Original Article

DOI: 10.7860/JCDR/2020/45840.14305

Dentistry Section

Evaluation of Marginal Adaptation and Wear Resistance of Nanohybrid and Alkasite Restorative Resins

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ABSTRACT

Introduction: Polymerisation shrinkage stresses developed during curing of adhesive resin cements may cause debonding at the margins of cavity leading to microgap formation with secondary caries and consequently restorative failure. Thus, a restoration should have good marginal integrity and wear resistance to obtain high success with clinical longevity.

Aim: To compare the influence of thermo-mechanical stresses on marginal quality and wear of class II Mesio-Occluso-Distal (MOD) restorations filled with Solare Sculpt or Cention N.

Materials and Methods: An in vitro study was conducted at GITAM Dental College and Hospital, Visakhapatnam on 80 human extracted mandibular molars by preparing mesio-occlusal-distal class two cavities that restored either with Solare Sculpt or Cention N resin composites. Baseline evaluations were recorded for marginal gaps (in µm) through Scanning Electron Microscope (SEM), and the weights of the samples were recorded by an electronic balancing instrument to measure the amount of wear (in grams). Following thermo-mechanical cyclic loading, all the restored teeth were evaluated again to record the same parameters. The statistical analysis was done using Statistical Package for the Social Sciences (SPSS) programme for windows version 22.0 (IBM, NY) software. An independent t-test for intergroup comparison and a dependent t-test for intragroup comparisons were done to analyse the tested parameters with the significance level established at ($p \leq 0.05$).

Results: In intergroup comparison, no difference in marginal adaptation was observed before thermo-mechanical loading between two materials with a p-value of 0.3625, but after thermomechanical loading Cention N exhibited significantly superior marginal adaptation with a p-value of 0.0374. Both the materials have shown a significant difference in the marginal adaptation after thermo-mechanical loading in the intragroup comparison with Cention N (0.0002) and Solare sculpt (0.0001) p-values. The wear rate was not different statistically between the materials with a p-value of 0.7144 before thermo-mechanical loading and 0.2285 after thermo-mechanical loading.

Conclusion: Marginal adaptation of Cention N was superior to Solare Sculpt, whereas both the materials exhibited a similar wear rate.

Keywords: Cention N, Electronic balancing instrument, Marginal seal, Solare sculpt, Wear resistance

INTRODUCTION

Resin composites are the most frequently advocated materials in more than 50% of the cases for restoring anterior and posterior teeth defects [1]. Even after achieving noted improvements in restorative resins, failure of the bond at the tooth-restorative interface due to polymerisation shrinkage stresses remains a major drawback. As a consequence, the formation of marginal gaps with seepage of oral fluids may occur, leading to secondary caries, pulpal inflammation, cuspal deflection, and postoperative sensitivity [1,2]. The gap formed at the tooth restorative interface is mainly associated with the resin's chemical composition, type of filler, the geometry of the cavity, and the restorative technique [3].

Marginal adaptation is one of the significant features that play a crucial role in the clinical outcome of the restoration [4]. Though the ideal marginal gap between restoration and tooth substrate should be 25-40 µm, it is rarely achieved clinically, especially at proximal gingival surfaces. This is due to the high amount of polymerisation shrinkage and thermal expansion [5].

Another clinical concern of resin restorative outcome in extensive posterior cavitated lesions, especially in patients with para-functional habits, is the wear property [6]. During thermal and mechanical cyclic changes, the differences in coefficient of thermal expansion between the resin matrix and fillers, induce interfacial stresses causing dislodgement of fillers, leading to wear [7].

Recently developed nanohybrid composites have exhibited better mechanical properties with minimal polymerisation shrinkage [8]. Solare Sculpt (GC Dent Corp, Toriimatsucho, Japan) is a newly introduced compactable nanohybrid restorative material with improved handling properties and wear resistance. The manufacturer claims that it has a unique pre-polymerised, homogenous strontium (300 nm glass) nanofillers with high density and uniform silane dispersive technology which provides high flexural strength and wear resistance [9].

Another innovative posterior restorative material introduced was Cention N (Ivoclar Vivadent Ag, Schaan, Liechenstein, Europe). It is an "alkasite" restorative material and during acidic attacks capable of releasing acid-neutralising ions that are incorporated in the resin matrix. This ormocer formulation is claimed to have excellent mechanical and physical (aesthetic, adhesive and fluoride-releasing) properties [10].

Ideally, restorative and tooth substrate interfaces are evaluated by assessing morphology and function. Morphological criteria are used for clinical evaluation and functional criteria for in vitro studies. These tests assess the marginal seal of the restoration placed in extracted teeth and guide us to predict their clinical performance [11]. According to American Dental Association (ADA) standards, the annual wear of any restorative material should not be more than 50 µm [12].

Thus, the present study was aimed to evaluate and compare the marginal adaptation and volumetric wear of Solare Sculpt and Cention N restorative resins before and after thermo-mechanical simulation.

MATERIALS AND METHODS

The present in vitro study was carried out at GITAM Dental College and Hospital, Visakhapatnam between March to June 2019. The protocol for the study was approved by the State Health University (D178601024), and the Institutional Review Board had granted the ethical clearance. A total of 80, periodontally involved extracted human non-carious mandibular molar teeth having similar buccolingual and mesiodistal dimensions were selected. All the collected teeth after disinfection in chloramine-T (0.5%) solution were stored for a maximum period of three months before use in saline at 4°C. Auto-polymerising resin (DPI-RR, Mumbai, India) was used in which each sample tooth was mounted with adjacent healthy teeth on both sides so that the appropriate proximal contacts and contours were maintained [Table/Fig-1].

[Table/Fig-1]: Sample tooth with MOD cavity preparation mounted in auto-polymerising resin with adjacent healthy teeth.

Polyvinyl siloxane impression material was used to cover the root surfaces of teeth to simulate the periodontal ligament. The periodontal ligament transfers the stresses during restorative procedure and occlusal loading to all the root surfaces without concentrating at a single point. Thus, to mimic the intraoral conditions during thermo-mechanical cyclic procedures, the periodontal ligament was simulated along the root surface [13]. Distilled water was used throughout the experimental period to store the teeth at room temperature.

Restorative Procedures

Standardised class II MOD cavities were prepared using a #245 tungsten carbide bur (SS White, New Jersey, USA) in 80 mandibular molar teeth. Class II cavities with 90° butt joint occlusal cavosurface margins were prepared with a 3 mm buccolingual width and pulpal floor depth. The axial walls were prepared 1.5 mm deep from the external surface. The gingival seat was prepared 0.5 mm coronally from the Cemento-Enamel Junction (CEJ). For every five tooth preparations, the bur was replaced with a new one.

The sample teeth were assigned into two groups (n=40 each) depending on the type of material used to restore the teeth. To maintain the proper proximal contour, a universal Tofflemire matrix system was used. In Group SS (Solare Sculpt), 37% phosphoric acid etchant (Eco-etch, IvoclarVivadent AG, Schaan, Europe) was applied to the prepared cavity walls for 20 seconds and cleansed thoroughly with a water jet for 15 seconds. Then, Solare universal bond (GC Dental Corp, Toriimatsu-Cho, Japan) was applied and light-cured for 10 seconds. Solare sculpt resin material was placed in an incremental manner and light-cured with the C8 LED unit (Vivadent, Schaan, Liechtenstein, USA) for 20 seconds [14].

In Group CN (Cention N) samples, after the etching process, Tetric N Bond (IvoclarVivadent Ag, Schaan, Liechtenstein, Europe) was applied and light-cured. Powder and liquid of Cention N were mixed in a 1:1 ratio with agate spatula to get a homogenous soft consistency mix. Initially, the material was placed and condensed by teflon coated instruments in the proximal cavity and then occlusally to avoid void formation. Setting time of four minutes was allowed for self-curing, followed by light-curing for 40 seconds [15].

Finishing of composite restorations was done initially with TR-25EF diamond abrasives (MANI, Utsunomiya, Tochigi, Japan) to remove the gross irregularities and marginal overhangs. Fine-grit Sof-Lex flexible disks (3M ESPE, MN, USA), and rubber cups (Shofu dental products, San Marcos, USA) at low speed were used to finish and polish the restorations. Following which the restored teeth were stored in distilled water at 37°C for 24 hours so as to mimic the clinical conditions and to allow final setting of restorative materials.

Baseline evaluation of the restorations: After 24 hours of completion of restorative procedure, the baseline evaluations were done by two examiners who were blinded about the samples.

Scanning Electron Microscopic (SEM) marginal adaptation observations: A total of 20 sample teeth in each group were chosen to evaluate the marginal adaptation of the restorative materials. Teeth samples were mounted on aluminium stubs, sputter-coated with gold, [Table/Fig-2] and assessed for quantitative marginal gaps under SEM (S3700N, Hitachi, Chicago, Tokyo, Japan). The width of the gaps at the restorative tooth interface was analysed at 18 pre-determined points (6 occlusal + 8 proximal + 4 gingival) under 350x magnification. These values in micrometers (μm) were averaged to record the marginal gap value for each sample.

[Table/Fig-2]: Gold sputter-coated tooth samples.

Wear measurement: A total of 40 restored samples (n=20 for each group) were pre-weighed with an electronic balancing instrument (Shimadzu Corporation ELB 300 Japan), and the values were recorded in grams.

Thermo-Mechanical Cyclic Loading

After recording baseline values, all the restored teeth were subjected to a thermo-mechanical loading procedure. Following thermocycling at 5°C and 55°C for 10,000 cycles, the teeth were loaded mechanically with a custom made chewing simulator for

2,50,000 cycles by which a vertical occlusal load of 50 Newtons at 20 cycles/minute was applied. On the occlusal cuspal inclines, a round piston of 5 mm diameter was used to apply the axial force at a frequency of 1 Hz. This thermo-mechanical loading procedure was employed to simulate the clinical performance of a restoration after one year of aging process [16,17].

Evaluation after Thermo-mechanical Loading

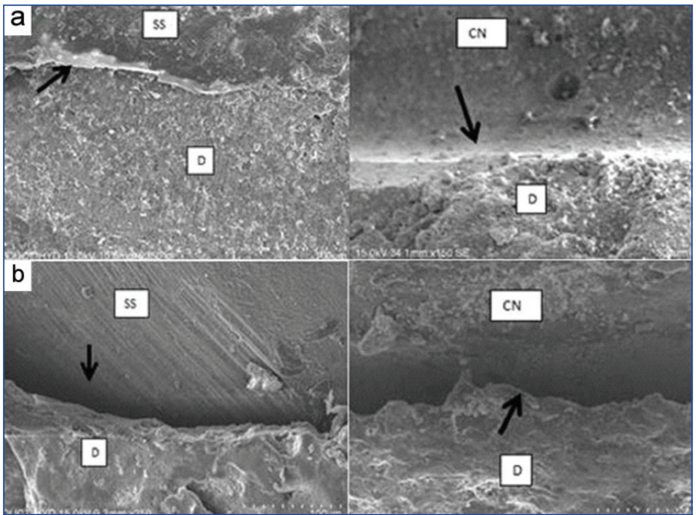
The samples were again evaluated for marginal gaps estimation through SEM, and the loss of marginal integrity was assessed. The specimens were again weighed to determine the amount of wear. The difference between the weights before and after cyclic loading was recorded.

STATISTICAL ANALYSIS

All the values that were obtained were subjected to statistical analysis using SPSS statistics for windows, version 22.0 (IBM, Armonk, NY) software. An independent t-test for intergroup comparison and a dependent t-test for the intragroup comparison of both the parameters tested were used. Statistical analysis was performed at a 95% level of confidence, with the significance level established at $p<0.05$.

RESULTS

[Table/Fig-3a,b] show SEM images of specimens of Solare Sculpt and Cention N showing marginal adaptation at gingival surface before and after thermo-mechanical loading, respectively.



[Table/Fig-3]: a: Scanning electron microscopic (SEM) images of specimens Solare sculpt (SS) and Cention N (CN) showing marginal adaptation at gingival surface before thermo-mechanical loading. Solare sculpt (SS), Cention N (CN), Dentin (D). b: Scanning electron microscopic (SEM) images of specimens Cention N and Solare Sculpt showing marginal adaptation at gingival surface after thermo-mechanical loading.

Before thermo-mechanical loading, a significant difference was not observed in the mean marginal gap values between Cention N and Solare Sculpt with a p-value of 0.3625. But after the thermo-mechanical loading, Cention N exhibited significantly superior marginal adaptation with a p-value of 0.0374 [Table/Fig-4], both the materials showed a significant difference in the marginal adaptation after thermo-mechanical loading in the intragroup comparison with Cention N (p=0.0002) and Solare sculpt (p=0.0001) [Table/Fig-5].

When marginal gaps at different regions (gingival, proximal, and occlusal) were compared, the differences were statistically highly significant for pre and post loading for both Cention N and Solare sculpt. The gingival cavosurface margin showed the highest mean difference in marginal gap values with a p-value of $p\leq0.0002$ in Cention N and $p\leq0.0001$ in Solare sculpt, [Table/Fig-6].

Time	Groups	n	Mean	SD	SE	t-value	p-value
Before thermo-mechanical loading	Group SS	20	2.41	2.88	0.64	-0.9216	0.3625
	Group CN	20	1.61	2.57	0.57		
After thermo-mechanical loading	Group SS	20	11.67	7.35	1.64	-2.1575	0.0374*
	Group CN	20	7.17	5.77	1.29		
Changes	Group SS	20	9.27	6.47	1.45	-1.9707	0.0561*
	Group CN	20	5.56	5.39	1.21		

[Table/Fig-4]: Intergroup comparison of marginal gaps (in μm) formed between the materials before and after thermo-mechanical loading using independent t-test.
SD: Standard deviation; SE: Standard error
$p\leq0.05$ indicates significant difference

Time	Groups	n	Mean	SD	SD Diff.	t-value	p-value
Before thermo-mechanical loading	Group CN	20	1.61	2.57			
After thermo-mechanical loading	Group CN	20	7.17	5.77	5.39	-4.6076	0.0002**
Before thermo-mechanical loading	Group SS	20	2.41	2.88			
After thermo-mechanical loading	Group SS	20	11.67	7.35	6.47	-6.4078	0.0001**

[Table/Fig-5]: Intragroup comparison of marginal gaps (in μm) before and after thermo-mechanical loading using dependent t-test.
SD: Standard deviation; SE: Standard error
$p\leq0.001$** statistically highly significant

Site	Group	Mean	SD	Mean difference	p-value
Gingival	Pre-loading CN	1.61	2.56	-5.55	0.0002**
	Post-loading CN	7.17	5.76		
	Pre-loading SS	2.41	2.87	-9.26	0.0001**
	Post-loading SS	11.67	7.34		
Proximal	Pre-loading CN	1.35	1.62	-1.86	0.001**
	Post-loading CN	3.21	2.69		
	Pre-loading SS	1.33	1.71	-3.82	0.001**
	Post-loading SS	5.15	3.53		
Occlusal	Pre-loading CN	0.90	1.54	-1.74	0.001**
	Post-loading CN	2.64	2.20		
	Pre-loading SS	1.02	1.61	-3.82	0.001**
	Post-loading SS	4.84	2.81		

[Table/Fig-6]: Comparison of marginal adaptation at different surfaces by Independent t-test.
$p\leq0.001$ statistically highly significant
SD: Standard deviation; SE: Standard error

Cention N and Solare Sculpt showed no significant difference in wear rate with a p-value of 0.7144 before thermo-mechanical loading and 0.2285 after the thermo-mechanical loading [Table/Fig-7].

Time	Groups	n	Mean	SD	SE	t-value	p-value
Pre-loading	Group SS	20	1.79	0.38	0.09	0.3687	0.7144
	Group CN	20	1.84	0.31	0.07		
Post-loading	Group SS	20	1.32	0.33	0.07	-1.2239	0.2285
	Group CN	20	1.19	0.34	0.08		
Changes	Group SS	20	0.48	0.37	0.08	1.8699	0.0692
	Group CN	20	0.65	0.16	0.04		

[Table/Fig-7]: Comparison of wear (in grams) between solare sculpt and cention N using independent t-test.
SD: Standard deviation; SE: Standard error; $p\leq0.05$ statistically significant

DISCUSSION

Evaluation of the restorative margins is essential to analyse the effects of curing shrinkage and thermo-mechanical stresses [18]. Several factors can affect the restoration longevity and the marginal integrity including the location of the margins, cavity geometry, restorative material composition and restorative technique [18].

Ideally, any restorative material should have good wear resistance. Multiple factors in the composition of the material such as the type, size, shade and volume of the filler content may affect the wear of a restoration [19]. The most important factor that play a critical role in influencing the wear of a restoration is polymerisation of the resin matrix and resin filler interface [19].

The percentage of tooth wear increases from 3-17% as age advances [20]. Of all the teeth in the oral cavity, mandibular molars are most severely affected by wear. Also, higher masticatory load on these teeth makes the survival of the restorations challenging on these teeth [20]. Thus, human mandibular molars were included, and thermo-mechanical cyclic loads were applied in the study to simulate the invivo conditions.

Class II MOD restorations were included in the present study, as adhesion is known to be more challenging in proximal areas due to minimal availability of enamel margins [21]. Marginal gap formation is more evident upon occlusal loading leading to failure of posterior composite restorations [21]. Two-step etch and rinse adhesive system was used since high retention rates, and excellent marginal seal have been reported in clinical techniques that involve bonding to phosphoric acid-etched enamel and dentin than self-adhesive systems [22].

For the insertion of Solare Sculpt, the manufacturers recommended a horizontal incremental layering method as it allows better adaptation of the material to cavity walls with the pluggers without voids [23]. In the case of Cention N, the organic to inorganic ratio, along with the monomer's composition, allows for bulk placement of the material. This alkasite material has a unique patented isofiller that acts as a stress reliever, thereby reducing volumetric shrinkage [24]. To simulate the invivo conditions, all the restored teeth were subjected to thermo-mechanical cyclic loading similar to one year of clinical life [17].

The study results revealed better marginal adaptation with minimal gap formations for Cention N ($p \leq 0.0374$) compared to Solare Sculpt, especially after the aging process. Similar positive findings were observed in previous studies related to Cention N in which Sahadev CK et al., in an in vitro study compared Cention N with Bulkfill SDR and Zirconomer with regards to microleakage. The results of the study showed better performance of Cention N with respect to minimal marginal microleakage at occlusal and gingival surfaces with a p-value of ≤ 0.001 [2]. In another study, Dedania MS et al., compared Cention N with Amalgam in regard to clinical performance for a period of one year, the study evaluation has shown an acceptable clinical performance in molars respectively with alpha scores for both materials and no statistically significant difference in the p-value [25]. The presence of isofillers in the material might expand like a spring when forces between the fillers grow during polymerisation and act as a shrinkage stress reliever. Having low elastic modulus (10 GPa) for Cention N allows for better marginal seal [26].

Solare sculpt contains 30-40% of silane coated, 300 nm size strontium nanoceramic fillers. Poor marginal quality for Solare Sculpt might be attributed to its less filler content and water sorption property leading to more porosity and void formation [27].

The gingival wall showed poorer marginal adaptation compared to occlusal and proximal walls for both the tested materials with $p \leq 0.0002$ for Cention N and $p \leq 0.0001$ for Solare sculpt. Similar findings were observed in several previous studies by Cavalcanti AN et al., and Salagalla UD et al., also where they found more marginal leakage and lowest bond strength at the gingival margins as compared to the proximal walls with p=0.001 [28,29]. This finding can be attributed to the factors like less availability of intertubular dentin at the gingival wall to form a hybrid layer, presence of less mineralised dentin for etching and also poor isolation with contaminated tooth surfaces [28,29].

Dodiya PV et al., evaluated the clinical performance of Cention N and nanohybrid composite resin in restoring non-carious cervical lesion with regard to the marginal integrity and surface texture. Clinical evaluation of both the restorative materials was done at a time period of one week, one month, three months and six months, according to USPHS Ryge criteria. The results showed alpha scores with no significant difference in the marginal integrity of both the materials whereas the surface texture of Cention N was inferior to nanohybrid composite presenting bravo scores with a significant difference of p=0.001 [30].

Regarding the wear loss, the results supported the proposed null hypothesis, showing no difference between the materials tested. However, Cention N showed slightly higher wear than Solare Sculpt with no statistical difference. This finding correlates with a previous study by Mahmoud SH et al., in which it was concluded that nanofilled and nanohybrid composites achieved a smoother surface with alpha scores than ormocer that had shown bravo results [31]. And the reason for the surface roughness of ormocer restorative material was attributed to its particle size, and was also affected by masticatory forces and abrasive foods [31]. Among the composites (nanofilled and nanohybrid) that were tested none of them have shown an unacceptable wear that was attributed to the filler size [31]. Another study by Mahmoud SH et al., clinically evaluated three different restorative materials in posterior teeth which included ormocer, nanohybrid and nanofilled composites. Various criteria were evaluated in the study for a period of two years of which marginal adaptation and surface roughness was also included. Results showed alpha scores with 100% marginal adaptation for nanohybrid and nanofilled composites and 97% for ormocer with no significant difference $p \geq 0.05$ and also the surface roughness of all the three materials showed no significant difference $p \geq 0.05$ [32]. Another in vitro study by Roulet JF et al., comparing two bioactive smart composite restorative materials (Activa and Cention N) and one glass ionomer cement concluded that the wear behaviour of Cention N is in the same range as nanohybrid composites i.e., Activa showed a wear rate of 1.571 mm^3, whereas Cention N showed 2.455 mm^3 and the reason for Activa showing minimal wear rate when compared to Cention N was the latter was supplied in powder liquid form which includes manual mixing [33].

Thus, the longevity of any restoration depends on its marginal adaptation and the amount of wear loss. With regard to the drawbacks and consequences, the available laboratory and clinical study results augment and provide guidance for a clinician to select better material for patient care.

Limitation(s)

The evaluation of quantitative wear clinically in different materials is scarce. Most of the existing wear simulators available are not able to simulate the exact masticatory forces exerted on teeth during mastication. A sliding lateral movement should be integrated into the wear simulator to test the materials. Furthermore, the occlusal contact area is not correlated with wear at the occlusal cavosurface margins. Ideally, a material wear rate should be similar to that of enamel, and in direct restorative materials, amalgam should be taken as a reference material for comparison, and that was not done in this study.

CONCLUSION(S)

The results of the current in vitro study revealed superior marginal adaptation for Cention N compared to Solare Sculpt restorative resin. Both the materials exhibited a similar wear rate. Clinicians should be aware of the impact of occlusal and thermal stresses on the degradation and wear characteristics while selecting the restorative material.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jul 11, 2020
- Manual Googling: Oct 14, 2020
- iThenticate Software: Nov 24, 2020 (10%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? No
- For any images presented appropriate consent has been obtained from the subjects. No

Date of Submission: **Jul 10, 2020**
Date of Peer Review: **Aug 31, 2020**
Date of Acceptance: **Oct 14, 2020**
Date of Publishing: **Dec 15, 2020**