ORIGINAL ARTICLE

The Effect of Multiple Sterilisation Cycles on Cutting Efficiency of a Diamond Bur

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ABSTRACT

Introduction: Sterilisation is an essential step in the reprocessing of reusable dental instruments including burs that have become contaminated, or potentially contaminated. Transmission of disease or infection may happen as an effect of improper sterilisation of the reused instruments. Dental burs are one of the essential tools in any conservative dental procedures, which undergo multiple sterilisation cycles before being discarded. However, repeated sterilisation process is associated with the reduction in cutting efficiency of a bur that is potentially due to corrosion. Thus, this study aims to compare the effect of two sterilisation methods on cutting efficiency of a diamond bur that is commonly used in dental procedures. **Methods:** 30 fissure diamond burs were randomly divided into three sterilisation groups: Group A (dry heat), B (steam under pressure) and C (control). Each bur was used to cut teeth for 45 seconds for ten cycles. Between cuts, the burs underwent sterilisation based on their sterilisation groups. Amount of cutting weight was measured after each cut. **Results:** This study shows that no significant difference ($p>0.05$) in the cutting efficiency of the burs following sterilisation of Groups A and B. However, there is a significant mean difference ($p<0.05$) of cutting efficiency between burs in Groups A, B, and C. **Conclusion:** Multiple sterilisation cycles is one of the factors that contribute to the cutting ability and effectiveness of a bur. However, there is no significant difference between dry heat and steam under pressure sterilisation methods toward the cutting efficiency of a bur.

Keywords: Sterilisation, Diamond bur, Dental instruments, Steam, Vacuum

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INTRODUCTION

Bur is a widely used component in dentistry to cut teeth and dental materials. It is used mostly in the procedure for caries removal, cavity and crown preparations, and trimming and polishing of dental restorations. During dental procedures, the bur will be contaminated with blood, saliva, necrotic tissue and various pathogens found in the mouth that potentially become the main route for transmission of infections (1, 2).

Sterilisation and disinfection procedures are routine practices, which is essential for controlling infectious diseases (3, 4). In dentistry, comprehensive surface disinfection, instrument and equipment sterilisation and disinfection are essential to ensure the public is protected from the disease transmission. Several organisations including The Centers for Disease Control and Prevention have made guidelines and recommendations to help dental personnel in preventing the infection transmission (5-8).

Transmission of infection can occur either directly or indirectly when a contaminated dental instrument from the use on one patient was reused on another patient without undergoing an effective laundering and sterilising process. According to Gordon et al., a dental procedure is identified as the cause of cross-infection of patients and dental personnel (9), in addition to the sophisticated design of the tools that makes it difficult to clean and sterilise (10). Additionally, microorganisms that attach to the dental instruments such as bur blades can be an infectious agent if the bur is not effectively sterilised.

It is therefore imperative that all reused equipment should undergo an effective sterilisation process to minimise the spread of infection. Effective sterilisation can be achieved by determining the right way of disinfection, correct preparation of the disinfectants, proper localisation of disinfection, and proper washing and packing of dental devices (4, 11). Additionally,

awareness, training, continuing education, and multiple modes of instruction of the importance of infection control also contribute towards effective sterilisation (12, 13).

There are many methods that can be used in sterilising a dental instrument include steam autoclave, chemical vapour autoclave, dry heat, and immersion in a chemical solution. The most common type of sterilisation methods are autoclave steriliser and dry heat (hot air oven) steriliser. Thus, this study chose these two sterilisation methods to investigate the effect of repeated sterilisation processes on the cutting efficiency of a diamond bur. Addittionally, these two methods are the common methods used for sterilising dental burs.

Sterilisation procedure of a dental instrument or equipment is normally conducted according to the specification by the manufacturer. A proper sterilisation procedure must account for the methods of sterilisation, type of sterilisers and the required cycles, and frequency of disinfection (14, 15). Most of the reusable dental instruments such as tweezer, scaler, mouth mirror, and bur undergo multiple sterilisation cycles before being discarded. These instruments are repeatedly sterilised between usage until it loses its functionality.

However, repeated sterilisation may affect the functionality of the bur. The most significant effect is the change in the cutting and efficiency, particularly after several times of use and sterilisation process (16-19). In several studies, repeated sterilisation is associated with the increase of surface roughness of the instrument (20, 21). Additionally, a study by Rotella et al. suggested that the sterilisation procedure between cuts improved the average cutting performance (21). However, a study by Boldieri et al. (2015) explained that sterilisation mechanisms in autoclaves cause corrosion to the hardware devices since it interferes with the durability and effectiveness of cutting equipment (22).

In a study conducted by Cooley et al., steam autoclave showed a statistically significant loss of cutting efficiency (16). Rapisarda et al. found that the cutting efficiency was decreased when repeated autoclave sterilisations were applied, which could be observed from the alterations in the outer surface of the instruments (23). The surface of the instruments became more irregular and rough when the instrument underwent sterilisations (24, 25). Moreover, a study done by Schäfer found that the sterilised uncoated files gave a significant loss of cutting efficiency compared to non-sterilised instruments (26).

The effectiveness of a bur is essential to ensure dental treatment goes smoothly without leaving the pain or causing heat to the tooth produced by a dulled bur. A study conducted by Fais et al. found that the sterilisation method used on a bur could affect the effectiveness of the bur cuts (27). However, different sterilisation methods affect microscopic features, durability, and strength of dental hardware devices differently, especially bur (28). Consequently, the sharpness, ability, and effectiveness of tooth structure cuts may also change depending on the dental device surface (29).

The purpose of this study is to investigate the effect of repeated sterilisation processes on the effectiveness of the diamond burs for dental cutting procedures. In particular, the cutting efficiency of diamond burs using two sterilisation methods will be compared to a non-sterilisation group. Burs from two types of sterilisation methods, which are dry heat sterilisation and pressurised steam sterilisation will also be compared to investigate the difference of sterilisation methods toward the cutting efficiency.

MATERIALS AND METHODS

Dental burs

30 units of flat fissure diamond burs (Edenta AG, Switzerland) were used in this study. The diameter and length of the burs were 1.6 mm and 19 mm, respectively. These 30 units of diamond burs were randomly divided into three groups; Group A: dry heat sterilisation, Group B: sterilisation with steam under pressure, and Group C: control group (non-sterilisation). 10 burs in Group A were labelled as A1 to A10, whereas burs in Groups B and C were labelled as B1 to B10, and C1 to C10.

Cutting procedures

Thirty sound human molar teeth extracted due to periodontal disease were used in this study. The teeth samples were moulded into several blocks with the crown parts being exposed up to the cementoenamel junction (Fig. 1). Each bur was used to make ten cuts in one tooth: buccal, lingual, mesial and distal surfaces. The bur was placed parallel to the tooth surface, and the cut was prepared from mesial to distal direction (30). The cutting procedure was performed for 45 seconds which could prepare a cavity depth about 2 mm (Fig. 1). After completing each cut, the block was weighed and reading was recorded. The weight of the block was measured to determine the amount of weight loss during the cutting procedure (27).

After each cutting procedure, the bur was cleaned with a nylon brush under running water for 40 seconds, wiped dry with tissue paper, weighed, and sterilised individually according to the sterilisation groups. After sterilisation, the same burs were used again to cut the moulded teeth for another 45 seconds. The sterilisation and the cutting process were repeated until each bur had a total of ten sterilisation cycles and ten cuts. The weight of the block was measured after each cutting procedure.

Sterilisation methods

Two types of autoclave were used in this study. For Group A, the autoclave used was a Type B vacuum,

Figure 1: Teeth samples moulded into a block and the cutting procedure

using the dry heat method. The temperature was set at 134°C for 15 minutes with a pressure of 20,400 kPa. For Group B, the autoclave used was Type N non-vacuum, using steam under pressure. The temperature was set at 134°C for 30 minutes with a pressure of 318 kPa. The flowchart of this study is shown in Fig. 2.

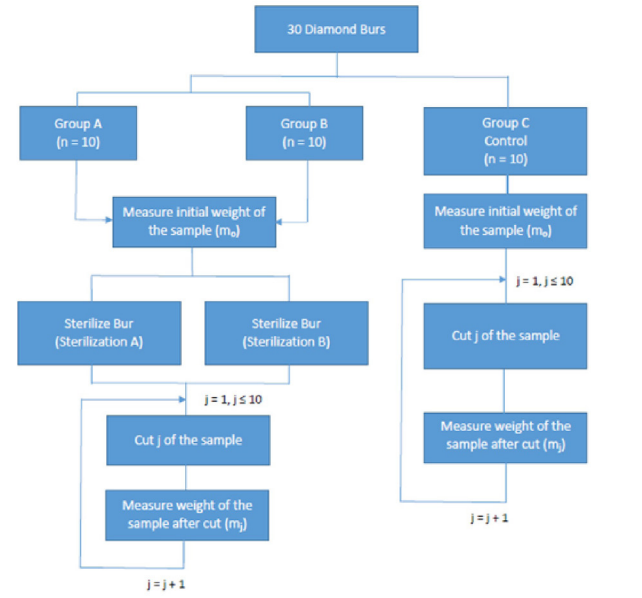

Figure 2: Flowchart of the study method

Data Analysis

The cutting rate of the bur is determined by using the weight loss method during the cutting procedure (27). Each bur was used to cut the sample block for 10 times and each cut was conducted for 45 seconds. Thus, the total cutting time for each bur was 450 seconds. Data were analysed statistically by one-way ANOVA test and Dunnet T3 Post Hoc test.

RESULTS

Fig. 3 shows the weight-loss of the samples of cut number 1 to cut number 10 for the ten burs in Group A, Group B, and Group C. Based on the top panel of Fig. 3, all burs (A1-A10) used in Group A show a reduction in the cutting rate from the first cut to the tenth cut even though the decline rates vary from one bur to another.

The cutting weight of the first cut to the tenth cut for the ten burs (B1-B10) in Group B is shown in the middle panel of Fig. 3. Similarly to the results of Group A, all burs in Group B show a reduction in the cutting rate from the first cut to the tenth cut, and the decline rates vary among all the burs.

The bottom panel of Fig. 3 shows the cutting weight from cut number 1 to cut number 10 for the ten burs (C1-C10) in Group C. All burs show a reduction in the cutting rate from the first cut to the tenth cut as seen in Group A and B. For example, C3 has a lower rate of decline than C8 since C8 has a steeper slope of cutting weight. Additionally, the decline rates also vary among the burs, as measured from the graph slope of each bur.

Table I shows the total cutting time in seconds, mean and standard deviation of the weight-loss of the samples according to the number of cuts for burs in Group A, B, and C. In general, the cutting rate is the highest at the first cut and continuously decreased from the second cut until the tenth cut. The samples' weight-loss of the first cut for all the groups is about the same, which ranging from 0.068 g to 0.069 g. However, a considerable drop can be observed when comparing the first cut to the final cut, especially in Group A and B. The percentage difference between the first cut to the final cut are 64.8%, 62.8%, and 50.2% for Group A, B, and C, respectively.

The descriptive analysis of weight-loss of the samples for each cut is shown in Table II. Cut 1 has the highest mean with 0.069 g while the lowest is at Cut 10 with 0.028 g. Overall, the mean of the cutting efficiency reduces as the number of cuts increases. One-way ANOVA test of analysis for comparing each cut (Cut 1 to Cut 10) indicates a significant p-value ($p<0.001$). Therefore, it is proven that there is a significant mean difference among all the ten cuts. Hence, further analysis was made using Dunnet T3 to compare the mean difference among the

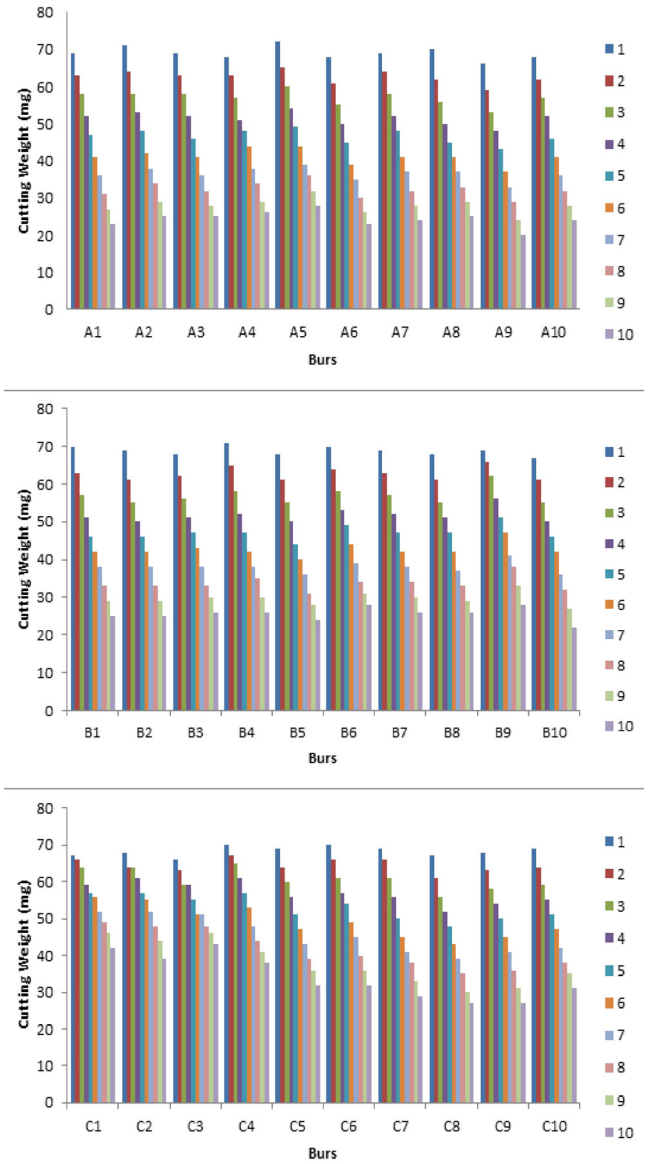

Figure 3: Sample's weight-loss of the first cut (1) to the tenth cut (10) for each bur in Group A, Group B, and Group C

cuts. The results show that each cut (Cut 1 to Cut 10) has a significant mean difference ($p<0.05$) except for pairs of Cut 7 and Cut 8, Cut 8 and Cut 9 and also Cut 9 and Cut 10 where these groups do not differ significantly ($p>0.05$).

Table III shows the mean weight-loss of the samples of each bur from Bur 1 to Bur 10. Bur 1, Bur 2 and Bur 4 have the highest mean with 0.049 g, while Bur 8 has the lowest mean of 0.045 g. By comparing between each bur using one-way ANOVA, the result has shown that there is no significant difference ($p=0.979$) among them.

Table IV represents the mean and the standard deviation of sample's weight-loss of Group C (control), Group A (dry heat sterilisation) and Group B (pressurised steam sterilisation). Group B has recorded a higher mean compared to Group A by a difference of only 0.001 g. One-way ANOVA test has been used to compare

Table I: Total cutting time, mean and standard deviation of weight-loss of the samples in gram according to the number of cuts for Group A, Group B, and Group C

Number of cut	Total cutting time (seconds)	Weight-loss (gram)		
		Group A	Group B	Group C
Cut 1	45	0.069±0.0016	0.069±0.0011	0.068±0.0013
Cut 2	90	0.063±0.0016	0.063±0.0017	0.064±0.0017
Cut 3	135	0.057±0.0018	0.057±0.0021	0.061±0.0028
Cut 4	180	0.051±0.0016	0.052±0.0017	0.057±0.0028
Cut 5	225	0.047±0.0018	0.047±0.0018	0.053±0.0032
Cut 6	270	0.041±0.0020	0.043±0.0017	0.049±0.0043
Cut 7	315	0.037±0.0016	0.038±0.0014	0.045±0.0047
Cut 8	360	0.032±0.0020	0.034±0.0018	0.042±0.0050
Cut 9	405	0.028±0.0020	0.030±0.0016	0.038±0.0057
Cut 10	450	0.024±0.0020	0.026±0.0017	0.034±0.0057

Table II: Comparison of weight-loss of the samples by number of cut (Cut 1-10)

Group	N	Mean	Std. Deviation	95% Confidence Interval for Mean		F test	P-value
				Lower Bound	Upper Bound		
Cut 1	30	0.069	0.001	0.068	0.069	310.321	< 0.001
Cut 2	30	0.063	0.002	0.063	0.064		
Cut 3	30	0.058	0.003	0.057	0.059		
Cut 4	30	0.053	0.003	0.052	0.055		
Cut 5	30	0.049	0.004	0.047	0.050		
Cut 6	30	0.044	0.005	0.043	0.046		
Cut 7	30	0.040	0.005	0.038	0.042		
Cut 8	30	0.036	0.005	0.034	0.038		
Cut 9	30	0.032	0.006	0.030	0.033		
Cut 10	30	0.028	0.006	0.026	0.030		

Table III: Comparison of weight-loss of the samples by burs (Bur 1-10)

Group	N	Mean	Std. Deviation	95% Confidence Interval for Mean		F test	P-value
				Lower Bound	Upper Bound		
Bur 1	30	0.049	0.014	0.043	0.054	0.285	0.979
Bur 2	30	0.049	0.014	0.044	0.054		
Bur 3	30	0.048	0.013	0.043	0.053		
Bur 4	30	0.049	0.014	0.044	0.054		
Bur 5	30	0.047	0.014	0.042	0.052		
Bur 6	30	0.047	0.014	0.042	0.052		
Bur 7	30	0.047	0.014	0.041	0.052		
Bur 8	30	0.045	0.014	0.040	0.050		
Bur 9	30	0.046	0.014	0.041	0.051		
Bur 10	30	0.046	0.014	0.041	0.051		

Table IV: Comparison of sample's weight-loss for Group C versus Group A versus Group B

Group	N	Mean	Std. Deviation	95% Confidence Interval for Mean		F test	P-value
				Lower Bound	Upper Bound		
Group C	100	0.051	0.012	0.049	0.053		
Group A	100	0.045	0.014	0.042	0.048	6.481	0.002
Group B	100	0.046	0.014	0.043	0.048		

between Group C, Group A and Group B. The result shows a significant mean difference between Group C, Group A and Group B (p=0.002). Further analysis of multiple comparisons using Dunnet T3 Post Hoc test shows that the control group has a significant mean difference on Group A (p=0.003) and Group B (p=0.008). The mean difference also shows that the control group has a higher mean difference with 0.0063 g compared to Group B with 0.0055 g. However, the comparison between Group A and Group B does not shows any significant difference.

DISCUSSION

In this study, two sterilisation methods were used to investigate the effect of sterilisation on the cutting efficiency of a diamond bur. Sterilisation A: 134°C for 15 minutes at 20, 400 kPa using dry air, and sterilisation B: 134°C for 30 minutes at pressure 318 kPa using pressurised steam. Additionally, the control group was also studied to compare the differences between sterilisation groups and the non-sterilisation group.

The cutting rates for all burs were high during the first cut as seen from the three groups in this study. The cutting efficiency deteriorates after several cuts, and it is highly variable among all the burs in the three groups as expected. The deterioration of cutting efficiency is mainly due to the cutting process that eventually blunted the surface of the burs. However, it is interesting to see whether sterilisation plays a role in worsening the cutting capacity of a bur.

The downturns of cutting ability were varied for all the burs in the three groups as observed in Fig. 4-6. There is a change in the weight of the sample from one cut to another. The changes in cutting rate are as expected. After several times of use, the burs lose its cutting ability as burs increasingly becoming blunt as a result of wear (18). The morphology analysis using scanning electron microscope (SEM) indicated the signs of wear of the burs. The wear effect is also translated to the amount of weight-loss of the samples during a cutting procedure. Therefore, the reduction of cutting rate of a bur is directly related to the reduction of the weight-loss of a sample during the cutting procedure.

Additionally, there is a significant mean difference between cuts from the initial cut up to the seventh cut. However, there is no significant difference for the seventh cut onwards. Thus, the further use of the bur after seven-time of cutting and sterilisation reduce the cutting efficacy. This study suggests that the bur loses its cutting efficiency after the seventh cut that is equivalent to 315 seconds of total time of cutting.

Group A uses dry air to allow hot air to be distributed through gravity convection. The advantage of this method is that the sterilisation cycle is short but with high temperatures. It is ideal for hardware tools made from carbon steel and bur as it is not rusted, uncrushed, or lost strength and sharpness of cutting if it is dry. However, this sterilisation method is not suitable for some high-temperature sensitive equipment as it can damage equipment such as rubber and plastic.

High-temperature sterilisation cycles cause dry and dehydrated environments. This environment maintains the integrity of equipment made of stainless steel, as it does not induce oxidation and corrosion (31, 32). In a case of carbide bur, sterilisation process using dry air causes a slight increase of visible crack, which alters the nature of the bur geometry, and eventually increases the cutting capacity of the burs (28). Therefore, the alteration of bur geometry can potentially be the reason for a significant decline of cutting efficiency in sterilised bur that underwent dry air sterilisation (Group A).

Group B using steam under pressure with a temperature of 134°C requires a hardware tool packed and put into an incomplete chamber to allow the steam to penetrate easily. The advantage of this method is that it is fast and beneficial for packaged equipment. However, this method is also not suitable for equipment that is sensitive to high temperatures. Hardware tools made of carbon steel such as diamond burs and carbide shank can become rustier due to the resulting vapour produce in pressurised sterilisation. The loss of cutting capacity in a pressurised steam bur is linked to the corrosion of the bur that causes a dulled bur (33).

The comparison between the non-sterilised (Group C) and the sterilised bur using dry heat sterilisation (Group A) and steam sterilisation (Group B) statistically showed a significant mean difference (p=0.002) on cutting efficiency. Multiple comparisons test shows that the control group has a significant mean difference on Group A (p=0.003) and Group B (p=0.008). However, no significant difference (p> 0.05) was observed between the Group A and Group B. Thus, multiple or repeated sterilisation cycles affect the cutting efficiency of diamond burs.

CONCLUSION

This study was conducted to examine the cutting efficiency of burs on the tooth sample following

repeated sterilisation processes. The difference between Group A (sterilisation process using Type B Vacuum autoclave), Group B (sterilisation process using Type N Non-vacuum autoclave), and Group C were recorded and discussed.

The effectiveness of the bur decreases following several cutting cycles. This is because, the longer the bur has been used, it becomes wear and the diamond particles on the bur are also blunt as observed with morphology analysis (34). The dentist is usually aware that the bur shows a decrease in the effectiveness when bur is blunt during the drilling or cutting procedure, but the cause is rarely addressed. A significant decrease in the effectiveness can be seen in the seventh and subsequent cuts of the control samples. This is equal to the total cutting time of 315 seconds. This can also be seen based on the weighted average weight of the deductions from the first cut until the last. Based on the results, it can be concluded that dried air or pressurised steam sterilisation methods do not show a significant difference to the cutting ability and efficiency of the diamond bur. However, there is a significant difference in cutting efficiency between non-sterilised and sterilised bur.

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