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Abrasion Effects Between Cockle Shell Waste Particles and Perlite Particles in Teeth Cleaning

Ngo Sin Ling[1], Shahmir Hayyan Sanusi[1]*

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: An abrasive agent in toothpaste is a substance that is used to clean the teeth by removing dental plaque with a toothbrush or other oral hygiene tool. Abrasive agents such as calcium carbonate ($CaCO_3$) can be extracted from natural resources such as limestones. However, improper collection of natural resources will cause pollution, but it will also disrupt its balance. As a result, using alternative resources such as recycling waste materials can help to solve this problem. This study aims to determine the possibilities of cockle shell wastes to act as toothpaste's abrasive agent with an ideal toothbrushing techniques in teeth cleaning. Cockle shell wastes was selected in this study due to their high calcium carbonate composition, and perlite (silica) particles was selected as to compare the performance between cockle shell wastes. Brushing tests was conducted using Reciprocating Toothbrushing Test Rig. Scratch analysis was conducted to investigate scratch factor and drag factor after the brushing test using Optical Microscope. At the same time, depth analysis was also conducted to discover the efficient toothbrushing parameters using Atomic Force Microscope (AFM). The wear rate for acrylic plates was investigated by the effect of load using the volume calculating method. Cockle shell wastes produced a similar trend compared to perlite particles. Hence, cockle shell wastes can act as an alternative abrasive agent in toothpaste for teeth cleaning purposes.

Keywords: Cockle Shell, Perlite, Abrasive Agent, Toothbrushing Parameter, Teeth Cleaning

1. Introduction

Getting clean and whiter teeth is now an essential part of health that helps to promote self-confidence. The most frequent method of maintaining oral hygiene is teeth whitening by tooth brushing with toothpaste. Abrasive agents serve an important function in teeth cleaning as they are present in toothpaste formulations. In addition, the abrasive ingredients in toothpaste should be sufficient to reduce dental plaque while not damaging the teeth' surface or enamel. As a result, it is critical to investigate the potential of alternative materials suited for use as an abrasive agent in toothpaste.

*Corresponding author: shahmir@uthm.edu.my

Cockles or scientifically known as Anadara granosa is a local bivalve mollusc, which can be found in the coastal regions of South-East Asia, particularly in Malaysia, Thailand, and Indonesia. Malaysia had produced 45,674.58 metric tonnes of cockle for the seafood industry [1]. After the flesh of the cockle has been consumed, the shells usually are removed and disposed. Because appropriate disposal is relatively expensive, the cockle shells are classified as trash from these by-product companies and are typically left to degrade naturally at the dumpsite [2]. Cockle shell wastes are suggested to be an alternative abrasive agent in toothpaste to achieve a sustainable environment and reduce pollution. It is due to their high composition of calcium carbonate.

Generally, calcium carbonate or silica is one ingredient that usually acts as an abrasive agent in the dentifrice. There are 98% of calcium carbonate can be synthesised from the cockle shell [3]. In comparison, 71% of silicon dioxide (known as silica) can be found in perlite particles [4], and perlite particles are commonly used in commercial toothpaste. Thus, cockle shells and perlite particles are selected as the testing materials to study how both materials achieve teeth cleaning efficiency with proper toothbrushing parameters.

This study aims to determine the possibilities of cockle shell wastes as an abrasive agent for teeth cleaning purposes. The abrasion performance between cockle shell wastes and perlite particles was analyzed. The abrasion effects of cockle shell wastes and perlite particles on an acrylic plate was analyzed under different toothbrushing parameters (brushing cycle and brushing load) to figure out efficient techniques in removing dental plaque stains on the teeth surface.

This study highlights the potential of cockle shell waste particles as abrasive agents in the teeth cleaning process. It was expected that cockle shell wastes would be suitable to be the alternative abrasive agent in the toothpaste since it contains a high composition of calcium carbonate. This analysis results would be beneficial to adopt a new toothpaste formulation by using green material in dental applications. It will also avoid the disposal of large and abundant cockle shell waste at the dumpsite.

2. Materials and Methods

This study comprises experimental and analytical approaches based on literature review and understanding. The purpose of this study was to identify an appropriate toothbrushing parameter that made use of cockle shell waste as an abrasive agent in toothpaste compared to perlite particles. Different toothbrushing parameters (brushing load and brushing cycle) were used in the data analysis.

2.1 Materials and Testing Preparation

In this study, two materials (cockle shell and perlite) were selected to investigate the abrasion effect caused by two materials and explore the suitability of cockle shell wastes as an alternative abrasive agent in the toothpaste.

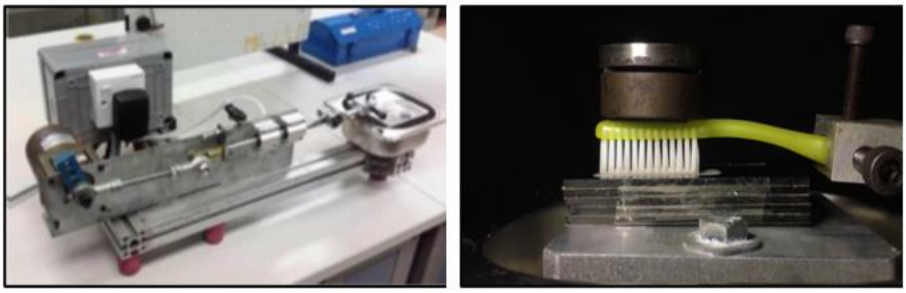

Figure 1: Reciprocating Toothbrushing Test Rig

The cockle shell wastes were scrubbed with a brush and then rinsed under running water to ensure the dirt and impurities had been removed. Both materials (cockle shell wastes and perlite) were dried in an industrial oven. Each material was crushed into fine powder form before being sieved using a stainless test sieve to obtain 63µm aperture size.

For testing preparation, a Reciprocating Toothbrushing Test Rig (Figure 1) was used to conduct the brushing tests to determine the abrasion effect of the cockle shell wastes and perlite particles towards the teeth cleaning process. To obtain the objectives of this study, different toothbrushing parameters had been applied in the experiment. The load cells (load applied) were placed on the head of the toothbrush. Next, a flat transparent acrylic plate was placed under the toothbrush. Before this action, each acrylic plate was checked to ensure its surface is free from damage or scratch. A single (medium type bristle) toothbrush was used for the tests. Finally, the powder form particles were mixed with glycerol, and the mixture was dropped on the acrylic plate. The testing list was tabulated in Table 1.

Table 1: Testing List of Cockle Shell Waste Particles and Perlite Particles

Toothbrush	Particle's Size (µm)	Brushing Speed (rpm)	Brushing Load (N)	Brushing Cycle
Medium Type Bristle	63	100	0	0.5
				1
				20
				50
			1.0	0.5
				1
				20
				50
			2.0	0.5
				1
				20
				50
			2.5	0.5
				1
				20
				50

2.2 Scratch Analysis

The scratch formed on the acrylic plate obtained from the scratch test was observed under the optical microscope. Two main factors were determined to analyse the scratching data: scratch factor and drag factor [5].

$$Scratch\ factor = \frac{Number\ of\ scratches}{Number\ of\ filaments} \quad Eq. 1$$

$$Drag\ factor = \frac{Scratch\ Length}{Stroke\ Length} \quad Eq. 2$$

The scratch factor (Eq.1) indicates how many filaments can hold the abrasive agents to produce scratches. In contrast, the drag factor (Eq.2) indicates how long the filament successfully holds the abrasive agent throughout the brushing motions to produce continuous scratch per stroke.

2.3 Depth Analysis

Atomic Force Microscopy (AFM) is an interference microscope used with high precision to measure surface height variations. The microscope was used to measure the surface depth and surface roughness accurately and precisely after the brushing process. Therefore, the depth analysis was conducted based on the effect of the number of brushing cycles (0.5 cycle, 1 cycle, 20 cycles) and brushing loads (0N, 1N, and 2N) throughout the experiments.

2.4 Wear Rate Analysis

In the wear test results, the removal of material from the test sample surface can be used to express the wear rate of the acrylic plate. As the cockle shell waste particles or the perlite particles rub the acrylic plate's surface during the toothbrush movement, abrasive wear happens. In general, the wear rate was calculated from the weight and volume of the acrylic plates [6]. In this study, the wear rate for acrylic plates was investigated by the effect of load using the volume calculating method.

<u>Theoretical Work</u>

Firstly, the volume of acrylic plate, V_n were calculated as

$$V_n = \frac{\pi}{4} d^2 l \qquad Eq.3$$

Where,

d^2 = scratch depth of the acrylic plate

l = length of the acrylic plate

The volume loss of acrylic plate after toothbrushing, V_L was calculated using Eq.4,

$$V_L = V_1 - V_2 \qquad Eq.4$$

And thus, the wear rate of the acrylic plate was calculated by volume, WR_v:

$$WR_v = \frac{(V_1 - V_2) \times p}{V_1}$$

$$WR_v = \frac{V_L \times p}{V_1} \qquad Eq.5$$

Where,

V_1 = Volume of acrylic plate before the toothbrushing process

V_2 = Volume of acrylic plate after toothbrushing process

V_L = Volume loss of acrylic plate

p = load applied in the toothbrushing process (0N, 1.0N, and 2.0N)

3. Results and Discussion

This chapter highlights the data acquired from the experiment. The brushing tests, scratch and depth analysis have been performed to determine the scratch characteristics (length, pattern, depth, scratch factor and drag factor) for cockle shell and perlite particles under different toothbrushing parameters. In addition, a validation test was conducted to prove the efficient toothbrushing parameters obtained from the results can remove the stain. The wear rate of acrylic plate was also analyzed to evaluate the effect of brushing load towards the efficiency of brushing parameters and thus highlighting whether these waste particles are suitable to be used in toothpaste that could remove stains efficiently from the teeth surface.

3.1 Scratch Analysis

The scratch analysis was conducted to obtain the scratch factor and drag factor after the brushing test. From the scratch factor (Eq.1) calculation, the efficiency of the abrasive particles can be obtained. To determine and analyse the scratch factor, the number of scratches was divided by the number of filaments per row, where the total number of filaments per row on the toothbrush was 200. The scratch factor produced by each type of abrasive particles (cockle shell and perlite), under 2N brushing load and 20 brushing cycles, were tabulated in Table 2.

Table 2: Scratch Factor Analysis under 2N Load (Cockle Shell and Perlite Particles)

Particle	Particle's Size (μm)	Speed (rpm)	Load (N)	Cycle	Number of Scratch	Scratch Factor	Efficiency (%)
Cockle Shell	63	100	2	0.5	85	0.425	42.5
				1	97	0.485	48.5
				20	189	0.945	94.5
				50	163	0.915	91.5
Perlite				0.5	160	0.800	80.0
				1	177	0.885	88.5
				20	291	1.455	145.5
				50	254	1.270	127.0

The data from Table 2 was converted in graphical form as shown in Figure 2, where it highlights the relationship between the scratch factor and brushing cycle under constant load (2N).

As brushing cycles increased, the number of scratches increased, increasing the amount of scratches produced. The scratch factor rises progressively from 0.5 cycle to 20 brushing cycles. However, the scratch factor started to decrease once it passed 20 brushing cycles. More brushing cycles will lead to an increment of the scratches produced due to the entrainment trapping of particles on the filament tip is less stable. During and after the brushing process, particles were observed to pass from the brushing edge into the filament tip contact region, circulate, and swept away from toothbrush. At the same time, only a few particles have remained on the filament tip contact. There is a tendency that the particles will not remain entrained after 20 brushing cycles to produce a higher number of scratches.

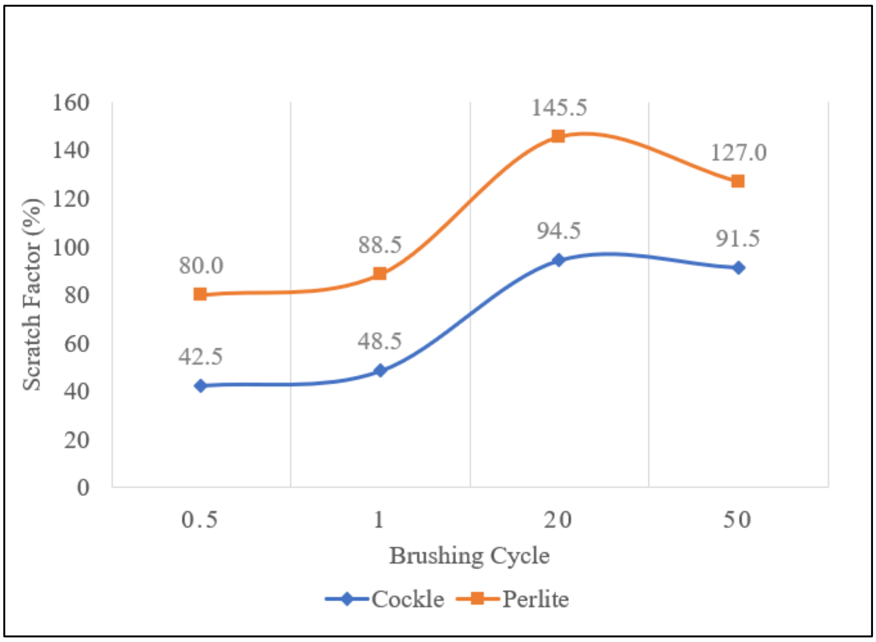

Figure 2: Effect on Brushing Cycle on Scratch Factor under 2N Load

Table 3: Scratch Factor Analysis under 20 Brushing Cycles (Cockle Shell and Perlite Particles)

Particle	Particle's Size (μm)	Speed (rpm)	Cycle	Load (N)	Number of Scratch	Scratch Factor	Efficiency (%)
Cockle Shell	63	100	20	0	92	0.460	46.0
				1	145	0.725	72.5
				2	189	0.945	94.5
				2.5	162	0.810	81.0
Perlite				0	228	1.140	114.0
				1	260	1.300	130.0
				2	291	1.455	145.5
				2.5	284	1.420	142.0

Figure 3 shows the relationship between the brushing load and scratch factor under constant brushing cycles (20 cycles) for cockle shell and perlite particles. The trend shows that the scratch factor increases along with increasing load, indicating more scratches under higher brushing load. However, the trend shifted once the optimal load (2N) exceeded.

The optimal load is the maximum load that the filament tip of toothbrush can withstand before it starts to bend and cannot trap the abrasive particles in which both particles (cockle shell and perlite) failed to be trapped under each other filament. It caused the particles to stay at the edge of a bent filament of the toothbrush, resulting in a lesser number of scratches to be produced on the acrylic plate.

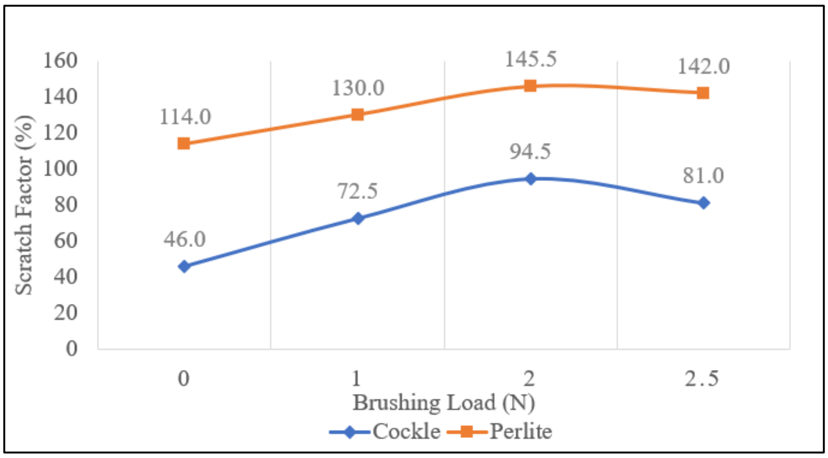

Figure 3: Effect on Brushing Load on Scratch Factor under 20 Cycles

The previous study reported that as the filaments deflected under excessive load, there is substantial evidence that the deflected filaments contained the abrasive particles on their bending side and could still cause scratches [7]. As the brushing load increases, the contact geometry changes, resulting in fewer particles staying in the filament tip contact zone. Abrasive particles are trapped under the ends of the filaments under larger loads and thus deflections, and none enter the contact zones. It will lead to the deflection of the toothbrush at the optimal load and produce fewer scratches.

Drag factor (Eq.2) indicates how long the filament successfully holds the abrasive agent throughout the brushing motions to produce continuous scratch per stroke. The brushing parameters' performance is also determined to remove the stain continuously on a single movement. The stroke length for the toothbrushing test rig was limited to 20 mm. Table 4 shows the data for cockle shell and perlite particles that undergo 0.5 brushing cycle under four brushing load conditions (0N, 1.0N, 2.0N, and 2.5N).

Table 4: Drag Factor Analysis under 0.5 Brushing Cycles (Cockle Shell and Perlite Particles)

Particle	Particle's Size (μm)	Speed (rpm)	Cycle	Load (N)	Scratch Length (mm)	Drag Factor	Efficiency (%)
Cockle Shell	63	100	0.5	0	9.194	0.4597	45.97
				1	10.492	0.5246	52.46
				2	12.294	0.6147	61.47
				2.5	10.055	0.5028	50.28
Perlite				0	10.884	0.5442	54.42
				1	11.545	0.5773	57.73
				2	13.761	0.6881	68.81
				2.5	10.744	0.5372	53.72

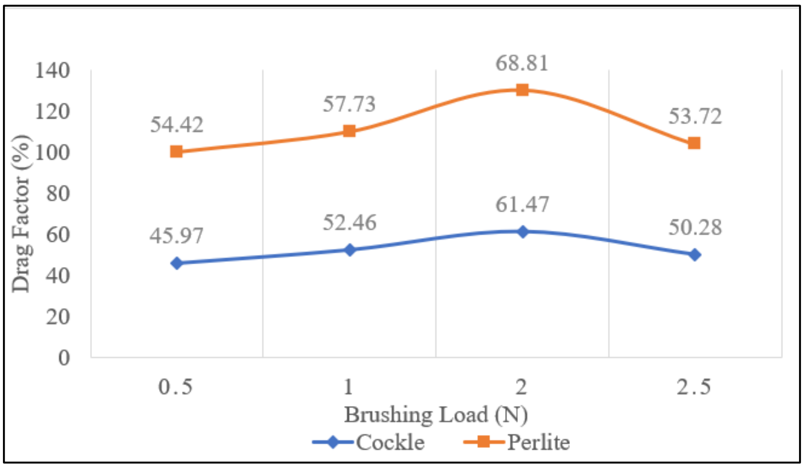

Figure 4: Effect of Brushing Load on Drag Factor under 0.5 Cycle

Figure 4 illustrates the drag factor that varies with different brushing loads at the constant of 0.5 cycle. The trend generally shows the drag factor increases with the increment of the brushing load and decreases when it reached a particular threshold load value which is 2N. It is due to a tendency that abrasive particles are carried away as the brush had moved to its maximum stroke length.

It was observed that there are fewer particles able to trap in the filament tip contact throughout the process at a much higher brushing load. As stated in the preceding section, when the brushing load surpasses its optimum, each filament can no longer tolerate the load and begins to bend. Particles will no longer be trapped at the filament tip, with only a few remaining entrained beneath the bent filament that generated long and continuous scratches.

3.2 Scratch Pattern

The scratch pattern analysis was critical in understanding the entrainment of abrasive particles within the brushing area on the acrylic plate. Under the microscope, different brushing parameters used during the brushing process, such as brushing load and brushing cycle, resulted in different scratch patterns. Therefore, the relationship between the brushing parameters and the scratch pattern was eventually determined and analyzed.

A series of brushing tests were carried out by applying different brushing cycles to investigate the influence of the brushing cycle on the abrasion performance of particles. Generally, there will be a higher number of scratches as the brushing cycle increases and lead to a broader and deeper scratching area. However, from the previous section, the number of scratches decreased after 20 brushing cycles. The filament tip of the toothbrush is more likely to be deflected and is unable to trap the particles in the contact region. So, the scratches produced by 20 cycles would be the best parameter for brushing cycles to be implemented in real-life teeth cleaning. Figure 5 – Figure 8 shows the results of the scratch patterns produced by different brushing cycles of 0.5, 1, 20, and 50 cycles, respectively, for cockle shell and perlite particles under a constant load of 2N.

Next, the applied load on toothbrushing changes the geometry of the contact, attracting fewer particles to the tips of the filament, with only a few penetrating the contact zone. Most of the particles are relocated from the contact region due to the filament deflection at higher brushing load. Therefore, the scratches increase with the brushing load increment, the scratches would be more profound (deeper). The number of scratches increased from 0N to 2N brushing load and then decreased after the optimal load (2N) due to the toothbrush’s deflection, hence fewer scratches produced. Based on Figure 7 and Figure 8, the scratches made at 2.5N are discontinuous and unorganised, almost similar to scratches produced under lower load. In addition, perlite particles produced more significant amounts of scratches than the cockle shell particles.

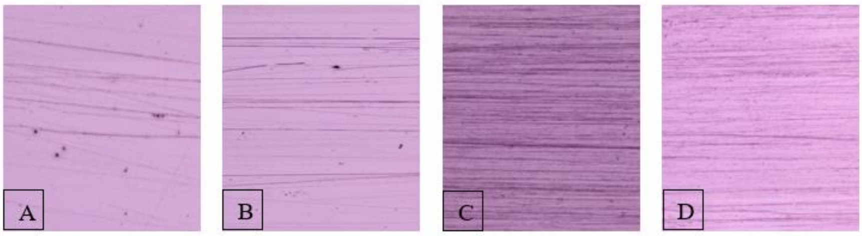

Figure 5: Scratch Pattern under Different Brushing Cycles for Cockle Shell Particles

(A - 0.5 Cycle; B – 1 Cycle; C – 20 Cycles; D – 50 Cycles)

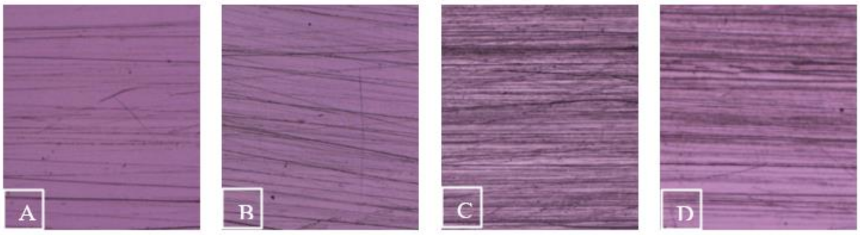

Figure 6: Scratch Pattern under Different Brushing Cycles for Perlite Particles

(A - 0.5 Cycle; B – 1 Cycle; C – 20 Cycles; D – 50 Cycles)

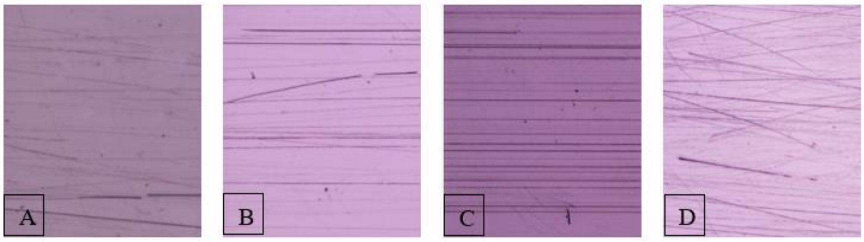

Figure 7: Scratch Pattern under Different Brushing Load for Cockle Shell Particles

(A – 0N; B – 1N; C – 2N; D – 2.5N)

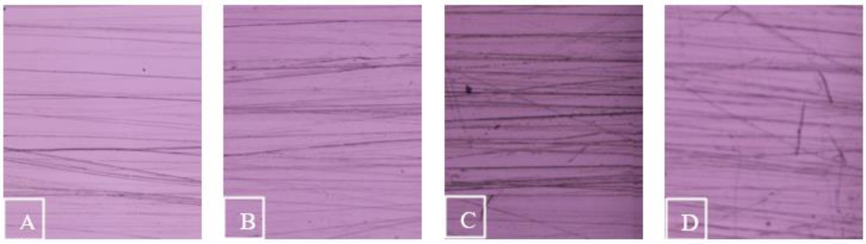

Figure 8: Scratch Pattern under Different Brushing Load for Perlite Particles

(A – 0N; B – 1N; C – 2N; D – 2.5N)

3.3 Depth Analysis

From the results, toothbrushing parameters influence the number of scratches and thus the depth of scratches. Therefore, there will be a higher number of scratches produced at higher brushing cycles and brushing loads. Hence, depth analysis of cockle shell and perlite particles was carried out at different brushing cycles and applied load.

Table 5: Depth of Scratch under Different Brushing Cycle (constant at 2N)

Particle	Particle's Size (μm)	Speed (rpm)	Load (N)	Cycle	Depth of Scratch (μm)
Cockle Shell	63	100	2	0.5	0.233
				1	0.282
				20	0.372
Perlite				0.5	0.339
				1	0.362
				20	0.492

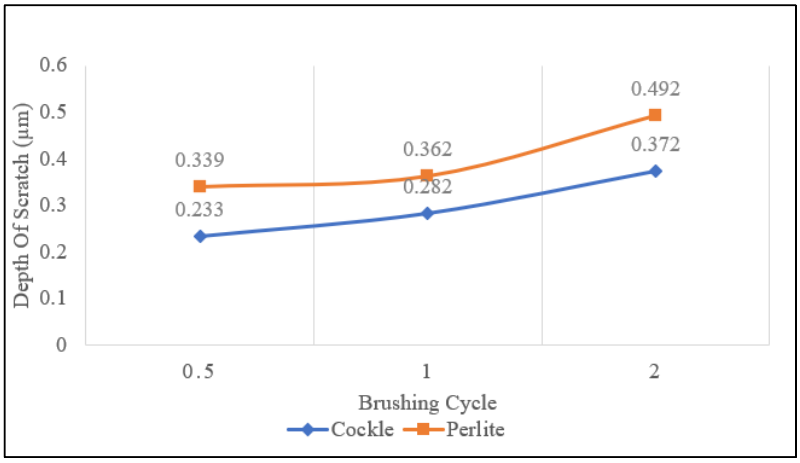

Figure 9: Effect of Brushing Cycle on Depth of Scratch under 2N Load

Table 5 summarise the depth of scratch for both particles under different brushing cycles at 2N load, while Figure 9 shows the relationship between the depth of scratch and brushing cycles. From the graphical data, both particles have a similar trend in which the depth of scratch increases as the number of brushing cycles increases. It indicates that the greater the brushing cycles, the deeper the depth of scratches. Therefore, it should be highlighted that 2N load would be the efficient toothbrushing parameter in removing dental plaque.

Table 6: Depth of Scratch under Different Brushing Load (constant at 0.5 cycle)

Particle	Particle's Size (μm)	Speed (rpm)	Cycle	Load (N)	Depth of Scratch (μm)
Cockle Shell	63	100	0.5	0	0.124
				1	0.156
				2	0.233
Perlite				0	0.242
				1	0.302
				2	0.339

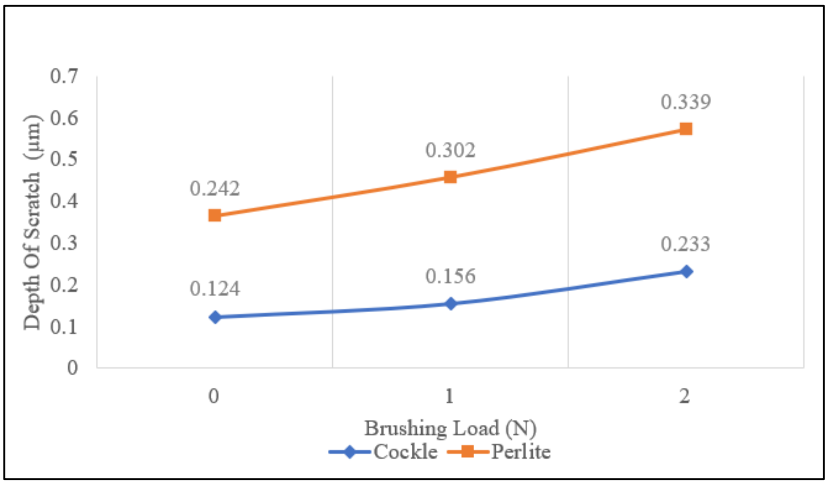

Figure 10: Effect of Brushing Load on Depth of Scratch under 0.5 cycle

Figure 10 indicates that perlite particles have the highest depth of scratch than cockle shell particles despite different brushing loads. The deepest scratch recorded was contributed by perlite particles (0.339 μm deeper from the surface) under 2N load. The deepest scratch of cockle shell particles under 2N is lower than the scratch produced by perlite particles (0.233 μm deeper from the surface). It might explain that the harder the abrasive particles, the deeper the scratch would be. From the Mohs scale, the hardness of silica is higher than calcium carbonate [8], while perlite particles contain silica and cockle shell particles contain calcium carbonate.

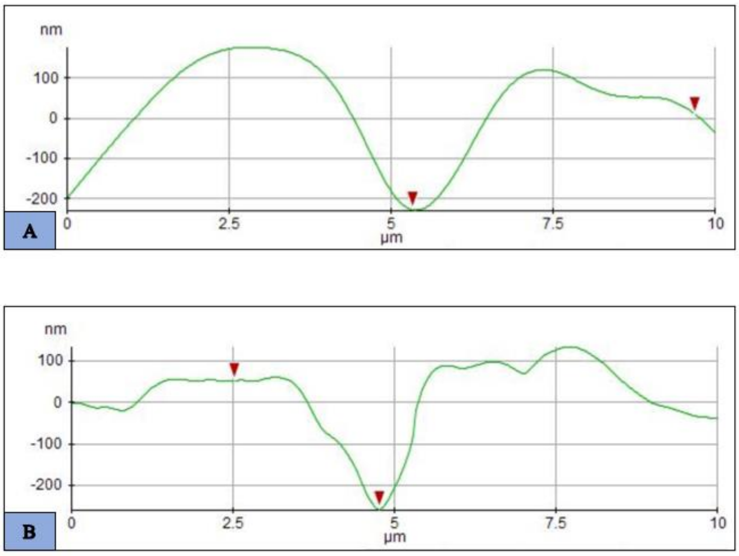

Figure 11: Surface Profile by 2N Brushing Load and 20 Brushing Cycles

[A – Cockle Shell Particles; B – Perlite Particles]

The surface profile shows the variation of the scratch depth by different toothbrushing parameters. The measurement was obtained by Atomic Force Microscope (AFM). Therefore, the surface profile supported the depth analysis. It was conducted against the scratch series to ensure the observation of the variation be more precise and accurate—the comparison of surface profile between cockle shell and perlite particles under 2N Brushing Load and 20 Brushing Cycles were shown in Figure 11.

3.4 Artificial Stain Removal

For validation purposes, an artificial stain with a thickness of 0.1 µm was fabricated on the acrylic surface using a permanent marker. Brushing tests were conducted to prove the efficient brushing cycle selected based on the analysis completely removes the artificial stain. The tests were conducted under 2N brushing load and 20 brushing cycles for both particles (cockle shell wastes and perlite). Results were tabulated in Table 7.

Table 7: Artificial Stain Removal of Cockle Shell and Perlite Particles by 2N Load and 20 Cycles

Particle	Particle's Size (µm)	Speed (rpm)	Load (N)	Cycle	Thickness of artificial stain (µm)	Depth of Scratch (µm)
Cockle Shell	63	100	2	20	0.1	0.237
Perlite					0.1	0.310

Based on the findings of artificial stain removal, both particles are efficient in removing the stain as its depth of scratch formed exceeds the thickness of the artificial stain (0.1 µm). It was discovered that the depth of scratch produced by perlite particles is significantly higher than cockle shell particles, which are 0.310µm and 0.237µm, respectively. Deeper scratch formed by perlite particles as perlite particles caused more sinusoidal curve on the surface profile and surface topography (Figure 12). It means more scratches produced on the acrylic plate surface. In short, this validation proves that the findings from the experimental work and analysis (scratch analysis and depth analysis) that 2N brushing load and 20 brushing cycles are efficient to remove the stain in the teeth cleaning process.

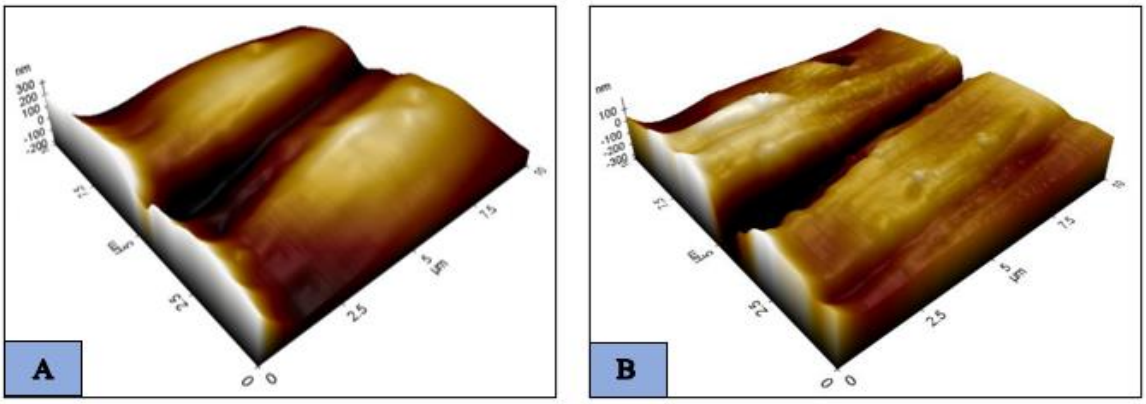

Figure 12: Surface Topography by 2N Brushing Load and 20 Brushing Cycles

[A – Cockle Shell Particles; B – Perlite Particles]

3.5 Wear Rate Analysis

Theoretical testing was performed to investigate the effect of different brushing parameters against the enamel surface using the method laid out in the previous section. The material removed from the acrylic plate is used to express the wear formals on dentin enamel. From the wear rate calculation, the efficiency of the abrasive particles can be obtained. The wear rate of cockle shell and perlite varies with brushing load under constant brushing cycles (0.5 cycle) were calculated, and the data were recorded and tabulated in Table 8 below.

Table 8: Wear Rate under Different Brushing Load (constant at 0.5 cycle)

Particle	Cycle	Load (N)	Depth of Scratch (µm)	Volume after Toothbrushing Process, V_2 (μm^3)	Volume Loss, V_L (μm^3)	Wear Rate ($N\mu m^{-3}$)
Cockle Shell	0.5	0	0.124	9.42361×10^{10}	1.17×10^{7}	0
		1	0.156	9.42331×10^{10}	1.47×10^{7}	1.560×10^{-4}
		2	0.233	9.42258×10^{10}	2.20×10^{7}	4.669×10^{-4}
Perlite		0	0.242	9.42245×10^{10}	2.33×10^{7}	0
		1	0.302	9.42193×10^{10}	2.85×10^{7}	3.024×10^{-4}
		2	0.339	9.42158×10^{10}	3.20×10^{7}	6.791×10^{-4}

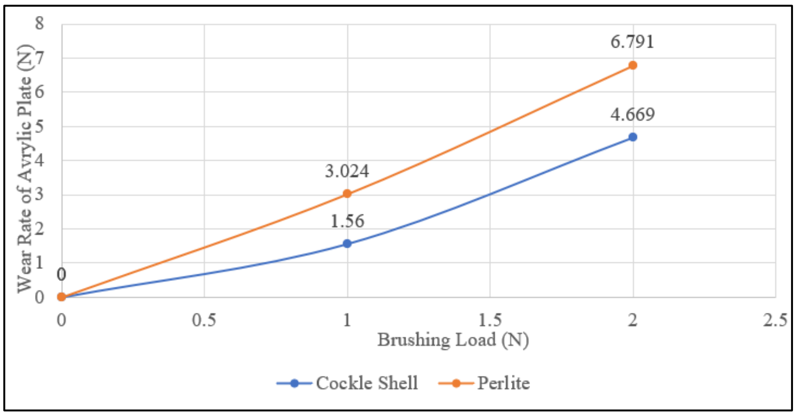

Figure 13: Graph of Relationship between Wear Rate against Brushing Load

The effect of brushing load on the wear of acrylic plate is represented in Figure 13. In the presence of cockle shell particles, it shows a similar trend with perlite particles. The overall results of cockle shell particles are recorded relatively lower than perlite particles. It can be obtained that the increment of brushing load would cause a greater wear rate. The results obtained show that there is no wear rate when the applied load is zero. But still, there is a volume loss of acrylic plate caused by the weight of the toothbrush without external load.

The wear of teeth increases when brushing load increased due to greater kinetic energy of abrasive particles on the surface of teeth, increasing the surface area of teeth exposed to abrasion. However, the abrasion wear depends on the surface hardness of the abrasive materials. According to the Mohr scale, the enamel is harder than calcium carbonate, and thus, the enamel surface will not get worn out. Two particles cause a lower wear rate, and therefore, both particles under these brushing parameters are safe and efficient for tooth cleaning purposes.

4. Conclusion

This study investigates how the abrasion performance of cockle shell and perlite particles was affected by different brushing parameters, resulting in teeth cleaning efficiency. Based on the analysis, cockle shell particles would be an alternative abrasive agent in toothpaste formulation to effectively remove the dental plaque and stains on teeth surface. The overall results showed the scratch analysis and depth analysis of cockle shell particles obtained similar patterns as what perlite particles did. In this study, efficient toothbrushing was achieved under a 2N brushing load and 20 brushing cycles with a speed of 100rpm.

The use of cockle shell waste in this study presents options for toothpaste manufacturers to perform additional research and evaluate its viability in toothpaste' formulation. Cockle shell wastes can be considered green materials that function as abrasive agents in toothpaste rather than being discarded at random. Reusing cockle shell wastes can help to minimise waste in the environment. It will help to achieve sustainable development in society.

Some recommendations can be addressed throughout the experimental work to obtain better and reliable results as improvement in the future. For the future project, different types of bristle toothbrushes are suggested to apply in the study to determine the efficiency of teeth cleaning using cockle shell particles. Next, to increase the credibility on the suitability of cockle shell particles to act as an abrasive agent, it is recommended to compare the performance between cockle shell particles and typical toothpaste.

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References

[1] F. Sahari, “Cockle Shell As An Alternative Construction Material For Artificial Reef Faridah Sahari Fakulti Seni Gunaan & Kreatif , Universiti Malaysia Sarawak Email : sfaridah@faca.unimas.my Nurul Aniza Mijan Fakulti Seni Gunaan & Kreatif , Universiti Malaysia Saraw,” no. March, 2015.

[2] G. O. Bamigboye, A. T. Nworgu, A. O. Odetoyan, M. Kareem, D. O. Enabulele, and D. E. Bassey, “Sustainable use of seashells as binder in concrete production: Prospect and challenges,” *J. Build. Eng.*, no. October, p. 101864, 2020, doi: 10.1016/j.jobe.2020.101864.

[3] M. Olivia, A. A. Mifshella, and L. Darmayanti, “Mechanical properties of seashell concrete,” *Procedia Eng.*, vol. 125, pp. 760–764, 2015, doi: 10.1016/j.proeng.2015.11.127.

[4] K. Srivastava, N. Shringi, V. Devra, and A. Rani, “Pure Silica Extraction from Perlite: Its Characterisation and Affecting factors,” *Int. J. Innov. Res. Sci. Eng. Technol.*, vol. 2, no. September 2020, 2013, [Online]. Available: www.ijirset.com.

[5] S. Subramanian, D. Appukuttan, A. Tadepalli, P. P. S. Gnana, and D. J. Victor, “The role of abrasives in dentifrices,” *J. Pharm. Sci. Res.*, vol. 9, no. 2, pp. 221–224, 2017.

[6] F. A. Abdulla, N. M. Moustafa, and E. S. Al-ameen, “Calculation of Wear Rate by Weight and Volume for Aluminum Samples,” no. 26, pp. 331–339, 2018.

[7] R. Lewis, R. S. Dwyer-Joyce, and M. J. Pickles, “Interaction between toothbrushes and toothpaste abrasive particles in simulated tooth cleaning,” *Wear*, vol. 257, no. 3–4, pp. 368–376, 2004, doi: 10.1016/j.wear.2004.01.015.

[8] M. Baig, “Understanding the role of tribology in maintaining oral hygiene,” *Thesis Ph.D*, no. September, 2018.