

The influence of implant channel preparation technique on the mechanical and radiological properties of bone during the dental mini-implants placement (*ex-vivo* experimental study)

Bohdan G. Mykhajlychenko¹, Vladyslav O. Humeniuk¹, Iurii O. Mochalov², Ihor V. Tukalo²,
Tetiana M. Vakhrusheva³, Ihor O. Bilichenko³, Oleksandr O. Mochalov³

¹NATIONAL UNIVERSITY OF HEALTH CARE OF UKRAINE NAMED BY P. L. SHUPIK, KYIV, UKRAINE

²UZHGOROD NATIONAL UNIVERSITY, UZHGOROD, UKRAINE

³OBUKHIV CITY DENTAL POLYCLINIC, OBUKHIV, UKRAINE

ABSTRACT

Aim: To compare the mechanical and radiological properties of animal bone after preparation with different surgical protocols (including tissue compaction/densification).

Materials and Methods: Samples of animal bone tissue (porcine ribs) were prepared according to 4 protocols: osteotomic, compaction with a bone condenser, slow (50 rpm) and osteocondensation without special burrs. After preparation, the torque was measured and relative radiological density of the bone was examined using CBCT.

Results: The torque when using the slow protocol (50 rpm) was $35.82 \pm 5.10 \text{ N}\times\text{cm}$ ($M = 36.48$), with the standard osteotomic technique – $37.27 \pm 2.14 \text{ N}\times\text{cm}$ ($M = 37.40$), with the bone condensers – $46.57 \pm 2.72 \text{ N}\times\text{cm}$ ($M = 46.75$) and with osteodensification – $50.61 \pm 6.77 \text{ N}\times\text{cm}$ ($M = 50.16$). The lowest relative x-ray density of the walls of the implantation channel was when using the osteotomy protocol (1000 rpm) – $372.85 \pm 181.01 \text{ dHU}$ ($M = 374.00$), with the slow protocol – $538.75 \pm 167.82 \text{ dHU}$ ($M = 522.50$). Slightly higher values were obtained with the use of bone condensers – $602.18 \pm 263.42 \text{ dHU}$ ($M = 549.00$), and the highest was with osteodensification technique – $877.75 \pm 226.25 \text{ dHU}$ ($M = 862.50$).

Conclusions: The use of bone condensers and osteodensification techniques (even without special burrs) during the preparation of the implantation channel for mini-implants leads to progressive improvement of bone tissue.

KEY WORDS: dental implantation, preparation protocol, bone, x-ray, torque

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INTRODUCTION

Bone compaction techniques for implant channel preparation are relatively new and innovative techniques that can be used, including when installing mini-implants. Since the purpose of such bone processing techniques is to increase its density, which has a positive effect on the primary stabilization of the installed implants. Unlike traditional preparation (osteotomic preparation technique), in which bone fragments are removed and, accordingly, the mechanical properties of bone tissue in the area of operation may decrease, during densification, bone hardness increases, and its volume is also preserved [1-3]. The vast majority of manufacturers of mini-implant systems do not focus the user's attention on the osteodensification technique when using their products. Although from the very beginning, the surgical kits include surgical

burs for osteotomy bone preparation, as well as bone condensers or taps, which partially work according to the bone densification technique [4-6].

When using the osteodensification technique to prepare the channel for mini-implants, several advantages may be identified and to be achieved in the clinic. The first advantage is better primary stability, and this is the most important advantage. By densifying the bone, osteodensification provides a tighter fit of the implant, which leads to higher insertion torque values and reduced micromovement of the product. For mini-implants, the functioning of which is often highly dependent on primary stability due to their smaller diameter, this is a critical condition for successful osseointegration. Another advantage of densifying the wall of the implant channel is improved bone-implant contact. These techniques increase direct bone-implant

contact, which is important for the long-term success of the implantation [7,8].

Also, osteodensificative techniques can locally improve the quality of bone tissue, especially in areas with low density (for example, the distal parts of the maxilla, where there is a high risk of osteoplasia). This technique can make it possible to place a dental implant in areas that, with the classic osteotomy technique of bone bed preparation, would require more extensive procedures and prior bone grafting. Another advantage of densification techniques is the achievement of a slight widening of the alveolar ridge. These techniques can contribute to the widening of narrow alveolar ridges (which is a "pleasant" side effect). This modification of the alveolar ridge allows for the placement of wider mini-implants or even conventional implants in affected areas, without resorting to the more invasive technique of lateral bone augmentation. An additional advantage of the above treatment is the higher potential for accelerated healing and immediate loading of the superstructure. Better primary stability could potentially allow for earlier or even immediate loading of mini-implants, reducing the patient's rehabilitation period. Another advantage of densification techniques is the preservation of bone tissue. By densifying rather than removing bone, the patient's existing bone tissue is preserved, which is a significant advantage in cases where available bone is limited [6,9,10].

AIM

The aim of the study was to compare the mechanical and radiological properties of animal bone after its preparation using different surgical protocols (including tissue compaction).

MATERIALS AND METHODS

To perform this study, 6 samples of animal bone tissue (pork ribs) were used. Bones were purchased from a retail chain (the animals for this experiment were not slaughtered in a planned manner, but ready-made food products produced by industrial livestock were used). The bone tissue was skeletonized mechanically and cleaned using metal spatulas and disposable scalpel blades. Subsequently, the ribs were fixed in a vice, as perpendicular as possible to the ground surface. On the upper edge, at a distance of 1.5-2.0 cm from each other, marks were made using the XFD1135 pilot drill from the SlimOneBody XIFS dental implant surgical set (Dentium). Further, according to the markings, the implantation channel was prepared to a depth of 10.0 mm for mini-implants with a diameter

of 2.5 mm with the following options for speed, direction and type of instrument:

No 1 (standard protocol) – at a speed of 1000 rpm, clockwise with a maximum torque up to 35 N×cm, using surgical burs XFD1635 and XFD2135;

No 2 (compaction) – at a speed of 100 rpm, clockwise with a maximum torque up to 50 N×cm, using osteocondensers (crest expanders) RS201036R and RS251036R;

No 3 (slow) – at a speed of 50 rpm, clockwise with a maximum torque up to 50 N×cm, using surgical burs XFD1635 and XFD2135;

No 4 (osteodensification) – at a speed of 100 rpm, counterclockwise with a maximum torque up to 50 N×cm, using XFD1635 and XFD2135.

Before using the final surgical burs, all canals were prepared to a depth of 10.0 mm using the pilot bur XFD1635. After preparation using the XHDHT hand driver, XRA3917 adapter and XRCA1 ratchet wrench, IUS251510 dental mini-implants were inserted into the prepared canals. After insertion, the torque (primary stabilization) was measured using an XNTW torque wrench (maximum value – 70 N×cm. Each measurement was performed 6 times and then entered into spreadsheets. In spreadsheets, descriptive and comparative statistics methods were used to establish a significant difference between groups of values. After measurements, mini-implants were removed from the implantation channels, and bone tissue samples after applying metal tags were stored in a refrigerator at a temperature of 4-6°C.

Subsequently, cone-beam computed tomography (CBCT) studies of the samples were performed in CBCT scanner "ACTEON X-MIND prime 3D" (France). The results of the study were analyzed in the "ACTEON® Imaging Suite 3D" software (based on the Obukhiv City Dental Clinic, Kyiv reg., Ukraine), in which the conditional radiographic density of the bone tissue of the walls of the implant channel was determined. channel in dHU. Measurements around each channel were carried out 10 times, the results were entered into spreadsheets, where statistical data processing was performed. Statistical analysis of the obtained data was performed by using the Microsoft Excel 2016 in the form of simple table analysis, descriptive statistics, and comparative statistics (t-test by Student). The level of significance was established at a value of 0.05.

RESULTS

RESULTS OF MEASURING THE LEVEL OF PRIMARY STABILIZATION OF MINI-IMPLANTS WITH DIFFERENT PREPARATION PROTOCOLS

The measurements showed that different methods of preparation of the implant canal on the jaw

Table 1. Torque indicators of the installed mini-implant with different implant channel preparation protocols, N×cm

	1000 rpm	Condensing	50 rpm	Osseodensification
Average	37.27	46.57	35.82	50.61
Standard deviation, ±	2.14	2.72	5.10	6.77
Median	37.40	46.75	36.48	50.16
Min.	33.55	41.80	26.22	42.75
Max.	41.25	50.60	49.02	68.69

Source: compiled by the authors of this study

Table 2. Relative bone density indicators of the implant channel margins for a mini-implant with different preparation protocols, dHU

	1000 rpm	Condensing	50 rpm	Osseodensification
Average	372.85	602.18	538.75	877.75
Standard deviation, ±	181.01	263.42	167.82	226.25
Median	374.00	549.00	522.50	862.50
Min.	77.00	89.00	163.00	418.00
Max.	805.00	1332.00	908.00	1483.00

Source: compiled by the authors of this study

bone model at the final stage of mini-implant installation showed different torque force, which was directly proportional to the possible level of primary stabilization of the dental implant. Thus, the lowest level of torque was determined when using the slow preparation protocol (50 rpm) – 35.82 ± 5.10 N×cm ($M = 36.48$), the minimum value was 26.22 N×cm, and the maximum – 49.02 N×cm. With the standard preparation method (1000 rpm), the torque force was slightly higher – 37.27 ± 2.14 N×cm ($M = 37.40$). The minimum value was 33.55 N×cm, and the maximum – 41.25 N×cm. When using the bone condenser from the surgical kit, the torque values of the installed implant increased significantly. The average value was 46.57 ± 2.72 N×cm ($M = 46.75$). Also, the minimum and maximum values changed in the direction of increase – 41.80 N×cm and 50.60 N×cm, respectively (Table 1). The highest torque values on the bone tissue model were obtained when using the fourth bone canal preparation protocol (osteodensification). The average value was 50.61 ± 6.77 N×cm ($M = 50.16$) with a minimum of 42.75 N×cm and a maximum of 68.69 N×cm (almost the upper limit of the torque wrench measurement).

The results of the statistical calculations showed that there was a statistically significant difference ($p < 0.05$) in the torque values during implant insertion between protocols 1 and 2, protocols 1 and 4, protocols 2 and 3, protocols 2 and 4, and protocols 3 and 4. There was no statistically significant difference in the torque levels after the use of protocols 1 and 3. That is, both osteotomic techniques – both high-speed (1000 rpm) and slow (50 rpm) – did not lead to a real difference

in the torque force during the installation of a dental mini-implant.

RESULTS OF MEASUREMENT OF RELATIVE RADIOGRAPHIC BONE DENSITY IN DHU

The performed measurements showed more heterogeneous results than were obtained at the previous stage of the study. Indeed, different protocols for preparing the implant channel caused different changes in the structure of the bone tissue, which could be registered during the performance of the CBCT and the corresponding image analysis in the software. Thus, the lowest level of relative density of the walls of the implant channel was when using the standard high-speed osteotomy protocol (1000 rpm). It was 372.85 ± 181.01 dHU ($M = 374.00$), the minimum value was 77.00 dHU, and the maximum was 805.00 dHU. In the conditional second place in terms of relative radiographic tissue density were the channels prepared using the slow osteotomy protocol (No 3). The average value was 538.75 ± 167.82 dHU ($M = 522.50$). The minimum was 163.00 dHU, and the maximum was 908.00 dHU. Slightly higher values were found in the canal walls prepared using bone sealers (protocol No 2). Here, the average value was 602.18 ± 263.42 dHU ($M = 549.00$), the minimum value was 89.00 dHU, and the maximum was 1332.00 dHU. Finally, the highest values of the conditional radiographic density of the walls of the implant canals were achieved when using the fourth preparation protocol (osteodensification). In such zones, the average bone density was 877.75 ± 226.25 dHU ($M =$

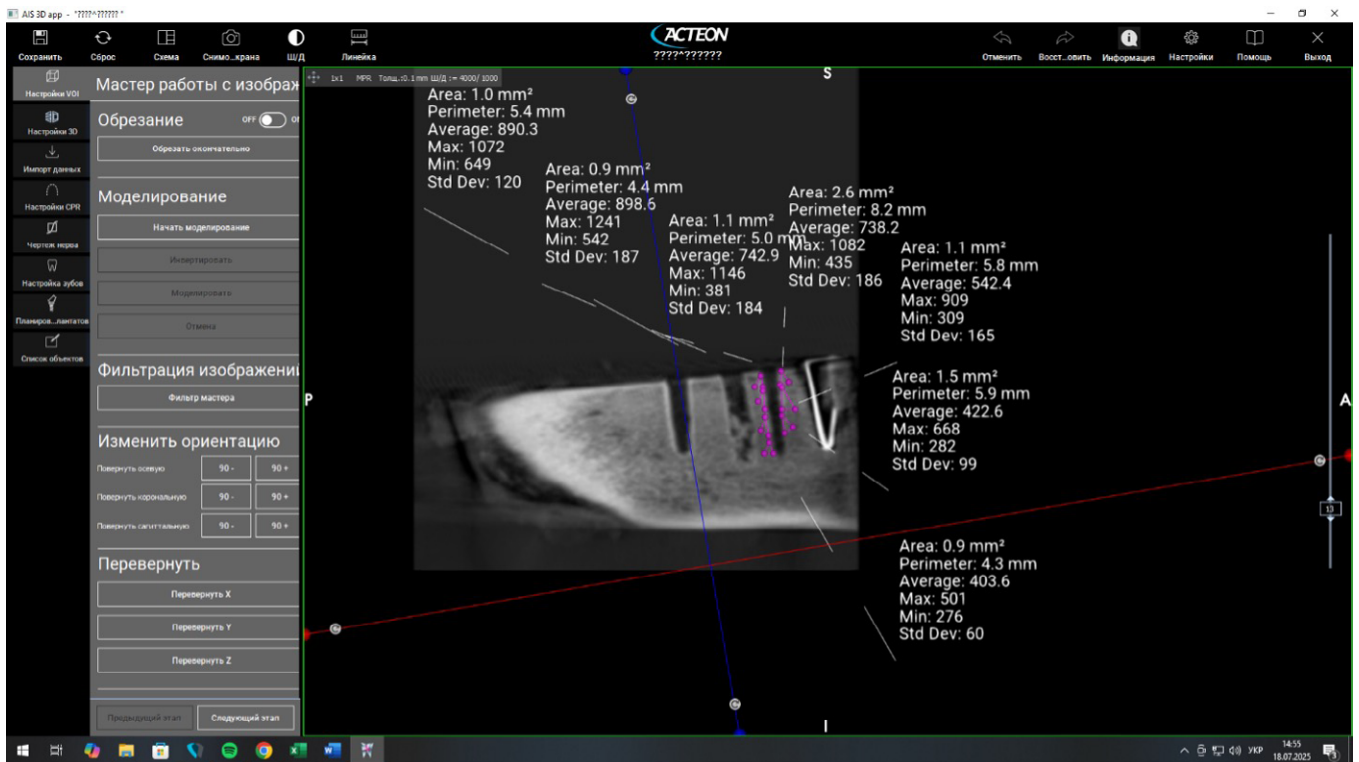


Fig. 1. Determination of the relative radiographic density of the walls of implant channels in the AIS 3D Acteon program environment
Picture taken by the authors

862.50); the minimum value was 418.00 dHU, and the maximum was 1483.00 dHU (Table 2)

The results of statistical calculations showed that the difference in the values between different protocols was significant ($p < 0.05$) in such compared pairs as Protocol 1/ Protocol 2, Protocol 1/Protocol 3, Protocol 1/Protocol 4, Protocol 2/Protocol 4 and Protocol 3/Protocol 4. The difference was insignificant in the relative radiological density of the walls of the implantation channel after the use of Protocol 2 and Protocol 3. That is, the level of bone density on the CBCT when using special sealants and the slow osteotomy protocol was similar. It is important to note that almost all preparation methods modified bone density to varying degrees (Fig. 1).

DISCUSSION

The data we obtained show that the use of bone condensers and osteodensification techniques leads to a progressive change in bone tissue in the area of the future implant canal. It is these two methods of preparation that allow a significant increase in the torque during the installation of a dental mini-implant, as well as an increase in the relative radiographic density of the prepared tissue. It is worth noting that a progressive change in the properties of bone tissue was achieved without the use of special

osteodensification burs. But only by changing the direction and speed of tissue preparation using a conventional bur for osteotomy preparation. As the results of similar studies show, bone densification itself is, in fact, a polishing process that redistributes material on the surface by plastic deformation. Counterclockwise rotation of the bur causes the edges to slide along the bone surface with a compressive force less than the ultimate strength of the bone. Since fresh, hydrated trabecular bone is a plastic material, it has a good capacity for plastic deformation. The irrigation fluid and the tissue fluid content of the bone itself assist this process by creating a lubricating film between the two surfaces to reduce friction and more evenly distribute compressive forces [11,12].

Morphological studies of the results of the osseodensification technique show that the most peculiar feature of the bone healing pattern is observed at the level of the more coronal cortical walls, where the bone acquires an unusual granular appearance. In these areas, osteoid tissue strands, osteons, and newly formed bone become visible. Also, the bone trabeculae in the treatment area demonstrate a specific granular appearance also in the inner part, while lamellar bone layers are visible on the outer side. It is believed that these bone trabeculae thicken due to the inclusion of autogenous bone fragments in the regenerate during the healing process. The granules in the trabeculae appear as nuclei of mineralization. Next

to these granules, interwoven bone areas are observed, mixed with lamellar bone [13,14].

The percentage of the bone surface lined with osteoid bands in the coronal region is much higher than in other areas around the implant canal. The increase in bone density is especially noticeable in the most coronal region. Along with this, bone chips and resorption of newly formed trabeculae are observed. It has been established that active bone remodeling is directed more towards bone attachment and increasing bone density than towards bone resorption. And such detected phenomena may indicate that in the long term, bone can still increase its density [7,13,14].

CONCLUSIONS

Thus, the use of bone condensers and osteodensification techniques in the preparation of the implant channel for mini-implants leads to a progressive change in the bone tissue in the area of future implantation, even without the use of special osteodensification burs. These preparation methods allow to increase the torque during the installation of a dental mini-implant (by 25% when using bone condensers and by 34% when using the osseodensification technique), and also increase the relative radiological density of the prepared tissue under the control of CBCT (by 47% and 130% in dHU, respectively).

REFERENCES

1. Huwais S, Meyer E. A novel osseous densification approach in implant osteotomy preparation to increase biomechanical primary stability, bone mineral density, and bone-to-implant contact. *Int J Oral Maxillofac Implants*. 2017;32:27–36. doi: 10.11607/jomi.4817. DOI
2. Frizzera F, Spin-Neto R, Padilha V. Effect of osseodensification on the increase in ridge thickness and the prevention of buccal peri-implant defects: an in vitro randomized split mouth pilot study. *BMC Oral Health*. 2022;22(1): 233. doi:10.1186/s1290302202242x. DOI
3. Tsuperiak SS, Mochalov IO. Pokaznyky renthenohrafichnoyi shchil'nosti kistkovoyi tkanyiny pislya vykorystannya riznykh khirurhichnykh protokoliv dental'noyi implantatsiyi. [The Indicators of X-ray Density of Bone Tissue after using the Different Surgical Protocols of Dental Implantation]. *Suchasna stomatolohiya*. 2023;1–2: 46–54. doi: 10.33295/1992576X20231246. (Ukrainian) DOI
4. Pellegrino G, Zaccheroni Z, Tayeb S et al. Flapless Mini Implants Immediately Loaded for Full-Arch Overdenture Rehabilitation: An Up-To-15-Year Retrospective Study. *Clin Oral Implants Res*. 2025. doi: 10.1111/clr.70017. DOI
5. Duraisamy R, Ganapathy DM, Rajeshkumar S, Ashok V. Mini-Implants in Dentistry – A Review. *J Long Term Eff Med Implants*. 2022;32(3):29–37. doi: 10.1615/JLongTermEffMedImplants.2022041814. DOI
6. Khubchandani SR, Dahane T, Dubey SA. Osseodensification: An Innovative Technique With Manifold Gains. *Cureus*. 2024;16(5):e60255. doi: 10.7759/cureus.60255. DOI
7. Bandela V, Shetty N, Munagapati B et al. Comparative Evaluation of Osseodensification Versus Conventional Osteotomy Technique on Dental Implant Primary Stability: An Ex Vivo Study. *Cureus*. 2022;14(10): e30843. doi: 10.7759/cureus.30843. DOI
8. Cáceres F, Troncoso C, Silva R, Pinto N. Effects of osseodensification protocol on insertion, removal torques, and resonance frequency analysis of BioHorizons® conical implants. An ex vivo study. *J Oral Biol Craniofac Res*. 2020;10(4):625–628. doi: 10.1016/j.jobcr.2020.08.019. DOI
9. Jarikian S, Jaafar MH, Al-Nerabieah Z. Clinical Evaluation of Two Techniques for Narrow Alveolar Ridge Expansion: Clinical Study. *Int. J. Dent. Oral Sci*. 2021;8:1047–1052. doi: 10.19070/2377-8075-21000264. DOI
10. Oliveira PGFP, Bergamo ETP, Neiva R et al. Osseodensification Outperforms Conventional Implant Subtractive Instrumentation: A study in sheep. *Mater. Sci. Eng. C Mater. Biol. Appl*. 2018;90:300–307. doi: 10.1016/j.msec.2018.04.051. DOI
11. Vaddamanu SK, Saini RS, Vyas R et al. A comparative study on bone density before and after implant placement using osseodensification technique: a clinical evaluation. *Int J Implant Dent*. 2024;10(1):56. doi: 10.1186/s40729-024-00565-8. DOI
12. Gayathri S. Osseodensification Technique – A Novel Bone Preservation Method to Enhance Implant Stability. *Acta Scientific Dental Sciences*. 2018;2(12):17–22.
13. Balasaheb S, Vidyapeeth MB, Lulla S et al. Enhancing Implant Stability With Osseodensification – A Review. *International Journal of Current Medical and Pharmaceutical Research*. 2019;5:4280–4284. doi: 10.24327/23956429.ijcmpr201906675. DOI
14. Slete FB, Olin P, Prasad H. Histomorphometric Comparison of 3 osteotomy techniques. *Implant. Dent*. 2018;27:424–428. doi: 10.1097/ID.000000000000076. DOI

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

Iurii O. Mochalov

Uzhhorod National University

16A Universytetska St., 88015 Uzhhorod, Ukraine

e-mail: yuriy.mochalov@uzhnu.edu.ua

ORCID AND CONTRIBUTIONSHIP

Bohdan G. Mykhajlychenko: 0009-0007-0001-1921 **B C D**

Vladyslav O. Humeniuk: 0009-0001-9384-678X **B C D**

Iurii O. Mochalov: 0000-0002-5654-1725 **A E F**

Ihor V. Tukalo: 0000-0002-8431-8133 **B C D**

Tetiana M. Vakhrusheva: 0009-0008-1212-5034 **B C E**

Ihor O. Bilichenko: 0009-0004-9225-8515 **B C E**

Oleksandr O. Mochalov: 0009-0003-1326-0717 **B C**

A – Work concept and design, **B** – Data collection and analysis, **C** – Responsibility for statistical analysis, **D** – Writing the article, **E** – Critical review, **F** – Final approval of the article

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