EVALUATION OF THE DIFFERENTIATION OF STRUCTURAL AND PHYSICOCHEMICAL PROPERTIES OF ORTHODONTIC WIRES OF AISI 304 STAINLESS STEEL

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Introduction

Wires used for orthodontic arches play a very important role in the process of orthodontic treatment [1,2]. In combination with the lock attached to the tooth, they are to move and align the teeth along the set trajectories [3]. Wires of stainless steel, nitinol, beta-titanium and cobalt-chromium alloy are commonly used [4,5]. Each of the specified orthodontic wire types, due to its specific, desirable properties is used at different stages of orthodontic treatment. Wires of stainless steel are commonly used in orthodontics for several reasons: they are characterised with high resistance to corrosion, high strength and elasticity, formability and a possibility of obtaining defined properties through cold working and annealing during production process, as well as low cost of manufacturing [4,5].

Materials and Methods

Purpose of the research presented in the work is analysis of differentiation of the selected structural properties in the context of corrosion resistance of the orthodontic wires material. The object of the research were edge arches of the 0,016"x0,022" size made of the stainless steel type AISI 304, provided by two different producers. The research methodology involved analysis of chemical and phase composition of the tested alloy, microscopic tests with application of the light and electron microscopy methods, as well as electrochemical direct current measurements.

Results and Discussion

The chemical composition tests have shown that the orthodontic wires from various producers differ in contents of individual alloy elements, as well as they exceed the contents of permissible manganese and sulphur values allowed by the standard. However, it could be stated, that the information provided by the producers that the wires are made of stainless steel of the AISI 304 type are consistent with reality.

Evaluation of the metallurgical purity degree has shown considerable diversity in terms of deployment and appearance frequency of non-metallic inclusions in the orthodontic wires from different producers. The research has shown that presence of the non-metallic inclusions in the tested materials is equal to the standard No. 2, according to the ISO standard, which is unacceptable for materials applied in the living body.

Microstructure of the tested wires applied for orthodontic arches have shown appearance of strongly deformed structure of austenite (the fibrous texture along the drawing direction). Between strongly deformed grains of austenite the clear initial etchings around other microstructures have been observed. The XRD tests have shown occurrence of austenite in the microstructure of martensite induced by α' draft, as well as chromium carbide of the M23C6 type. The three-phase structure is particularly unfavourable due to the corrosion resistance, as presence of the M23C6 carbide in the tested material will favour the intercrystalline corrosion. Instead, presence of martensite, the ferromagnetic phase will adversely affect the body the orthodontic wires will be in, possibly causing magnetotropism of blood components and additionally be a source of corrosion.

The corrosion of orthodontic wires is closely related to the acidic environment of the mouth and the presence of fluoride ions, prophylactic agents and mouthwash solutions. Due to the thermic, microbiological and enzymatic properties aspects, the mouth environment is favourable in terms of biodegradation of metal and their alloys aspect, resulting in releasing metallic ions in the mouth. Along with the release of ions from metals or alloys the corrosion of orthodontic wires may lead to increase in surface roughness and their weakening, which can seriously impact the material strength, leading to mechanical damage or even fracture of the orthodontic materials. Based at the obtained test results of the orthodontic wires of the same geometry coming from two different producers it has been observed that in the environment of the Ringer solution they do not show the ability to passivate. At the polarization curves in the anodic area only the clear dissolution area is noticeable. At the surface of the orthodontic wires also the phenomena of pitting corrosion take place, which is confirmed by the course the anodic curves. Moreover, it has been found that content of non-metallic inclusions and carbides occurring in the material microstructure definitely lowers corrosion resistance of the material.

Conclusions

The research presented in the work have shown significant differentiation of structural and physical-chemical properties of the orthodontic wires of the AISI 304 type stainless steel. Despite the fact, that the tested arches were manufactured of the theoretically the same materials, but by different producers, they significantly differ with chemical composition, metallurgical purity, phase build and corrosion resistance. In addition, it is worth noticing that the tested materials, in terms of structure, do not meet the normative requirements obligatory for biomaterials.

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