

SPECTROGRAPHIC ANALYSIS OF TITANIUM ALLOYS IN PROSTHETIC DENTISTRY

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Abstract: This paper considers changes in the chemical composition of titanium alloys according to the method of their treatment. It investigates the chemical composition of three original samples of titanium alloys, three samples after their casting and three samples after their milling. It is revealed that different methods of alloy handling lead to dissimilar changes in its chemical composition.

Keywords: *Spectrographic analysis, Titanium, Casting, Milling, Billet.*

For fabricating dental prostheses, dentistry uses a great variety of different metal alloys. Available studies of interacting metal implants with a human body indicate that metal ions released into the oral fluid are absorbed by it due to a significant permeability of the oral mucosa [1]. Besides, in the mouth cavity, metal alloys are exposed to electrochemical corrosion and cause diseases such as galvanosis, lichen planus, candidiasis and others [2]. People with oral metal devices have significant changes in the trace substances' composition of hard dental tissues including changes in the teeth located on the opposite side. There are also changes in the qualitative and quantitative composition of trace elements in the lower jawbone of persons using metal dental prostheses [3].

Modern prosthodontics applies titanium-based alloys both in fixed and removable dentures. Titanium alloy prostheses can be fabricated by a casting machine and a milling machine; factory-prepared workpieces can also be used.

However, it should be noted that the majority of works dedicated to the effect of metal prosthetic devices on oral health evaluated the properties of stainless steel, cobalt-chromium and nickel-chromium alloys, etc. Titanium alloys' properties are

still insufficiently studied because titanium casting and milling require special equipment. Therefore, despite the superior biocompatibility properties of titanium, the lightness and strength of titanium structures, changes in the properties of titanium alloys depending on the conditions of their production remain virtually unexplored. Meanwhile, the results of such investigations can become a basis for choosing an optimal method for the treatment of alloys and, subsequently, for fabricating biocompatible orthopedic devices. This idea determined the relevance of the current study.

The aim of this research is studying changes in the chemical composition of the titanium alloy used in prosthetic dentistry depending on the method of its treatment.

In total, there were nine samples in the study. First, the authors identified the chemical composition of three alloys (three billets) made by different producers - Morita (Japan), Zirconszahn (Italy) and MIS (Israel). Then, each sample out of the three alloys was subjected to casting; the changes in the chemical compositions of the alloys were examined. Next, each sample out of the three alloys was subjected to milling and the changes in the chemical compositions of the alloys were examined again. The chemical

compositions of the samples were studied using the methods of scanning electron microscopy and energy dispersive spectrometry. The measurements were done by means of a scanning electron microscope JSM-6480LV (JEOL, Japan) equipped with an energy dispersive spectrometer INCAENERGY Dry Cool (OXFORDINSTRUMENTS, Great Britain). The detection limit of the energy dispersive spectrometry method was 0.2 weight percent. Relative measurement error for main elements was equal to 10%.

The data obtained during the study were processed by the methods of variation statistics. The reliability of the revealed

differences in the studied parameters was evaluated by the Mann-Whitney test for independent samples. The critical significance level (p) of the null statistic hypothesis (absence of significant differences) was taken to be equal to 0.05. The calculation was done in Microsoft Office Excel 2013.

The chemical composition analysis of the first original titanium alloy sample after milling showed that in its structure, titanium compounds statistically prevailed while the proportions of aluminum and vanadium compounds were comparable. (Table1).

Table 1: The chemical composition of the first original sample after milling

Element	Weight %	Atomic %
Al K	5.98	10.17
Ti K	90.62*	86.77*
V K	3.40	3.06
Total	100.00	100.00

Note: *Significant differences with the share of other compounds ($p < 0.01$).

After casting, its chemical composition considerably changed (Table 2).

Table 2: The chemical composition of the first original sample after casting

Element	Weight %	Atomic %
Na K	1.53	3.03
Al K	4.51	7.60
Cl K	0.85**	1.09*
K K	0.38**	0.44**
Ti K	89.22*	84.70*
V K	3.52	3.14
Total	100.00	100.00

Note: *Significant differences with the share of other compounds ($p < 0.01$); ** - Significant differences with the share of aluminum and vanadium compounds ($p < 0.05$).

The data in Table 2 illustrate the changes in the alloy composition after casting. Thus, despite the fact that the alloy retained high proportion of titanium, its composition included compounds of sodium, chlorine and potassium. We can assume that these

chemical elements appeared because of the alloy preparation for casting in the packing material.

Table 3 shows the chemical composition of the original sample.

Table 3: The chemical composition of the first original sample

Element	Weight %	Atomic %
Al K	3.08	5.35
Ti K	93.43*	91.43*
V K	3.50	3.22
Total	100.00	100.00

Note: * - Significant differences with the share of other compounds ($p < 0.01$)

It is clear that in the alloy original composition, titanium compound statistically prevailed and aluminum and vanadium compounds were present in almost equal

proportions. The comparison of the titanium alloy compositions according to the method of its treatment is given in Figure 1.

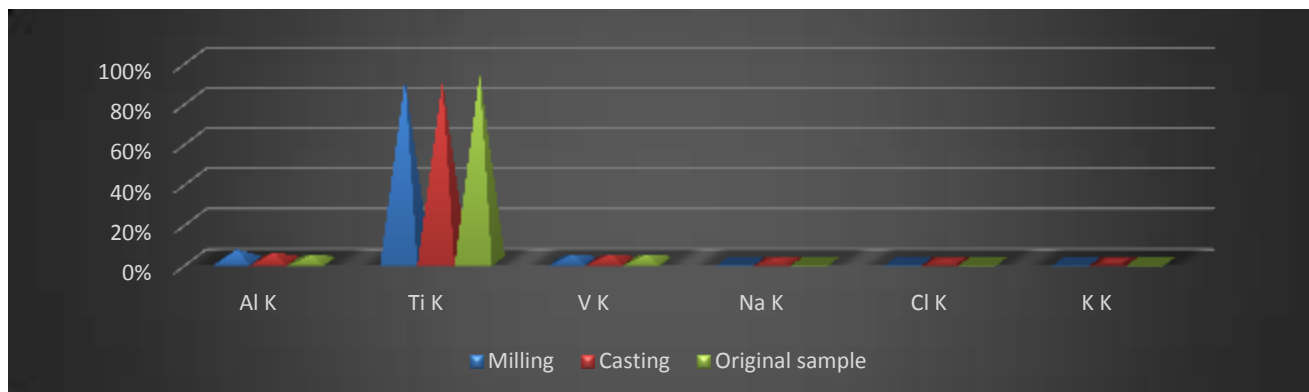


Figure 1: The first titanium alloy sample – the comparison of its chemical composition after different methods of treatment.

The diagram clearly shows that the chemical composition of the titanium alloy after milling and the original billet composition were very similar - there were no significant differences. At the same time, alloy treatment by casting substantially modified the alloy chemical composition – it introduced new elements and the proportion

of titanium compounds were lower, although the differences with milling and original sample did not reach the statistically significant level ($p > 0.05$).

The changes in the surface texture of the first alloy sample according to the method of treatment are presented in Figure 2.

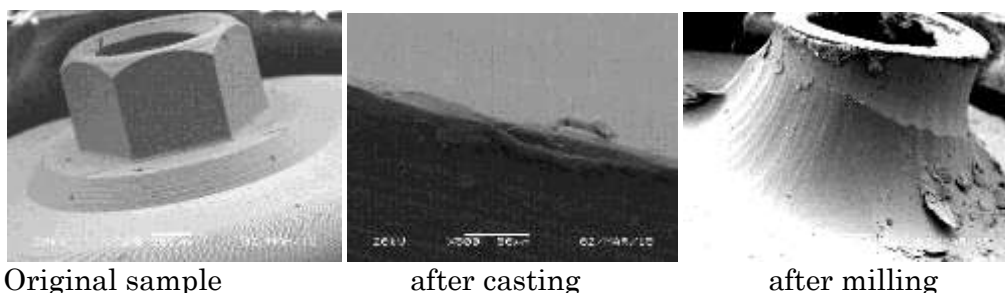


Figure 2: The first titanium alloy sample – the images of its surface after different methods of treatment.

The comparative analysis of the second titanium alloy sample did not reveal any significant changes in its chemical

composition after all the methods of treatment (Figure 3, Table 4).

Table 4

Element	ALK	TIK	VK
Milling	5.21%	90.79%	4.00%
Casting	7.02%	89.27%	3.70%
Original billet	6.65%	90.16%	3.18%

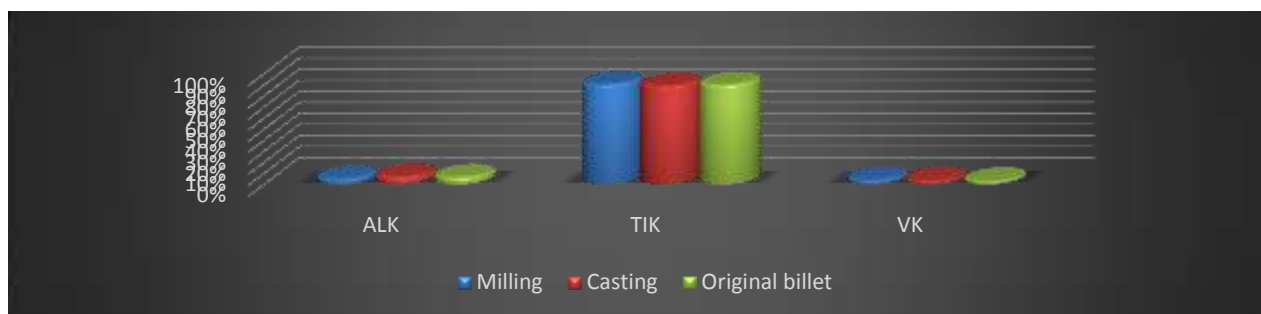


Figure 3: The second titanium alloy sample – the comparison of its chemical composition after different methods of treatment

Note: *Significant differences with the share of other compounds in the same method of treatment ($p < 0.01$)

After the analysis of the data presented at the diagram, it was found out that the alloy compositions for all the studied treatment methods was almost identical – the share of titanium was statistically predominant and the proportions of aluminum and vanadium compounds were comparable. Significant differences in the alloy chemical composition according to the method of treatment were absent.

However, the alloy composition after milling was most similar to the original sample composition.

The changes in the surface texture of the second alloy sample according to the method of treatment are presented in Figure 4.

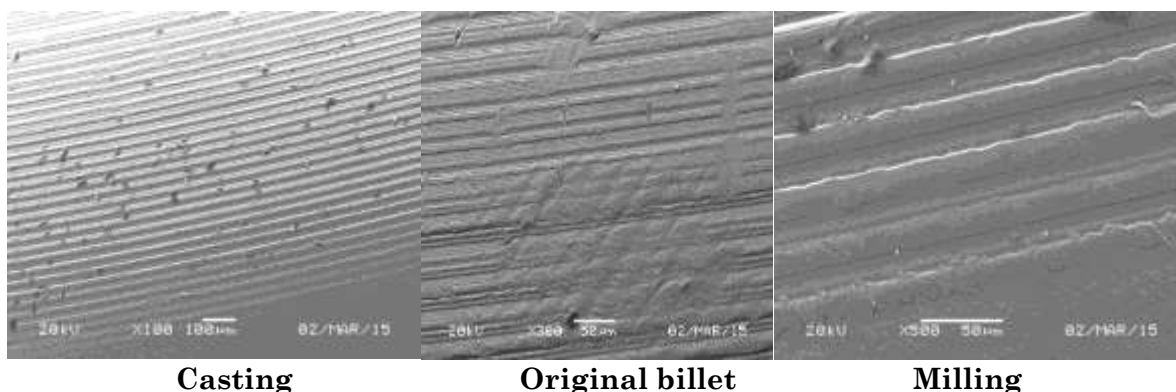


Figure 4: The second titanium alloy sample – the images of its surface after different methods of treatment

It is well seen in the microphotographs that the alloy surface texture of the original billet was, in general, very similar to the texture after milling and, although it had a finer striation after milling. At the same time, the surface texture after casting looked reticulated.

In studying the changes in the chemical composition of the third titanium alloy sample, it was found that the original sample and the sample after milling were most similar in composition (Table 5).

Table 5: The third titanium alloy sample- the comparison of its chemical composition after different methods of treatment (weight %)

Element	Casting	Milling	Original sample
Na K	0.54%	0.00%	0.00%
Al K	1.83%	1.13%	1.96%
Si K	1.13%	0.95%	1.60%
P K	0.82%	0.57%**	1.15%
Cl K	0.35%	0.00%	0.00%
Ti K	95.34%*	97.35%*	94.61%*
SK	0.00%	0.00%	0.37%
CaK	0.00%	0.00%	0.30%

Note: *Significant differences with the share of other compounds in the same method of treatment ($p < 0.01$); significant differences with P K share in factory treatment ($p < 0.05$).

The data in the table show that after each considered method of treatment, titanium compounds statistically prevailed. However, the alloy composition differed greatly after all methods. Thus, there were no sulfur and calcium compounds in the alloy composition after casting and there were no sodium and chlorine compounds after milling (please,

note - the study did not reveal any sodium and chlorine compounds in the initial

sample's composition). Moreover, there were significant differences in the ratio of the alloy compounds. For instance, the original alloy had a statistically bigger share of phosphorus than the one after milling.

The images below allow comparing the third sample's alloy texture depending on the method of treatment (Figure 5).

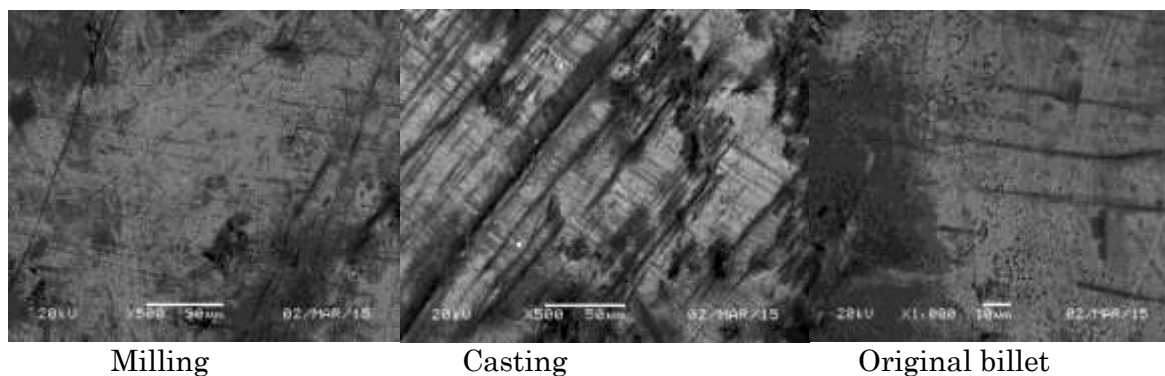


Figure 5: The third titanium alloy sample – the images of its surface after different methods of treatment.

The micro images demonstrate substantial variations in the third sample's titanium alloy surface texture after different methods of treatment. The surface was quite similar in the cases of milling and original billet but different in the case of casting.

The results of the study suggest that the method of titanium alloy treatment substantially affects its chemical composition – there are changes in the ratio of compounds' shares, new compounds appear as well. The pattern of changes is largely determined by the original alloy composition. Thus, in the first sample, the most significant changes in the alloy chemical composition occurred during casting; in the second sample, treatment methods had no noteworthy effects on the alloy chemical composition, while in the third sample, small changes were visible in

the factory treatment. In addition, the method of alloy treatment had a significant impact on the alloy surface texture – it was very similar in the cases of milling and original sample and quite different after casting. The obtained findings allow making a conclusion that the changes in the chemical composition and the surface of titanium alloys after a certain treatment method should be taken into consideration if such alloys are used in fabricating dental prosthetic devices. We can also conclude that titanium alloys after milling do not differ greatly from their original billets. Consequently, it is possible to give recommendations that titanium is better to be milled rather than casted because casting changes its chemical composition, which subsequently may have different effects in the mouths of patients with prosthetic devices [4-10].

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