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PECULIARITIES OF TITANIUM IMPLANTS IN PATIENTS WITH LONG-TERM ABSENCE OF TEETH AND SIGNIFICANT ATROPHY OF HARD AND SOFT TISSUES OF THE JAWS

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SPECIFIČNOSTI TITANIJUMSKIH IMPLANTATA KOD PACIJENATA S DUGOROČNIM NEDOSTATKOM ZUBA I ZNAČAJNOM ATROFIJOM TVRDIH I MEKIH TKIVA VILICA

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ABSTRACT

Objective. The placement of artificial teeth in case of significant atrophy of hard and soft tissues of the jaws remains one of the most difficult problems in dentistry. The task was set to eliminate the unsolved problems by modernizing the existing methods of transplantation and implantation and analyzing the results of their application in clinical conditions.

Methods. In the period from 2002 to 2022, standard surgical dentistry operations of transplantation and implantation were performed in several dental clinics in Russia for 5,280 men and women aged 22 to 85 years. Of these, autogenic bone materials were used in 788 patients, and surgical operations were performed with transplantation of xenogenic OsteoBiol biomaterials in 4492 patients. All patients were implanted with titanium implants Replace Select (Nobel Biocare, Switzerland).

Results. It was shown that transplantation of autogenous bone and xenogenic biomaterials lasted on average about 2.5 and 1.5 hours and resulted in successful engraftment in 83% and 94% of cases (respectively). To exclude accidental perforation of Schneider's membrane during biomaterial transplantation in conditions of significant maxillary crest atrophy, a method of elevating the floor of the maxillary sinus under illumination with blue light from the nasal cavity was proposed. To improve the aesthetic result when placing the crown on the implant in the conditions of soft tissue deficiency around it the method of transplantation of autogenous material in the form of a round disk with a hole in the center for "dressing" on the implant is proposed.

Conclusion. Modern dental technology makes it possible to restore significant defects of soft and bone tissues of the jaws and replace teeth in patients of all age groups.

Key words: *transplantation; biocompatible materials; dental ımplants.*

SAŽETAK

Cilj. Postavljanje veštačkih zuba u slučaju značajne atrofije tvrdih i mekih tkiva vilica ostaje jedan od najtežih problema u stomatologiji. Cilj je bio eliminisati nerešene probleme modernizacijom postojećih metoda transplantacije i implantacije, te analizom rezultata njihove primene u kliničkim uslovima.

Metode. U periodu od 2002. do 2022. godine standardne hirurške stomatološke operacije transplantacije i implantacije izvođene su u nekoliko stomatoloških klinika u Rusiji za 5.280 muškaraca i žena starosti od 22 do 85 godina. Od toga su kod 788 pacijenata korišćeni autogeni koštani materijali, a kod 4.492 pacijenta izvođene su hirurške operacije s transplantacijom ksenogenih biomaterijala OsteoBiol. Svim pacijentima su ugrađeni titanijumski implantati Replace Select (Nobel Biocare, Švajcarska).

Rezultati. Pokazano je da je transplantacija autogenih kostiju i ksenogenih biomaterijala trajala u proseku oko 2,5 i 1,5 sati i rezultirala uspešnim usađivanjem u 83% i 94% slučajeva (redom). Da bi se isključila slučajna perforacija Šnajderove membrane tokom transplantacije biomaterijala u uslovima značajne atrofije grebena gornje vilice, predložena je metoda podizanja dna maksilarnog sinusa pod osvetljenjem plavim svetlom iz nosne šupljine. Za poboljšanje estetskog rezultata prilikom postavljanja krunice na implantat u uslovima nedostatka mekih tkiva oko njega predložena je metoda transplantacije autogenog materijala u obliku okruglog diska sa otvorom u centru za „oblačenje“ na implantat.

Zaključak. Savremena stomatološka tehnologija omogućava rekonstrukciju značajnih defekata mekih i koštanih tkiva vilica i zamenu zuba kod pacijenata svih starosnih grupa.

Ključne reči: *transplantacija; biokompatibilni materijali; zubni implantati.*

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INTRODUCTİON

Modern dentistry is armed with a wide arsenal of surgical technologies that allow to restore almost all possible defects of soft and bone tissues of the jaws and teeth replacement in patients of all age groups (1-4). Among these technologies, the so-called "gold standard" of transplantation occupies a central place, the essence of which is the use of an autograft (5-7). At the same time, for transplantation, it is recommended to use a portion of fresh venous blood, its elements, or pieces of soft and hard tissues excised from various parts of the patient's body immediately before dental transplantation (8-11). However, the use of autogenic materials is not a panacea, as there are situations when their use is less profitable than the use of xenogenic materials (12-13). One of the advantages of xenogenic biomaterials is their much greater diversity and full readiness for immediate transplantation (14-16). Therefore, clinical dentistry still retains the need to expand the list of existing dental engineering technologies and modernize existing technologies using xenogenic biomaterials (17-19).

To date, a large arsenal of xenogenic biomaterials and titanium implants has been developed (20). However, the pioneers in this field were xenogenic biomaterials OsteoBiol (Tecnoss, Italy) and titanium implants Replace Select (Nobel Biocare, Switzerland). Therefore, they and their application technologies can enrich our experience with the most valuable information (18,19,21).

The aim of our study is to evaluate the advantages and disadvantages of using autogenic and xenogenic biomaterials OsteoBiol (Tecnoss, Italy) and titanium implants (Nobel Biocare, Switzerland) when installing artificial teeth in conditions of loss of natural teeth and the development of significant atrophy of the hard and soft tissues of the jaws of patients.

MATERIALS AND METHODS

In the period from 2002 to 2022, standard surgical dentistry operations of transplantation and implantation were performed in several dental clinics in Russia for 5,280 men and women aged 22 to 85 years. Of these, autogenic bone materials were used in 788 patients, and in 4492 patients, surgical operations were performed with transplantation of xenogenic OsteoBiol® biomaterials. In particular, “mp3” and “Gen-Os” materials (OsteoBiol®) were used to elevate the floor of the maxillary sinus, increase the bone volume and increase the height of maxillary alveoloplasty, and “Evolution” (OsteoBiol®) was used to cover the exposed Schneider's membrane in the bone "window" of the maxilla. All patients were implanted with titanium implants Replace Select (Nobel Biocare, Switzerland). In order to obtain autogenic transplants, segments of soft or hard living tissues from various parts of the patients' bodies were excised in each case. In particular, for this purpose, segments of the bones of the chin, the hillock of the upper jaw, the outer surface of the branch of the lower jaw, the crest of the ilium or tibia were excised, or a portion of venous blood was taken. Before transplantation and implantation, the condition of teeth and/or adentia, the presence, localization and degree of defects in hard and/or soft tissues of the jaws, the degree of deformation of the alveolar ridges, body temperature and the temperature of the inner surface of the oral cavity were carefully evaluated in each patient. The dynamics of general and local body temperature in patients was recorded in the infrared range of the tissue radiation spectrum using a TH91XX thermal imager (NEC, USA) in the temperature range of +26-37 °C at indoor air temperature +24 – +25 °C. The data obtained were processed using the Thermography Explorer and Image Processor software (NEC, USA). The condition of the soft and bony tissues of the oral cavity and the facial part of the skull was assessed in the visible range of the tissue radiation spectrum using household photo cameras, as well as in the X-ray range using the Planmeca Proline EC orthopantomograph with Dimax 3 system, the Planmeca Infra visiograph and the Planmeca ProMax 3D classic computed tomograph.

The following groups of patients were included in the study. The first group consisted of 788 patients who were implanted with autogenic bone materials. Of these, transplantation was performed in the lower jaw of 296 patients, in the upper jaw of 298 patients, and in both jaws of 194 patients. The second group consisted of 4,492 patients who were implanted with xenogenic OsteoBiol biomaterials. Of these, dental transplantation and implantation were performed in the lower jaw area in 1694 patients, in the upper jaw area in 1807 patients, and in both jaws in 991 patients. At the same time, from the group of patients with transplantation to the upper jaw, 597 patients underwent bone plastic surgery to raise the bottom of the maxillary sinus in the area of the missing tooth to the required height, since the height of the alveolar ridge of the upper jaw was less than 5 mm. At the same time, in 389 patients, access to the maxillary sinus was formed through a window in the anterolateral wall of the upper jaw bone according to a well-known method. In 208 patients, the original Russian method was used for this (RU Patent No. 2397719, effective from 04/20/2009). Its essence was reduced to the layer-by-layer removal of bone mass in the selected area under conditions of illumination of the maxillary sinus with blue-violet light from the nasal cavity.

Moreover, the bone was thinned with the help of a round boron until the appearance of a blue-purple bone layer. The subsequent implantation of titanium implants was carried out after the full completion of the graft

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osteification process, and the installation of artificial crowns on the implanted implant was carried out 4 months after the implantation. After the implants were fully implanted in 942 patients, the tops of the implants were exposed from the gingival tissue using surgical incisions and crowns were applied to the bare tops of the implants according to standard technology. In 489 patients, the application of crowns was postponed due to significant atrophy of the soft tissues around the implanted implant and the need to replenish them with additional transplantation. For this purpose, before installing crowns, an original Russian method of filling in the missing soft tissues with an autogenous graft was applied (RU Patent No. 2558996, entered into force on 06/05/2014). The essence of this method is that a transformer graft is prepared from the selected autogenic biomaterial in the form of a round pancake with a hole in the middle and this leaky "pancake" is applied to the implanted implant like a skirt on a stump from a sawn tree.

The “Investigation of the efficacy and safety of autogenic and xenogenic biomaterials transplantation and titanium implants implantation in patients of all age groups when providing surgical dental care in outpatient settings” was approved by the Ethics Committee of dental clinic ReSto (Izhevsk) (No. 3 from 01/08/2001). All patients at the clinic gave voluntary informed consent for dental care.

In statistical processing of the results, the Kraskel-Wallis criterion and the Mann-Whitney U-criterion were used to determine the normality of the distribution. To detect a statistically significant difference between the groups, the Student's paired t-test was used. $P < 0.05$ was considered statistically significant.

RESULTS

Our clinical results demonstrate high efficiency and safety of surgical implantation of titanium implants and transplantation of autologous bone grafts (the "gold standard" of transplantation) and preserved collagenized pig OsteoBiol® grafts. The greatest difficulties with implants were encountered in cases of excessive reduction of jaw bone thickness, as this precluded implantation without prior artificial bone thickness augmentation. Bone thickness augmentation was achieved by means of bone grafting materials. The results showed that the cause of significant bone atrophy in patients was most often the complete and prolonged absence of teeth in the dentition. The greatest difficulties for implantation were caused by excessive bone atrophy in the maxilla, when the maxillary alveolar process was about 2.0 mm or less in height. The fact is that in such cases we had to perform tissue transplantation associated with a complex surgical operation of raising the floor of the maxillary sinus (sinus lifting). Our experience showed that the use of autologous grafts for this purpose was less effective than the use of xenogeneic collagenized pig OsteoBiol® grafts. In our opinion, the reason for higher efficacy of xenogeneic biomaterials transplantation is that they are designed for a special type of transplantation, have the most optimal properties and are standardized.

The results of surgical transplants combined with sinus inlay surgery for maxillary alveolar heights of around 2.0 mm showed that engraftment occurred in 147 of 177 patients (83%) when autogenous bone was used and in 357 of 380 patients (nearly 94%) when the collagenized pig OsteoBiol® graft was used. Our X-ray studies showed that the process of bone regeneration in the place of transplantation began after 3 months and was finally completed 6-9 months after alveoloplasty regardless of the type of used transplant.

In addition, the results showed that the duration of transplantation combined with sinus elevator surgery depended on the type of graft used. Thus, in cases where autogenous bone materials were used, the duration of the surgical operation of transplantation in the upper jaw during sinus lifting was 2.33 ± 0.11 hours, and in cases where xenogenic biomaterials were used, the duration of the surgical operation of transplantation in the upper jaw during sinus lifting was 1.27 ± 0.07 hours. In other words, the duration of surgical treatment involving the use of the "gold standard" transplantation and sinus lifting surgery was 88% longer than the same surgical treatment using xenogeneic OsteoBiol biomaterials.

We investigated the reason for this circumstance and found that the main reason for the long duration of surgical treatment when using the "gold standard" transplantation was the additional surgical procedure performed to excise bone material from a healthy part of the patient's body. The fact is that in the "gold standard" transplantation such fresh bone material should be used for transplantation. In our study we used autogenous bone materials that were dissected from the upper jaw tubercle of the patient during the ongoing sinus lifting surgery. The results showed that in this group of patients the duration of bone excision surgery was 0.96 ± 0.09 hours ($P \leq 0.05$, $n = 177$). In addition, it was found that excision of bone material from a healthy part of the patient's body inevitably expanded the scope of the intervention and caused tissue trauma in the healthy part of the patient's oral cavity. It was also shown that application of the "gold standard" transplantation required additional use of local anesthetics in the region of the maxillary tubercle. At the same time, tissue excision itself in the upper jaw tubercle was accompanied by acute bleeding, which required closure of the surgical wound with surgical sutures using suture materials and appropriate surgical instruments.

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It should be noted that in 380 standard sinus lifting surgeries, we allowed perforation of the Schneider's membrane in 95 of the surgeries. The reason for this complication was the lack of a generally accepted criterion for the adequacy of the process of deepening dental instruments into the upper jaw bone when they detach from the Schneider's membrane. To compensate for the identified shortcoming, we studied the possibility of optimizing the surgical procedure by means of artificial illumination of the maxillary sinus cavity with cold blue-violet light from the side of the nasal passage using a nasopharyngoscope. Studies have confirmed that the formation of a recess in the jaw bone using a dental boron under conditions of illumination by blue-violet light from the side of the maxillary sinus increases the preservation of Schneider's membrane. The fact is that in this case there is an opportunity to stop the deepening of the dental instrument deep into the bone at the moment when a spot of blue-violet light appears under it. It was found that the appearance of blue-violet illuminated tissue under the surgical instruments indicates the denudation of the Schneider's membrane, as it is transparent and transmits light, while bone tissues do not have transparency. As a result, we developed a "Method of sinus-lifting in dental implantation" (RU Patent No. 2397719, 20/04/2009). Our modernized sinus lifting method was used in 221 surgeries in 208 patients. The application of the developed method made it possible to avoid perforation of the Schneider's membrane and infection of the sinus during surgery in all cases without exception. It was fully confirmed that the appearance of a transparent blue-violet membrane under the surgical instruments is a symptom of the maximum permissible and safe deepening into the bone tissue of the jaw when raising the floor of the maxillary sinus.

Simultaneously we studied the dynamics of local temperature of facial tissues with the help of thermal imaging device. The results obtained showed that the cooling pack applied to the patient's cheek skin in the projection area of the graft and implant inserted into it caused multidirectional changes in the local temperature of the cheek skin and in the jaw tissues inside the closed oral cavity, in the projection area of the ice pack. In particular, under the cooling package the skin temperature decreased, forming a zone of local hypothermia, in which the tissues had a temperature in the range of +12 - +18 °C, and in the tissues of the jaw the local temperature increased, forming a zone of local hyperthermia in the range +38.5 - +38.9 °C. To optimize the application of the cooling pack and its fixation on the patient's cheek, we developed an original "Compression cooling face mask" (RU Patent No. 2682473, 10/01/2018). We used the developed compression cooling mask in 563 patients after various dental surgeries. The results obtained testify to the convenience of individual use of this device by patients.

The final stage of our study was the study of the application of artificial crowns on the implanted implants. It turned out that after standard application of crowns, 1392 out of 1780 patients had a gap between the soft tissues of the jaw and the cervical part of the crowns. This gap worsened the aesthetic result. Since this gap was caused by soft tissue deficiency, we decided to study the problem in order to develop a new technique for surgical autogenous grafting. As a result, we managed to develop a special cutout for the autogenous graft and the original technology of its one-stage transplantation around the implanted implant (RU Patent No. 2558996, 10/08/2015). The essence of our invention is that we proposed a flattened graft with a thickening in the middle in the form of a roll, in the central part of which a transverse incision is made with the possibility of turning it into an opening for dressing on the implant. The finished graft is placed around the implant like a skirt.

The above invention was applied in the application of implant crowns on implants in 489 patients with the loss of lateral teeth and with the presence of marked soft tissue atrophy of the lower jaw. All 489 patients in this group were found to have soft tissue deficits more than 1 mm wide all around the perimeter around the implant. An "apron" of connective biopsy tissue excised from the patient's maxillary tubercle was placed on each implant by giving it a perforated circle of the required thickness and dimension. After that, the graft was placed tightly on the implant, straightened and the wound was sutured. The results of dental implant defect prevention were evaluated for two years after the surgery. It was found that the application of the developed method resulted in the absence of gaps between the artificial crowns and soft tissues in all 489 patients.

DISCUSSION

Modern methods of surgical grafting and implantation allow very good results in the treatment of patients with a variety of dental problems, including the complete and long-term absence of teeth in the dental rows, which keeps dental care highly attractive to patients, despite the high cost of skilled dental care provided to them (22). Titanium implants have played a major role in the continued high attractiveness of surgical dental care, more specifically, the discovery that titanium is highly biocompatible with human tissues. Because of this, titanium can be used to make various implants (21,23,24). To date, a wide arsenal of titanium implants has been developed for use in dentistry (21). However, there are no titanium implants in dentistry for a single-stage and reliable implantation in the very thin bone of the patient's upper jaw (25,26). At the same time, the number of patients with adentia in the upper jaw has been increasing in recent decades due to increasing longevity, which is complicated by a significant

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decrease in its bone thickness (27). When there is no other more reliable way to install artificial teeth than dental crowns on implanted titanium implants, there is no other way to increase the thickness of the jaw bone. Various autogenous grafts and xenogeneic biomaterials are used for this purpose (28-30). Xenogenic biomaterials OsteoBiol (Tecnoss, Italy) and titanium implants Replace Select (Nobel Biocare, Switzerland) were among the first in the international market. That is why we used them and their application technologies during the last 20 years in our clinical dental practice in Russia. At the same time, we focused on optimizing surgical transplantation and implantation in conditions of significant atrophy of hard and soft tissues in the upper jaw.

The results of our study showed that the use of the "gold standard" transplantation for further implantation of titanium implants into the upper jaw bone with significant atrophy is inferior to the use of xenogenic materials. The fact is that the use of autogenous bone-plastic material forces doctors to expand the area of surgical care. This requires a parallel surgical excision of a healthy tissue segment in a selected area of the patient's body (in our case, by excising a segment in the maxillary tuberosity). Such additional surgical "help" automatically increases the severity and duration of the surgical treatment, including not only the preparation of a graft in the maxillary tubercle, but also the transplantation of excised bone tissue, which in this case is associated with another surgical operation - an operation called a sinus lifting. That is why our use of the "gold standard" autogeneic transplants for sinus elevators caused an 88% increase in the duration of surgical care compared to the use of xenogeneic OsteoBiol biomaterials for this purpose. At the same time, the results of using xenogenic biomaterials showed the following advantages over autogenic materials: xenogenic OsteoBiol biomaterials have high quality of storage, full readiness for immediate transplantation in dental transplantation and high biocompatibility with the tissues of the patient's body.

In parallel, we noted that the technology of standard sinus lifting surgery does not have an adequacy criterion ensuring mechanical bone perforation without perforation of the Schneider's membrane. Therefore, standard sinus lifting surgery allows perforation of the Schneider's membrane (31-33). Therefore, in order to exclude Schneider's membrane perforation, we suggested supplementing the standard sinus lifting surgery with such a criterion. For this purpose, we suggested to make bone deepening under conditions of maxillary sinus cavity illumination with blue-violet light, as it allows bone perforation under control of light in the region of perforation bottom, namely, to go deep into bone thickness only up to the moment of appearance of the layer illuminated with blue-violet light (RU Patent No 2397719, April 20, 2009). The point is that the formation of a recess in bone tissue under conditions of maxillary sinus illumination provides the doctor with visual identification of the moment of Schneider's membrane exposure and stopping the process of deepening into bone, because bone is opaque and Schneider's membrane transmits light.

Since surgical dentistry has long used local cooling of tissues in the area of surgery, we conducted infrared monitoring of the dynamics of local temperature of the facial skin and oral mucosa in patients immediately after the completion of surgical transplantation and/or implantation. The results showed that the application of a standard cooling pack to the patient's cheek skin causes multidirectional changes of local temperature in the cheek skin and oral mucosa: a zone of local hypothermia developed in the skin under the cooling pack, and a zone of hyperthermia formed in the tissues of the oral cavity. To optimize the use of the cooling pack, we developed an original compression cooling face mask (RU Patent No. 2682473, 10/01/2018). The use of this cooling mask showed its convenience for individual application by patients and high reliability of precise change of local facial temperature in the selected area. In addition, the compression cooling face mask we developed proved to be very advantageous for use by patients during the COVID-19 pandemic, as this mask is similar to an ordinary hygienic mask.

At the end of the study, we studied the possibilities of optimizing the imposition of artificial dental crowns on implanted titanium implants in cases of soft tissue deficiency of the jaws, since in such cases, the probability of the formation of a gap between the gingiva and the cervical part of the dental crown increases, which worsens the aesthetic result, since the mentioned problem has not yet been finally solved (34-36). We have studied the arsenal of known technologies and grafts used to solve the above problem. On the basis of this analysis, a conclusion was made about the obvious advantages of using autologous grafts to eliminate the crevices. Then, it was found that the cause of the gap was the lack of grafts in the form of special "cutouts" capable of filling the entire soft tissue defect around the implant. Therefore, we developed a special form of cutout for a prepared autogenous graft using a special "mold" having the form of a round pad with a hole in the middle. It was then proposed to place the prepared graft on the implanted implant in the form of a circular apron (skirt) (RU Patent No. 2558996, 05/06/2014). The method we developed was used in 489 patients with hard and soft tissue deficiencies predetermining a high probability of gaps under dental crowns placed on the implanted implants. The results showed that the graft not only successfully engrafted in 483 patients after the first transplantation, but also completely eliminated the presence of a cervical gap under

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the dental crown. In 6 cases the graft was lost, but then these patients underwent a second similar autologous transplant in the shape of a circle with a hole in the middle. The results of repeated transplantation were successful; the graft took root in all patients and excluded the presence of a cervical gap after the placement of the dental crown. Consequently, the developed method of gingivoplasty provides reliable elimination of the cervical gap under the dental crown and improves the aesthetic result.

Thus, the results of long-term use of autogenic and xenogenic biomaterials for dental transplantation in atrophy of soft and hard tissues of the jaws in patients of different age groups have shown the advantages and disadvantages of both types of biomaterials. The advantage of the "gold standard" of transplantation based on the use of autogenic materials is not dependence on the availability of preserved biomaterial "in stock" of the dental clinic. Therefore, it can be used even when the reserve of preserved biomaterials is completely depleted. However, the "gold standard" also has a significant drawback in the form of the absence of a ready-made and standardized graft with consistently repeating shapes, sizes and properties. In turn, the advantage of preserved xenogenic biomaterials is their standardization and full readiness for transplantation at any time. The use of collagenized bone materials OsteoBiol (Tecnoss, Italy) for transplantation reduces the trauma and reduces the duration of surgery by 1.5 hours. At the same time, xenogenic materials are standardized, so their use ensures high repeatability of transplant results and predictability of their readiness for subsequent implantation of titanium implants. In turn, the results of implantation of titanium implants Replace Select (Nobel Biocare, Switzerland) showed their reliability, durability, high engraftment rate and safety.

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose.

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