Original Article

The Effect of Powered Toothbrushes on Surface Roughness and Wear of Direct Restorative Materials

Sookwasa Hirunmekavanich[1] and Chaiwat Maneenut[1]

[1]Department of Operative Dentistry, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

Abstract

The study aims to evaluate surface roughness and wear or volume loss of three direct restorative materials after brushing with oscillating and sonic-vibrating powered toothbrushes. Twenty specimens of each material: conventional nanofilled resin composite (FiltekZ350XT), flowable resin composite (Filtek Supreme flowable restorative) and resin-modified glass ionomer cement (Fuji II LC), were prepared and divided into two groups according to the type of powered toothbrush used. Brushing was conducted using a toothbrushing simulator that applied a consistent force of 1 newton (N) for one hour, simulating one year of brushing. Surface roughness and wear or volume loss tests were performed on each specimen before and after brushing to assess the impact of the different toothbrush types and materials. The surface roughness (Sa), the differences of roughness change (ΔSa) and volume loss were analysed using the paired *t*-test and two-way ANOVA with LSD post hoc tests. The results showed no statistically significant difference of roughness, roughness change and wear after one year of simulated tooth brushing by the powered toothbrush in all groups. Two-way ANOVA analysis showed that type of powered toothbrush and material do not significantly influence the surface roughness alteration of all three direct restorative materials. However, the type of materials significantly influenced the volume loss. A greater surface roughness value changes were observed in sonic-vibrating powered toothbrush groups. Resin-modified glass ionomer cement brushed by a sonic-vibrating powered toothbrush (GS) showed the most surface roughness change. The highest volume loss was detected in resin-modified glass ionomer cement brushed by the oscillating powered toothbrush (GO) group. There is a statistically significant difference in wear between resin-modified glass ionomer cement groups and resin composite groups in both powered toothbrush types. In conclusion, in this *in vitro* study, brushing with powered toothbrushes does not affect the surface roughness and wear of direct restorative materials.

Keywords: Powered toothbrush, Resin composite, Resin-modified glass ionomer, Surface roughness, Wear

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Correspondence to:

Chaiwat Maneenut , Department of Operative Dentistry, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

Tel. 081-6979682 E-mail: chaiwat.m@chula.ac.th

Introduction

Tooth brushing is the act or method of cleaning the teeth with a toothbrush together with toothpaste. It is the simplest and the most effective way to eliminate dental plaque. Incorrect tooth brushing (toothbrush, toothpaste and technique), resulting in inadequate plaque removal, could lead to many problems including dental caries, periodontal problems and malodor breath.[1] In addition, excessive brushing force could cause tooth wear and non-carious cervical lesions (NCCLs).[2] These oral health problems can occur in all groups of age and eventually affect their quality of life.

The powered toothbrush was developed to be more user-friendly, eliminate incorrect brushing techniques and provide consistent ability to eliminate dental plaque.[3] Previous studies found that the safeness of using powered toothbrushes was not significantly different from the conventional manual toothbrush.[3,4] Thus, many people start to pay more attention to the powered toothbrush since it can deliver a simpler method of daily oral care. Moreover, the powered toothbrush is beneficial to people who aregeriatric or handicapped who have weakened muscle movement especially fine muscle movement which is important for tooth brushing.[5] So, as a dental professional, it can be assumed that a powered toothbrush is more suitable for some special patients compared to the conventional manual toothbrush and it can eliminate technique sensitivity, control brushing force and help motivate good oral care for everyone.

Powered toothbrushes vary in head size, head shape, speed of movement and the whole brush design. Nowadays marketed powered toothbrushes have three types of action which are rotating or oscillating, sonic vibrating and ionic-powered. The rotating or oscillating toothbrush usually comes with a round head design. The head spins with speed when moving the brush along the teeth and gum line causing the dislodgement of food particles. While the sonic vibrating toothbrush comes with a vibrating head that emits ultrasonic waves that are claimed to cause vibration, resulting in fluid movement and air vibration.[6] Sonic vibration combined with the vibrating bristle will loosen the plaque and food particles. The ionic-powered toothbrush temporarily alters the tooth ion charge from negative to positive by the circuit under the head and handle. This polarity helps push away food particles, which are also positive charges.[7] However, there is no mechanical action from the brush itself unlike as in an oscillating or sonic-vibrating powered toothbrush.

Improper tooth brushing is not only one of the various factors causing oral health problems but also plays a part in damaging dental restoration over time, especially direct restoration.[8] Several previous studies[9-10] showed the effects of tooth brushing to resin composite which were increased surface roughness, decreased surface gloss and increased wear. These effects can lead to increased plaque accumulation which ultimately results in restoration failure.[9,11,12] However, literature reviews revealed only the effect of manual toothbrushes or compared the effect between manual and powered toothbrushes. There are still limited studies that compared the effect among the powered toothbrushes.

From the knowledge gap and the raising popularity of powered toothbrush and its benefits, this present study aims to investigate and compare the surface roughness and wear of the direct restorative materials which are a conventional nanofilled resin composite, a flowable resin composite and a resin-modified glass ionomer, after brushing using the oscillating and sonic-vibrating powered toothbrushes. The null hypothesis of this study is that the powered toothbrush does not affect the surface roughness and wear of direct restorative material. Clinically, understanding these specific effects can help dental professionals to provide evidence-based recommendations on the most appropriate oral hygiene instruments for patients with direct restorations, potentially influencing restorative material selection, maintenance protocols, and patient education to enhance the survival and esthetic integrity of restorations.

Materials and Methods

Sample size calculation

Sample size was calculated using G*power 3.1.9.4 (Kiel University, Germany) utilizing Power β = 80% and α = 5%, cited from the study of Sayed *et al.*, 2022.[9] The total sample size from the calculation was at least 46.2 (8 specimens per group), including 10% compensation. However, to avoid discrepancy, the specimens in this study were increased to ten specimens per group. A total of 60 specimens were investigated, which were categorized into two divisions based on toothbrush type and further segmented into three types of direct restorative materials.

Specimen fabrication

Sixty cylindrical specimens (20 for each material) with dimensions of 10 mm in diameter and 2 mm in thickness were prepared using polyethylene molds (Fig. 1.). The materials used in this study are shown in Table 1.

Table 1 The direct restorative materials and toothpaste used in this study

Material	Type	Composition	Filler content	Manufacturer	Lot number
Filtek™ Z350 XT Universal Restorative (Shade A3)	Nanofilled resin composite	Bis-GMA, UDMA, TEGDMA and Bis-EMA, PEGDMA photoinitiator	78.5% by weight (63.3% by volume) non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non-aggregated 4 to 11 nm zirconia filler and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles)	3M, ESPE, USA	10136730
Filtek™ Supreme Flowable Restorative (Shade A3)	Flowable resin composite	Bis-GMA, TEGDMA, Bis-EMA, dimethacrylate polymer photoinitiator	65% by weight (55% by volume) 75 nm diameter non-agglomerated/non-aggregated silica nanofiller, 5-10 nm non-agglomerated/non-aggregated zirconia nanofiller, loosely bound agglomerated zirconia/silica nanocluster, consisting of agglomerates of 5-20nm primary zirconia/silica particles. The cluster particle size range is 0.6 to 1.4 microns.	3M, ESPE, USA	10019057
Fuji II LC® Capsule (Shade A3)	Resin modified glass ionomer	Liquid: Acrylic maleic acid copolymer, HEMA, UDMA, camphoroquinone Powder: fluoro-alumino-silicate glass		GC, Japan	2302206
Colgate® Cavity Protection Toothpaste	toothpastes	Dicalcium phosphate dihydrate, Water, Sorbitol, Sodium lauryl sulfate, Hydrated silica, Arginine, Sodium monofluorophosphate, Flavor, Cellulose gum, Phosphoric acid, Tetrasodium pyrophosphate, Sodium saccharin, CI 77891, tetrasodium pyrophosphate		Colgate-Palmolive, USA	TH112B

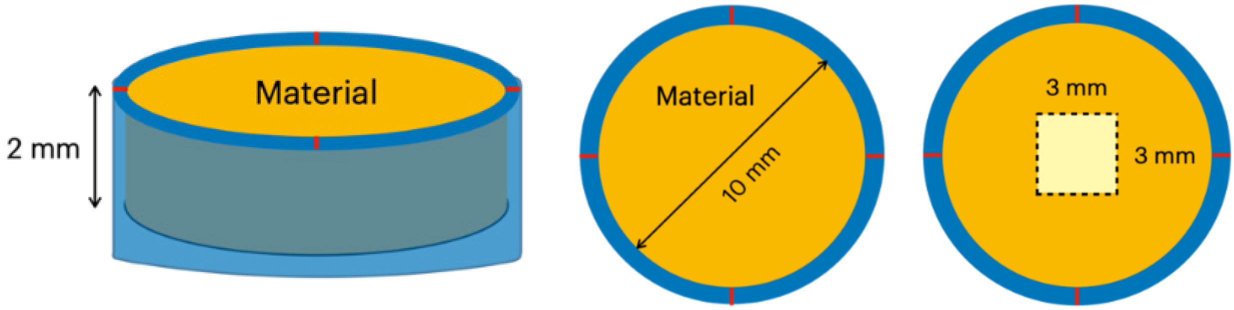

Figure 1 *Specimen fabrication and area of brushing (3x3 mm) at the middle*

Conventional resin composite, Filtek™ Z350 XT Universal Restorative shade A3 (3M™, ESPE, USA), was placed in the mold with a plastic instrument. The sample was covered with a celluloid strip and a glass slide, followed by putting a metal weight of 1 kg on the top for 20 seconds to ensure the flat surface of the specimen. The metal weight was removed, the curing tip was placed perpendicularly to the surface of the material and it was light cured through a glass slide with LED light curing unit (DemiTM Plus, Kerr, USA) using approximately 1000 mW^2 for 40 seconds. The light intensity was confirmed with a radiometer (100 Optilux Radiometer®, Sds Kerr, USA). In order to imitate the clinical polishing technique, the top surface of the specimen was polished with Softlex discs (Sof-Lex™ XT Contouring and Polishing Discs, 3M™, ESPE), using coarse, medium, fine and superfine discs respectively, with a micro-motor handpiece at 10,000 rpm for ten strokes in the same linear direction for each disc. After polishing with each disc type, the specimen was rinsed off for ten seconds and air-dried for ten seconds with a triple syringe (Mobile Unit, Super Mobile 85, T.D.P. Thailand). The polishing disc was discarded after every four specimens were polished to ensure the efficiency of the disc.

Flowable resin composite specimens, Filtek™ Supreme Flowable Restorative shade A3 (3M™, ESPE, USA), were prepared by injecting material from tube into the mold, followed by the same procedures as previously described.

Resin-modified glass ionomer specimens, Fuji II LC® Capsule shade A3 (GC, Japan), were prepared by mixing in an amalgamator (Ultramat 2, SDI, Australia) for ten seconds as per the suggestion of the manufacturer and injected into the mold, followed by the same procedures as previously described.

All specimens were stored in distilled water at a temperature of 37°C in an incubator for 24 hours before submitted to surface roughness analysis (Sa) at a square area of 3 x 3 mm at the middle of the polished surface (Fig. 1). The surface roughness values of all specimens in each material type were verified not to be significantly different to ensure the homogeneity of the baseline value before performing the brushing test.

Brushing test

Each material specimen was randomly divided into two groups for the powered brushings (n=10). The first group was brushing performed with an oscillating-rotating powered toothbrush (Oral-B pro-2000 powered toothbrush, Procter and Gamble, USA). The bristle type was medium, end-rounded nylon bristle (Braun Oral-B EB17-2 Precision Clean Replacement, Procter and Gamble, USA). The toothbrush head spun using sensitive mode with 33,000 rounds per minute. The second group was brushing performed with a sonic-vibrating power toothbrush (Sonicare 1100 series, Philips, Netherlands) with medium, end-rounded nylon bristle (Sonicare C2 Optimal Plaque Defense HX9022/28, Philips, Netherlands). The sonic-vibrating powered toothbrush ran with 31,000 rounds per minute.

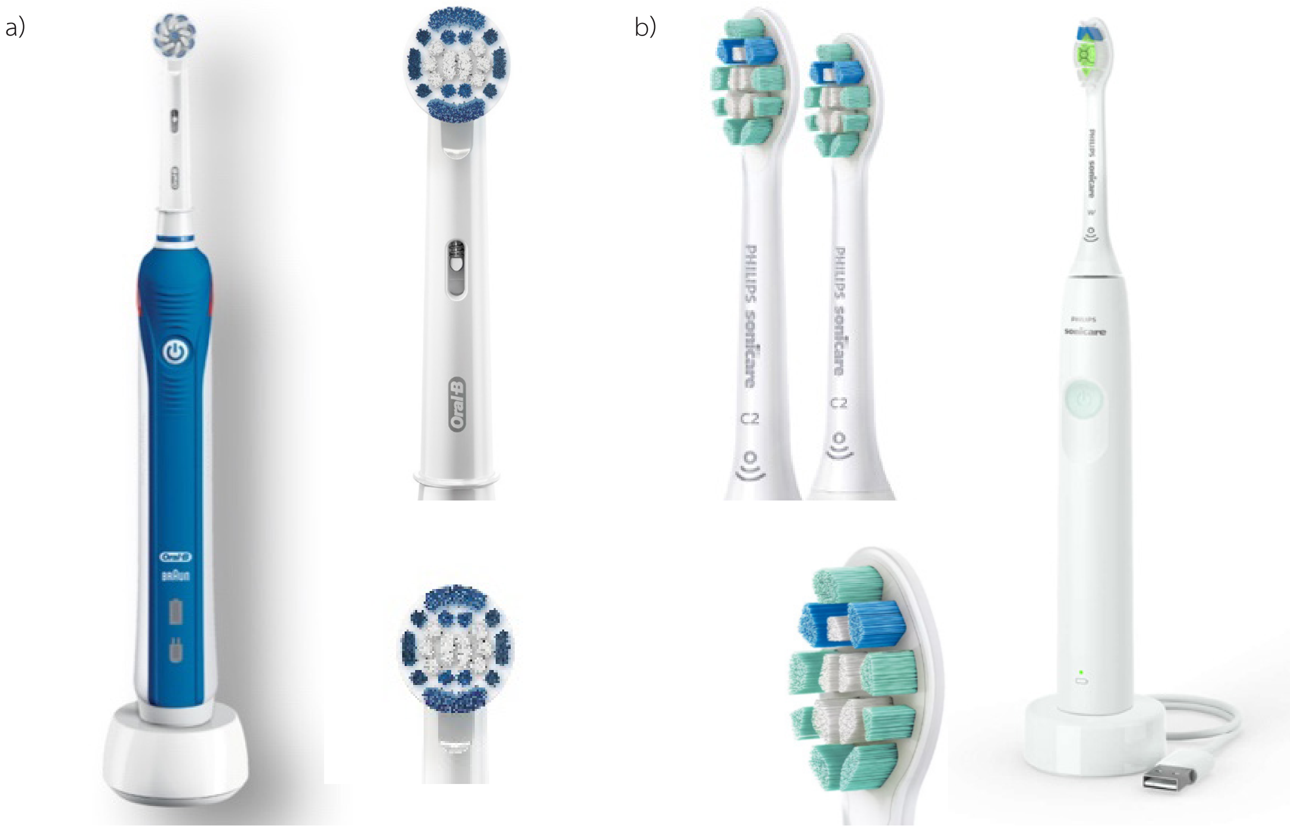

Figure 2 *a). Oral-B pro 2000 powered toothbrush with medium bristle13 and b). Philips Sonicare 1100 series powered toothbrush with a medium bristle*[14]

The powered toothbrush was attached to the modified tooth brushing simulator (Fig. 3). The simulator consisted of two parts which were the adjustable toothbrush holder and the plastic container that had the silicone specimen holder in the middle. The toothbrush holder consisted of three adjustable screws and the toothbrush grip. The first adjustable screw was used to adjust the toothbrush position in the vertical dimension. The other two were used to finely adjust the toothbrush horizontal plain.

In order to keep the margin of the specimen surface to be the unaffected area from the brushing procedure, a waterproof sticker tape was applied on the surface, leaving an area of 3x3 mm square shape at the middle to have direct contact with the brush bristles as shown in Figure 1. The specimen was inserted into the silicone holder followed by the addition of 100 ml of toothpaste solution to completely submerge its surface. The toothpaste solution was prepared by mixing 33.3 g of measured toothpaste (Colgate® Cavity Protection Toothpaste, Colgate-Palmolive, USA) with 100 ml distilled water, following a 1:3 ratio as ISO11609:2017. The container was placed on the digital scale and the weight was set as zero (0). The powered toothbrush was attached to the toothbrush holder grip.The height and the horizontal plain were adjusted assuring that the bristle was pressed against the specimen surface and the pressure was set at 1 newton (N) (approximately 100 gram), simulating the force applied when brushing the teeth.[15]

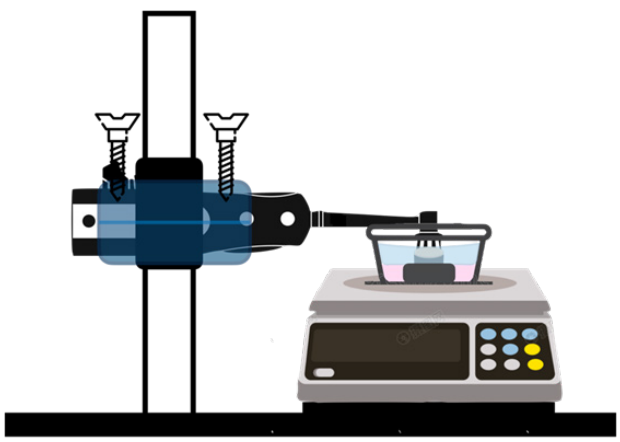

Figure 3 *The modified tooth brushing simulator, consisting of two parts which are the toothbrush holder part (left) and the specimen holder part (right)*

Since the powered toothbrush did not require horizontal movement of the head like the manual toothbrush, brushing time was used instead of cycles of movement in this experimental method. Since the American Dental Association recommends two minutes (120 seconds) tooth brushing time, twice a day[16], and according to a previous study[17] which the maximum duration of toothbrush contact with each tooth surface is five seconds per two-minute interval of brushing (equating to ten seconds per day), in this study, each specimen was brushed for 60 minutes which represent one year of tooth brushing. The toothbrush head was changed after six specimens of brushing, which referred to changing of toothbrush every three months as per the recommendation of the American Dental Association.[1,16]

After the brushing test, the specimen was washed for 60 seconds with water from a triple syringe (Mobile Unit, Super Mobile 85, T.D.P. Thailand) followed by immersion in the ultrasonic bath (Ultrasonic cleanser: 5210 (Heidolph, Germany) for two minutes to remove the smear layer, and air dried for 60 seconds with a triple syringe (triple syringe, Mobile Unit Super Mobile 85, T.D.P. Thailand). The specimens were stored in distilled water at 37°C followed by the surface roughness and wear after brushing evaluations.

Surface roughness analysis

The surface roughness of all the specimens were measured before brushing simulation by contact profilometer (TalyScan 150, Taylor Hobson Limited, England). The measured area was 3 x 3 mm (Fig. 1)which was saved as the reference area for after the brushing measurement. The profilometer setup was using a cut-off at 0.8 mm, a speed of 1000 μm/s, spacing 0.5 μm in the x-axis and 10 μm in y-axis. The surface roughness was analyzed to Sa value by TalyMap software (Taylor Hobson Limited, UK) which analyzed both surface profile and surface parameters. To standardize the baseline surface roughness value, all the data were collected and statistically analysed for data distribution in each material. The same procedure was done to the specimen after the brushing test. The surface roughness value after the brushing test was collected at the same reference area. The difference in surface roughness between before and after brushing or roughness change (ΔSa) within the same material and the same toothbrush type were calculated.

Wear analysis

After the brushing test, the wear of each specimen was measured by measuring the volume loss of the material using the contact profilometer (TalyScan 150, Taylor Hobson Limited, England) and analyzed with The TalyMap software (Taylor Hobson Limited, UK). After removing the sticker tape, the measurement area was 5 x 5 mm area which included the brushing area and the surrounding unaffected area (Fig. 4). The profilometer setup was a speed of 1000 μm/s, spacing 0.5 μm in the x-axis and 20 μm in the y-axis. The volume loss (mm^3) of the material was calculated by subtracting the whole volume of brushing area out of the surrounding unaffected area. This value was the wear of the material after brushing.

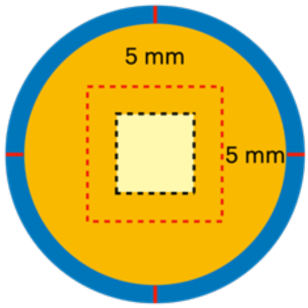

Figure 4 *The measurement area for wear, the red dotted area (5 x 5 mm). The black dotted area was the brushing area*

Statistical analysis

The data was statistically analyzed by SPSS statistics version 22.0 programs. The confidence interval in this study was determined at 95%, (p=0.05). The homogeneity test was evaluated using Levene's test. The Shapiro-Wilk test was used to analyze data distribution. The paired *t*-test was applied for analyzing the surface roughness (Sa) value of the same material before and after the test in the same toothbrush group. The Two-way ANOVA was used to analyze the interaction between two factors, types of powered toothbrush and material. Also, the Two-way ANOVA was used for analyzing means of difference in roughness or roughness change (ΔSa) and wear among materials in the same toothbrush type group followed by post-hoc LSD analysis. To compare between two types of powered toothbrushes in the same material, a two-sample *t*-test was used.

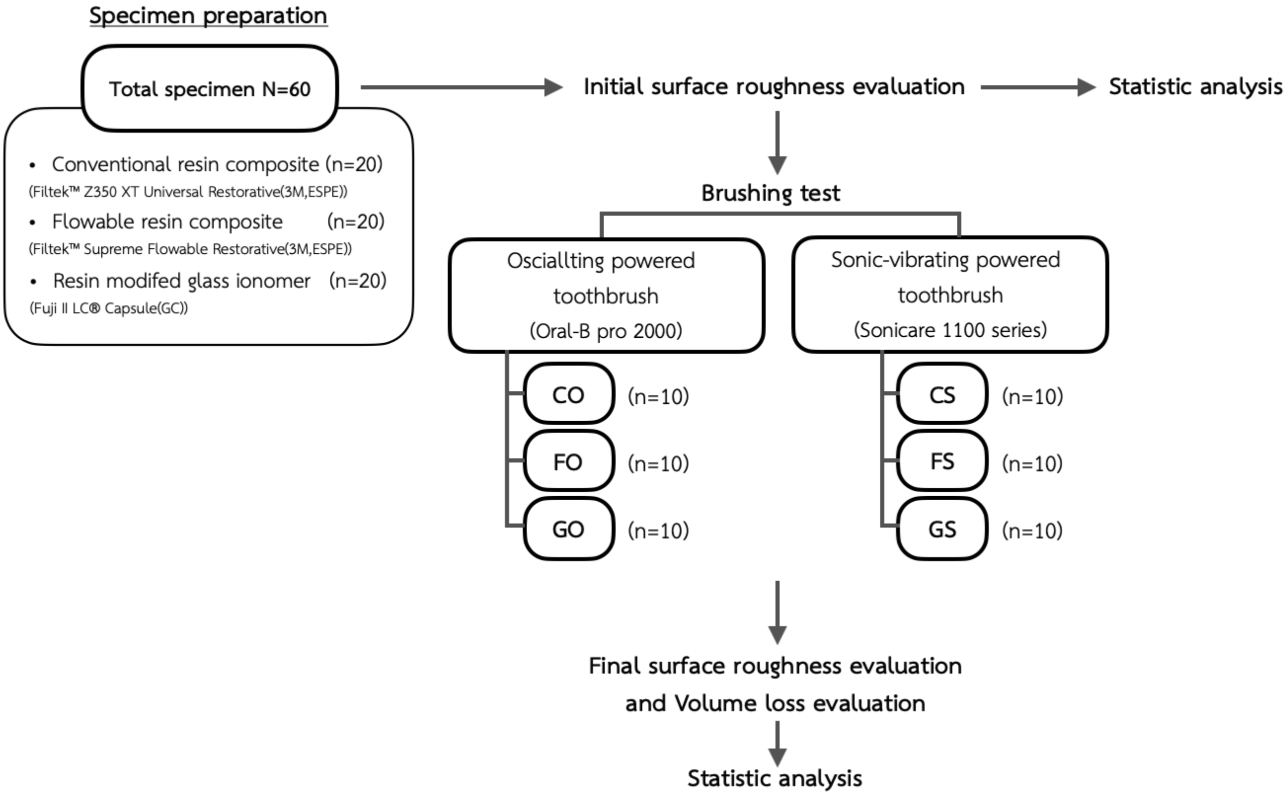

Figure 5 *Study design diagram illustrates group deviations, abbreviation and sample size in each group*

Results

Surface roughness

The surface roughness value (Sa) at baseline, before the brushing test, showed no statistically significant difference between the two powered toothbrush groups of each material (Table 2). After the brushing test, the paired *t*-test demonstrated no statistically significant differences of the surface roughness values in all groups (Table 2).

The mean of the difference in surface roughness between before and after brushing value or roughness change (ΔSa) of all groups is demonstrated in Table 2. The GS group showed the most surface roughness change followed by the FS, GO, CS, FO and CO groups respectively. All groups, except the GO group, presented a smoother surface after the brushing test, as the means of ΔSa values were negative values. Oscillating-powered toothbrush groups presented rougher surfaces than sonic-vibrating powered toothbrush groups for all materials. Yet, greater surface roughness value changes were observed in sonic-vibrating powered toothbrush groups compared to oscillating power toothbrush groups.

However, there was no statistical difference when comparing ΔSa values between two different toothbrush types for the same material. Also, there was no statistically significant difference comparing ΔSa values of the same toothbrush type among the three materials (Table 2). The two-way ANOVA indicated that powered toothbrush type and material did not influence ΔSa values (p=0.100, p=0.859), and these two factors had no interaction with each other (p=0.550).

Table 2 *Surface roughness (Sa) values and difference (ΔSa) of before and after brushing test*

Groups	Sa before (μm)	Sa after (μm)	Difference (ΔSa)
Conventional resin composite			
CO	1.361 ± 0.526^{aA}	1.355 ± 0.608^{dA}	$-0.006 \pm 0.472^{*A}$
CS	1.188 ± 0.298^{aB}	1.133 ± 0365^{dB}	$-0.055 \pm 0.297^{\#A}$

Table 2 Surface roughness (Sa) values and difference (ΔSa) of before and after brushing test (cont.)

Groups	Sa before (μm)	Sa after (μm)	Difference (ΔSa)
Flowable resin composite			
FO	1.569 ± 0.534^{bC}	1.557 ± 0.495^{eC}	$-0.012 \pm 0.336^{*B}$
FS	1.556 ± 0.444^{bD}	1.344 ± 0.585^{eD}	$-0.212 \pm 0.552^{\#B}$
Resin-modified glass ionomer			
GO	2.004 ± 0.722^{cE}	2.149 ± 0.818^{fE}	$0.145 \pm 0.504^{*C}$
GS	2.129 ± 0.668^{cF}	1.888 ± 0.681^{fF}	$-0.241 \pm 0.696^{\#C}$

The same letters refer to no statistically significant difference (p>0.05). The lowercase letters show the column comparison within each material. The uppercase letters show the row comparison of before and after the brushing test in each group.

In ΔSa column, the uppercase letters show the column comparison within each material. The symbols show the column comparison in each toothbrush type among all materials. The same symbol refers to no statistically significant difference (p>0.05). The negative value represented a smoother surface after the brushing test.

Wear (Volume loss)

The two-way ANOVA indicated that the materials significantly influenced volume loss ($p<0.05$). On the other hand, the type of powered toothbrush did not affect the volume loss ($p=0.414$) and both factors showed no interaction with each other ($p=0.511$).

The average volume loss of each group is presented in Table 3. The highest volume loss was detected in resin-modified glass ionomer, the GO group (0.011265 mm^3 ± 0.005709) followed by the GS group (0.009418 mm^3 ± 0.004194). On the contrary, the lowest volume loss was detected in conventional resin composite, the CO group (0.000012 mm3 ± 0.000006). Comparing between toothbrush types, greater volume loss was observed in oscillating powered toothbrush type of resin-modified glass ionomer groups and flowable resin composite groups. However, in conventional resin composite groups, the CS group presented a greater volume loss than the CO group.

In the same powered toothbrush type, conventional resin composite and flowable resin composite showed statistically significantly less compared to resin-modified glass ionomer ($p<0.05$). There was no statistically significant difference in volume loss between conventional resin composite and flowable resin composite. These results were similar in both oscillating-powered toothbrush groups ($p=0.983$) and sonic-vibrating powered toothbrush groups ($p=0.989$). In all three material types, there were no statistically significant differences in volume loss between powered toothbrush groups (Table 3)

Table 3 Mean ± standard deviation of wear (Volume loss) (mm^3)

Volumes loss (mm^3)	Conventional resin composite	Flowable resin composite	Resin-modified glass ionomer
Oscillating powered toothbrush	$0.000012 \pm 0.000006^{aA}$	$0.000039 \pm 0.000020^{bA}$	$0.011265 \pm 0.005709^{cC}$
Sonic vibrating powered toothbrush	$0.000017 \pm 0.000009^{aB}$	$0.000035 \pm 0.000019^{bB}$	$0.009418 \pm 0.004194^{cD}$

Lowercase letters show the comparison between powered toothbrush types. Uppercase letters show the comparison among materials. Different letters refer to a statistically significant difference (p<0.05)

Discussions

Toothbrushing can cause various effects on direct restorative materials, especially on the surface of restoration where the toothbrush directly contacts. This could apply to the clinical situation in restoring class V, class IV and class III cavities. Those restored cavities are affected by toothbrushing more than the occlusal load.[18] Due to the great esthetic properties and dentine-liked physical properties of resin composite, nowadays it has become a popular material of choice for dentists in restorative work.[19] Accordingly, in this present study, high polishing ability, suitability for restoring in anterior teeth, and lower abrasive wear than hybrid composite[19], a nanofilled resin composite (Filtek™ Z350 XT Universal Restorative, 3M, ESPE) was selected. Additionally, with a lower flexural strength and stiffness than the conventional resin composite, the flowable resin composite was used in a small abfraction class V cavity.[20] Following this reason, flowable resin composite (Filtek™ Supreme Flowable Restorative, 3M, ESPE) were also chosen. And since powered toothbrushes are suggested for patients who are handicapped and geriatric and tend to have high caries risk levels.[21] Fluoride-releasing direct restorative material as resin-modified glass ionomer (Fuji II LC®, GC) was added in this study.

As the result of this study which there is no statistically significant differences in surface roughness and wear in all groups after one year simulated brushing test with both types of powered toothbrushes, the null hypothesis that the powered toothbrush does not affect surface roughness and wear of direct restorative material was accepted. Moreover, there is no statistically significant difference when comparing surface roughness change (ΔSa) value and wear between two powered toothbrush types. And there is no statistically significant difference in ΔSa value among three different direct restorative materials in the same powered toothbrush group. However, a statistically significant difference exists between the wear of resin-modified glass ionomer and the resin composites.

This statistically significant difference in volume loss may due to material composition and physical properties which resin-modified glass ionomer is inferior to resin composite.[22] According to lower fracture toughness, lower surface hardness[23] and more solubility[22], resin-modified glass ionomer groups demonstrated significantly greater wear and surface roughness value change than resin composite groups after the brushing test as shown in this current study. Additionally, Kormandal and co-workers, in 2021, found that the surface roughness of resin-modified glass ionomer (Fuji II LC gold label, GC) was significantly different from baseline at three months of the simulated tooth brushing test with an oscillating powered toothbrush.[24]

Moreover, it is found that the resin-modified glass ionomer structure is porous.[25] This air trapping inside the material structure occurs during the mixing process. In this study, a machine mixing method was chosen to avoid mixing errors and minimize the porosity.[25,26] Accordingly, this porous structure of the material can also affect the amount of wear and surface roughness of the material due to the exposure of pores after surface loss, resulting in higher volume loss for the GO and GS groups compared to others. However, this porous structure and high-water sorption of material promote fluoride-releasing ability of resin-modified glass ionomer.[27] Furthermore, in a clinical situation, resin-modified glass ionomer is capable of recharging and releasing fluoride over time which causes the ion exchange of FAS glass that provides strength for the material, resulting in decreasing of surface hardness.[23] This could lead to further surface degradation of the material over time.

On the contrary, the conventional resin composite group (Filtek™ Z350 XT Universal Restorative, 3M, ESPE) presented the least surface roughness alteration and volume loss after brushing test. Resin composite consists of two main parts: organic resin matrix and inorganic filler particles. The filler particle plays an important role in the physical and mechanical properties of the material, including wear resistance.[28] The smaller the filler, the more filler loading could be added to the resin composite. The surface roughness of resin composite can be a result of degradation of the resin matrix and the dislodgement of the filler particle.[29] Increasing the surface roughness of restorative material can eventually lead to the wear of material over time. In this study, Filtek™ Z350 XT Universal Restorative has nano filler size particles, 4-20 nm, with a filler load of 78.5% by weight (66.3% by volume). The small filler size of nanofilled resin composite provides good polishability, performing a smooth surface after the polishing procedure. Heintze and co-workers[29] found that the nanofilled resin composite appears to have the lowest surface roughness increased after brushing test among types of resin composites, including hybrid resin composites. The distribution of the filler also influenced the wear.[30] Densely packed filler leads to less chance of matrix exposure and accelerates the wear. In addition, the SEM shows that the nanofilled resin composite shows uniform abrasion due to the same filler particle size and distribution[30] and less surface morphology alteration[10] after the toothbrushing test.

To improve the adaptability of conventional resin composite, flowable resin composite was invented with less filer load, 37% - 53% by volume, or adding other modifying agents.[31] Providing flowable resin composite to be less viscosity, to flow and adapt itself into the margin or the irregularity of the tooth structure. This material also be used in small abfraction class V cavity since the flowable resin composite has a lower flexural strength and stiffness than the conventional resin composite, providing more success rate.[20,32] The drawback of the flowable resin composite is the weaker mechanical properties and higher polymerization shrinkage due to the lower percentage of filler load.[33]

For wear resistance, Fernanda and co-workers[34] compared the mass loss of five flowable resin composites and two resin composites after the simulated tooth brushing test. They found no significant mass loss among resin composites. However, all five flowable resin composites showed higher mass loss percentages compared to microfilled resin composite. Corresponding to the previous study results, in this present study, Filtek™ Supreme Flowable Restorative, 3M, ESPE consisted of a filler loading of 65% by weight (55% by volume), which is a lower filler load than the conventional resin composite (Filtek™ Z350 XT Universal Restorative, 3M, ESPE). This results in more difference in roughness or roughness change (ΔSa) value and more volume loss than conventional resin composite groups in both powered toothbrush types. However, there was no statistically significant difference between conventional resin composite and flowable resin composite. It can be assumed that with the reduced filler content, degradation of the matrix after the dislodgement of filler could be increased, resulting in a lower wear resistance of this material.

Besides the materials factors, using different powered toothbrushes also play an important role in surface roughness alteration and wear of materials. The oscillating powered toothbrush used in this present study was an Oral-B pro 2000 powered toothbrush (Procter and Gamble, USA) with oscillating-rotating, 45,000 rounds per min (normal mode) and 33,000 rounds per min (sensitive mode). While the sonic-vibrating powered toothbrush (Sonicare 1100 series powered toothbrush, Phillips, Netherland) vibrates with 31,000 rounds/min. An oscillating power toothbrush was selected in sensitive mode to eliminate the amount of cycle factor.

Two-way ANOVA results of the current study showed that toothbrush type did not statistically significantly influence surface roughness alteration and wear of tested materials. However, greater surface roughness value changes (ΔSa), were observed in sonic-vibrating powered toothbrush groups compared to oscillating power toothbrush groups. The same result was presented in volume loss of the conventional resin composite groups which the CS group presented greater wear than the CO group. Nevertheless, there is no statistical difference of two toothbrush types in both ΔSa value and wear. These results correspond to the results of Ahmed and co-workers, in 2022[9], that the sonic vibrating powered toothbrush demonstrated a stronger action than the oscillating powered toothbrush in both surface roughness and wear of materials with no statistical difference. These could be explained by the cleaning action of a sonic-vibrating powered toothbrush that used hydrodynamic fluid forces[6,35] other than only actual brittle reaching[6] that benefit in plaque and biofilm removal. Besides, the toothbrush claimed to emit ultrasonic waves which can create cavitation theoretically[35,36] where gas bubbles grow and collapse in an alternating pressure field, resulting in highly destructive shear forces.[35] It was suspected that the wave can promote destruction of the filler-matrix interface in materials, leading to filler dislodgment. However, the effects of cavitation depend on ultrasonic frequency and intensity. Even though, the sonic vibrating powered toothbrush only emits 260 Hz, which is not an actual ultrasonic wave.[35] This sonic wave has also been proven to create fluid and air movement around the bristle, creating turbulent and associated shear force, and effectively removing stain and bacteria adhesion.[37,38]

Furthermore, the previous study found that oscillating power toothbrush also create low sound wave as sonic-vibrating powered toothbrush does.[39] By only 63 Hz rotating causes dislodgment of plaque in the range of 1 - 2 mm from the bristle tip similar to the result from 260 Hz of sonic vibrating powered toothbrush, which suggest that dynamic fluid activity is not solely restricted to a sonic vibrating powered toothbrush. In this current study, the oscillating powered toothbrush spined 33,000 rounds/minute which is converted to 550 Hz. Combined with the rotating action of the toothbrush head, the oscillating powered toothbrush could lead to greater wear of materials and rougher surface after toothbrushing especially the lower surface hardness material as resin-modified glass ionomer and flowable resin composite. This reason explained the results of the current study in which the GO group demonstrated a rougher surface after brushing and the FO and GO groups showed the greater volume loss compared to the FS and GS groups, respectively. To eliminate the confounding factors, the current study chose the sensitive mode, which was recommended for periodontal problem patients. The normal mode has a greater cycle of rotation (45,000 rounds/min), which could lead to a different result in wear and roughness alteration, this could be further studied. However, this current study only focused on the difference in action of the powered toothbrushes.

Abrasive agents in toothpaste are added to aid the mechanical cleaning efficacy of toothbrushing. Toothbrushing with only saliva does not create wear on the enamel surface, while brushing with toothpaste does.[40] The Relative Dentin Abrasivity (RDA) is a standardized scale for measuring the quantity of abrasiveness of toothpaste. The standard reference abrasive RDA value is around 100. However, the ADA recommends toothpaste with an RDA below 250, which produces no wear to enamel and limited wear to dentin with proper brushing technique.[41] In the current study, low-abrasive toothpaste (Colgate® Cavity Protection) was selected to eliminate the confounding factors. The RDA value is 65.

The hardness of the filler particle and the abrasive agent in toothpaste also impacted the wear.[30] If the filler particle has more hardness than the abrasive particle, there is a lower chance of wear. In the present study, the main abrasive agents are hydrated silica and dicalcium phosphate dihydrate ($CaHPO_4 H_2O$), which are medium hard and soft relative hardness[42], respectively. The Moh's hardness of hydrated silica is 5 and dicalcium phosphate dihydrate ($CaHPO_4 H_2O$) is 2.5.[43] While the filler particles in nanofilled resin composite (Filtek™ Z350 XT Universal Restorative, 3M, ESPE) and flowable resin composite (Filtek™ Supreme Flowable Restorative, 3M, ESPE) are silica filler and zirconia filler which has Moh's hardness 7 and 8, respectively. Since the filler particles have a higher hardness than toothpaste abrasive agents resulting in less wear from abrasive agents' factor. However, the correlation between the abrasiveness of the toothpaste particle and surface roughness is still controversial.

Boyd and co-worker, in 1997[44] demonstrated the force applied to brushing with a powered toothbrush is only 1/3 of the force applied to brushing with a manual toothbrush. The previous study[45] found that the habitual toothbrushing force using a manual toothbrush was in the range of 1-4 N, depending on multiple factors including measuring technique, gender, age, toothbrushes and dental characteristic of the study group. The most effective brushing force for plaque removal using a manual toothbrush is around 300 mg (3N).[46] In addition, Van der Weijden and co-worker, in 200415found that an oscillating powered toothbrush, a low brushing force (±1.5N) showed more plaque removal efficacy than a high brushing force (±3.5N). In this study, a brushing force at 1 N was chosen, following the literature review. However, the results of this study showed no statistically significant differences when comparing the roughness values before and after the brushing test in all groups. Most groups presented a smoother surface after the brushing test. On the contrary, previous studies[9,12,18] showed a rougher surface of resin composite after brushing, which used greater brushing force with different study designs.

In the present study, although specimens were polished before being submitted to the brushing test, a surface irregularity was still present, as shown in the value at baseline. A low brushing force of 1 N might not cause much dislodgment of filler particles but rather polish the irregularity of the exposed resin matrix, resulting in a smoother surface of materials. Especially in the resin composite, which consists of the more durable bond of silane coupling agent between glass filler and resin matrix compared to the loosely ionic bond of polyacid molecule in resin-modified glass ionomer.[47] As most groups in the current study, except for the GO group, presented a smoother surface after brushing.

The homogeneity of specimens in the same material group was statistically analysed before undergoing the brushing test. As the baseline values for the material group were effectively controlled, allowing the baseline Sa value of the specimen to function as an internal control for variations in the Sa value after brushing. Nevertheless, this study aimed to compare the difference in the alteration of the Sa value (ΔSa) among materials. However, different materials have a variety of properties, so the mean Sa values could not be compared directly with one another. For wear measurement, the specimen was partially covered with the adhesive tape, which would be the unaffected area from brushing. This area of the specimen was used as a control or reference area for measuring volume lost (wear).

The limitation of this study was the duration of brushing. The cycle of brushing was one hour straight, which represented one year of brushing. Nevertheless, in the clinical situation tooth brushing occurs twice a day with about eight hours in between, causing more storage time intervals, which could lead to further degradation of material. Further study with intervals brushing time might refer to closer clinical situations. In addition, this current study is still an *in vitro* study.

As the results in the current study demonstrated that brushing with a powered toothbrush with 1 N force does not affect the surface roughness and wear of direct restorative materials - nanofilled resin composite, flowable resin composite and resin-modified glass ionomer, after brushing for one year. Implied in clinical situations, dentists can safely recommend using the powered toothbrush in both types with the proper brushing technique and appropriate brushing force for people who need it such as the elderly and people with handicaps, instead of a manual toothbrush. However, dentists should be aware of greater wear of resin-modified glass ionomer restoration than resin composite restoration over time.

Conclusion

In this *in vitro* study, brushing with powered toothbrushes showed no significant influence or effect on surface roughness and wear of direct restorative materials.

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