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Comparative Analysis of Surface and Chemical Composition of Various Dental Implant Systems and Their Influence on Degree of Sensitization in Humans

Nowadays dental implantology is the leading method for restoration of the masticatory efficiency in patients with secondary partial edentia. Dental implants are often made from corrosion-proof bioinert materials (titanium, zirconium, corundum ceramics), which promote proper osseointegration (adhesion of the dental implant surface with bone tissue), do not cause allergy and are well compatible with materials, from which the implant suprastructures are made. Critical factors enhancing osseointegration are biological compatibility of the implant; form and quality of the implant surface. Surface of used implants shall be of the highest purity and sufficient roughness to ensure proper osseointegration due to the improved bone-implant contact achieved through the improved topography of its surface [1, 3, 7, 12, 13, 18].

Effectiveness of the reparative regeneration process is essential for securing of the mechanical integrity of bone-implant contact. It was demonstrated that rough implant surfaces with different topography have better bone contact. Buser et al. have discovered direct relationship between the roughness level of the implant surface and the increased surface of the bone-implant contact. It was assumed that rough implant surface is one of the key factors of successful implantation. However, structure of the implant surface is not the only criteria of optimal osseointegration. Implant surface pattern, which characterizes its topography, in combination with the chemical purity level of the surface ensures optimal response reaction of the implantation bone bed [3, 4, 14, 15].

Nevertheless, upon use of modern implant systems, both national and foreign, various complications in the post-implantation period, which do not relate to performance pathology of patients, breach of drilling protocol or complications at the orthopedic treatment stage, occur in 3-7% of cases [3, 5, 10, 17]. Accordingly, revealed complications may be directly related to quality of substructure surface of different implant systems.

Purpose of present study is investigation of topography and chemical composition of the substructure of implant systems of various producers.

MATERIALS AND METHODS

Present study involves comparative analysis of the surface quality of 5 different dental implant systems: Alpha Dent, Alpha-Bio and NOVA (Israel), Densply (Ankylos, Germany) and NDI (De Luxe, Germany). Substructure quality in all the above-listed implant systems and spectrum of its chemical composition were examined with the use of scanning-electron microscope JSM-6490LV (JEOL, Japan) by nitrogen-free energy-dispersive spectrometer INCA Energy 450XT prior to injection thereof to the implantation area. Alpha Dent and NOVA implants have been examined following their rejection from the bone tissue.

Level of microbal sensitization of staphylococcus was determined by testing of the neutrophil damage index (NDI) in human blood according to Fradkin, V.A. [9]. Obtained indicators were processed by variation statistics method with calculation of the Student criteria. Indicators were deemed to be valid at $p<0.05$.

RESULTS AND DISCUSSION

Performed studies allowed characterization of the chemical composition and structure of used implants.

It is well known, that metals used for medical purposes are divided into 3 main groups:

1. **Toxic metals (vanadium, nickel, chromium, cobalt)**
2. **Interim metals (ferrum, gold, aluminum)**
3. **Inert metals (titanium, zirconium)**

Nowadays, dental implants are made from titanium and its alloys as it is biologically compatible and corrosion-proof material. Thus, substructure surface shall be free from any foreign matters or shall involve minimum quantity of contaminants[1], which may be present due to physical and/or chemical treatment of surfaces to increase roughness level of the implant surface [1, 6, 8, 11, 20].

Alpha Dent

During examination of Alpha Dent implants (Fig. 1), it was noted that their substructure contains significant quantity of contaminants (Exh. 1).

In furtherance, attention was drawn to the analysis of titanium (Ti) being the material from which the implant is made, as well as to the analysis of aluminum (Al) and ferrum (Fe) falling in the category of interim metals, and the analysis of vanadium (V) included in the category of toxic metals.

Concentration of metals significantly varied depending on the examined surface area: Ti -2.00 – 94.40% (mass); Al-1.55-49.58% (mass); Fe -0.44 – 1.80% (mass) and V – 1.00 – 5.13% (mass).

EXHIBIT 1. EXAMPLE OF THE CHEMICAL COMPOSITION OF ALPHA DENT IMPLANT SURFACE

[1] Contaminant is an impurity, contaminating substance

Item	Mass content, %	Atomic content, %
O	50.47	69.96
Na	0.67	0.65
Mg	4.66	4.25
Al	6.48	5.33
Si	6.98	5.51
K	1.88	1.07
Ca	0.37	0.20
Ti	25.26	11.69
V	1.43	0.62
Fe	1.80	0.71
Total	100.00	99.99

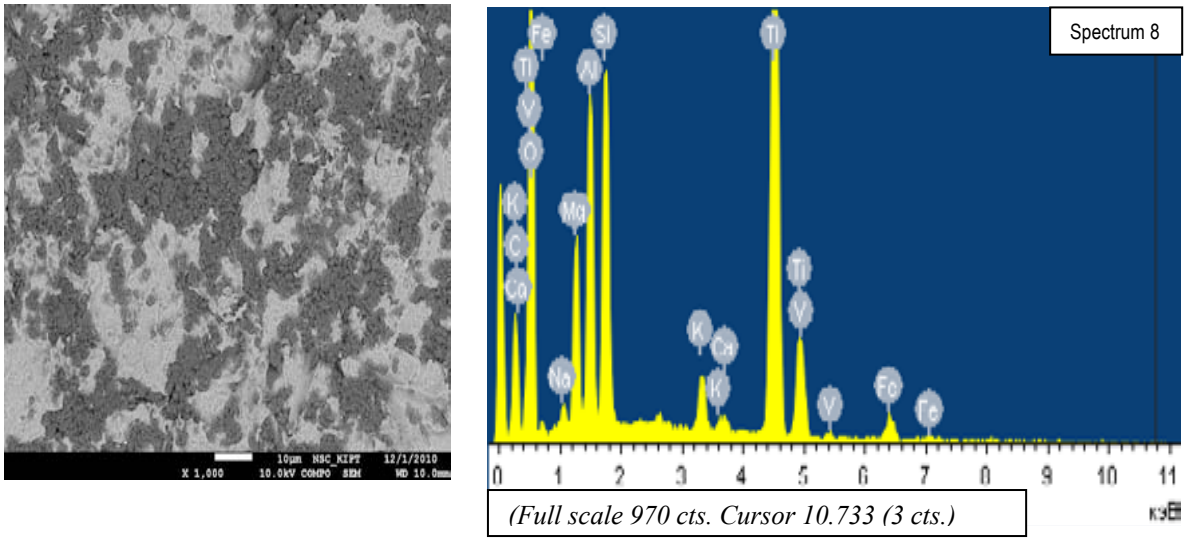


Figure 1. Structure and Chemical Composition of Alpha Dent Implants

As Fig. 1 demonstrates, surface of implant substructure has non-homogenous topography that may obstruct even absorption of protein, optimal implantation of fibrin fiber, collagen, and adhesion of osteogenic cells (fibre and osteoblasts), and may result in express mosaic synthesis of specific proteins, including growth factors, that decreases osseointegration area.

Presence of significant quantity of aluminum on surface of the examined implants was due to improper air-abrasive treatment of the substructure by alumina-ceramic powder without further effective decontamination by way of chemical etching. Presence of Al on the implant surface in concentrations exceeding 0.1% has toxic effect on metabolism, of which mineral metabolism, by competing with calcium and magnesium ions. It directly impacts growth and reproduction of cells causing negative effect on the cell membrane, i.e. prevents effective process of reparative regeneration in the implantation area [6, 8]. Presence of ferrum, admixture of which is disallowed on the implant surface, is an additional reason for disruption of the osseointegration process.

Specific attention shall be drawn to vanadium contaminants revealed during study, which have toxic effect on the human body. Although physiological role of vanadium is poorly studied, it is assumed that

vanadium participates in regulation of the metabolism, including metabolism of bone and teeth tissues. However, in case of excessive intake by a human being, it may hamper phosphorylation and synthesis of ATP (Adenosine-triphosphate) affecting activity of monoamine oxidase, thus, being a hemorrhagic-endotheliotoxic poison. Such specific effects of vanadium result in disruption of trophic processes in body tissues, in particular, including paradentium tissues, and, thus, disrupt reparative regeneration processes in the implantation area [2, 11, 16].

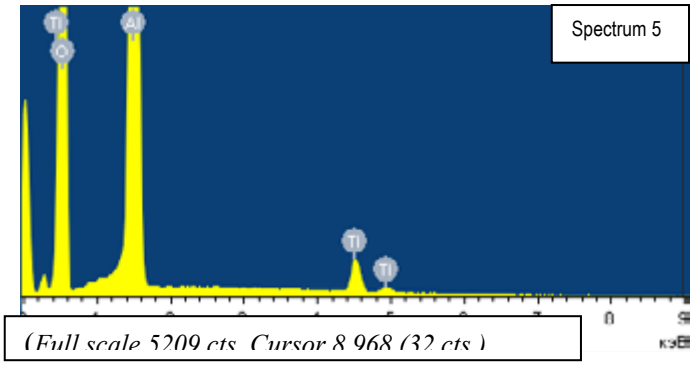
NOVA

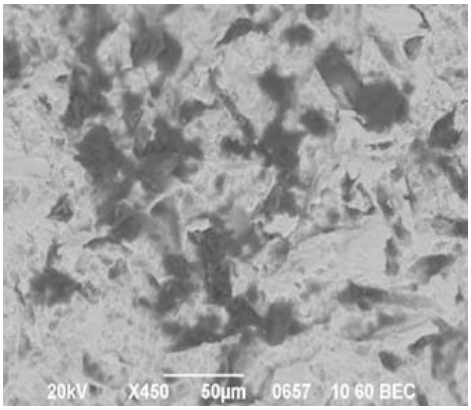
Upon examination of NOVA implants (Fig.2), as in the previous case it was noted that its substructure contains significant quantity of contaminants (Exh.2). Content of the above contaminants revealed in the substructure of the examined implants was as follows: Ti – 1.70 – 82.75% (mass); Al – 0.80 – 62.82% (mass); Fe – 0.14 – 0.20% (mass) and V – 0.31 – 1.05% (mass). Aluminum contaminants had mosaic pattern on the implant surface, ferrum was present only in traces, and quantity of vanadium on the implant surfaces in average was 4.5 times less that it was during examination of Alpha Dent implants.

EXHIBIT 2. EXAMPLE OF THE CHEMICAL COMPOSITION OF NOVA IMPLANT SURFACE

Item	Mass content, %	Atomic content, %
O	11.99	19.45
Na	1.27	1.43
Al	2.18	2.09
Si	0.32	0.30
S	0.26	0.21
Cl	1.25	0.91
K	0.36	0.24
Ca	1.44	0.93
Ti	59.26	32.11
V	2.74	1.40
Total	81.07	59.07

As Fig. 2 shows, NOVA implant substructure surface has more homogenous topography as compared to implants of previously discussed system; however its surface is undeveloped for the effective osseointegration. Although quantity of Fe and V in the substructure of NOVA implants was significantly lower, thus, favorably distinguishing it from Alpha Dent implants, aluminum contaminants in certain areas of study occupied major specific area of the surface, which, in furtherance, prevents achievement of the optimal osseointegration area (see Fig.2).





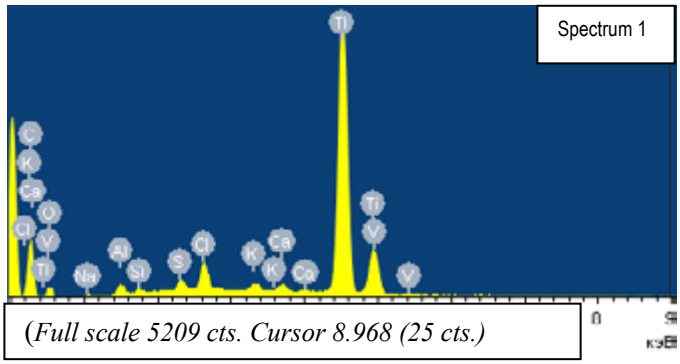


Figure 2. Structure and Chemical Composition of NOVA Implants

Alpha-Bio

Upon examination of Alpha-Bio implants (Fig.3), it was noted that their substructure contains insignificant quantity of alloy elements (Exhibit 3). The substructure has revealed: Ti – 36.10 – 88.51% (mass); Al – 0.80 – 5.40% (mass) and V – 0.10 -0.51% (mass).

As it is shown, implant surface has sufficiently homogenous and rough topography of substructure, which in complex with insignificant quantity of contaminants on its surface may secure quite effective osseointegration process in the implantation area.

EXHIBIT 3. EXAMPLE OF THE CHEMICAL COMPOSITION OF ALPHA-BIO IMPLANT SURFACE

Item	Mass content, %	Atomic content, %
Al	5.40	9.23
Ti	94.10	90.63
V	0.50	0.45
Total	100.00	100.31

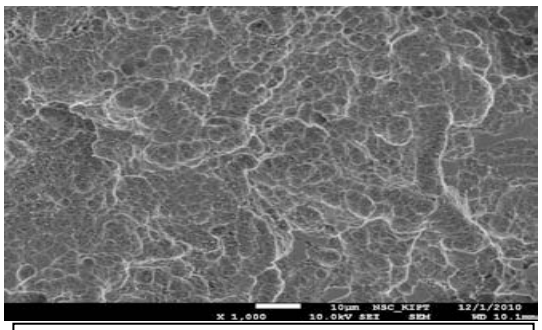
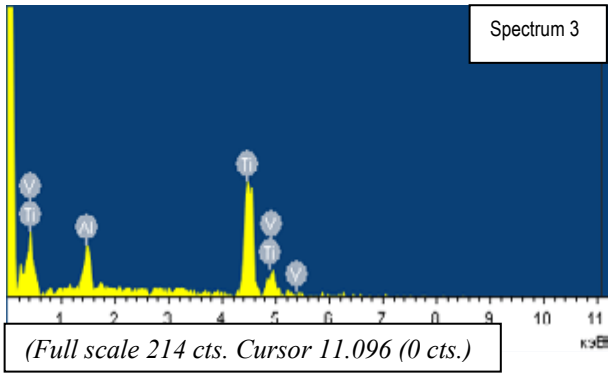


Figure 3. Structure and Chemical Composition of Alpha-Bio Implants



While, during the technologic formation of the surface, Alpha-Bio implants are treated by acid-based etching aimed at removal of foreign matters from its titanium substructure, certain quantity of aluminum contaminants was revealed on the surface. As aluminum and its alloys have polytrophic effect on human body, degree of which is not in direct relationship to its concentration, during implantation process main attention shall be drawn to possibility of complications in post-implantation period for sensitization reasons [6, 8].

Densply

During examination of Densply (Ankylos) implants, it was noted that their substructure is free from any contaminants and consists from titanium only. Besides, it shall be noted that due to chemical etching implant surface has high-structure topography, which significantly increases specific area of surface contacting with the bone, and thus, results in the effective osseointegration (Fig.4).

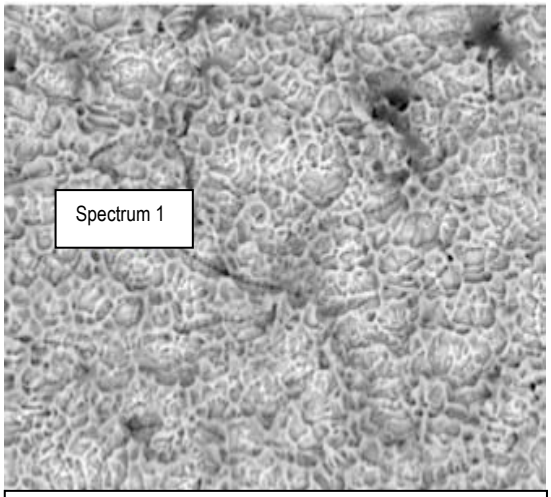


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Figure 4. Structure and Chemical Composition of Densply (Ankylos) Implants

NDI De Luxe

During examination of NDI implants, it was noted that their substructure is 100% titanium. Implants of given system are an example of the positive effect of acid-based etching of the surface free from any contaminants (Fig.5). Such treatment results in increase of microdepression depth of the implant surface, formation of even microgeometric surface topography that significantly increases specific implant-bone contact area, along with optimization of the osseointegration process in the implantation area and decrease of the mechanical pressure in bone surrounding the implant.

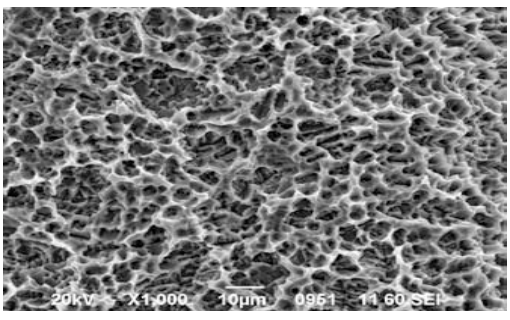

Figure 5. Structure and Chemical Composition of NDI (De Luxe) Implants

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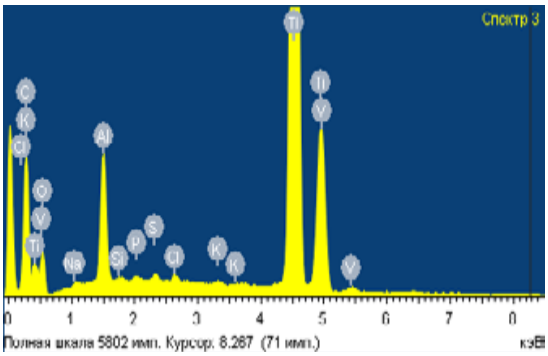
As it is known, osseointegration is not an insulated process and to the large extent depends on the property of materials from which an implant is made. Herewith, fibrotic or cartilaginous tissues are not formed in the space between the implant surface and bone tissue [19]. Upon performance of the microscopic analysis, osseointegrated implants are classified as a substance being in direct contact with the bone tissue without any signs of connective tissue between the bone and an implant [7, 14].



Spectrum 3

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Figure 6. Structure and Chemical Composition of rejected implant

EXHIBIT 4. EXAMPLE OF THE CHEMICAL COMPOSITION OF THE REJECTED IMPLANT SURFACE

Item	Mass content, %	Atomic content, %
O	19.74	41.23
Na	0.31	0.45
Al	4.51	5.59
Si	0.07	0.08
P	0.15	0.16
S	0.24	0.25
Cl	0.21	0.19
K	0.20	0.17
Ti	70.91	49.47
V	3.66	2.40
Total	100.00	99.99

Upon examination of the rejected Alpha Dent and NOVA implants, it was noted that their substructure was covered by organic residues (Fig.6) consisting of such elements as phosphorus and sulfur, free from calcium (Exh.4), that is peculiar to fibrotic and cartilaginous tissues, but not for the mineralized bone. Such tissue may be formed as a result of any contaminants on the implant surface containing toxic metals.

Consideration of clinical-based implantation issues (selection of the surgical indications, selection of implant and orthopedic structure) prevails over settlement of issues related to the biological compatibility as fundamental prerequisites to successful outcome of the treatment in general [15]. Certain share of unsuccessful outcomes may be observed due to the underestimation of such intricately controlled factors as reaction to material, sensitization of patient [5, 11, 20]. Present conclusion was validated during the study. It was revealed that during use of Alpha Dent and NOVA dental implants containing significant

quantity of aluminum, ferrum, and vanadium contaminants, nearly 5% of the installed implants were rejected during the first 3 months. One of the reasons for rejection could be sensitization of the patient due to intake of toxic and interim metals.

It was noted that during osseointegration (3 months following implantation), neutrophil damage indexes for all patients of study, to whom Alpha-Bio, Densply (Ankylos) and NDI (De Luxe) implants have been installed, did not definitely differ from the indexes typical for healthy persons (Fig.7).

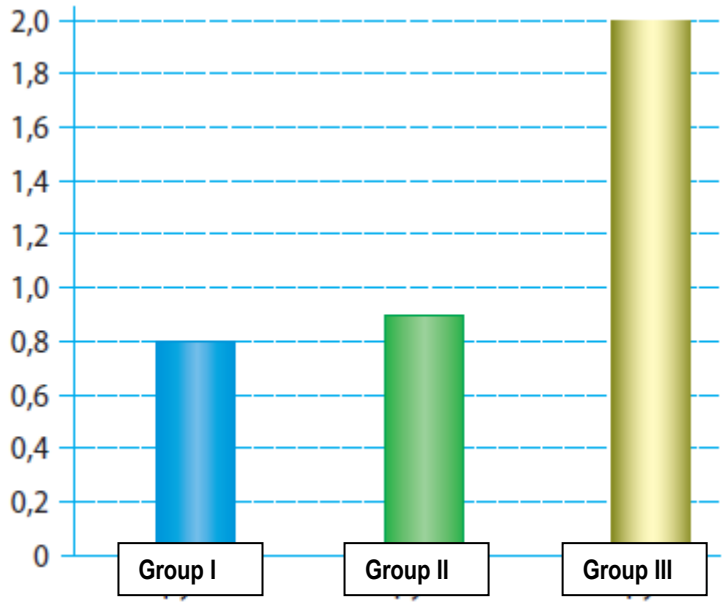

Fig. 7. Level of microbial sensitization to staphylococcus. Group I – control, Group II – first 3 months after implantation, Group III - first 3 months after implantation with rejection of implants ($p<0.05$ in relation to control group)

For 5.2% of patients with partial defects of the dental arch, to whom Alpha Dent and NOVA implants were installed, such indexes were significantly increased by 2.5 times. Such category of patients had periimplant pathology due to which implants were rejected.

CONCLUSIONS

Based on the performed studies, substructure of Alpha Dent and NOVA implants contains significant quantity of contaminants with toxic and interim metals (aluminum, ferrum) without any bioinert properties.

Presence of the significant quantity of contaminants in substructure of Alpha Dent and NOVA implants is one of the reasons of periimplant pathology in patients due to the sensitization resulting in rejection of implants in 5.2% of cases, and, thus, requires determination of the degree of patient sensitization during the pre-implantation period.

As it is shown, substructure of the implant surface has quite homogenous and rough topography, which jointly with insignificant quantity of contaminants on its surface may secure quite effective osseointegration process in the implantation area.

Regardless of the fact that Alpha-Bio implants contain insignificant quantity of the alloyed aluminum and vanadium metals having polytrophic effect in humans, possibility of the occurrence of complications in post-implantation period shall be taken into account.

Substructures of Densply (Ankylos) and NDI (De Luxe) implants consist solely from titanium.

Besides, surface of NDI (De Luxe) implants is characterized by even developed microgeometrical pattern that significantly increases specific area contacting with the bone and promotes optimization of the osseointegration processes.

Based on present study results, no rejection was observed during the use of Densply (Ankylos) and NDI (De Luxe) implants, thus evidencing proper osseointegration process in the implantation area and no signs of sensitization.

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