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RESEARCH

A comparative evaluation of mechanical wear of adhesives used for bonded retainers that underwent brushing for 1 hour under 36 mm of linear action, using computer-aided 3D scan—an in vitro study

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Abstract

Objectives The aim of the present study was to comparatively evaluate the mechanical wear of adhesives used in bonded retainers.

Materials and methods Eighty mandibular acrylic teeth were included in the study that were divided into 4 different groups based upon the composite used. Each acrylic tooth was bonded with a retainer wire and composite of their respective group (Heliosit, Restofill, Tetric-N-flow, and Filtek Z350 XT). These bonded acrylic teeth were subjected to 3D scan in order to evaluate the volume and surface area of the composite. The 3D scans were recorded using MEDIT 3D scanner. After evaluating, the samples were subjected to brushing with the aid of a custom-made brushing simulator using a toothbrush with soft bristles and toothpaste slurry. The samples were subjected to 1 hr of brushing. These samples were again subjected to 3D scans to evaluate (post-test volume and surface area) and underwent statistical analysis.

Results The results showed the Heliosit group exhibited the highest mean volume (1.76 mm^3) and surface area (4.81 mm^2) difference between the pre-test and post-test values whereas the least mean volume difference (1.10 mm^3) and surface area difference (3.21 mm^2) were seen in the Tetric-N-flow group.

Conclusion All the four composites underwent change in the mean surface area and volume after being subjected to brushing, suggesting that the composites routinely used for bonding fixed bonded lingual retainers are subjected to changes due to abrasion. The Heliosit group, which showed least filler loading among the 4 composites, exhibited least resistance to wear, whereas the Tetric-N-flow group which had highest filler loading among the composites exhibited highest resistance to wear.

Clinical relevance The most crucial phase during orthodontic treatment is the retention phase. This phase is responsible for the long-term results of the treatment. The retainers that are placed in the oral cavity are subjected to changes due to oral environment, chemical changes, and mechanical changes. These changes have a direct effect on the retainers, which tend to alter their properties. Thus, the effects of these changes are to be studied thoroughly.

Keywords Heliosit · Restofill · Tetric-N-flow · Filtek Z 350 · Bonded retainers · Computer-aided 3D scan · Mechanical wear

Introduction

Retention is considered to be one of the most crucial phases in the completion of orthodontic treatment. It begins once the active treatment phase is completed and the desired tooth position is obtained. This stage mainly focuses on stabilizing and maintaining the attained position and further avoids any undesirable or unwanted tooth movement that might occur after the fixed appliance is removed. The negligence in carrying out the retention phase increases the vulnerability to relapse. The rationale behind relapse is the changes that occur in the periodontal ligament and gingival fibers [1].

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Retainer ideally helps in maintaining the treated position of teeth while exerting the least adverse effect on the surrounding tissues [1]. Scenarios where the opening of spaces is anticipated will require a more precise and longer retention phase, to maintain treatment outcomes. Sometimes procedures such as pericision, interproximal reduction, gingival recountering etc. are done adjunct to retainers.

Retainers are broadly classified into two types. (1) Removable retainers, can be easily removed and placed back into the oral cavity by patients, on their own and also, allows them to clean the retainers efficiently. (2) Bonded retainers are those where an orthodontic retainer wire of adequate length is bonded to the lingual surface of the teeth by orthodontist. These bonded retainers are also known as "fixed retainers" [2].

Fixed retainers are also considered to be permanent retainers. Knierim introduced the bonded retainers to orthodontics [3]. Later Zachrisson and Antrum [3] fabricated retainers using multistranded stainless steel wire that was attached using composites on canines alone. Later in 1983 Zachrisson also included the other teeth in the labial segment [3].

Fixed retainers are fabricated by attaching the retainer wire to the lingual surface of the teeth with the aid of composites. Since composites are an integral part of retainers, it is important to consider their properties [3].

Composites consist of resin matrix, filler particles, and coupling agents. The filler particles are either organic or inorganic particles that are added to the resin matrix to strengthen the composite. The increase in the amount of filler content increases the wear resistance, compressive and tensile strengths. The effect of the filler particles on the composite is also dependent upon the size of the fillers incorporated. The filler sizes can be classified as macrofillers, microfillers, and nanofillers. Hybrid fillers are reinforced fillers containing two or more types of filler particles in them [4]. Macrofilled composites exhibited poor wear resistance and, thus, were considered to be clinically ineffective [5]. Later microfilled composites were introduced which exhibited excellent wear resistance properties but lacked popularity due to polymerization shrinkage and increased viscosity. With the advent of nanotechnology, attempts were made to incorporate nanoparticles as filler content in composites. The nanofilled/nanohybrid composites exhibited excellent physical properties, mechanical wear, and optical properties [5]. Among the various properties of composites, mechanical properties such as mechanical wear and hardness are of paramount importance when used in the fabrication of retainers.

Failure in the bonded retainer might occur due to fracture of the wire, disunion of the adhesive layer, insufficient curing time, inadequate etching, inability to achieve dry oral conditions while bonding, crack in the acrylic portion or dislodgement of wire components from the acrylic in case of removable retainers. Removable retainers tend to exhibit a higher failure rate than bonded retainers. In the bonded retainers, the retainers that are bonded only to canines exhibit higher failure rates (13–37%) than those that contact all the lower anterior teeth (9–14%). Apart from these, aging can alter the mechanical properties of the retainers ultimately leading to their failure. These changes may be due to brushing, various liquids that are consumed, the aging process, and other activities that might lead to wear of the material and ultimately failure of the lingual bonded retainer. Studies have shown that the abrasive wear of composites of the bonded retainers accounts for about 62%, thereby affecting the overall success rate of bonded retainers. Brushing is considered to be a daily activity and has a greater role in the wear of the material. Not much literature is available to estimate the wear of commercially available composites used in bonding fixed retainers. Thus, it is important to know the efficacy of various composite materials against mechanical wear that might occur during brushing as mechanical wear might lead to the failure of bonded retainers.

The present study was intended to evaluate the mechanical wear of Heliosit (microfilled), Restofil (nanohybrid), Tetric-N-flow (nanofilled), and Filtek Z350 XT (nanofilled) composites that are used in the fabrication of retainers.

Materials and methods

The present study was conducted to comparatively evaluate the mechanical wear of Heliosit, Restofil, Tetric-N-flow, and Filtek Z350 used for bonding fixed retainers using computer-aided 3D scans.

Sample selection

Eighty lower incisor acrylic teeth were taken and divided into four groups of twenty teeth in each group.

Study groups

A total of eighty lower incisor acrylic teeth were divided into four equal groups of 20 each based on the composite material that is used for bonding in fixed lingual retainers. The 20 acrylic teeth were further grouped into 10 blocks consisting of two teeth in each block that acted as a unit representing the two adjacent teeth of the lower arch. Each unit was bonded with retainer wire and composite adhesive of the respective group.

Study group 1—twenty lower incisor acrylic teeth consisting of ten blocks with 2 teeth each were bonded with Heliosit (Ivoclar-Vivadent) light cure adhesive system.

Study group 2—twenty lower incisor acrylic teeth consisting of ten blocks with 2 teeth each were bonded with Restofil (Anabond-Stedman) light cure adhesive system.

Study group 3—twenty lower incisor acrylic teeth consisting of ten blocks with 2 teeth each were bonded with Tetric-N-Flow (Ivoclar-Vivadent) light cure adhesive system.

Study group 4—twenty lower incisor acrylic teeth consisting of ten blocks with 2 teeth each were bonded with Filtek Z 350 (3 M, ESPE) light cure adhesive system.

Bonding procedure

The lingual surfaces of the lower incisor acrylic teeth were cleaned and it was made sure that no particles of dust or any other sediment were present that would lead to inadequate bonding. After adequate cleaning, mechanical roughening was done using a carbide bur to imitate the surface obtained after acid etching. The multistranded wire was adapted to the lingual surfaces of the acrylic teeth and excess wire extensions were cut. In order to ensure uniform distribution and equal amount of composite on each tooth, a rubber mold from Orthodontic Mould Starter Kit manufactured by ACMDENT Company was used.

The respective light cure adhesive systems were dispensed into the mold and were placed over the retainer wire on the lingual surface of acrylic teeth and curing was done for 40 s.

Scanning and brushing

All the samples underwent 3D scans immediately after bonding of lingual retainers and the scans were documented in STL format. The teeth were subjected to brushing for around 1 hr at a rate of 10 strokes/10 s which is approximately equivalent to 6 months of brushing. The brushing procedure was carried out using a custom-made brushing simulator which demonstrated sixty reciprocal strokes for 1 min and exhibited a linear action of 36 mm. Soft bristle brush (Colgate) and toothpaste slurry (Colgate toothpaste) were used for the samples to undergo brushing. Each group of samples was subjected to brushing for 1 hr. These samples were immediately subjected to 3D scans for analyzing the change in volume and surface area post brushing. All the other sets of samples underwent a similar procedure after replenishing with a newer set of brushes and fresh toothpaste slurry for each group. All the eighty samples underwent 3D analysis, to evaluate the mechanical wear of Heliosit, Restofill, Tetric-N-flow, and Filtek Z 350.

Evaluation

In order to measure composite material wear changes before and after brushing, a computer-aided 3D scanner (MEDIT T 500) was used to scan all the teeth. The scanning was performed at two intervals, once immediately after bonding which was considered as pre-test records and later, immediately after brushing, these were considered as post-test records. Scanned data was saved in STL format. The volume of the composite resin material in each group was calculated by subtracting the composite from the complete sample digitally using software and later this subtracted component was analyzed for its volume and surface area. The volume (mm^3) and surface area (mm^2) were recorded. A similar procedure was carried out for all the samples. Later superimposition of pre- and post-test samples was done in order to evaluate the change in the volume and surface area post brushing. Bonding material volume and surface area loss of each sample were assessed by subtracting the pre-brushing test composite volume and surface area from the post-brushing test composite volume and surface area of the same sample.

The data hence obtained was subjected to statistical analysis.

Results

Statistical analysis

The eighty acrylic teeth were divided into four different groups based on the composite (Heliosit, Restofill, Tetric-N-flow, and Filtek Z350 XT) used as fixed bonded retainer. These samples were subjected to brushing to evaluate the wear resistance. The values obtained were subjected to one-way ANOVA test to analyze if there exists a statistically significant difference in the mean values of volume (mm^3) and surface area (mm^2) means between the four groups. The post hoc Tukey test (HSD) was implied for multiple pairwise comparisons of volume and surface area loss means between the four composite groups.

Applying the Pearson correlation coefficient (Pearson's r correlation) analysis in each group and relationship between the groups were established. p-value ≤ 0.05 was considered significant in all statistical analyses.

Volume (in mm3)

There was a significant difference ($p < 0.001$) in mean volume within groups and between groups ($p < 0.001$). The mean volume and standard deviations are depicted in Table 1. Comparisons within the group and between groups are shown in Tables 2 and 3 respectively.

Table 1 The mean score of volume in mm^3 of pre-test and post-test samples of all the four (Heliosit, Restofill, Tetric-N-flow, and Filtek Z 350) composites

Treatments	Composite	Mean	SD	SE	95% CI for mean	
					Lower bound	Upper bound
Pre-test	Filtek	7.98	0.27	0.09	7.78	8.18
	Heliosit	8.84	1.35	0.43	7.87	9.81
	Restofill	8.54	0.52	0.16	8.17	8.91
	Tetric	8.27	1.23	0.39	7.39	9.15
Post-test	Filtek	6.66	0.15	0.05	6.55	6.77
	Heliosit	7.08	1.06	0.34	6.32	7.84
	Restofill	6.95	0.53	0.17	6.57	7.33
	Tetric	7.18	1.13	0.36	6.36	7.99
Difference	Filtek	1.32	0.13	0.04	1.23	1.41
	Heliosit	1.76	0.29	0.09	1.55	1.97
	Restofill	1.64	0.24	0.08	1.47	1.82
	Tetric	1.10	0.10	0.03	1.02	1.17

Table 2 Comparison of mean score of volume in mm^3 of pre-test and post-test of all the four (Heliosit, Restofill, Tetric-N-flow, and Filtek Z 350) composites by one-way ANOVA test

Treatments	SV	Sum of squares	df	Mean square	F-value	*p*-value
Pre-test	Between groups	4.0860	3	1.3620	1.4720	0.2390
	Within groups	33.3150	36	0.9250		
	Total	37.4010	39			
Post-test	Between groups	1.5060	3	0.5020	0.7400	0.5350
	Within groups	24.4130	36	0.6780		
	Total	25.9190	39			
Difference	Between groups	2.7800	3	0.9270	21.5100	0.0001*
	Within groups	1.5510	36	0.0430		
	Total	4.3310	39			

*$p < 0.05$

Surface area (in mm^2)

There was a significant difference ($p < 0.001$) in mean surface area within groups and between groups ($p < 0.001$). The mean surface area and standard deviations are depicted in Table 4. Comparisons within the group and between groups are shown in Tables 5 and 6 respectively.

The maximum mean volume was observed in the Heliosit group (8.84 mm^3) and the minimum mean volume was seen in the Filtek Z 350 XT group (7.98 mm^3). When the mean difference of pre-test and post-test volume was observed, the maximum mean difference was seen in Heliosit group (1.7 mm^3) and the minimum mean difference was seen in Tetric-N-flow group (1.10 mm^3) (Table 1).

From Table 2, it can be inferred that no significant difference was observed between four composites with mean pre-test volume (in mm^3) ($F = 1.4720$, $p = 0.2390$). The mean post-test volume (in mm^3) was also found to be similar among four composites ($F = 0.7400$, $p = 0.5350$). A significant difference was however observed between four composites with mean changes from pre-test to post-test of volume (in mm^3) scores ($F = 21.5100$, $p = 0.0001$).

A statistical significant difference was observed between Filtek and Heliosit, Filtek and Restofill, Heliosit and Tetric, and Heliosit and Restofill with mean changes from pre-test to post-test scores of volume (in mm^3) scores ($p < 0.05$) (Table 3).

In the pre-test group the highest mean surface area was in Restofill group and the least mean surface area was seen in Tetric-N-flow group. In the post-test group, the highest mean surface area was seen in the Restofill group and the least mean surface area was observed in Tetric-N-flow. When the mean difference between the groups was observed, the Heliosit group exhibited the highest mean surface area difference and the Tetric-N-flow group exhibited the least mean surface area difference. Tetric-N-flow group exhibited the least mean surface area difference (Table 4).

The post-test surface area difference was statistically significant difference ($F = 19.0440$, $p = 0.0001$) between groups suggesting that the post-test caused change in the surface area between the 4 composites. The mean difference between

Table 3 Pairwise comparisons of mean score of volume in mm^3 of pre-test and post-test of four (Heliosit, Restofill, Tetric-N-flow, and Filtek Z 350) composites by Tukey's multiple post hoc procedures

Treatments	Composites		Mean difference	Std. error	*p*-value
Pre-test	Filtex vs	Heliosit	−0.8630	0.4302	0.2050
	Filtex vs	Restofill	−0.5590	0.4302	0.5690
	Filtex vs	Tetric	−0.2900	0.4302	0.9060
	Heliosit vs	Restofill	0.3040	0.4302	0.8940
	Heliosit vs	Tetric	0.5730	0.4302	0.5490
	Restofill vs	Tetric	0.2690	0.4302	0.9230
Post-test	Filtex vs	Heliosit	−0.4200	0.3683	0.6670
	Filtex vs	Restofill	−0.2900	0.3683	0.8600
	Filtex vs	Tetric	−0.5150	0.3683	0.5090
	Heliosit vs	Restofill	0.1300	0.3683	0.9850
	Heliosit vs	Tetric	−0.0950	0.3683	0.9940
	Restofill vs	Tetric	−0.2250	0.3683	0.9280
Difference	Filtex vs	Heliosit	−0.4430	0.0928	0.0001*
	Filtex vs	Restofill	−0.3230	0.0928	0.0070*
	Filtex vs	Tetric	0.2250	0.0928	0.0910
	Heliosit vs	Restofill	0.1200	0.0928	0.5730
	Heliosit vs	Tetric	0.6680	0.0928	0.0001*
	Restofill vs	Tetric	0.5480	0.0928	0.0001*

*$p < 0.05$

the groups also exhibited statistically significant difference ($F = 42.5770$, $p = 0.0001$) suggesting that there is a difference in the mean surface areas between groups (Table 5).

No significant difference was observed between Filtek and Restofill. When pairwise comparison of mean difference of surface area of the 4 composites was done, a statistically significant difference was observed between Filtek and Heliosit, Filtek and Tetric-N-flow, Heliosit and Restofill, Heliosit and Tetric-N-flow, and Restofill and Tetric-N-flow. The data suggests that highest mean surface area difference was observed in the Heliosit group (Table 6).

Discussion

Maintaining the achieved end result is one of the greatest challenges encountered in orthodontic treatment. To avoid post-treatment changes, an adequate retention phase is to be planned after correction of the malocclusion. The retention phase is carried out using retainers that are either removable or fixed. The fixed retainer comprises a retainer wire and composite resin that is bonded on the lingual aspects of the teeth. Since the composites are present in the oral cavity, they are subjected to intraoral changes due to both mechanical and chemical changes. Brushing is an integral part of our day-to-day life and its effect on the wear of the composites should not be underrated. Therefore, the aim of the study was to evaluate the wear resistance of various composites that are used as bonded retainers using a brushing simulator. The composites that are part of the study are those routinely used in orthodontic practice.

The pre and post samples when subjected to 3D scans and analysis demonstrated a statistically significant difference in the mean volume and surface area among all 4 types of composites (Tables 2 and 5).

The present study suggests that the highest wear resistance was demonstrated by Tetric-N-Flow followed by Filtek Z 350XT, Restofill, and Heliosit. This could be attributed to the amount of filler content and size of filler that is incorporated in the respective composites. Sifakakis et al. [6] in their study described that composites with higher filler content exhibited better wear resistance. Tetric-N-Flow exhibited better wear resistance as it contained the highest filler content when compared to other composites used in this study. On the other hand, Heliosit exhibited the least wear

Table 4 The mean score of surface area in mm^2 of pre-test and post-test samples of all the four (Heliosit, Restofill, Tetric-N-flow, and Filtek Z 350) composites

Treatments	Composites	Mean	SD	SE	95% CI for mean	
					Lower bound	Upper bound
Pre-test	Filtek	32.32	1.75	0.39	31.50	33.14
	Heliosit	34.96	1.42	0.32	34.29	35.62
	Restofill	35.25	1.52	0.34	34.54	35.96
	Tetric	31.52	1.16	0.26	30.97	32.06
Post-test	Filtek	28.50	1.51	0.34	27.79	29.21
	Heliosit	30.15	1.21	0.27	29.58	30.71
	Restofill	31.17	1.64	0.37	30.40	31.94
	Tetric	28.31	1.20	0.27	27.75	28.87
Difference	Filtek	3.82	0.73	0.16	3.48	4.16
	Heliosit	4.81	0.48	0.11	4.59	5.03
	Restofill	4.08	0.26	0.06	3.96	4.20
	Tetric	3.21	0.04	0.01	3.19	3.22

Table 5 Comparison of mean score of surface area in mm^2 of pre-test and post-test of all the four (Heliosit, Restofill, Tetric-N-flow, and Filtek Z 350) composites by one-way ANOVA test

Treatment	SV	Sum of squares	df	Mean square	F-value	*p*-value
Pre-test	Between groups	209.9740	3	69.9910	31.9590	
	Within groups	166.4420	76	2.1900		
	Total	376.4170	79			
Post-test	Between groups	112.5560	3	37.5190	19.0440	0.0001*
	Within groups	149.7320	76	1.9700		
	Total	262.2880	79			
Difference	Between groups	26.4040	3	8.8010	42.5770	0.0001*
	Within groups	15.7110	76	0.2070		
	Total	42.1150	79			

*$p < 0.05$

Table 6 Pairwise comparisons of mean score of surface area in mm^2 of pre-test and post-test of four (Heliosit, Restofill, Tetric-N-flow, and Filtek Z 350) composites by Tukey's multiple post hoc procedures

Treatments	Composites		Mean difference	Std. error	*p*-value
Difference	Filtex vs	Heliosit	−0.9855	0.1438	0.0001*
	Filtex vs	Restofill	−0.2535	0.1438	0.2990
	Filtex vs	Tetric	0.6175	0.1438	0.0001*
	Heliosit vs	Restofill	0.7320	0.1438	0.0001*
	Heliosit vs	Tetric	1.6030	0.1438	0.0001*
	Restofill vs	Tetric	0.8710	0.1438	0.0001*

*$p < 0.05$

resistance because it contained the least amount of filler content in weight percentage. Apart from the filler loading, filler particle size also plays a major role in the wear resistance of the material. Microfilled composites tend to exhibit lesser resistance to wear than nanocomposite or nanohybrid composites. Heliosit being a microfilled composite showed the least amount of wear resistance.

Results show a clinically significant change in the volume of the composites after brushing. Composites undergo a certain amount of polymerization shrinkage and this shrinkage occurs as a result of the transformation of Vander wall bonds to covalent bonds in the resin, which in turn reduces the volume occupied by the resin. Each composite undergoes a different amount of polymerization shrinkage after curing depending upon its composition. This volumetric change due to polymerization can be regarded as the reason for the difference in the mean volumes of the 4 composites, when the pre-test values were observed as seen in Table 1. In the pre-test values, the highest mean volume (mm^3) was shown by the Heliosit group and the least mean volume (mm^3) was shown by the Filtek Z 350 XT group. In the post-test volume, the least mean volume (mm^3) was shown in the Filtek Z350 XT group and the highest mean volume (mm^3) by the Tetric-N-flow group. Tetric-N-flow group exhibited the least mean volume difference and Heliosit group exhibited the highest mean volume difference when the pre-test and post-test volumes were compared as observed in Tables 1 and 2. Thus, it can be concluded that tooth brushing leads to abrasion of the composites that eventually lead to a volumetric change in the composites.

A pairwise post hoc test was conducted to compare the mean volumetric change between the groups. Statistically significant differences were found between (a) Filtek Z 350 XT–Heliosit, (b) Filtek Z 350 XT–Restofill, (c)Tetric-N-flow–Heliosit, and Tetric-N-flow and Heliosit groups. No statistical difference was observed when Filtek Z 350 XT–Tetric-N-flow groups and Heliosit-Restofill groups were compared (Table 3). Nayyar et al. [7] in their study described that Filtek Z 350 exhibited better resistance to wear due to increased filler content. Moraes et al. [8] described that nanohybrid composites exhibit properties such as wear resistance inferior to that of nanofilled composites. Data from Table 3 depicts that Filtek Z350 XT exhibited higher resistance to a change in the mean volume difference when compared with Restofill which is a nanohybrid composite. Tetric-N-flow showed a statistically significant change in the mean volume difference when compared with Restofill. Both Tetric-N-flow and Restofill are nanohybrids but Restofill exhibited inferior wear resistance properties than Tetric-N-flow due to decreased amount of filler content (Tables 1 and 3). Johnsen et al. [9]. in their study highlighted that filler loading is more crucial than the size of the filler particle when change in volume and wear resistance are considered.

Thus, it can be concluded that composites with higher filler load such as Filtek Z 350 XT and Tetric-N-flow group exhibit less mean volumetric change and greater wear resistance when compared to composites (Heliosit and Restofil groups) with lesser filler loading.

The filler particles are incorporated in the composite resins to reduce the polymerization shrinkage during curing and ultimately improve mechanical properties. The filler particles are placed between the voids of the resin matrix molecules. The finer and smaller the size of the filler particles, the better the packaging, and greater the surface area. Wear of the material also depends upon the hardness of the material. The hardness of the material in return depends upon the filler content and the filler size. The resin matrix when subjected to mechanical stresses such as brushing causes attrition thereby leading to surface abrasion.

When subjected to repeated forces, the surface of the composite undergoes deterioration of the structure of the material, eventually causing the loss of the material. A statistically significant difference in the post-test surface area and mean difference in the surface area (mm^2) was observed (Table 5), indicating that abrasive forces lead to changes in the structural organization of composite which causes the loss of the structure. It is evident that there is a change in the surface area of the composites post brushing (Table 5). Thus, to evaluate the difference between groups, pairwise analysis of the composites was performed. Nanofilled (Filtek Z350 XT) and nanohybrid (Tetric-N-flow and Restofill) resins exhibited smoother and better wear resistance than microfilled resin (Heliosit) (Table 6).

Mitra et al. [10] suggested that nanofilled particles exhibited lesser polymerization shrinkage, increased hardness, and better wear resistance when compared with microfilled composites. Similar results were put forth by Monfared et al. [11]. According to them, the harder the composite material, the greater the resistance to wear and the lesser the change in the surface area when subjected to abrasion. They concluded that the composites that are incorporated with nanofilled filler particles displayed a higher degree of resistance to wear. Scougall-Vilchis et al. [12] also in their study presented results that were similar to the results of previous literature which concluded that the size of the filler particle determines the hardness of the composite resin, which in turn has its influence on the wear resistance.

Similar results were seen in the present study. Tetric-N-flow exhibited significantly less change in the mean surface area than the Heliosit resin which had less filler loading and larger particle size (Tables 4 and 6).

Rodrigues Junior et al. [13]. and Johnsen et al. [9]. suggested that the amount of filler loading is said to be crucial for improving the surface hardness and ultimately the resistance to wear than the filler particle size. The results of their study are in unison with the present study where it can be observed that despite both Restofill and Tetric-N-flow being nanohybrids exhibited a statistically significant difference in the mean difference in the surface area (Table 6). Tetric-N-flow exhibited less mean difference in the surface area than Restofil and this is due to difference in filler loading (Table 4). When Tetric-N-flow and Filtek Z 350 XT were compared (Tables 4 and 6), there was no statistical difference in change in mean surface area suggesting that filler loading is the determining factor in evaluating the changes in the surface area between composites.

Limitations

There are certain limitations to the present study. The samples used in the present study are acrylic teeth which do not exactly replicate the natural teeth. The samples were stored in a dry environment and were not exposed to oral environment; hence, the influence of oral fluids and microbial flora on the composite could not be analyzed. Abrasion of composites is also influenced by different types of food particles as well as the masticatory forces which is not included in the present study. Apart from this, the size of the abrasive particle in the tooth paste and nature of the toothbrush bristles also influence the wear of the composites. Thereby further studies are to be carried out considering all the mentioned factors to provide detailed information regarding the wear resistance of the various composites.

Future scope

In laboratory studies, simulating the oral environment and effect of various types of fluids and food particles on composites is to be done. Adoption of three-dimensional technologies for accurate analysis of the wear resistance of bonded composites to natural teeth that are subjected to abrasion via both brushing and chewing is to be studied in future. Different abrasive particles and textures of bristles and their effect on the bonded retainers are the scope for future studies. Studies on reinforced composites and composites with varied filler loading with similar particle size and vice versa are required. Studies are to be done to determine the changes in the surface morphology of composites using 3D technologies post abrasion which also indicate the wear of composite. In vivo studies are to be performed for better conclusions.

Conclusion

The present study suggests that both changes in the volume and surface area of the bonded composites are influenced by the amount of filler loading as well as the particle size. Composites with higher filler content such as Tetric-N-flow and Filtek Z350 XT exhibited better wear resistance to tooth brushing abrasion than composites with lesser filler loading and small particle sizes such as Restofill and Heliosit. The study also concluded that filler loading is of greater importance than filler morphology when composites exhibited a similar range of particle size. All the 4 composites can be used for bonding the retainers, but as per the present study, Tetric-N-flow provides better results than other composites.

Abbreviations 3D: Three dimensional; STL : Stereolithography ; mm: Millimeter

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Author contribution The complete research and manuscript were scrutinized by all the four authors and suggestions at each level were put forth to improve the efficacy of the study. The study design was planned by Dr Y.N. Sasidhar and was executed by Dr C. Kamala under the guidance of Dr. P. Ujwala. Dr .P. Ujwala and Dr Y.N. Sasidhar scrutinized each sample and made sure that the methodology was carried out in the described manner. The manuscript was written by Dr C. Kamala and reviewed by Dr. P. Ujwala, Dr. Y.N Sasidhar and Dr. B Sudheer. Dr. P. Ujwala has been a constant source of support, guided throughout the research, and her suggestions and inputs helped in executing the research work. Dr. Y.N. Sasidhar has been a rock support throughout the research; his eagle eye vision helped in correcting the minute mistakes during the designing of study, procedure execution, and in the construction of the manuscript.

Data availability Not applicable

Declarations

Ethical approval Not applicable

Competing interests Not applicable

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