Avicenna J Dent Res. 2021 December;13(4):119-123

doi 10.34172/ajdr.2021.23

AJDR
Avicenna Journal of Dental Research

Original Article

Effect of Sterilization (Autoclave) on Wear of Tungsten-Carbide Burs Coated With Diamond Particles With Different Thicknesses

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Abstract

Background: Extending the lifespan and improving the physical properties of dental burs as the most extensivly used instruments have been the subject of several studies. One of the proposed methods is using surface coatings for the burs. Since the dental instruments are reused, they require sterilization. One of the possible causes of the damage to dental burs is autoclaving process. This study aimed to investigate sterilization (autoclave) effect on wear of diamond coated tungsten-carbide burs with different thicknesses.

Methods: In this in vitro study, 40 tungsten-carbide dental burs (IQ DENT, Poznan, Poland) were selected, out of which 20 burs were coated with 1.5-µm-like diamond particles, and 20 burs were coated with 3.5-µm by PVD method using Swin Plasma Coating Machine. Then, the burs were randomly divided into four groups (n=10) as follow: G1: 1.5 µm thickness coated burs without sterilization; G2: 3.5 µm thickness coated burs without sterilization; G3: 1.5 µm coated with sterilization; and G4: 3.5µm thickness coated burs with sterilization. Their weights were measured before wear test.Wear test was performed and then they were re-weighted. Data were analyzed using SPSS software (version 21) as well as Two-way ANOVA and Tukey HSD supplementary tests ($\alpha=0.05$).

Results: Mean and standard deviation of the burs weights without sterilization in the control groups were 7.31 ± 2.63 and 7.96 ± 1.61 mg, respectively; and mean and standard deviation of the burs weights in the sterilization groups were 7.06 ± 0.98 and 7.12 ± 1.11 mg, respectively. The study results showed that "sterilization application" and "thickness of coated layer" were the main factors and their intraction had no statistically significant difference ($P=0.589$).

Conclusions: The sterilization process had no effect on wear of diamond coated tungsten-carbide burs with different thicknesses.

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Keywords: Burs, Diamond, Tungsten-carbide, Sterilization

Received April 10, 2021
Accepted May 17, 2021
ePublished December 16 2021

Citation: Khamverdi Z, Yarmohammadi E, Tolaminejad B, Barghilashgari A. Effect of Sterilization (Autoclave) on Wear of Tungsten-Carbide Burs Coated With Diamond Particles With Different Thicknesses. Avicenna J Dent Res. 2021;13(4):119-123. doi: 10.34172/ajdr.2021.23.

Background

Due to the significant role played by dental burs in dental processes – including restorative treatment, oral surgeries, as well as praparation of access cavity in root canal treatment, improving the physical properties and extending the avarage lifespan of rotary cutting instruments have been the subject of several research studies (1,2).

Two of the most important physical properties of dental burs are their cutting efficiency and wear (3). Wear is the first and most important reason for reducing cutting efficiency of a dental bur (4). It is believed that the bur wear is the main cause of its destruction (5).

Using improper cutting instruments can cause heat and vibration on the enamel and dentin and, subsequently, lead to microleakage of the restoration and damage to the pulp (6).

There are various methods to improve the physical properties of dental burs (7). The nanostructured coating on dental bur is one of the most important applications of nanotechnology in the 21st century, which can be adopted as an effective method to achieve the given purpose. This method, which requires applying a harder layer of materials such as diamond coatings (DLC), has provided a favorable opportunity with practicioners working in medicine and dentistry (8). DLC technique was used for the dental implants that have good wear resistance and a low coefficient of friction and corrosion resistance. Also, the cutting blades of the ultrasonic stainless steel instruments pointed out that it has reduced the amount of

Highlights

- Effect of sterilization on wear of burs coated with diamond
- The sterilization process had no effect on wear of diamond coated tungsten-carbide burs with different thicknesses

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material loss (MRR) consumed are prepared in according technology (9,10).

The diamond-like carbon (DLC) coatings on the nickel and titanium orthodontic wires improve abrasion and corrosion resistance. In addition, these coatings also prevent the release of nickel ions (11). We can also consider the obvious effect of DLC coating on the function of new generation of dental burs (12,13).

Reusing dental instruments is a vey common practice in dentistry and, therefore, the instruments reasonably require cleaning and sterilization after each time they are used (14). However, the reliability of the sterilization methods is a decisive factor for reusing the instruments (15). The complex structure of burs may keep debries and pathogen microorganisms residues on the surface, which directly affects the cutting efficiency and acts as a contamination or disease transmitter (1,12).

The most common sterilization methods are dry heat, autoclave, and immersion in chemical solutions, all of which have beoth some advantages and/or disadvantages (16).

Autoclave is one of the most effective and safest strilization methods, but it suffers from some disadvantages including corrosion of steel parts, long process time, and high cost (17).

Previouse studies have shown that sterilization processes can affect the lifetime and performance of the cutting instrument (3). Since there is no information available about the effect of sterilization on the wear of tungsten-carbide dental burs coated with DLCs particles, this study aimed to evaluate the effect of sterilization on the wear of these burs by using autoclave method.

Materials and Methods

Sample Preparation

In this invitro study, 40 tungsten-carbide fissural dental burs (IQ Dent, Poznań, Poland) without defect and cracks were selected. Each bur was first examined under a stereomicroscope with 64X in order to find any probable defects or cracks.

The burs were randomly divided into four groups (N = 10): G1: 1.5 µm thickness coated burs without sterilization; G2: 3.5 µm thickness coated burs without sterilization; G3: 1.5 µm coated with sterilization; and G4: 3.5 µm thickness coated burs with sterilization. The parameters required to determine the sample size were obtained using a pilot study (5 samples in each group), then according to alpha error of 0.05 and power of 90% and the minimum significant difference of 3 in each group, 10 was estimated.

Coating Method

The samples were cleaned with detergent solutions in an ultrasonic bath and, then, cleaned with acetone and 99% ethyl alcohol. The burs were fixed on fixtures of the cell in the machine inside the vacuum chamber so that each sample could rotate on both its central axis and the central axis of the cell in the machin during the coating process with speeds of 50 and 4 rpm, respectively. The distance between the samples and the spattering source was set at 30 cm, and vaccum conditions were provided in chamber up to a pressure of 3×10^{-5} millibars. The burs were then heated by resistance heaters up to 350°C. Before initiating the coating process, the surfaces were cleaned by the ionized argon gas in order for removing possible surface contaminations from the samples.

As for DLC coating, the argon penetration into the chamber was halted until a vacuum of approximately 3×10^{-5} millibars was obtained and, then, acetylene gas with a ratio of 8 to 2 was diffused for reaching to pressure of 2×10^{-2} millibar. The chromium spattering process was started and the crc-DLC phase coating was performed on the bur surface. Then by increasing the amount of input acetylene, the amount of chromium spattering decreased while the amount of DLC phase deposition increased.

This process was continued for 120 and 240 minutes in order to obtain a thickness of at least 1.5 and 3.5 µm coating, respectively.

Wear Test

All burs were weighted by a digital caliper (Radwag, ASR2) and recorded in mg. To perform the wear test, each bur was placed inside a special pin on a stainless steel disk and the machine was rotated automatically.

The parameters were set for a force of 500 N, speed of 1.5 m/s, radius of 15 mm, distance of 20 m, and 954 rpm. The weight of each bur was re-measured and considered as secondary weight. Values of wear were estimated by calculating differences between primary wheights and secondary weights.

Sterilization Method

Half of the burs coated with thicknesses of 1.5 and 3.5 µm by PVD method were placed in autoclave (Plus Andromeda, Tecno-Gaz model, Italy) at a temperature of 134°C and a pressure of 15 lbf/in^2 (pound per square inch) for 30 minutes.

Stereomicroscopic Assessment

One sample drawn from each group was examined under a stereomicroscope (Nikon Eclipse E600; Tokyo, Japan) at ×64 magnification.

Statistical Analaysis

The collected data were analyzed by SPSS software (version 21). Due to normaliry of the data, two-way ANOVA test was used. Significance level was considered as 0.05.

Results

The results from Kolmogorov-Smirnov statistical test

revealed that the data were normal. The highest wear occurred in the second group, and the lowest one occurred in the third group (Table 1).

According to the results from two-way analysis of variance tests for the studied groups, the factors of "coating thickness" and "sterilization", also, their interactions showed no significant difference (Table 2).

Discussion

Since the dental burs are extensively used instruments in dentistry, extending their lifespan and improving their physical properties take on a considerable importance. This study aimed to evaluate the effect of sterilization (autoclave) on the wear of tungsten-carbide burs coated with diamond-like particles.

Diamond coatings have been used in some dental products due to their biocompatibility, high wear resistance and coefficient of friction, low corrosion resistance, and low Ni ion release (10, 11). The findings from some studies have shown that the use of diamond coatings on the tip of the bone cutting ultrasonic instruments reduces the temperature and applied materials (9).

Nanostructured coatings are used in various methods, including sputtering and vapor deposition. From among various methods, steam phase deposition processes have received special attention recently. These processes are divided into two general categories: physical vapor deposit ion (PVD) and chemical vapor deposition (CVD), which are commonly used methods. In this study, vapor phase physical deposition (PVD) is used. The PVD process is directional in nature, and is performed at low temperatures (8). According to the results from some studies, DLC coating in the range of 0.7 to 3.5 µm has no negative effect on the abrasion properties of Ti6Al4V biomedical alloy (18). Ahmed et al applied a diamond coating on cobalt tungsten-carbide tungsten using the HF-CVD method and found that the thickness of the coating layer was also higher due to the higher temperature of the milling tip during the process. It was also confirmed by the size of the larger crystals in the SEM images of the milling tip. In addition, the stress calculations based on Raman spectroscopy data showed a higher compressive stress in the bur tip (7).

In the present study, DLC nano particles with thicknesses of 1.5 and 3.5 µm were used to coat . The reason for using two thicknesses could be explained by the findings from some studies which have indicated that thicker coatings display better abrasion resistance than thinner coatings (14).

The most common methods of sterilization for medical and dental instruments are dry heat, autoclave, and immersion in chemical solutions, all of which have some advantages and disadvantages (19). Autoclave is one of the most effective and safest sterilization methods due to its good permeability, high humidity, low cost, low complexity, easy monitoring, short time cycle, fast antimicrobial properties, and non-toxic characteristics (12). To determine the effect of sterilization on the wear of tungsten-carbide burs coated with diamond particles, therefore, an autoclave at a temperature of 134°C and a pressure of 15 P/I^2 was used.

According to our study results, there was no significant difference in the group types (control and sterilization). Seemingly, sterilization caused no significant changes in the wear rate of the coated burs, and protective effect of the nanoparticle layer was not decreased by autoclaving. The results from studies on the effect of the sterilization process on the dynamic coverage of surgical and dental burs are different and somewhat contradictory. According to the results from some studies, despite different sterilization methods including dry and without steam (12), autoclaving with NaOCL (20), chemical sterilization, autoclaving, dry heat and steam(15), and also frequency of sterilization sessions, sterilization process does not have an adverse effect on dynamic coverage and resistance to the fragility of the burs (12,15,20,21).

In the present study, only the thickness of sterilized and non-sterilized milling cutters in two different coatings thickness was evaluated and, therefore, our findings were consistent with the results from these studies.

On the other hand, a number of researchers have reported that sterilization methods have a negative effect on the structure and cutting capacity of the dental burs (17,22).

Our study findings also showed that wear rate was not dependent on "thickness" as a main factor. Thicknesses of 1.5 and 3.5 µm produced the same effect on wear of them.

Our study results were confirmed by the SEM images. According to Figures 1-3, no difference was observed between sterilized and non-sterilized coated bur edges. The edges were neither sharp nor rounded. Sharp blades are usaully pron to wear.

Table 1. The War Values in the Studied Groups ($P=0.05$)

Groups	Thicknesses	
	1.5 (µm)	3.5 (µm)
Control	7.31±2.63	7.96±1.61
Autoclave	7.06±0.98	7.12±1.11

Table 2. Two-way ANOVA Test Between Study Groups ($P>0.05$)

Variance Source	Sum of Squares	df	Mean of Squares	F	*P* Value
Group	2.97	1	2.97	1.02	0.320
Thickness	1.26	1	1.26	0.43	0.515
Interaction effect	0.87	1	0.87	0.3	0.589
Error	105.133	36	2.92		
Total	2278.49	40			

Figure 1. The uncoated tungsten- carbide bur

Figure 2. The coated tungsten- carbide bur before sterilization

Figure 3. The coated tungsten- carbide bur after sterilization

Conclusions

Given limitations of this study, it was concluded that the sterilization process had no effect on wear of diamond coated tungsten-carbide burs with the studied thicknesses.

Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

Ethical Statement

Ethical approval of this study was granted by the Ethical Committee of Hamadan University of Medical Sciences (no. IR.UMSHA.REC.1398.007).

Authors' Contribution

Zahra Khamverdi: study design, writing manuscript, leader of research team, Ebrahim Yarmohammadi: study design,writing manuscript, Behzad Tolaminejad: performance of coating of specimens, Anahita Barghilashgari: Data collection

Funding

This research was founded by Vice Chancellor Research and Technology

References

1. Gwoździk M, Bałaga Z, Wróbel D, Nitkiewicz Z. Evaluation of wear degree of rotational instruments with diamond coat. Composites Theory and Practice. 2017;17.
2. Klimecka-Tatar D. The Wear-Resistant Evaluation of Dental Milling Cutters Based on Cemented Carbides. Zeszyty Naukowe Quality Production Improvement; 2014.
3. Ahmed W, Sein H, Jackson M, Polini R. Chemical vapour deposition of diamond films onto tungsten carbide dental burs. Tribol Int. 2004;37(11-12):957-64. doi: 10.1016/j.triboint.2004.07.013.
4. Pines MS, Schulman A. Characterization of wear of tungsten carbide burs. J Am Dent Assoc. 1979;99(5):831-3. doi: 10.14219/jada.archive.1979.0403.
5. www.nanocoating.nanoindustry.ir. Available from: http://nanocoating.nanoindustry.ir/.
6. Simamoto-Júnior PC, Soares CJ, Rodrigues RB, Veríssimo C, Dutra MC, Quagliatto PS, et al. Comparison of different wear burs after cavity preparation and sterilization methods. Rev Odontol Bras Central. 2012;21(59):547-52. doi: 10.36065/robrac.v21i59.702.
7. Ahmed W, Sein H, Ali N, Gracio J, Woodwards R. Diamond films grown on cemented WC–Co dental burs using an improved CVD method. Diam Relat Mater. 2003;12(8):1300-6. doi: 10.1016/s0925-9635(03)00074-8.
8. He Y, Apachitei I, Zhou J, Walstock T, Duszczyk J. Effect of prior plasma nitriding applied to a hot-work tool steel on the scratch-resistant properties of PACVD TiBN and TiCN coatings. Surf Coat Technol. 2006;201(6):2534-9. doi: 10.1016/j.surfcoat.2006.04.064.
9. Liao YS, Lin TC, Lai CY, Chen YL, Chang HH, Lin CP. Cutting performance of diamond-like carbon coated tips in ultrasonic osteotomy. J Dent Sci. 2014;9(1):63-8. doi: 10.1016/j.jds.2013.02.014.
10. Yule PL, Durham J, Wassell RW. Pain part 6: temporomandibular disorders. Dent Update. 2016;43(1):39-48. doi: 10.12968/denu.2016.43.1.39.
11. Kobayashi S, Ohgoe Y, Ozeki K, Sato K, Sumiya T, Hirakuri KK, et al. Diamond-like carbon coatings on orthodontic archwires. Diam Relat Mater. 2005;14(3-7):1094-7. doi: 10.1016/j.diamond.2004.11.036.
12. Klaic M, Staroveski T, Udiljak T, Catlak Z, Ehrenfreund T, editors. The Influence of Drill Sterilization and Drill Guide Modifications on the Quality of Bone Drilling Process. The 2018 IAENG International Conference on Engineering Physics; 2018.
13. Roghanizad N, Khalilak Z, Vatanpour M, Haghi S, Alizadeh P, Movassagh Z. The effect of autoclave sterilization on the fracture resistance of ProTaper rotary files. J Res Dent Maxillofac Sci. 2016;1(3):33-7. doi: 10.18869/acadpub.jrdms.1.3.33.
14. Qin F, Chou YK, Nolen D, Thompson RG. Coating thickness effects on diamond coated cutting tools. Surf Coat Technol.

2009;204(6-7):1056-60. doi: 10.1016/j.surfcoat.2009.06.011.
15. Gureckis KM, Burgess JO, Schwartz RS. Cutting effectiveness of diamond instruments subjected to cyclic sterilization methods. J Prosthet Dent. 1991;66(6):721-6. doi: 10.1016/0022-3913(91)90402-I.
16. Viana AC, Gonzalez BM, Buono VT, Bahia MG. Influence of sterilization on mechanical properties and fatigue resistance of nickel-titanium rotary endodontic instruments. Int Endod J. 2006;39(9):709-15. doi: 10.1111/j.1365-2591.2006.01138.x.
17. Fais LM, Pinelli LA, Adabo GL, Tavares da Silva RH, Marcelo CC, Guaglianoni DG. Influence of microwave sterilization on the cutting capacity of carbide burs. J Appl Oral Sci. 2009;17(6):584-9. doi: 10.1590/s1678-77572009000600009.
18. Dorner A, Schürer C, Reisel G, Irmer G, Seidel O, Müller E. Diamond-like carbon-coated Ti6Al4V: influence of the coating thickness on the structure and the abrasive wear resistance. Wear. 2001;249(5-6):489-97. doi: 10.1016/s0043-1648(01)00587-7.
19. Zettlemoyer TL, Goerig AC, Nagy WW, Grabow W. Effects of sterilization procedures on the cutting efficiency of stainless steel and carbon steel Gates Glidden drills. J Endod. 1989;15(11):522-5. doi: 10.1016/s0099-2399(89)80193-1.
20. Harano K, Satoh T, Sumiya H. Cutting performance of nano-polycrystalline diamond. Diam Relat Mater. 2012;24:78-82. doi: 10.1016/j.diamond.2011.11.005.
21. Bulem ÜK, Kececi AD, Guldas HE. Experimental evaluation of cyclic fatigue resistance of four different nickel-titanium instruments after immersion in sodium hypochlorite and/or sterilization. J Appl Oral Sci. 2013;21(6):505-10. doi: 10.1590/1679-775720130083.
22. Alexandrou G, Chrissafis K, Vasiliadis L, Pavlidou E, Polychroniadis EK. Effect of heat sterilization on surface characteristics and microstructure of Mani NRT rotary nickel-titanium instruments. Int Endod J. 2006;39(10):770-8. doi: 10.1111/j.1365-2591.2006.01147.x.