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The evaluation of wear of tungsten carbide dental bur

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Abstract
Due to its durability, tungsten carbide has long been used as a material to produce dental burs. WC–Co burs are designed for smooth, efficient cutting and extended life. Dental burs are available in different sizes and shapes, for example round burs, pear and cylinder-shaped, egg-shaped, as well as there are various tapered ones, which enable an individual selection of the drill for the right treatment. Carbides can be used for standard crowns and bridges, for extensive surgical procedures and they should minimize damage to the existing teeth. The design of WC–Co dental bur reduces a patient's discomfort because of the operating time and the fact that its liquidity is preserved. The head of the bur (the cutting edge) delivers optimum concentricity and strength. The shank is made from stainless steel allowing a bur to be autoclaved multiple times without the risk of corrosion. The main purpose of this study was to evaluate the wear of a tungsten carbide dental bur. The results of stereoscopy microscope and SEM/EDS analysis are presented.

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1. Introduction

Dental engineering is one of developing supply branches of medicine. The main task of this industry is a proper design and quality control of dental instruments. The quality of workmanship, safety of use for operators and patients, corrosion resistance are only a few features that should be taken into account when designing for example dental burs and drills (Klimecka-Tatar, 2014; Gwoździk et al., 2017; Ahmedet al., 2014).

The dental burs and drills are small dental tools that are generally used in the laboratory and dental practice. They are used for cutting hard tissues, for example bones or teeth. Conventional dental burs are made of stainless steel, diamond grit or particles, and tungsten carbide. Dental burs have different shapes and dimensions depending on their purpose. In addition, they must be adapted to a dental drill equipped with an air turbine. The construction of dental burs consists of three parts: shank, shaft and bur head (the cutting edge). The most common cause of dental burs damage are exploitation, sterilization and disinfection (Gwoździk et al., 2014, Sein et al., 2002).

Tungsten carbide is an extremely hard (three times harder than steel) and, at the same time, brittle material. The cemented WC–Co is a composite composed of ceramic–like tungsten carbide (WC) grains that are settled in cobalt (Co). This material has excellent mechanical and physical properties, hardness, good fracture toughness, high strength at elevated temperature, good thermal and electrical conductivity and good wear resistance. Tungsten carbide is widely used in many industries, e.g. components in mining industries, dental burs, surgical tools and punches used in pharmaceutical industry (Takahashi et al., 2017; Ahmed et al., 2004; Fayyaz, et al., 2014).

Most tungsten carbide dental burs contain an additional amount of cobalt. Depending on the WC grain size, which may be in the sub–micron (0.5–0.8 mm) to ultra–fine (0.2–0.5mm) range, 6–16 wt.% of cobalt (Co) is added as the binder. Very important parameters are the Co/WC ratio and the WC particle size on which depend the control of the bulk material properties. To obtain a material with a better shock resistance and impact strength, course grained WC with a higher wt.% of Co should be combined. However, as far as materials with harder and greater wear resistance are concerned, finer grained WC and lower wt.% of Co can be used (Ali et al., 2004; Zhang et al., 2014).

Tungsten carbide dental burs are accurate dental instruments with high cutting capacity and long service life. Taking into account their different shapes, special coatings and different blade configurations, a variety of dental treatments can be performed with them. WC–Co burs are used most commonly for crown preparation and crown cutting, preparation of fillings,

including removal of old fillings, root canal preparation and root smoothing, caries removal, contouring bone, removing impacted teeth and many other (Silva et al., 2016).

Tungsten carbide dental burs are much more expensive than their steel equivalents, but they compensate for this due to their increased working life. Carbide burs can maintain a sharp cutting edge and be used many times without becoming dull. WC–Co burs deteriorate prematurely if they are used in contact with enamel. They work best at high speed-with light pressure (Maass et al., 2008; Yin eta al., 2004).

2. Experimental

The investigation was made on commercial tungsten carbide dental bur. The working part (head) of the bur was made of tungsten carbide with an addition of cobalt. The shank of the bur was made of stainless steel. The dental bur had a long round end tapered shape and it was used in a dental surgery every day for three months.

The analysis of the surface after three months of use was performed by means of a stereo microscope Olympus SZ61 and a scanning microscope Jeol JSM–6610LV.

Additionally, the analysis of chemical composition of both the worn and the undamaged surface was carried out with a scanning microscope Jeol JSM–6610LV working with an Oxford EDS electron microprobe X–ray analyser.

3. Results and discussion

The macroscopic image of the surface of the tungsten carbide dental bur obtained from a stereo microscope Olympus SZ61 is presented in Figure 1. Figure 1b presents the working part of the long round end tapered shape bur, on which edge abrasion and crumbling away of surface were observed.

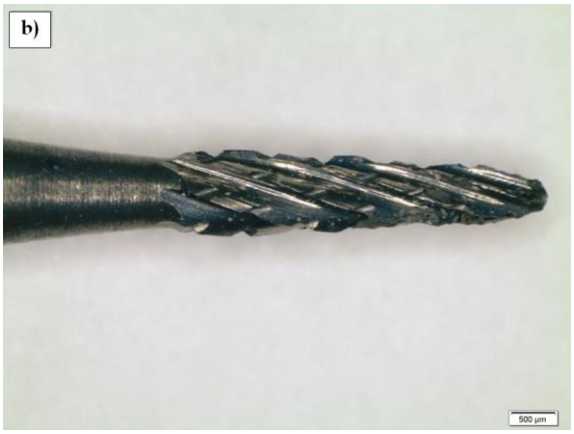

Fig. 1. Tungsten carbide dental bur after use: a) all shape, b) bur head (the cutting edge)

SEM analysis was carried out to observe the surface of the tungsten carbide dental bur by scanning with a microscope Jeol JSM–6610LV. After three months' use, traces of wear were observed on the tested bur. Figure 2 presents the surface of the wear on the head of the bur (the cutting edge). Figure 3 presents the surface of round end taper of the head of the bur.

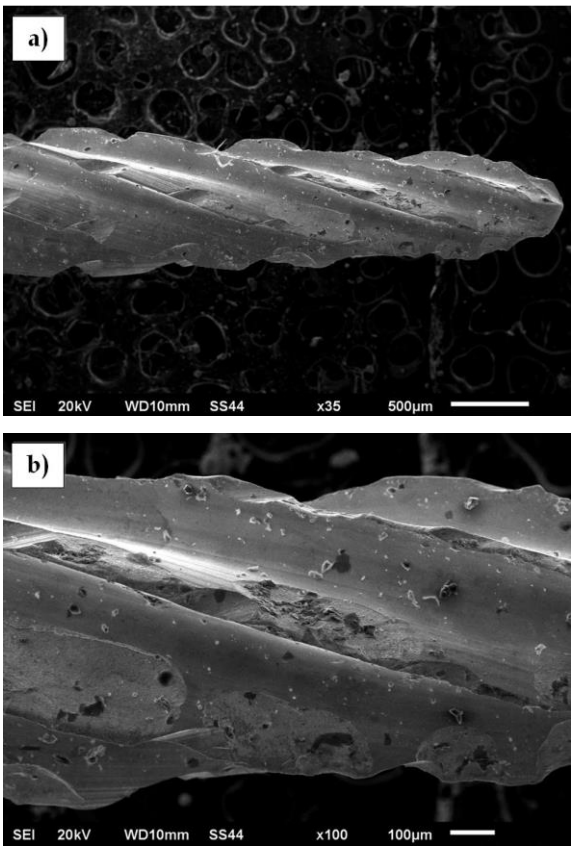

Fig 2. WC–Co dental bur after use: bur head (the cutting edge)

Tungsten carbide burs are designed to cut more effectively and reduce the risk of chipping or breakage. The working part of the long round end taper bur was degraded as a result of abrasion. Defects in the form of cracks, crumbling and microcraks were observed on the surface of the tungsten carbide bur.

Moreover, depositing of tooth enamel dust on the working part was also observed.

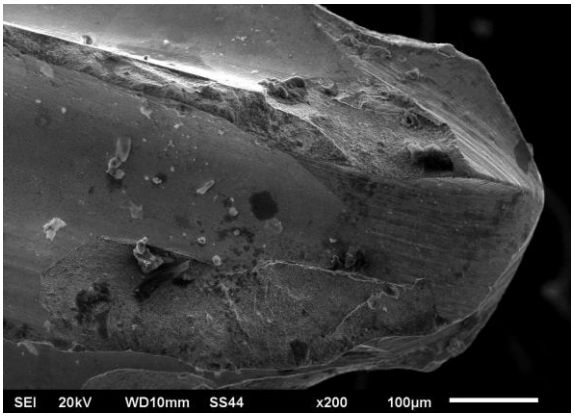

Fig 3. WC–Co dental bur after use: surface of round end taper of bur head

Figure 4 shows the losses of the surface of dental bur after three months' use.

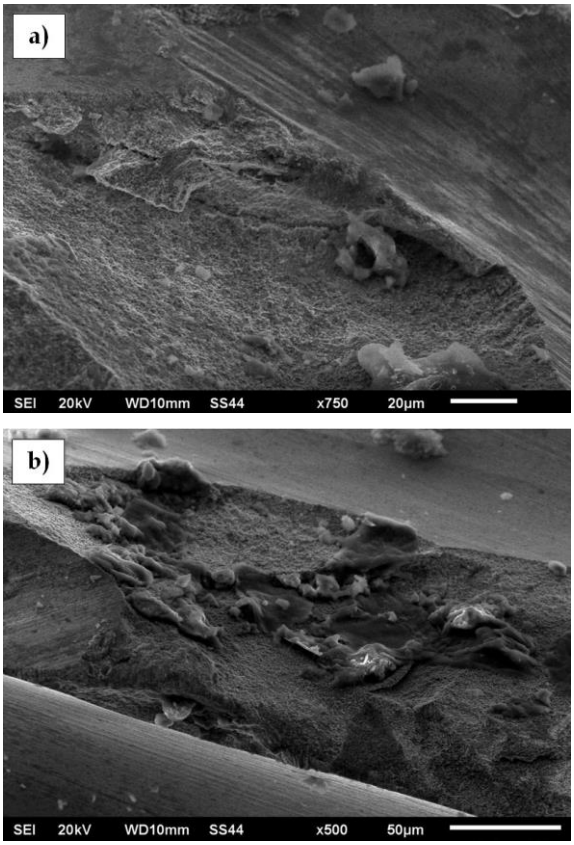

Fig 4. The losses of the surface of WC–Co dental bur

Figure 5 shows the analysis of chemical composition of the surface of WC–Co bur without damage. The results of EDX–analysis of chemical composition is presented in Table 1. The analysis of chemical composition of the surface WC–Co revealed the content of elements from which the working part of the bur was built.

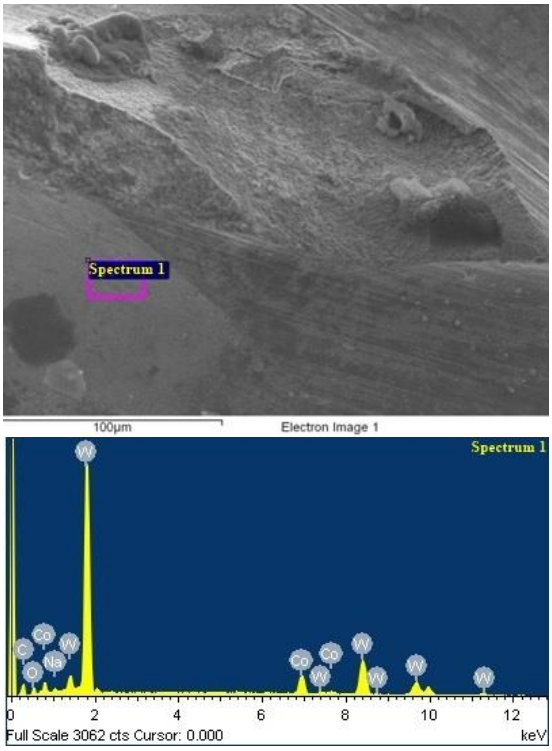

Fig 5. The analysis of chemical composition of surface of WC–Co bur (Spectrum 1) without damage

Table 1. EDX–analysis of chemical composition of surface of WC–Co bur without damage

	Weight [%]
Element	**Spectrum 1**
C	11.08
O	2.93
Na	0.33
Co	11.03
W	74.64

Figure 6 presents the analysis of chemical composition of the surface of WC–Co bur with damage. The results of EDX–analysis of chemical composition are presented in Table 2.

Table 2. EDX–analysis of chemical composition of surface of WC–Co bur with damage

	Weight [%]
Element	**Spectrum 1**
C	28.31
O	11.39
Na	1.73
Cl	0.19
Ca	0.23
Cr	0.40
Co	6.28
Zn	12.04
W	39.42

The analysis of chemical composition of the surface WC–Co revealed elements from damage caused by the use of the bur. The elements are from tooth tissues during use of burs and their sterilization.

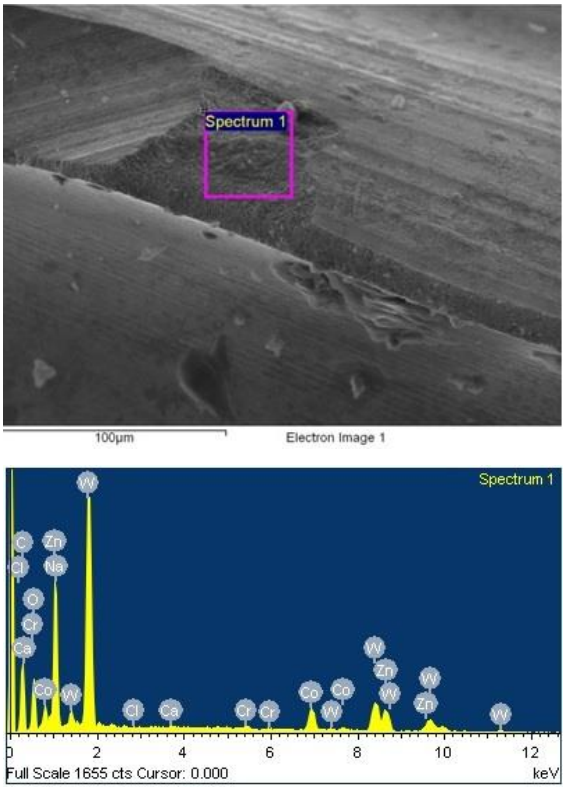

Fig 6. The analysis of chemical composition of surface of WC–Co bur (Spectrum 1) with damage

4. Summary and conclusion

Dental burs must be durable when working at very high speed. Tungsten carbide dental burs have this function and they are very often used in dental laboratories. The use of tungsten carbide results in peak performance and durability. Additionally, tungsten carbide dental bur can cut up to 2.5 time faster than others burs.

The assessment comprised burs used in special areas, such as orthodontics, implantology and crown and bridge technology. WC–Co burs are used for functional precision toothing, reducing or dental restorations. The study analyzed the wear of the tungsten carbide dental bur after three months of use.

The obtained results show that corrosion was nearly unnoticeable. It was observed that the surface of the working of the WC–Co dental bur part degraded. The degradation of the working part of WC–Co dental bur occurred in the form of abrasion round end taper of bur head, crumbling and surface delamination.

To reduce the wear of the WC–Co bur slightly, it should be used as intended. In addition, sterilization processes should be controlled, which also affects the damage in the bur.

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碳化钨牙钻的磨损评估

關鍵詞
碳化钨棒
的 WC-Co
牙科车针

摘要
由于其耐用性，长期以来，碳化钨一直被用作生产牙齿钻头的材料。 WC-Co 齿轮设计用于平稳，高效的切割和延长使用寿命。牙钻具有不同的尺寸和形状，例如圆形钻，梨形和圆柱形，蛋形以及各种锥形钻头，可单独选择钻头进行正确的处理。碳化物可用于标准牙冠和牙桥，广泛的外科手术，他们应该尽量减少对现有牙齿的损害。 WC-Co 牙科钻头的设计减少了患者的不适，因为其操作时间和流动性保持不变。刀头（刀刃）提供最佳的同心度和强度。该柄由不锈钢制成，可以多次高压灭菌，不会有腐蚀风险。本研究的主要目的是评估碳化钨牙钻的磨损。介绍了立体显微镜和 SEM / EDS 分析的结果。