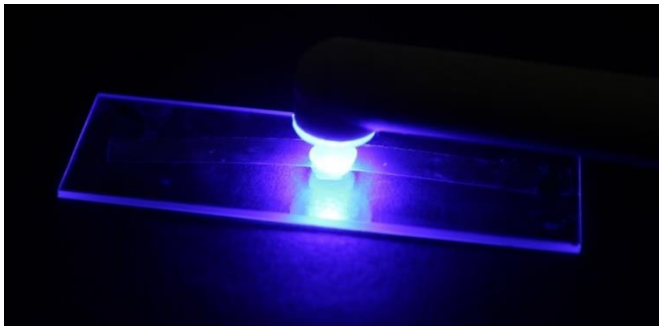


Fig. 8. Curing of the resin cement using LED curing light over the mylar strip.

Description of the specimen

The cured dual-cure resin cement was retrieved from the mold with the help of a thin instrument through the ejection tunnel that was created (Fig. 9). The top surface of the cured resin cement was marked using a permanent marker. The specimens were then embedded in a slow-setting self-polymerizable resin of 10x10mm (Fig. 10). Once the resin is set completely, the upper surface is polished using silicon carbide paper under water spray.

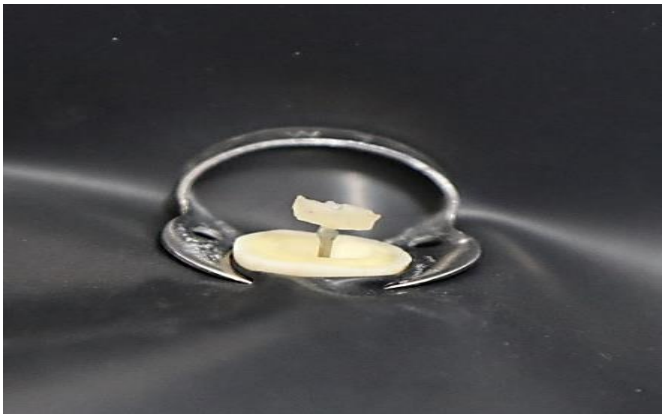


Fig. 9. The cured resin cement is retrieved by inserting a thin instrument through the prepared ejection tunnel.

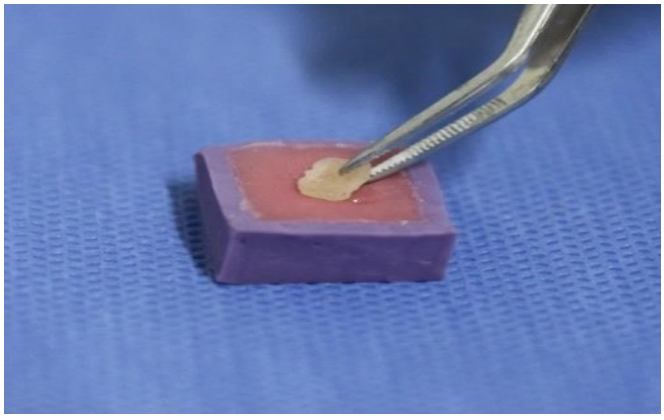


Fig 10: Embedding the cured resin cement into the self-polymerizable mold.

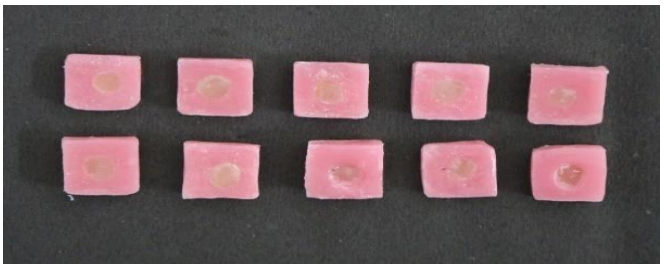


Fig. 11. Group 1 testing samples.

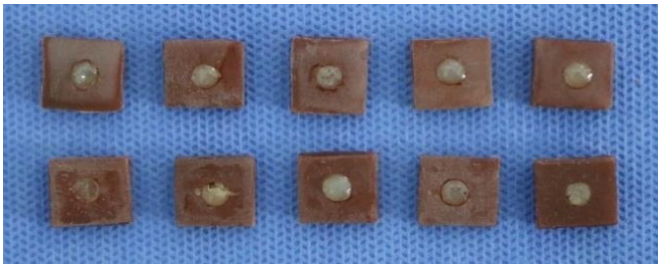


Fig. 12. Group 2 testing samples.

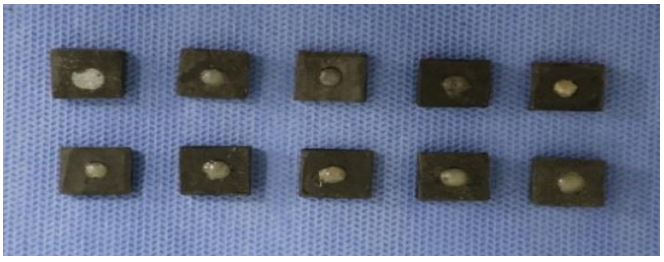


Fig. 13. Control Group testing samples.

Testing of the specimen

Vickers microhardness test

Fig. 14. Vickers Microhardness tester for measuring microhardness of cured resin cement.

The surface hardness is measured with a Vickers microhardness testing machine using a predetermined load of 1 N and a dwell time of 15 seconds at 0.5mm depth. For each specimen, 4 horizontal indentations with 0.1-mm intervals are made next to the vertical center line of the specimen at 0.5 mm below the surface. The hardness of each specimen was calculated as the average of these four indentations. Thus, microhardness testing is a simple method of indirectly assessing a specific resin's relative depth of polymerization. A test-to-control Vickers microhardness (VMH) values ratio of 0.80 at a depth of 0.5mm below the surface was assumed as the criterion for adequate conversion. Fourier Transform Infrared (FTIR) spectroscopy with an Attenuated Total Reflectance (ATR) unit Degree of Polymerization of the resin cement is determined using a Fourier Transform Infrared (FTIR) spectroscope with an attenuated total reflectance (ATR) unit. The resin film crystals are pressed against an ATR prism. The absorbance spectrum is acquired by scanning the specimens 10 times over a 1670–1550 cm-1 range with a resolution of 4 cm-1. The Degree of Polymerization was determined from the aliphatic C=C peak at 1638 cm-1, while the aromatic C=C peak at 1608 cm-1 was used as the internal calibration for calculating the final value. The Degree of Polymerization is then calculated by comparing the height of the peaks for the methacrylate vinyl group in the cured material against that in the uncured material using the following formula:

Degree of Polymerization (%) = (1 − C/U) × 100.

Hence, the test to control the Degree of Polymerization ratio of 0.90 was assumed as the criterion for adequate conversion.

Fig. 15. Sample placed in the FTIR spectroscope.

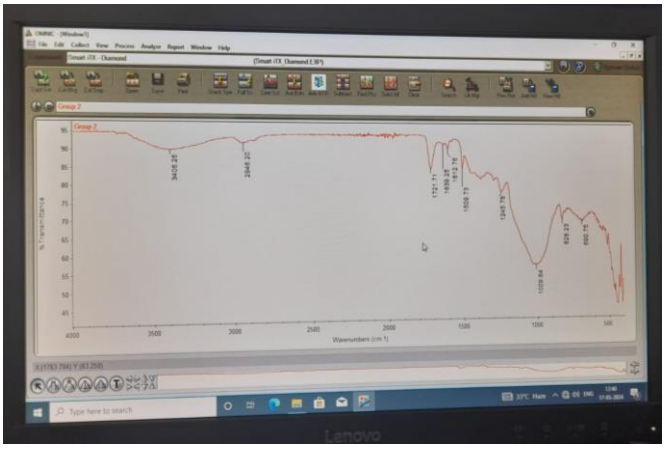


Fig. 16. Spectra obtained in FTIR spectroscopy.

3. Results

The study compared the microhardness of dual-cure resin cement used for luting composite resin endocrowns with thicknesses of 5.5 mm and 7.5 mm. The microhardness was measured using the Vickers microhardness test, and the results are detailed in Table 1. The mean microhardness across all groups was 7.4663, with an overall standard deviation of 0.30963 and a standard error of 0.05653. The 95% confidence interval for the total mean ranged from 7.3507 to 7.5820, with observed microhardness values between 7.02 and 7.96.

Table 1. Comparison of microhardness of dual-cure resin cement used for luting composite resin Endocrowns of 5.5mm and 7.5mm thicknesses using the Vickers microhardness test.

	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	P-value
				Lower Bound	Upper Bound			
Control group Dual cure resin cement of 2.0 mm.	7.8690	.08293	.02622	7.8097	7.9283	7.72	7.96	
Group 1 Dual cure resin cement under composite endocrown of 5.5 mm.	7.3530	.06165	.01950	7.3089	7.3971	7.23	7.44	<0.001
Group 2 Dual cure resin cement under composite endocrown of 7.5 mm.	7.1770	.10393	.03287	7.1027	7.2513	7.02	7.29	
Total	7.4663	.30963	.05653	7.3507	7.5820	7.02	7.96	

The ANOVA test results revealed a significant difference in microhardness values between the groups ($F = 180.665$, $p < 0.001$). The sum of squares between the groups was 2.587 with 2 degrees of freedom, resulting in a mean square of 1.293. Within groups, the sum of squares was 0.193 with 27 degrees of freedom, yielding a mean square of 0.007. The total sum of squares was 2.780 with 29 degrees of freedom, as presented in Table 2.

Table 2. Comparison of Vickers microhardness using ANOVA test of dual-cure resin cement used for luting composite Endocrowns of 5.5mm and 7.5mm thicknesses.

ANOVA Test						
		Sum of Squares	df	Mean Square	F	Sig.
Vickers microhardness (VMH)	Between Groups	2.587	2	1.293	180.665	**<.001**
	Within Groups	.193	27	.007	-----	-----
	Total	2.780	29	-----	-----	-----

Overall, the microhardness of dual-cure resin cement significantly decreased with increasing thickness of the composite resin endocrown. The highest microhardness was observed in the control group with 2.0 mm thickness, followed by the 5.5 mm and 7.5 mm groups. These findings suggest that the thickness of the composite resin endocrown plays a critical role in the microhardness of the underlying dual-cure resin cement. The study also evaluated the degree of polymerization of dual-cure resin cement used for luting composite resin endocrowns with 5.5 mm and 7.5 mm thicknesses. Fourier Transform Infrared (FTIR) Spectroscopy was employed to measure the degree of polymerization, and the results are summarized in Table 3. The mean degree of polymerization across all groups was 7.8723, with an overall standard deviation of 0.35528 and a standard error of 0.06487. The 95% confidence interval for the total mean ranged from 7.7397 to 8.0050, with observed values between 7.34 and 8.38.

Table 3. Comparison of the degree of polymerization of dual-cure resin cement used for luting composite resin Endocrowns of 5.5mm and 7.5mm thicknesses using Fourier Transform Infrared (FTIR) Spectroscopy.

	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	P-value
				Lower Bound	Upper Bound			
Control group Dual cure resin cement of 2.0mm	8.3110	.03843	.01215	8.2835	8.3385	8.26	8.38	
Group 1	7.8050	.17772	.05620	7.6779	7.9321	7.34	7.94	

Dual cure resin cement under composite endocrown of 5.5mm Group 2								
Dual cure resin cement under composite endocrown of 7.5mm	7.5010	.04012	.01269	7.4723	7.5297	7.43	7.55	<0.001
Total	7.8723	.35528	.06487	7.7397	8.0050	7.34	8.38	

The ANOVA test results revealed a significant difference in the degree of polymerization between the groups (F = 144.873, p < 0.001). The sum of squares between the groups was 3.349 with 2 degrees of freedom, resulting in a mean square of 1.674. Within groups, the sum of squares was 0.312 with 27 degrees of freedom, yielding a mean square of 0.012. The total sum of squares was 3.661 with 29 degrees of freedom. The ANOVA test results revealed a significant difference in the degree of polymerization between the groups (F = 144.873, p < 0.001). The sum of squares between the groups was 3.349 with 2 degrees of freedom, resulting in a mean square of 1.674. Within groups, the sum of squares was 0.312 with 27 degrees of freedom, yielding a mean square of 0.012. The total sum of squares was 3.661 with 29 degrees of freedom.

Table 4. Comparison of the degree of polymerization using ANOVA test of dual-cure resin cement used for luting composite resin Endocrowns of 5.5mm and 7.5mm thicknesses.

ANOVA Test						
		Sum of Squares	df	Mean Square	F	Sig.
Degree of Polymerization (FITR)	Between Groups	3.349	2	1.674	144.873	**<.001**
	Within Groups	.312	27	.012	-----	-----
	Total	3.661	29	-----	-----	-----

Overall, the degree of polymerization of dual-cure resin cement significantly decreased with increasing thickness of the composite resin Endocrown. The highest degree of polymerization was observed in the control group with 2.0 mm thickness, followed by the 5.5 mm and 7.5 mm groups. These findings suggest that the thickness of the composite resin endocrown plays a critical role in the polymerization of the underlying dual cure resin cement. The study conducted multiple comparisons of microhardness values among the studied groups using the Vickers microhardness test, as detailed in Table 3.

The analysis revealed significant differences in microhardness (VMH) between the control and experimental groups. Specifically, the control group (dual cure resin cement of 2.0 mm) exhibited a significantly higher microhardness compared to Group 1 (dual cure resin cement under composite endocrown of 5.5 mm) and Group 2 (dual cure resin cement under composite endocrown of 7.5 mm), with mean differences of 0.51600 and 0.69200, respectively, both with a standard error of 0.03784 and p-values less than 0.001. Additionally, Group 1 had a significantly higher microhardness than Group 2, with a mean difference of 0.17600 (p < 0.001).

Table 5. Multiple comparison of microhardness (Vickers microhardness test) among the studied groups.

Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.
Vickers microhardness (VMH)	Control group	Group 1	.51600*	.03784	<.001
		Group 2	.69200*	.03784	<.001
	Group 1	Control group	-.51600*	.03784	<.001
		Group 2	.17600*	.03784	<.001
	Group 2	Control group	-.69200*	.03784	<.001
		Group 1	-.17600*	.03784	<.001

Test: Post hoc TUKEYs test

*. The mean difference is significant at the 0.05 level.

Group 2 had the lowest mean VMH of 7.1770, Group 1 had a mean VMH of 7.3530, and the control group had the highest mean VMH of 7.8690. The differences between these subsets were statistically significant (alpha = 0.05). These results indicate that the thickness of the composite resin endocrown significantly affects the microhardness of the underlying dual cure resin cement, with thinner endocrowns associated with higher microhardness values. The study conducted multiple comparisons of the degree of polymerization among the studied groups using Fourier Transform Infrared (FTIR) Spectroscopy, as detailed in Table 6.

Table 6. Shows the Post hoc Tukey's test of the Vickers microhardness, categorizing the groups into distinct subsets.

Vickers microhardness (VMH)

Tukey HSD[a]				
Groups	N	Subset for alpha = 0.05		
		1	2	3
Group 2	10	7.1770	-----	-----
Group 1	10	-----	7.3530	-----
Control group	10	-----	-----	7.8690
Sig.	-----	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.

Table 7. Multiple Comparison of degree of polymerization (Fourier Transform Infrared (FTIR) Spectroscopy) among the studied groups.

Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.
Degree of Polymerization	Control group	Group 1	.50600*	.04808	**<.001**
		Group 2	.81000*	.04808	**<.001**
	Group 1	Control group	-.50600*	.04808	**<.001**
		Group 2	.30400*	.04808	**<.001**
	Group 2	Control group	-.81000*	.04808	**<.001**
		Group 1	-.30400*	.04808	**<.001**

Test: Post hoc TUKEYs test

*. The mean difference is significant at the 0.05 level.

The results revealed significant polymerization differences between the control and experimental groups. Specifically, the control group (dual cure resin cement of 2.0 mm) exhibited significantly higher polymerization compared to Group 1 (dual cure resin cement under a 5.5 mm composite endocrown) and Group 2 (dual cure resin cement under a 7.5 mm composite endocrown), with mean differences of 0.50600 and 0.81000, respectively (both $p < 0.001$). Additionally, Group 1 had significantly higher polymerization than Group 2, with a mean difference of 0.30400 ($p < 0.001$). Post hoc Tukey's test confirmed these findings, categorizing the groups into distinct subsets: Group 2 had the lowest mean polymerization at 7.5010, Group 1 had a mean of 7.8050, and the control group had the highest mean of 8.3110. The significant differences between these subsets indicate that the thickness of the composite resin endocrown substantially impacts the polymerization of the underlying dual cure resin cement.

Charts. 1 and 2 depicted the pictorial representation of the comparison of microhardness and degree of polymerization of dual-cure resin cement used for luting composite resin Endocrowns of 5.5mm, 7.5mm, and control groups.

Table 8. Shows the Post hoc Tukey's test of the degree of polymerization, categorizing the groups into distinct subsets.

Degree of Polymerization

Tukey HSD[a]

Groups	N	Subset for alpha = 0.05		
		1	2	3
Group 2	10	7.5010	-----	-----
Group 1	10	-----	7.8050	-----
Control group	10	-----	-----	8.3110
Sig.	-----	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.

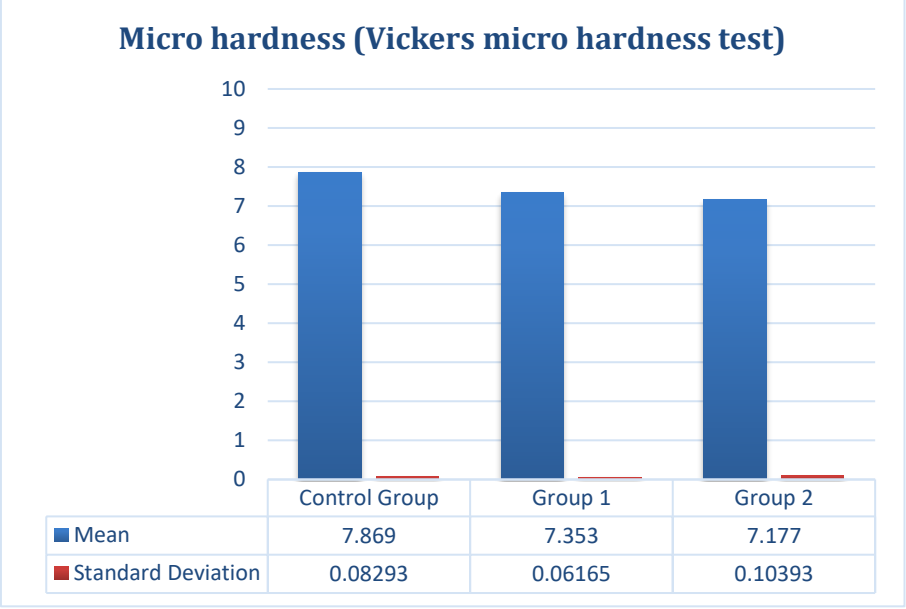


Chart. 1. Comparison of microhardness of dual-cure resin cement used for luting composite Endocrowns of 5.5mm and 7.5mm thicknesses using the Vickers microhardness test.

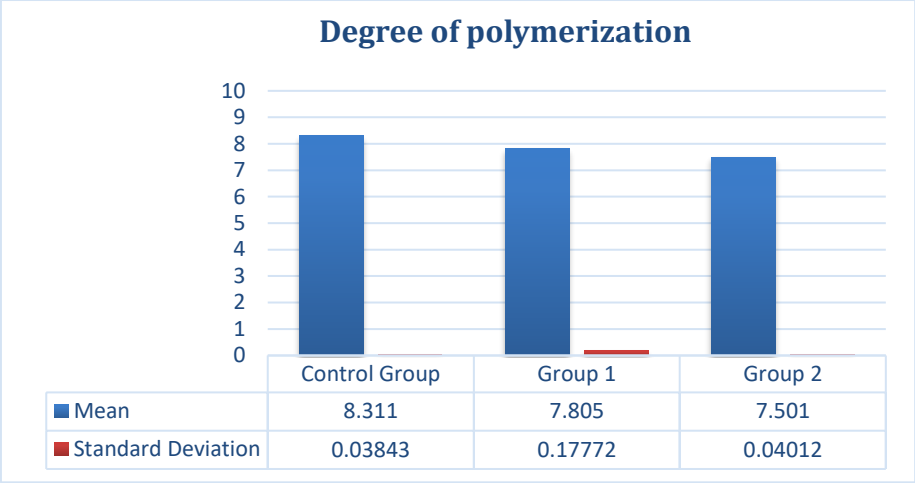


Chart. 2. Comparison of the degree of polymerization of dual-cure resin cement used for luting composite resin Endocrowns of 5.5mm and 7.5mm thicknesses using Fourier Transform Infrared (FTIR) Spectroscopy.

4. Discussion

Endodontically treated teeth' longevity depends on minimally invasive preparations with maximal tissue conservation. Indirect adhesive procedures have now become integral to restorative treatment modalities. The coronal restoration for the ETT has a statistically significant influence on the success rate of root canal treatments. An ample post-endodontic restoration influenced the long-term result significantly more positively than a sufficient root canal filling. Furthermore, if there is poor coronal restoration, it was reported that the success rates of sufficient root canal treatments dropped from 81% to 71%. Coronal restoration is of utmost importance in maintaining the healing of an apical lesion, creating a barrier for the oral bacteria to re-enter the root canal. It mainly reinforces the weakened tooth structure. As per the older literature, according to Ray., et al.,[7] an adequate coronal restoration has a stronger long-term impact on the RCT than the treatment itself. Conventional treatment options like post and core have been implied to restore teeth with large coronal defects. As the preparation of post space has the increased risk of root fracture and root perforation with further weakening of tooth structure, it was way back in 1995 that Pissis presented a novel technique that utilized a porcelain core/crown unit in a single unit. The monobloc technique was called, and the author suggested replacing the traditional metal post and core.[4] Subsequently, in 1999, based on the Pissis concept, Bindle and Mörmann introduced the Endocrown, an adhesive-based restoration. Endocrown is an adhesive crown characterized as the full crown of tooth colored restorative material that presents a central extension into the pulp chamber to increase the surface area of bonding, fixed to posterior endodontically treated teeth with a supragingival butt joint retaining as much as possible enamel for improved adhesion. Thus, it is minimally invasive of root canals and will be limited to pulp chambers.[3, 4] For endocrown restorations, CAD/CAM materials are favored because of their durability, aesthetic qualities, and adhesive bonding abilities.[2] Endocrowns are restorations that present the advantage of constructing the crown and core as a single unit, allowing for greater stability and retention. The main advantage of Endocrowns is related to the fact that they do not require root dentin removal for the retainer installation, in addition to preventing the risk of recontamination during disobturation. Additionally, during an endodontic failure, reinterventions can be performed more easily. Initial reports have demonstrated the favorable clinical performance of endocrown restorations. At the same time, Bindl and Mormann observed that only one out of 19 EC in 13 patients (95.5% survival) after 28 months failed because of recurrent caries, and recent results of seven and 10-year clinical studies are the first long-term reports that further suggest the viability of the endocrown method, with the success rate being much higher for endocrowns than that obtained for peripheral crowns (99.78% vs. 98.66%).[8] Irrespective of the aforementioned features, adequate polymerization of the luting resin beneath the restoration is mandatory. Therefore, the extent of the polymerization of the resin cement indirectly plays an important role in the ultimate success of the restoration. Clinically, dual polymerizable resin cements are frequently preferred to light-polymerizable ones. The present study evaluated the microhardness and degree of polymerization of dual-cure resin cement used for luting composite endocrowns with varying thicknesses. The findings revealed that both microhardness and degree of polymerization were significantly influenced by the thickness of the composite resin Endocrowns, with thinner Endocrowns showing higher values in both parameters.[1] Additionally, the inclusion of a sufficient sample size for each group (n=10) enhanced the statistical power and allowed for a more accurate assessment of variability. The clear comparative framework, which examined different thicknesses of composite resin endocrowns (2.0 mm, 5.5 mm, and 7.5 mm), provided a direct evaluation of the impact of thickness on microhardness and polymerization, elucidating the relationship between endocrown thickness and the properties of the underlying resin cement. The study's relevance was clinically significant, as its findings directly impact dental practice, guiding dentists in optimizing restorative procedures for better outcomes. Henceforth, the present study is favorable to the studies done by Gregor et al.,[5] and Daher et al.,[6] which states that the degree of polymerization of light and dual-polymerizable luting resins irradiated for 3x90 seconds with a high irradiance light-emitting diode lamp under thick indirect endocrowns using Vickers microhardness measurements and found out that under the conditions of this in vitro study, reached at least 80% of the control Vickers microhardness values.

5. Conclusion

The present study aimed to elucidate the polymerization behavior of dual-cure resin cement in endocrowns by examining the Vickers microhardness and degree of polymerization after curing with varying thicknesses of CAD/CAM composite resin Endocrowns. Considering the limitations of this study, the following conclusions were drawn. Polymerization of the dual-cure resin cement decreased with increasing CAD/CAM material thickness, suggesting that thicker materials impeded the curing process. Significant differences in polymerization were observed between samples with a 1.5 mm

thickness (conventional crowns) and those with thicker Endocrowns. The results obtained were statistically significant in achieving the minimum required polymerization. Thus, these findings suggest that future research directions could explore advanced measurement techniques to elucidate further the nanoscale effects of endocrown thickness on resin cement properties. Nanoindentation and real-time monitoring of polymerization kinetics hold promise in providing deeper insights into material behavior and performance.

Conflict of Interest

The authors declared that there is no conflict of interest.

Acknowledgments

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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How to Cite this Article: Nallikatte PT, Mohan S, Karunakaran HK, Rajagopal R, Nair VV, Shajahan A. Comparative Evaluation of Microhardness and Degree of Polymerization of Dual-cure Resin Cement on Luting Composite Resin Endocrowns of 5.5mm and 7.5mm Thicknesses: An in-vitro Study. International Journal of Scientific Research in Dental and Medical Sciences. 2024;6(4):168-177. https://doi.org/10.30485/IJSRDMS.2025.490011.1621.