Effect of Autologous Modification of Dental Implants Based on Non-Woven Titanium Material with a Through Porosity on the Primary Stability Indices in Experiment

DOI: 10.17691/stm2015.7.2.08
Received December 21, 2014

A.E. Scherbovskih, PhD Student, Department of Maxillofacial Surgery and Dentistry[1];
S.A. Gafurov, Assistant, Department of Automatic Systems of Energy Devices[2]

[1]Samara State Medical University, 89 Chapaevskaya St., Samara, 443099, Russian Federation;
[2]Samara State Aerospace University named after Academician S.P. Korolev (National Research University), 34 Moskovskoye shosse, Samara, 443086, Russian Federation

The aim of the investigation is to compare primary stability values of dental implant models based on titanium non-woven material with a through porosity mounted by traditional technology and the technology of autologous modification in experiment.

Materials and Methods. A randomized study was performed on 18 mandible models of pigs aged 9 to 13 months. Periotestometry method was used for comparative assessment of primary stability of dental implant models based on non-woven titanium material with a through porosity placed by traditional technology (the first series of tests, n=18) and that of autologous modification (the second series of tests, n=18). The diameter of pin spacers was 1.8; 2.0; 2.3 mm.

Results. Pin spacer diameter increase from 1.8 mm to 2.3 mm in dental implant models with titanium sleeves made of non-woven material with a through porosity increases stability values by 7.8 times, whereas for implant models with the sleeves made of the same non-woven titanium material but modified by autologous bone tissue — by 10.06 times. Autologous bone modification of titanium non-woven material with a through porosity increases stability indices of an implant with a pin spacer diameter of 1.8 mm by 1.39 times, 2.0 mm — by 3.5 times, and 2.3 mm — by 1.79 times.

Conclusion. Use of autologous modification technology of dental implants made of non-woven titanium material optimizes stability values of dental implants.

Key words: dental implant; non-woven titanium material with a through porosity; primary stability of dental implant; autobone; osseointegration; porous metal.

The progress in understanding the osseointegration processes gave impetus to the development of new materials for dental implantology. However, various complications associated with their application demand further investigations. Of special importance for osseointegration is biological interaction between an implant and the bone surrounding it [1–4]. In recent years, the attempts were made to optimize bone tissue formation at the implant–bone interface using osteoblasts modulation, adhesion, and proliferation by inducing structural modifications of implant surface, including the improvements on the nanolevel as well. To reach the best implantation results conventional technologies are being developed, aimed at chemical and physical modification of the dental implants surface [5–9]. On the macroscopic level an implant design, the form and pitch of the thread, and porosity are the main parameters providing stability. For example, a smaller pitch of the thread and its profile, material with a through porosity, longer and larger implants increase the surface area contacting the surrounding bone tissue [10].

One of the promising directions in manufacturing dental implants is the application of non-woven titanium material with a through porosity (metal rubber), which is an elasto-dampering porous material [11]. At present, there is a broad spectrum of stomatological biomaterials, possessing a marked osteoinductive and osteoconductive potential [12]. Today autologous osseous tissue remains the most optimal type of osseoplastic materials [13, 14]. Biologically active coatings are deposited on implants electrochemically or by plasma, magnetron and laser sputtering techniques. High-energy effects of these methods partially destroy the materials and decrease their efficiency. Deposition of such coatings requires complex and expensive equipment, the operation and maintenance of which need highly-qualified personnel, special premises, etc., which lead to high costs of the end product [15]. Therefore, the most perspective technology of imbedding osteoinductor or osteoconductor into the implant structure will be that of cold pressing, enabling preservation of the bioactive material properties.

For contacts: Scherbovskih Alexey Evgenievich, e-mail: scherbowskih@mail.ru

Stabilization of a dental implant is one of the fundamental factors of successful osseointegration and must be maintained at all stages of treatment to prevent implant microexcursions, which may result in its disintegration. Initial stability has a mechanical nature and depends on the implant form and size, osseous tissue quality, and clinical method of implantation. Structural and functional integration of the dental implant surface with the surrounding osseous tissue (osseointegration) is of crucial importance for a short- and long-term outcome of dental implantation. Currently, there are enough clinical methods for assessing the condition of the implant-bone complex, which show both the optimization of implant osseointegration processes and their abnormalities. One of the modern techniques of measuring dental implant mobility is evaluation with PERIOTEST M system (Siemens, Germany). It provides reliable information on the condition of the implant–bone complex [16]. Application of this system for stability assessment of implants, manufactured according to the technology of autologous modification of non-woven titanium material with a through porosity, is of great interest.

The aim of the investigation is to assess primary stability indices of dental implant models made from non-woven titanium material with a through porosity, mounted according to the conventional technology and the technology of autologous modification.

Materials and Methods. 18 mandible models of pigs aged 9 to 13 months were used in the randomized investigation. The models were studied within 2 h after animal slaughter. Mandible models were cleaned of the soft tissues and wrapped in the cloth moistened with saline solution. Spraying with saline was done at all preliminary stages and during mandible bone preparation to minimize tissue dehydration. All models included into the study were partially edentulous or had an intact dentition (Table 1).

A lower margin of the mandible mental part was used as an experimental implantation zone.

Experiment description. An original design, consisting of a pin spacer wedging intraosseous porous cylindrical sleeve of non-woven titanium material (metal rubber) with a through porosity was used as a prototype for the experimental implant model [17]. The technology of autologous modifying of dental implant models made of non-woven titanium material with a through porosity has been also developed by the authors [18]. During bone bed formation the bone chips were collected into the dosing device, the volume of which corresponded to the volume of implant porosity, then the non-woven titanium material with a through porosity was placed into the mold. While placing the material into the mold, bone chips were poured to the mold funnel, the prepared specimen was put into the mold and underwent cold pressing (Figure 1).

Porcine mandible models were fixed in the bench vise.

The dental implant model consisted of a pin spacer and a cylindrical sleeve made of non-woven titanium material with a through porosity, titanium wire being 0.08 mm thick, BT-00 grade. The sleeve was 7 mm long, had a 3.5 mm outer diameter, 1.6 mm inner diameter, and 70±2% porosity volume. The cylindrical sleeve, the porosity volume of which was modified by autologous bone tissue, had similar dimensions (Figure 2).

Screws for osteosynthesis (Stryker, Germany, Switzerland) having diameters of 1.8; 2.0; 2.3 mm were used as pin spacers. Bone beds 3.5 mm in diameter and 7 mm deep were formed with the help of 6 dental cutters in a step-by-step manner along the lower mandible margin in the mental area symmetrically to the midline (Figure 3).

Investigation was carried on simultaneously with the two groups of teeth, located within one jaw to the right and left from the sagittal line, passing through the

Table 1

Animal age, dentition state

Number of mandible model	Animal age (months)	Dentition state
1	10	Intact
2	11	Intact
3	10	Intact
4	10	Intact
5	13	Intact
6	11	Partially missing teeth
7	11	Intact
8	10	Intact
9	10	Intact
10	9	Intact
11	10	Intact
12	11	Intact
13	12	Intact
14	10	Intact
15	10	Intact
16	9	Partially missing teeth
17	10	Intact
18	13	Intact

Figure 1. Cylindrical sleeve modified by autologous bone tissue

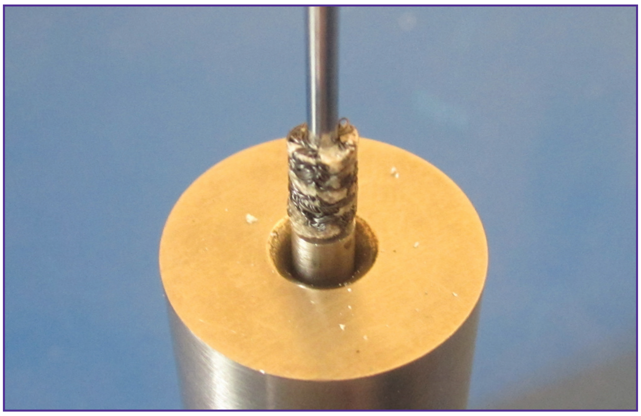

Figure 2. Dental implant models mounted in the mandible lower margin

Figure 3. Technology of autologous modification of non-woven titanium material with a through porosity

middle of the mental part of the mandible lower margin. In group 1 dental implant models of non-woven titanium material with a through porosity were mounted in the three jaw bone beds; in group 2 three implant models of non-woven titanium material with a through porosity, modified by autologous bone tissue, were placed on the opposite mandible side. A sleeve was installed in each bone bed, and a pin spacer was screwed into the inner channel. Thus, in each group three pin spacers of 1.8; 2.0; 2.3 mm diameters were placed.

Description of the data measuring technique. Primary stability of dental implants was evaluated using PERIOTEST M device (Siemens, Germany). The device consists of a tapping metallic rod in a handpiece, and a unit measuring the time of returning the unit mobile part to the initial position. The handpiece transmits an electronically controlled mechanical pulse to the tooth, an adjusting coil provides a constant pulse frequency of the tapper with the compensation for friction and weight. The force of tapper-tooth interaction is transformed by a piezocrystal into analog electric signal, which is digitized in the analog-to-digital transducer and is transmitted to the processor. When a cycle of 16 hits is completed, the processor calls the data from the main memory, and having averaged their values compares them logically with the matrix (experimentally obtained values). Having determined the group to which the results are referred, the device sends signals to the sound and indicator units to enter the data in the voice and digital forms. The result is stored and displayed in the form of a digital index till the beginning of the next measurement. Each test was repeated at least 3 times, after which the mean statistical value was determined. During statistical processing of the results arithmetical mean (M) and average error of the mean (m) were calculated. To assess the significance of differences nonparametric Mann–Whitney criterion was used for independent groups. Differences of the sign level in the compared groups were considered statistically significant at $p<0.05$.

Results and Discussion. Periotestometry values of primary stability, obtained in the course of the investigation for the dental implant models, showed its dependence on the pin spacer diameter and availability of autologous modification of the non-woven titanium material with a through porosity (Table 2).

Comparison of implant models with pin spacer diameters of 1.8; 2.0; 2.3 mm showed, that increase of the diameter results in better stability of implant models in both groups. Comparison of implant models with similar pin spacer diameters in group 1 and 2 demonstrated that in all cases readings of PERIOTEST M device for non-woven titanium material with a through porosity modified by autologous bone tissue were higher compared to the models of the same material without modification. This conclusion is true for all pin spacer diameters in the tested implant models (Figure 4).

Change of the pin spacer diameter from 1.8 to 2.3 mm in the models, where the sleeves were made of non-woven titanium material having a through porosity, increases primary

T a b l e 2

Periotestometry values of primary stability for dental implant models (standard units) depending on the pin spacer diameter and availability of autologous modification of the non-woven titanium material with a through porosity (M±m)

Pin spacer diameter (mm)	Group 1 — non-woven titanium material with a through porosity	Group 2 — non-woven titanium material modified by autologous bone chips	Difference of values
1.8 (n=18)	40.33±0.24	29.06±0.19*	11.27
2.0 (n=18)	18.67±0.28	5.33±0.14*	13.34
2.3 (n=18)	5.17±0.17	2.89±0.14*	2.28

N o t e: * statistically significant difference of values in groups 1 and 2; $p<0.05$.

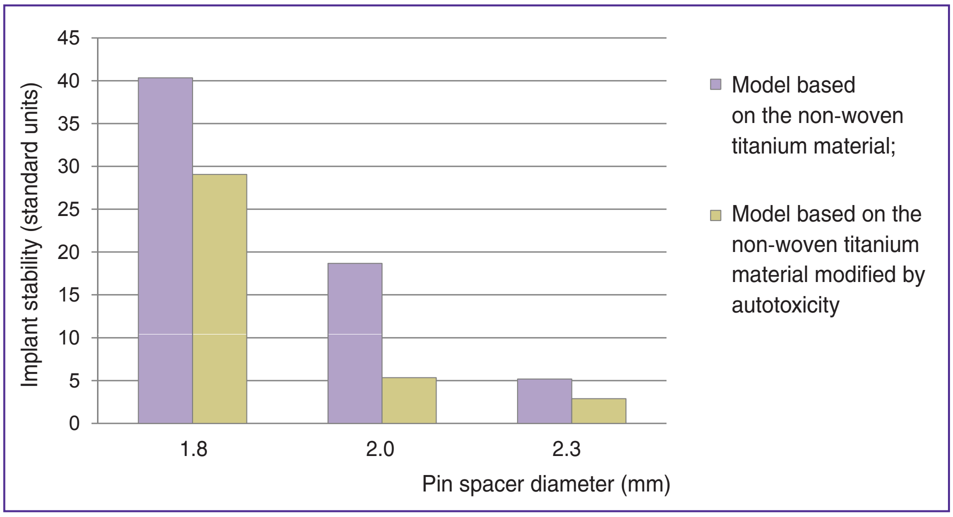

Figure 4. Readings of PERIOTEST M device for the two tested groups

stability values by 7.8 times; whereas in the sleeves of the same material but modified by autologous bone tissue stability increase is by 10.06 times. Modification of non-woven titanium material with a through porosity by autologous bone tissue improves primary stability values of implants for pin spacer diameter of 1.8 mm by 1.39 times, 2.0 mm by 3.5 times and for the diameter of 2.3 mm by 1.79 times.

Thus, findings of our experimental study, aimed to assess the possibility of using autologous modification of non-woven titanium material with a through porosity for optimization of implants primary stability demonstrate, that PERIOTEST M readings depend on the diameter of the pin spacer of the intraosseous part of the dental implant model, and on the density of the non-woven titanium material with a through porosity, regulated by means of autologous bone modification. Increase of the pin spacer diameter results in stabilization of dental implants in the both tested groups. Besides, stability of implants modified by autologous bone chips is, on average, 2 times higher than that of non-modified implants. However, stability of implants of non-woven titanium material with a through porosity is higher in the models with a large diameter of intraosseous pin spacers.

Conclusion. The technology of autologous modification optimizes the indices of primary dental implants by increasing the density of the non-woven titanium material with a through porosity.

Study Funding and Conflict of Interests. The study was funded by the authors. There is no topic specific conflict of interest related to the authors of this study.

References

1. von Wilmowsky C., Moest T., Nkenke E., Stelzle F., Schlegel K.A. Implants in bone: part I. A current overview about tissue response, surface modifications and future perspectives. *Oral Maxillofac Surg* 2014; 18(3): 243–257, http://dx.doi.org/10.1007/s10006-013-0398-1.

2. von Wilmowsky C., Moest T., Nkenke E., Stelzle F., Schlegel K.A. Implants in bone: Part II. Research on implant osseointegration. *Oral Maxillofac Surg* 2014; 18(4): 355–372, http://dx.doi.org/10.1007/s10006-013-0397-2.

3. Gittens R.A., Scheideler L., Rupp F., Hyzy S.L., Geis-Gerstorfer J., Schwartz Z., Boyan B.D. A review on the wettability of dental implant surfaces II: Biological and clinical aspects. *Acta Biomater* 2014; 10(7): 2907–2918, http://dx.doi.org/10.1016/j.actbio.2014.03.032.

4. Mathieu V., Vayron R., Richard G., Lambert G., Naili S., Meningaud J.P., Haiat G. Biomechanical determinants of the stability of dental implants: influence of the bone-implant interface properties. *J Biomech* 2014; 47(1): 3–13, http://dx.doi.org/10.1016/j.jbiomech.2013.09.021.

5. Markhoff J., Mick E., Mitrovic A., Pasold J., Wegner K., Bader R. Surface modifications of dental ceramic implants with different glass solder matrices: in vitro analyses with human primary osteoblasts and epithelial cells. *Biomed Res Int* 2014; 2014: 742180, http://dx.doi.org/10.1155/2014/742180.

6. Cheng A., Humayun A., Cohen D.J., Boyan B.D., Schwartz Z. Additively manufactured 3D porous Ti-6Al-4V constructs mimic trabecular bone structure and regulate osteoblast proliferation, differentiation and local factor production in a porosity and surface roughness dependent manner. *Biofabrication* 2014; 6(4): 045007, http://dx.doi.org/10.1088/1758-5082/6/4/045007.

7. Hong Y.S., Kim J., Han J.S., Yeo I.S. Effects of hydrophilicity and fluoride surface modifications to titanium dental implants on early osseointegration: an in vivo study. *Implant Dent* 2014; 23(5): 529–533, http://dx.doi.org/10.1097/id.0000000000000131.

8. Lugovskoy A., Lugovskoy S. Production of hydroxyapatite layers on the plasma electrolytically oxidized surface of titanium alloys. *Mater Sci Eng C Mater Biol Appl* 2014; 43: 527–532, http://dx.doi.org/10.1016/j.msec.2014.07.030.

9. Ballo A.M., Cekic-Nagas I., Ergun G., Lassila L., Palmquist A., Borchardt P., Lausmaa J., Thomsen P., Vallittu P.K., Närhi T.O. Osseointegration of fiber-reinforced composite implants: Histological and ultrastructural observations. *Dent Mater* 2014; 30(12): e384–e395, http://dx.doi.org/10.1016/j.dental.2014.08.361.

10. Bressan E., Sbricoli L., Guazzo R., Tocco I., Roman M., Vindigni V., Stellini E., Gardin C., Ferroni L., Sivolella S., Zavan B. Nanostructured surfaces of dental implants. *Int J Mol Sci* 2013; 14(1): 1918–1931, http://dx.doi.org/10.3390/ijms14011918.

11. Scherbovskih A.E. Assessment of biocompatibility of non-tissue titanium material with continuous porosity on the culture of multipotent mesenchymal stromal cells in experiment. *Aspirantskiy vestnik Povolzh'ya* 2014; 1–2: 210–213.

12. Nazirkar G., Singh S., Dole V., Nikam A. Effortless effort in bone regeneration: a review. *J Int Oral Health* 2014; 6(3): 120–124.

13. Jindal V., Gill A.S., Kapoor D., Gupta H. The comparative efficacy of decalcified allogenic bone matrix and intra-oral free osseous autografts in the treatment of periodontal intrabony defects. *J Indian Soc Periodontol* 2013; 17(1): 91–95, http://dx.doi.org/10.4103/0972-124x.107482.

14. Jensen S.S., Broggini N., Hjörting-Hansen E., Schenk R., Buser D. Bone healing and graft resorption of autograft, anorganic bovine bone and beta-tricalcium phosphate. A histologic and histomorphometric study in the mandibles of minipigs. *Clin Oral Implants Res* 2006; 17(3): 237–243, http://dx.doi.org/10.1111/j.1600-0501.2005.01257.x.

15. Leonova L.A., Guzeeva T.I., Guzeev V.V. Kompozitsionnye pokrytiya dlya implantatov i endoprotezov. V kn.: *II Mezhdunarodnaya nauchno-prakticheskaya konferentsiya molodykh uchenykh "Resursoeffektivnye tekhnologii dlya budushchikh pokoleniy*", 23–25 noyabrya 2010 g. [Composite coatings for implants and endoprostheses. In: II International scientific and practical conference of the young scientists "Resource-effective technologies for future generations", 23–25 November, 2010]. Tomsk; 2010.

16. Truhlar R.S., Morris H.F., Ochi S. Stability of the bone-implant complex. Results of longitudinal testing to 60 months with the Periotest device on endosseous dental implants. *Ann Periodontol* 2000 Dec; 5(1): 42–55, http://dx.doi.org/10.1902/annals.2000.5.1.42.

17. Scherbovskih A.E., Bayrikov I.M., Mizina P.G. *Dental'nyy implantat (varianty).* Patent RF na poleznuyu model' 143685 [Dental implant (variants). RF Utility Patent 143685]. 2014.

18. Scherbovskih A.E., Bayrikov I.M., Volova L.T., Mizina P.G. *Sposob dental'noy implantatsii (varianty).* Patent RF na izobretenie 2 544 804 [Method of dental implantation (variants). RF Patent for invention 2 544 804]. 2015.