Dmitry Mishin, Sergei Kalinovsky, Vyacheslav Ilyasov, Veronika Dedova*

INVESTIGATION OF AXIAL DISPLACEMENT OF SUPRASTRUCTURES AT THE CONICAL IMPLANT-ABUTMENT INTERFACE

ISTRAŽIVANJE AKSIJALNOG POMERANJA SUPRASTRUKTURA NA KONUSNOJ VEZI IMPLANTA-ABATMENTA

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Adresa autora / Author's address:
Ryazan State Medical University, Ryazan, Russia
*email: ilyasov.vyacheslav2010@gmail.com

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- axial displacement
- implant
- abutment
- conical connection
- simulation complex

Abstract

Currently, implant-supported prosthetics are widespread in dental practice. However, this type of treatment has a number of features, namely the attachment of the crown of the tooth to the implant. The aim of this work is to study the degree of axial displacement of abutments made by different methods in comparison with implants and their analogues.

The study was carried out on implants and analogues of MIS C1 (conical connection), standard platform. The following types of abutments are chosen: standard transgingival abutments, milled, cast, SLA - abutments (selective laser sintering). The task was to study the change in the height of the abutment on the analogues depending on the tightening torque of the fixing screw, as well as to study the change in the height of the abutment on the implant under chewing load.

The results on analogues revealed axial displacement on original abutments 92-109 μm, on milled abutments 104-129 μm, casting abutments 66-93 μm, in SLA abutments 55-78 μm.

Results on implants showed axial displacement on original and milled abutments 1-2 μm, weak abutment 2-7 μm, and cast abutment 2-12 μm.

The design of the implant-supported prostheses requires attention to the height of the structure. When modelling on analogues, the peculiarities of axial displacement of each type of abutment should be taken into account. Axial misalignment of the implants indicates that SLA and cast abutments are unreliable. Priority should be given to original products and milled abutments.

Ključne reči
- aksijalno pomeranje
- implant
- abatment
- konusna veza
- kompleks simulacije

Izvod

Trenutno je u stomatološkoj praksi široko rasprostranjena protetika sa implantima. Međutim, ova vrsta lečenja ima niz prednosti, a to je vezivanje krunice zuba na implant. Cilj rada je u ispitivanju stepena aksijalnog pomeranja abatmenta izrađenih različitim metodama u poređenju sa implantima i njihovim replikama.

Istraživanje je izvedeno na implantima i replikama MIS C1 (konusna veza), standardne platforme. Izabrani su sledeći tipovi abatmenta: standardni transgingivalni abatmenti, obrađeni rezanjem, liveni, SLA - abatmenti (selektivnim laserskim sinterovanjem). Zadatak je u proučavanju promene visine abatmenta na replikama u zavisnosti od momenta zatezanja vijka za vezu, kao i u proučavanju promene visine abatmenta na implantu pod opterećenjem žvakanja.

Rezultati sa replikama otkrivaju aksijalno pomeranje na originalnim abatmentima od 92-109 μm, na brušenim 104-129 μm, na livenim 66-93 μm, i kod SLA abatmenta 55-78 μm.

Rezultati na implantima su pokazali aksijalno pomeranje na originalnim abatmentima i obrađenim rezanjem 1-2 μm, slabi abatmenti 2-7 μm, i na livenim 2-12 μm.

U dizajnu proteza s implantom, posebnu pažnju zahteva visina konstrukcije. Pri modeliranju sa replikama treba uzeti u obzir karakteristike aksijalnog pomeranja svakog tipa abatmenta. Aksijalna neusklađenost na implantima ukazuje na nepouzdanost SLA i livenih abatmenta. Prioritet treba dati originalnim proizvodima i abatmentima proizvedenim rezanjem.

INTRODUCTION

Lack of teeth as a result of various diseases is a common pathology encountered in dentistry /1-4/. The proliferation of dental implantation in the delivery of dental care to patients has made incredible strides in recent years. A significant amount of basic and applied research on the surgical phases of dental implantation has contributed to this, /2-5/. However, do not forget that the final stage of implant treatment is the placement of an orthopaedic structure, /6/.

Often, annual improvements in implant systems that change both the external structure of the implant and the types of connection between the implant and the prosthetic structure cause orthopaedic treatment errors, /7-10/. The most common connection at the moment is the tapered connection, in which the outer cone is represented by the abutment and the inner cone by the implant socket. The inside of such an implant is made in the form of a Morse taper with a specific angle that the manufacturer chooses. The success of this type of connection is due to the combination of fixation with a clinical screw and taper embedding, /11-13/.

Different types of abutments are used in dental practice: both original and non-original (individual), /14/. Standard kit parts must have high accuracy. Their use implies the achievement of the best clinical result. In addition to the original suprastructures, customized abutments can be used in orthopaedic treatment with dental implants. The casting method makes it possible to obtain abutments using previously fabricated wax models. Thanks to the use and adaptation of numerically controlled machines in dentistry, it is now possible to obtain dental products by milling from prefabricated blanks. The selective laser sintering method, used in dentistry, is also widespread. All of the above methods are used for the fabrication of custom abutments, /15/.

When using a custom-made abutment, there is an increased likelihood of misalignment of the outer cone relative to the inner cone as a result of manufacturing irregularities, /16-18/. There is also the possibility of axial displacement of the mating tapered parts during connection, /19-20/. This can lead to a change in the height of the abutment rising above the implant. It has been practically proven that the proprioceptive sensitivity of the muscular organ of the maxillofacial system is capable of sensing changes within 8 μm. This necessitates the precise creation of prosthetic constructions in order to reproduce the occlusal contacts of the antagonist teeth without premature contacts.

The cause of such irregularities as communication of the implant socket with the oral cavity, breakage of the implant or prosthetic structure, fixation screws, mismatch of the occlusal relationship due to axial displacement, is often a mismatch in the congruence of the implant-abutment interface surface.

Purpose: to investigate the degree of axial displacement of abutments fabricated in different ways relative to implants and their counterparts.

Tasks: to study the magnitude of axial displacement of abutments of each type relative to the implant analogue from the force of screw tightening; to study the magnitude of axial displacement of abutments of each type relative to the implant when simulating masticatory loading.

MATERIALS AND METHODS

Abutment axial displacement studies were performed on a standard orthopaedic implant platform with a tapered MIS C1 system connection. C1 implant analogues were also used to compare the laboratory and clinical stages of orthopaedic constructs supported by dental implants.

To study the axial displacement of the original abutment relative to the implant, titanium transgingival standard abutments (Fig. 1), as well as individually fabricated non-original abutments by milling (Fig. 2), selective laser melting (Fig. 3), and casting (Fig. 4), were used as restorations.

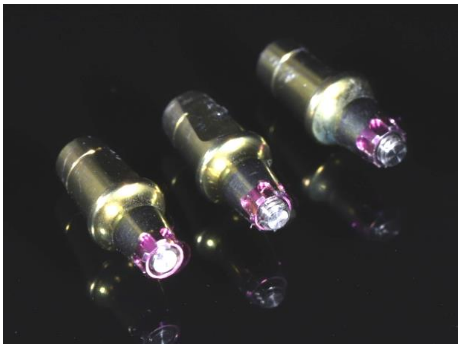

Figure 1. Titanium transgingival standard abutments.

Figure 2. Milled abutments with conical interface for MISC1 implant.

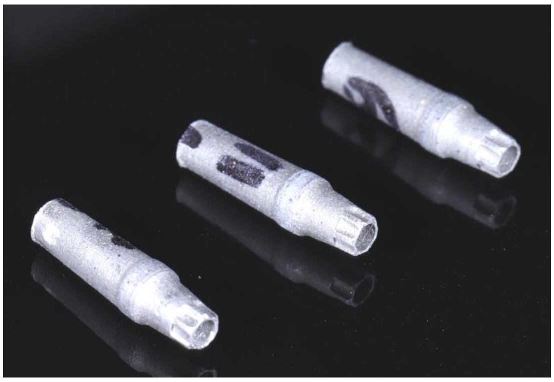

Figure 3. Selective laser sintering abutments with a conical interface for the MISC1 implant.

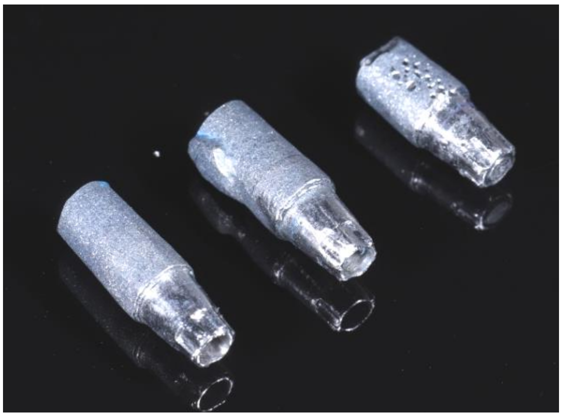

Figure 4. Abutments cast using wax models with a conical interface for the MISC1 implant.

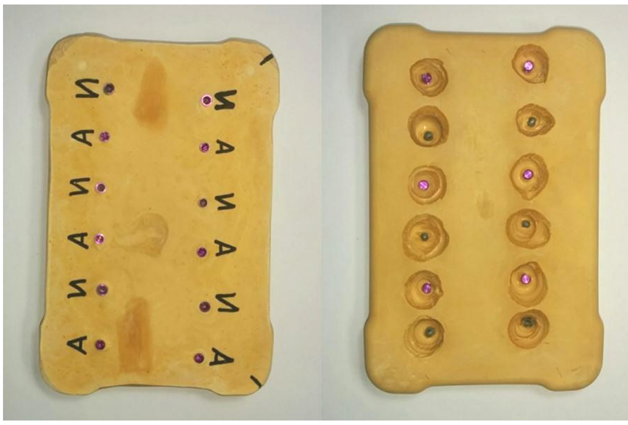

Figure 5. Class 4 plaster block (photo of two surfaces) with implants (locations marked 'И') and counterparts (marked 'A'). The tops of the implants and analogues are exposed to gain access to the micrometre screw.

Methodology

The implants and analogues were plastered into a class 4 plaster block to further simulate loading (since the implants and analogues will be stressed in the future and need to be rigidly fixed). The peculiarity of the location of the implant and analogue in the plaster block is the open apex.

This is created so that the micrometre screw 2 (Fig. 6) has access to the apex of the implant and analogue for measurement (Fig. 5). Measurements were taken using an Inforce 06-11-44 digital micrometre with an error of 0.002 μm (Fig. 6).

Figure 6. Inforce 06-11-44 digital micrometre: 1-heel of the micrometre; 2-micrometre screw; 3-liquid-crystal display; 4-control buttons; 5-micrometre screw stroke knob.

Figure 7. Torque wrench (a), and standard hex screwdriver (b), from the implantation system MIS prosthetic kit.

The study was conducted in two stages.

In the first phase of the study, the axial displacement of abutments on implant counterparts was studied as a function of screw torque. The force with which the screw was tightened was 7, 30 Ncm. These values were chosen because within 7 Ncm it is possible to tighten with a screwdriver by finger forces without a torque wrench, the force of 30 Ncm is the value of the screw tightening force on implants with a torque wrench (Fig. 7). After positioning the abutment in the analogue (Fig. 8), the screw was tightened with a force of 7 Ncm, the resulting length was measured with a micrometre and the length La1 (length at abutment) is obtained. Then the screw was tightened to a force of 30 Ncm, and the La2 value was measured. Since the height implant analogue Hia is known in advance, by obtaining values La1 and La2 it is possible to calculate the height abutments Hab1 and Hab2 that are elevated over the analogue at each screw tightening:

Hab1 (on analogues) = La1 – Hia ,

Hab2 (on analogues) = La2 – Hia.

The calculation of axial displacement AD of abutment cone to the analogue cone can be calculated using the formula: AD (on analogues) = Hab1 (on analogues) – Hab2 (on analogues), Fig. 9.

a)

b)

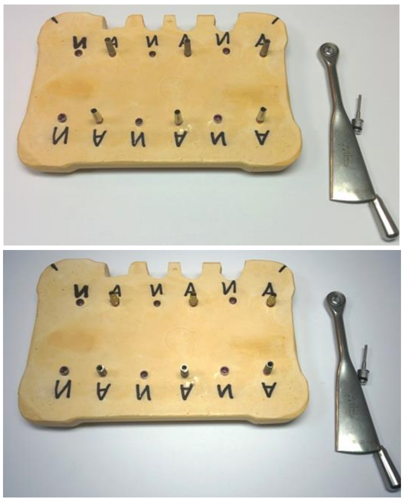

Figure 8. Abutments obtained by milling, laser sintering (a); original and cast abutments (b) were placed in the plaster block on analogues.

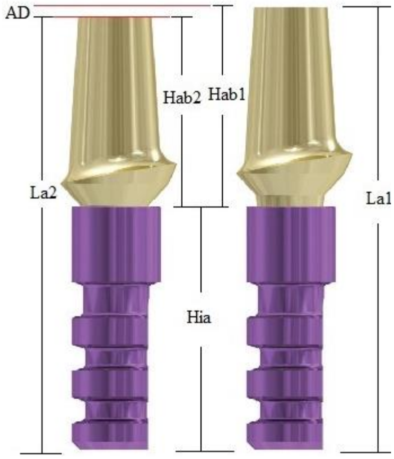

Figure 9. Scheme of stage 1, where analogue and abutment on the right are in weak screw tightening; on the left in strong tightening.

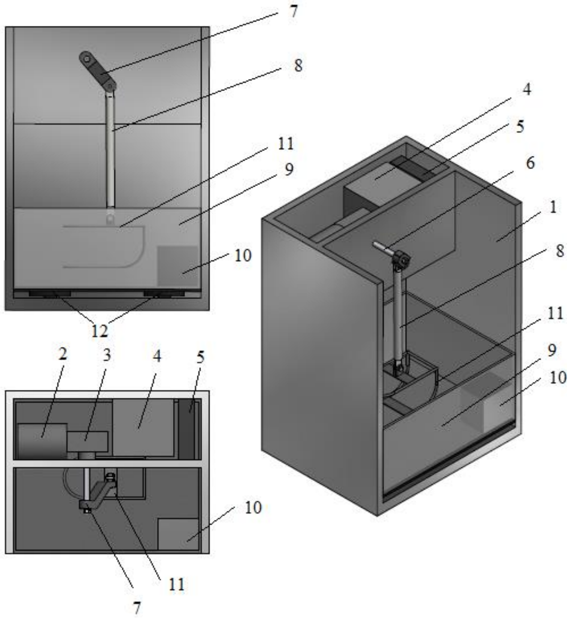

Figure 10. Simulation complex: 1-hull; 2-motor; 3-reducer; 4-power unit; 5-microcontroller; 6-secondary shaft; 7-crank; 8-rod; 9-vessel with solution; 10-thermo-regulating unit; 11-occlusion unit (replaced by plaster blocks and response part); 12-tensometric sensors.

In the second step, axial displacement of abutments on implants with loading is studied. The abutment screw is tightened with a torque of 30 Ncm following the orthopaedic abutment placement protocol prescribed in the guidelines for the use of tapered orthopaedic elements. Implants with Li1 abutments fixed on them (length on implant) are measured. The plaster block is placed in the original simulation complex, /21/ (Fig. 10). The response piece (Fig. 11), made of plaster and having abutment impressions, is attached to the connecting rod of the device so that when it is lowered onto the abutments, they would make contact with the surface of the block. In this way, uniform pressure is achieved on all abutments at the same time. The exercise is performed three times a day, simulating morning, lunch, and evening meals for 10 minutes each for two weeks, /31/. After the end of the load, Li2 measurements are taken. To detect AD axial displacement at the implants, the height of the suprastructure, Hab, is calculated by the difference of Li and the height of the implant Hi, before and after loading (Hab1 and Hab 2). Then we found the difference in abutment height:

Hab1(on implants) = Li1 – Hi,

Hab2 (on implants) = Li2 – Hi,

AD (on implants) = Hab1 (on implants) – Hab2 (on implants) (Fig. 12).

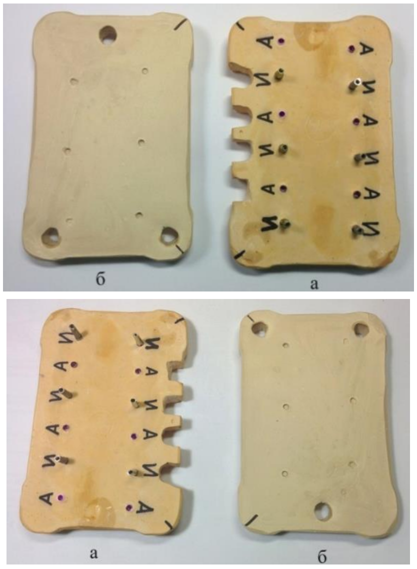

Fig. 11. Plaster blocks with implants and abutments (a) and counterparts (b) necessary to create the load on the abutments.

RESULTS

The axial displacement of abutments relative to implant counterparts with a difference in fixation screw tightening force (7-30 Ncm) show the following values:

1. Original abutments show maximal axial displacement in the range of 92-109 μm.
2. Milled abutments show axial displacement in the range of 104-129 μm.
3. Casting abutments show axial displacement ranging from 66-93 μm.
4. Minimal axial displacement is detected in laser sintered abutments, ranging from 55-78 μm, Table 1.

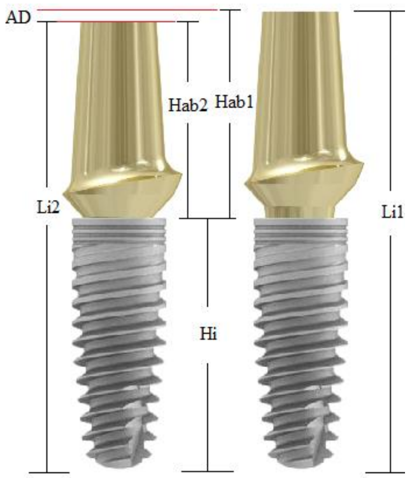

Figure 12. Scheme of 2-stage study: implant and abutment on the right - before loading; on the left - after loading.

Table 1. Measurement of axial displacement of abutments relative to counterparts as a function of screw torque.

	Standard abutments (μm)			Milled abutments (μm)		
7 Ncm	20.134	20.177	20.135	23.517	22.963	22.973
30 Ncm	20.025	20.077	20.043	23.413	22.839	22.844
7-30 Ncm	0.109	0.1	0.092	0.104	0.124	0.129

Table 1 (continued). Measurement of axial displacement of abutments relative to counterparts as a function of screw torque.

	Abutments cast using wax models (μm)			SLS abutments (μm)		
7 Ncm	19.915	17.8	19.773	23.202	23.221	23.186
30 Ncm	19.822	17.722	19.707	23.147	23.164	23.108
7-30 Ncm	0.093	0.078	0.066	0.055	0.058	0.078

Indentation size of the abutment and implant cone from the simulated masticatory load with the same screw tightening force (30 Ncm) shows the following values:

1. minimal axial displacement relative to the implants is detected in the original and milled abutment (1-2 μm);
2. larger values of height deviation of the prototype restoration elevated above the implant are detected in abutments obtained by moulding (2-12 μm) and laser sintering (2-7 μm), Table 2.

Table 2. Measurement of axial displacement of abutments relative to implants before and after loading.

	Standard abutments (μm)			Milled abutments (μm)		
before loading	16.009	18.029	18.077	18.280	19.977	22.198
after loading	16.008	18.027	18.076	18.279	19.975	22.196
Δ	0.001	0.002	0.002	0.001	0.002	0.002

Table 2 (continued). Measurement of axial displacement of abutments relative to implants before and after loading.

	Abutments cast using wax models (μm)			SLS abutments (μm)		
before loading	17.110	19.140	15.731	22.584	22.599	19.086
after loading	17.098	19.138	15.728	22.582	22.597	19.079
Δ	0.012	0.002	0.003	0.002	0.002	0.007

DISCUSSION AND CONCLUSIONS

A study of axial displacement of abutments relative to their counterparts reveals that the height of the suprastructure changes as a function of screw tightening strength.

Large axial displacement is detected in the original and milled abutments when the screw is tightened with 7 and 30 Ncm. Casting and laser-fused abutments show less axial displacement.

The study of axial displacement of abutments relative to the implant under load shows that the original and milled abutments show the smallest axial displacement. The study of cast and laser-fused abutments reveals significant axial displacement.

We found a pattern: the flatter the surface of the tapered parts, the greater the axial displacement on the analogues, which directly depends on screw tightening force (in the range from 7 to 30 Ncm). The uneven surface of the outer cone gives the smallest axial displacement.

The original and milled abutments, which had a smooth cone surface, show the smallest axial displacement when the screw is tightened with 30 Ncm in the load simulation. At the same time, cast and laser-fused abutments, which did not have an even surface, show significant displacement.

The positive effect of the tapered connection is the wedging of the tapered parts, thereby distributing various types of loads (vertical and horizontal) on the restoration. At the same time, with implants with a planar connection, most of the load was on the screw. However, there is a significant change in the height of the structure elevated above the implant as a result of clinical and laboratory phases of prosthetic fabrication. There is a difference between abutment fixation on analogues and implants. Effective decisions made in the clinical setting can have the opposite effect in the laboratory fabrication steps, which have a major role in the creation of an accurate design. The existing problem of obtaining precision structures requires further study and identification of a solution for successful treatment and rehabilitation of patients with adentia (total or partial) through prosthetics supported by dental implants.

REFERENCES

1. Sasada, Y., Cochran, D.L. (2017), *Implant-abutment connections: A review of biologic consequences and peri-implantitis implications*, Int. J Oral Maxillofac. Implants, 32(6): 1296-1307. doi: 10.11607/jomi.5732
2. Liu, Y., Wang, J. (2017), *Influences of microgap and micromotion of implant-abutment interface on marginal bone loss around implant neck*, Arch. Oral Biol. 83: 153-160. doi: 10.1016/j.archoralbio.2017.07.022
3. Gherlone, E.F., Capparé, P., Pasciuta, R., et al. (2016), *Evaluation of resistance against bacterial microleakage of a new conical implant-abutment connection versus conventional connections: an in vitro study*, New Microbiol. 39(1): 49-56.
4. Camós-Tena, R., Escuin-Henar, T., Torné-Duran, S. (2019), *Conical connection adjustment in prosthetic abutments obtained by different techniques*, J Clin. Exp. Dent. 11(5): e408-e413. doi: 10.4317/jced.55592
5. Caricasulo, R., Malchiodi, L., Ghensi, P., et al. (2018), *The influence of implant-abutment connection to peri-implant bone loss: A systematic review and meta-analysis*, Clin. Implant Dent. Relat. Res. 20(4): 653-664. doi: 10.1111/cid.12620
6. Lops, D., Stocchero, M., Motta Jones, J., et al. (2020), *Five degree internal conical connection and marginal bone stability around subcrestal implants: A retrospective analysis*, Materials (Basel), 13(14): 3123. doi: 10.3390/ma13143123
7. Lauritano, D., Moreo, G., Lucchese, A., et al. (2020), *The impact of implant-abutment connection on clinical outcomes and microbial colonization: A narrative review*, Materials (Basel) 13(5): 1131. doi: 10.3390/ma13051131
8. Ceruso, F.M., Barnaba, P., Mazzoleni, S., et al. (2017), *Implant-abutment connections on single crowns: a systematic review*, Oral Implantol. (Rome), 10(4): 349-353. doi: 10.11138/orl/2017.10.4.349
9. Flanagan, D., Phillips, J., Connor, M., et al. (2015), *Hoop stress and the conical connection*, J Oral Implantol. 41(1): 37-44. doi: 10.1563/AAID-JOI-D-12-00180
10. Kofron, M.D., Carstens, M., Fu, C., Wen, H.B. (2019), *In vitro assessment of connection strength and stability of internal implant-abutment connections*, Clin. Biomech. (Bristol, Avon), 65: 92-99. doi: 10.1016/j.clinbiomech.2019.03.007
11. Candotto, V., Gabrione, F., Oberti, L., et al. (2019), *The role of implant-abutment connection in preventing bacterial leakage: a review*, J Biol. Regul. Homeost. Agents, 33(3 Suppl. 1): 129-134. Dental Supplement. PMID: 31538459.
12. Carnovale, F., Patini, R., Peñarrocha-Oltra, D., et al. (2020), *Measurement of gap between abutment and fixture in dental conical connection implants. A focused ion beam SEM observation*, Med. Oral Patol. Oral. Cir. Bucal. 25(4): e449-e454. doi: 10.4317/medoral.23281
13. Hurson, S. (2018), *Implant/abutment biomechanics and material selection for predictable results*, Compend. Contin. Educ. Dent. 39(6): 440-444. quiz 446. PMID: 30020799.
14. Yao, K.-T., Chen, C.-S., Cheng, C.-K., et al. (2018), *Optimization of the conical angle design in conical implant-abutment connections: A pilot study based on the finite element method*, J Oral Implantol. 44(1): 26-35. doi: 10.1563/aaid-joi-D-17-00149
15. Pozzi, A., Mura, P. (2016), *Immediate loading of conical connection implants: Up-to-2-year retrospective clinical and radiologic study*, Int. J Oral Maxillofac. Implants, 31(1): 142-152. doi: 10.11607/jomi.4061
16. Mishra, S.K., Chowdhary, R., Kumari, S. (2017), *Microleakage at the different implant abutment interface: A systematic review*, J Clin. Diagn. Res. 11(6): ZE10-ZE15. doi: 10.7860/JCDR/2017/28951.10054
17. Hsu, P.-F., Yao, K.-T., Kao, H.-C., Hsu, M.-L. (2018), *Effects of axial loading on the pull-out force of conical connection abutments in Ankylos implant*, Int. J Oral Maxillofac. Implants, 33(4): 788-794. doi: 10.11607/jomi.6016
18. Schmitt, C.M., Nogueira-Filho, G., Tenenbaum, H.C., et al. (2014), *Performance of conical abutment (Morse Taper) connection implants: a systematic review*, J Biomed. Mater. Res. A, 102(2): 552-574. doi: 10.1002/jbm.a.34709
19. Karl, M., Irastorza-Landa, A. (2018), *In vitro characterization of original and nonoriginal implant abutments*, Int. J Oral Maxillofac. Implants, 33(6): 1229-1239. doi: 10.11607/jomi.6921
20. Berberi, A., Maroun, D., Kanj, W., et al. (2016), *Micromovement evaluation of original and compatible abutments at the implant-abutment interface*, J Contemp. Dent. Pract. 17(11): 907-913. doi: 10.5005/jp-journals-10024-1952
21. Ilyasov, V., Mitin, N., Mishin, D., et al. (2020), *Study of temporary fixation materials on single orthopaedic structures by simulating chewing load*, Struct. Integ. Life, 20(2): 165-168.