PHYSICS AND CHEMISTRY OF SOLID STATE
V. 24, No. 4 (2023) pp. 722-728

Section: Technology

DOI: 10.15330/pcss.24.4.722-728

Vasyl Stefanyk Precarpathian National University

ФІЗИКА І ХІМІЯ ТВЕРДОГО ТІЛА
Т. 24, № 4 (2023) С. 722-728

Технічні науки

UDC 681.3; 616.314 ISSN 1729-4428

B.S. Dzundza[1], Y.S. Yavorsky[1], V.V. Fedoriuk[2], M.M. Rozhko[2], U.M. Pysklynets[2], O.I. Bulbuk[2]

Hardware and software for automated examination of defects of hard tissues of teeth after endodontic intervention for fatigue and destruction

[1]*Vasyl Stefanyk Precarpathian National University, Ivano-Frankivsk, Ukraine, bohdan.dzundza@pnu.edu.ua*
[2]*Ivano-Frankivsk National Medical University, Ivano-Frankivsk, Ukraine*

The work developed circuit engineering, design and software of the loading machine for automated examination of dental hard tissue defects after endodontics intervention for fatigue and destruction. The advantage of this development is the combination as cyclic loading methods simulating chewing movements and force effects on compression in a compact small-sized case, with low power consumption and small noise level. Thanks to the use of a screw transmission and a stepper motor in combination with a sensitive tensoresistive force sensor, it was possible to achieve high accuracy and resolution of 0.1 microns.

A series of tests was conducted on real samples of endodontically treated teeth restored using fiberglass pins and cast metal stump inserts. It is shown that methods of restoring incisors and premolars of the upper jaw with the help of fiberglass pins have an advantage when the residual structure of the tooth is lacking due to a more uniform distribution of deformation stresses, since their elastic modulus is close to the elastic modulus of dentin.

Keywords: loading machine, automation, tooth restoration, fiberglass pin, cast metal stump tab.

Received 29 August 2023; Accepted 14 December 2023.

Introduction

Currently, the rapid development of electronics and information technology is causing the emergence of new tools and creates additional opportunities for clinical and laboratory research. In particular, in recent years, there has been an active discussion on the effectiveness of the use of intracanal pins in endodontic treatment in dentistry. The literature [1-3] shows that the pins do not strengthen the tooth, moreover, the preparation procedures remove additional healthy tooth structures, thus weakening the tooth and increasing the risk of root fractures [4,5]. In other clinical and laboratory studies, the positive influence of the introduction of fiberglass pins was noted, which helped to improve the distribution of stresses, since their elastic modulus is close to the elastic modulus of dentin [6,7]. Currently, the concept of minimal invasiveness of adhesive restorations is being followed, as studies have shown that the amount of axial dentin surrounded by a crown is more important than the length of the pin [8], so short pins have been evaluated as an effective alternative to traditional pins [9-10]. But there are not enough studies on this problem, in particular, only a few studies conducted cyclic fatigue tests [11,12], and the conclusions were mainly based solely on static compression tests [13,14]. In the above works, during the research, automated means for cyclic studies and separately load-bursting test machines were used, which are dimensional and little adapted for such tasks. Cyclic fatigue tests are quite long and time-consuming, so the development of hardware and software for the automated study of defects in hard tissues of teeth after endodontic intervention for fatigue and destruction is relevant. The authors have considerable experience in developing automated laboratory tools for physical research [15-18]. The purpose of the work is to develop hardware and software to ensure complete automated cycling of laboratory studies of teeth both for fatigue from cyclic loads and for destruction under a single load.

I. Software and hardware development

Software and hardware design is divided into a number of stages, each of which solves specific development tasks. In particular, at the first stage, the design of mechanics and kinematics was carried out, which makes it possible to both conduct cyclic fatigue tests and single force loads on destruction. In order to achieve high positioning accuracy, a screw pair is selected for linear movement. The pitch of the lead screw is 2 mm. The lead screw is fixedly connected to the platform moving up and down along two linear cylindrical guides on sliding bearings. If you loosen the bearings so that they can move in a given direction, then simultaneously with the vertical movement it will be possible to move in the horizontal plane, which will occur under the influence of the rotational forces of the screw, which makes it possible to more accurately simulate chewing movements. Also, horizontal movement can be defined by a linear guide profile. The running nut with the gear pulley is fixed from vertical movements to the housing by means of two radial-stop bearings, and is driven in rotary motion by means of a step motor and a gear train with a reduction factor of 1:5. The object table is fixedly fixed to the update through the strain gauge load sensor CZL-601 a force of up to 1000 N.

The limit of 1000 N is sufficient both for cyclic loads on fatigue where forces usually do not exceed 100 N and power loads on destruction and made it possible to develop a universal desktop small-sized laboratory setup, the dimensions of which do not exceed (W x D x H) - 140x180x300 mm with a mass of - 8 kg. Strain measurement limits are 0... 100 mm.

The stepper motor provides the required load force accuracy and fluff speed of 0.5 mm/min to 300 mm/min. The stepper motor driver supports step crushing and allows you to choose from 200 steps per turn to 6400 steps per turn, and current from 0.7 to 4 A.

The body of the installation is cut from steel by laser cutting, which ensured the accuracy of geometric dimensions.

The second stage was the development of structural and circuit diagram, as well as software. The structural diagram of the unit is shown in fig. 1.

To ensure the operation of the strain gauge sensor and digitize the signal from it, a specialized 24-bit ADC was used, which has a software-controlled gain factor and can produce up to 80 readings per second, which made it possible to ensure the passport accuracy of the tensor. In general, the measurement error does not exceed 1%. Four character display and encoder are used for indication and control. Communication with the computer is implemented on the basis of a hardware UART microcontroller. General view of the unit is shown in fig. 2.

The program for the microcontroller AtMega168 written in the language C. The menu interface provides manual control, as well as an automated experiment with specified parameters, in particular the number of cycles, the maximum force to which to load, speed, exposure time under load and without load. Data on movement and pressure force are transmitted to the computer for their visual display in the form of graphs and transferred to Exel for further processing.

II. Methods of sample preparation and research

Intact teeth removed according to periodontal indications in the surgical department of the IFNMU dentistry center were used for the study. The time from tooth extraction to the time of the study did not exceed four weeks.

Studies were conducted in the following groups of teeth:

1st group - Endodontically treated teeth, the root canal is sealed with a fiberglass pin, 1-2 mm of the crown part height is preserved in the teeth, the tooth stump is restored with a composite material.

2nd group - Endodontically treated teeth, the root canal is sealed with a fiberglass pin, the teeth are destroyed at the gum level without maintaining the height of the crown part, the tooth stump is restored with a composite material.

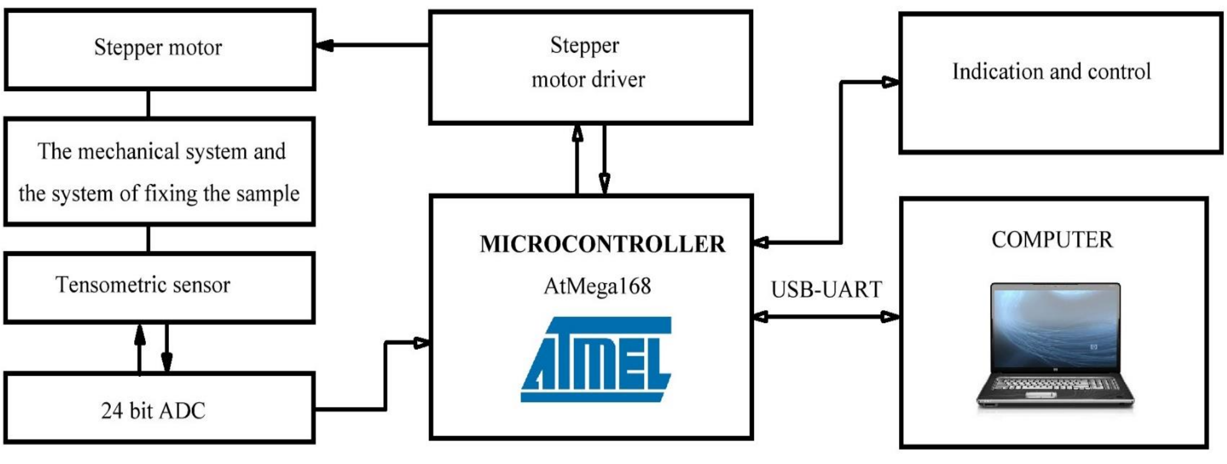

Fig. 1. Structural diagram of the setup for the automated examination of endodontically treated teeth for fatigue and destruction.

Fig. 2. General view of the setup.

3rd group - Endodontically treated teeth, 1-2 mm of the crown part height is preserved in the teeth, the tooth stump is restored with a cast metal stump tab.

4th group - Endodontically treated teeth, teeth destroyed at the level of the gums without maintaining the height of the crown part, the tooth stump is restored with a cast metal stump tab.

Endodontic treatment and preparation of teeth was carried out according to a standardized method. The tooth crown was prepared according to the parameters specified in each study group. Restoration was carried out with glass fiber pins (Glassix glass fibre composite posts) (Nordin), which were fixed with glass inomer cement (RIVA Self cure). In the crown part, the tooth was made of stump from composite (Sagen Balance), and cast metal stump inserts were used, which were fixed with glass-inomer cement (RIVA Self cure) (Fig. 3).

The finished sample was placed in a block of self-hardening plastic (Remont-03) and epoxy glue (PENOSIL Epoxy Fix Coat 507) so that the load was transmitted at specified angles with respect to the tooth.

III. The results of the experiment and their discussion

To determine how cyclic loads affected the strength of the samples, a portion of the test samples were subjected to cyclic fatigue loads. After that, all samples were subjected to force loads for destruction. This made it possible to determine the effect of cyclic fatigue on the strength of the structure. The presence of plastic deformations was determined by the shape of the curve in accordance with Fig. 4. [14], and differences between the course of the loading and unloading curve.

All samples withstood a 10-time vertical load of 500 N without visible damage and plastic deformation (Fig. 5.), The curve is sufficiently linear, indicating the elastic nature of the deformation.

After 1500 cycles of deformation with a vertical load of 100 N, sample of group number 2 could not withstand a load of 500 N, the destruction occurred sharply, which indicates the high rigidity of the sample (Fig. 6).

Fig. 3. General view of test specimens at different stages of preparation.

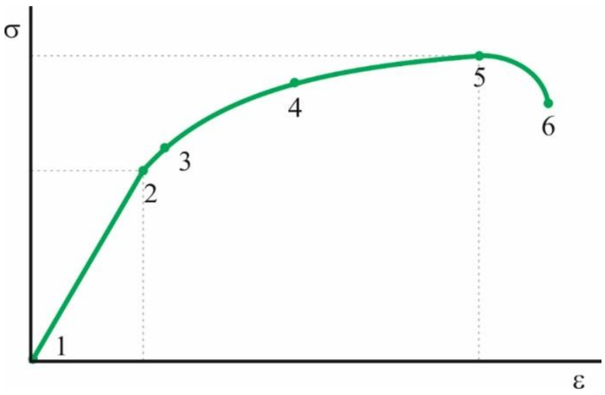

Fig. 4. Schematic representation of the deformation diaphragm. The stress is shown in the function of deformation: 1 is the limit of true elasticity; 2 – the limit of proportionality; 3 – elasticity limit; 4 – yield point; 5 – ultimate strength; 6 – destruction.

It testifies that for samples of group number 2 where teeth are destroyed at the level of gums without preservation of height of a crown part the expressed linearity of deformations with sharp destruction already at vertical loadings of about 500 N is characteristic. Teeth of other three groups do vertical load withstand.

At loads of teeth placed at an angle of 35-40 degrees from the vertical axis, samples recovered by cast metal stump inserts (3,4 group), slower deformation and higher indices of destructive force were observed compared to samples recovered by glass fiber pins and artificial stump from composite materials (1,2 group). In particular, samples from the first group where the root canal is sealed with a fiberglass pin showed significantly less strength under side loads (Fig. 7) than similar samples from the third group restored with a cast metal stump insert (Fig. 8). The amount of the preserved height of the crown part of the tooth also significantly affects its strength, in particular, a sample from the first group with a preserved height of the crown part of the tooth 1.5 mm (F1.5) withstood 20% more load than a similar sample with a preserved height of the crown part of the tooth 1 mm (F1) (Fig. 7).

Figure 9. shows the results of tooth destruction, we see a slightly different nature of destruction. The teeth of the root canal of which is sealed with a fiberglass pin receive longitudinal cracks, and the teeth of the stump of which are restored with a cast metal stump tab break in the transverse direction.

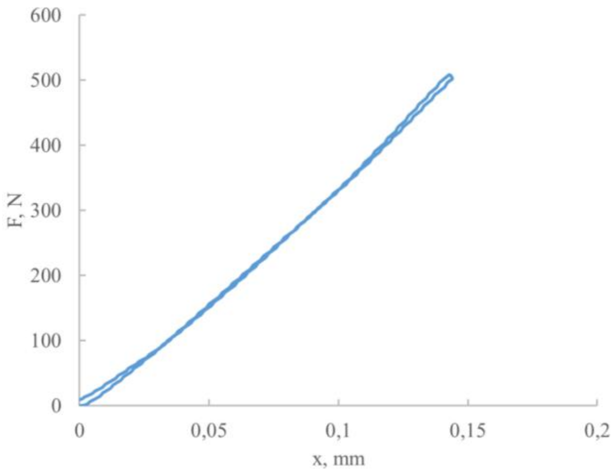

Fig. 5. Diagram of the vertical load of the F1m sample (first group).

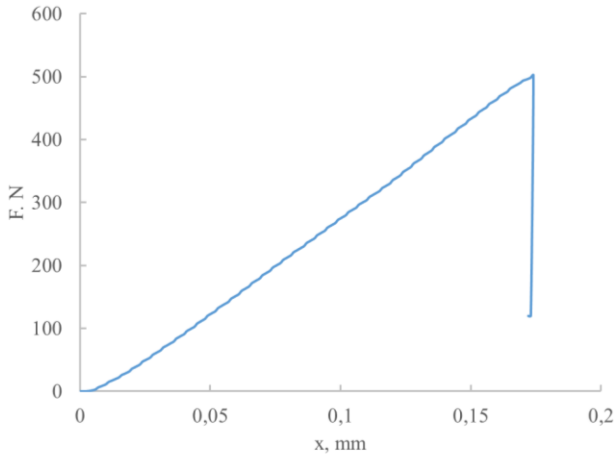

Fig. 6. Diagram of the vertical load of the F0 sample (second group).

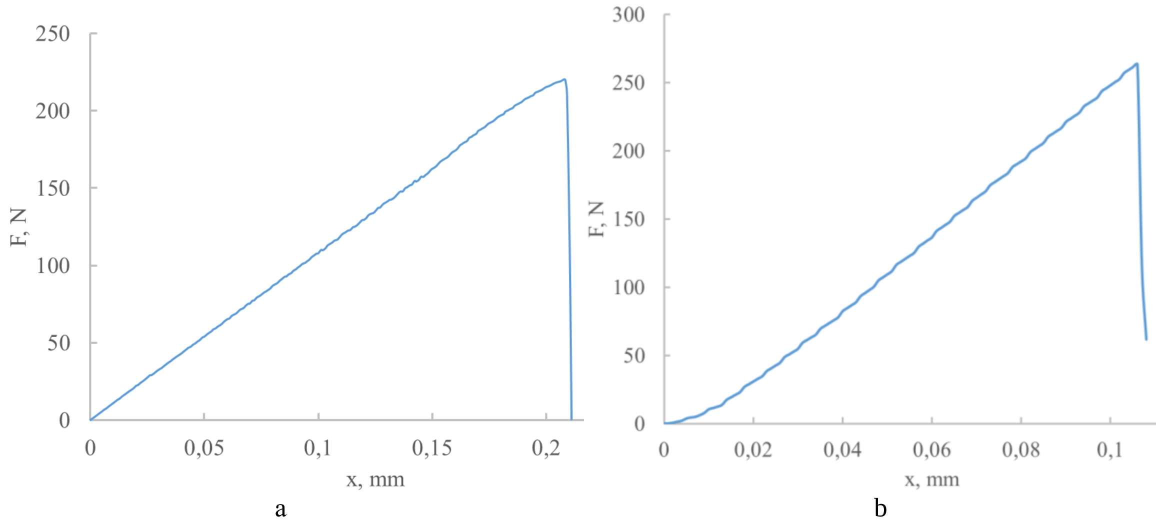

Fig. 7. Load diagram at an angle of 35 degrees relative to the vertical axis of the sample F1m and F1.5 (first group).

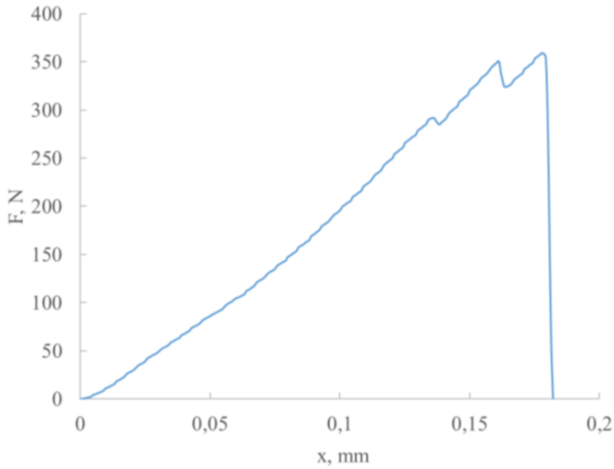

Fig. 8. Load diagram at an angle of 37 degrees relative to the vertical axis of sample F2 (the third group, the saved height of the crown part of the tooth is 2 mm).

a b

Fig. 9. Results of destruction: the root canal is sealed with a fiberglass pin (a) and the tooth stump is restored with a cast metal stump insert (b).

In all groups of maximum deformation under loads, incisors and premolars of the upper jaw were subjected, where the molars withstood all maximum loads and did not suffer damage, for this type of teeth additional studies with higher force loads are required.

Samples of incisors and premolars of the upper jaw of teeth restored using fiberglass pins showed a more uniform deformation curve (Fig. 5), since the elastic modulus of the pins is close to the elastic modulus of dentin. The volume and properties of the fiberglass pin material are recovered by an artificial composite stump having a greater degree of strain under loads and a lesser degree when using a cast metal stump insert. Also of some importance is the methods of choosing the fixation of a fiberglass pin and an artificial stump.

When comparing samples of all groups, a significant decrease in the strength and increase in deformation of samples with defects in hard tissues destroyed at the gum level is noticeable, which may indicate the preservation of the height of the crown part of the tooth (ferula effect) in sizes of 1-2 mm gives significantly better indicators for deformation and destruction.

Conclusions

The design, circuitry and software of the setup for automated study of defects in hard tissues of teeth after endodontic intervention for fatigue and destruction have been developed. The advantages of this development are a combination of both cyclic loading methods that emulate chewing movements and force effects on compression in a compact small-sized case, with low power consumption and low noise level. Thanks to the use of precise mechanics in combination with a sensitive tensoresistive force sensor, it was possible to achieve a high resolution of 0.1 microns and minimize the error, which does not exceed 1%.

A series of tests was conducted on real samples of teeth restored using fiberglass pins and cast metal stump inserts. It is shown that samples of cutters and premolars of the upper jaw of the stump of which are restored with a cast metal stump insert withstand slightly greater loads than those restored with fiberglass pins, but such a restoration has some advantages due to a more uniform distribution of deformation stresses, since the elastic modulus of fiberglass pins is close to the elastic modulus of dentin. Such advantages are insignificant and the main role in the strength against deformation and destruction of endodontically treated teeth is the preservation of the height of the crown part of the tooth.

Dzundza B.S. – PhD, Associate Professor;
Yavorskyi J.S. – PhD, Associate Professor;
Fedoriuk V.V. – PhD, student;
Rozhko M.M. – Doctor of Sciences, Professor
Pisklynets U.M. – PhD, Associate Professor
Bulbuk O.I. – PhD, Associate Professor.

[1] M. Trope, I. Langer, D. Maltz, L. Tronstad, *Resistance tofracture of restored endodontically treated premolars,* Endodontics and Dental Traumatology, 2, 35 (1986); https://doi.org/10.1111/j.1600-9657.1986.tb00120.x.
[2] J.A. Sorensen, J.T. Martinoff, *Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth.* Journal of Prosthetic Dentistry, 51, 780 (1984); https://doi.org/10.1016/0022-3913(84)90376-7.
[3] W.A. Fokkinga, C.M. Kreulen, P.K. Vallittu, N.H. Creugers, *A structured analysis of in vitro failure loads and failure modes of fiber, metal, and ceramic post-and-core systems,* International Journal of Prosthodontics, 17(476), 82 (2004).
[4] H.P. Bolhuis, A.J. De Gee, A.J. Feilzer, C.L. Davidson, *Fracture strength of different core build-up designs,* American Journal of Dentistry, 14(5), 286 (2001).
[5] K.E. Manning, D.C. Yu, H.C. Yu, E.W. Kwan, *Factors to consider for predictable post and core build-ups of endodontically treated teeth. Part II: Clinical application of basic concepts,* Journal of Canadian Dental Association, 61, 696 (1995).
[6] F. Monticelli, C. Goracci, M. Ferrari. *Micromorphology of the fiber post-resin core unit: a scanning electron microscopy evaluation,* Dent Mat., 20, 176 (2004); http://doi.org/10.1016/S0109-5641(03)00089-7.
[7] S. Toksavul, M. Zor, M. Toman, M.A. Gungor, I. Nergiz, C. Artung, *Analysis of dentinal stress distribution of maxillary central incisors subjected to various post-and-core applications*, Oper Dent., 31, 89 (2006); https://doi.org/10.2341/04-192.
[8] M. Schmitter, P. Rammelsberg, J. Lenz, S. Scheuber, K. Schweizerhof, S. Rues. *Teeth restored using fiberreinforced posts: in vitro fracture tests and finite element analysis*, Acta Biomaterialia, 6(3747), 54 (2010); https://doi.org/10.1016/j.actbio.2010.03.012.
[9] L. Buttel, G. Krastl, H. Lorch, M. Naumann, N.U. Zitzmann, R. Weiger, *Influence of post fit and post length on fracture resistance.* International Endodontic Journal, 42, 47 (2009); https://doi.org/10.1111/j.1365-2591.2008.01492.x.
[10] J. Nissan, E. Barnea, D. Carmon, M. Gross, D. Assif, *Effect of reduced post length on the resistance to fracture of crowned, endodontically treated teeth.* Quintessence International, 39,179 (2008).
[11] F. Zicari, B. Van Meerbeek, R. Scotti, I. Naert, *Effect of ferrule and post placement on fracture resistance of endodontically treated teeth after fatigue loading,* Journal of dentistry, 41, 207 (2013); https://doi.org/10.1016/j.jdent.2012.10.004.
[12] Haneef Sherfudhin, Joseph Hobeich, Carlos Augusto Carvalho, Moustafa N. Aboushelib, Walid Sadig, Ziad Salameh, *Effect of different ferrule designs on the fracture resistance and failure pattern of endodontically ceramic crowns*, J Appl Oral Sci., 19(1), 28 (2011); https://doi.org/10.1590/s1678-77572011000100007.
[13] S. Garoushi, P.K. Vallittu, L.V. Lassila, *Continuous and short fiber reinforced composite in root post-core system of severely damaged incisors,* Open Dental Journal, 3, 36 (2009); https://doi.org/10.2174%2F1874210600903010036.
[14] A. V. Borisenko, P. Koidis, A. A. Savichuk, Influence of the design and material of in-channel pins on the mechanical characteristics of restored endodontically treated mandibular incisors. Modern dentistry, 1, 23 (2013).
[15] R. Dunets, B. Dzundza, M. Deichakivskyi, A. Terletsky, O. Poplavskyi, *Methods of computer tools development for measuring and analysis of electrical properties of semiconductor films*, Eastern-European Journal of Enterprise Technologies, 1(9-103), 32 (2020); https://doi.org/10.15587/1729-4061.2020.195253.
[16] M.A. Ruvinskii, O.B. Kostyuk, B.S. Dzundza, I.P. Yaremiy, M.L. Mokhnatskyi, Ya.S. Yavorskyy, *Kinetic phenomena and thermoelectric properties of polycrystalline thin films based on PbSnAgTe compounds*, Journal of Nano- and Electronic Physics, 9(5), 05004 (2017); https://doi.org/10.21272/jnep.9(5).05004.
[17] B.S. Dzundza, I.T. Kohut, V.I. Holota, L.V. Turovska, M.V. Deichakivskyi, *Principles of construction of hybrid microsystems for biomedical applications,* Physics and Chemistry of Solid State, 23(4), 776 (2022); https://doi.org/10.15330/pcss.23.4.776-784.
[18] B.S. Dzundza. Software and hardware complex for research of thermoelectric properties of semiconductor structures. Patent of Ukraine for the invention No. 126766, Application No. a201910764, publication date: 02/02/2023.

Б.С. Дзундза[1], Я.С. Яворський[1], В.В. Федорюк[2], М.М. Рожко[2] ,У.М. Писклинець[2], О.В. Бульбук[2]

Апаратно-програмні засоби для автоматизованого дослідження дефектів твердих тканин зубів після ендодонтичного втручання на втому та руйнування

[1]Прикарпатський національний університет імені Василя Стефаника, м. Івано-Франківськ, Україна, *bohdan.dzundza@pnu.edu.ua*
[2]Івано-Франківський національний медичний університет, м. Івано-Франківськ, Україна

В роботі розроблено схемотехніку, конструкцію та програмне забезпечення навантажувальної машини для автоматизованого дослідження дефектів твердих тканин зубів після ендодонтичнго втручання на втому та руйнування. Перевагою даної розробки є поєднання як циклічних методів навантаження що симулюють жувальні рухи так і силових впливів на стиск в компактному малогабаритному корпусі, з невеликим енергоспоживанням та малим рівнем шуму. Завдяки застосуванню гвинтової передачі та крокового двигуна у поєднанні з чутливим тензорезистивним давачем сили вдалося досягнути високої точності та роздільної здатності в 0,1 мкм.

Проведено серію випробувань на реальних зразках ендодонтично оброблених зубів відновлених за допомогою скловолоконних штифтів і литих металевих куксових вкладок. Показано, що способи відновлення різців та премолярів верхньої щелепи за допомогою скловолоконних штифтів мають перевагу при недостачі залишкової структури зуба завдяки більш рівномірному розподілу деформаційних напруг, оскільки їхній модуль пружності близький модулю пружності дентину.

Ключові слова: навантажувальна машина, автоматизація, реставрація зуба, скловолоконний штифт, лита металева куксова вкладка.