HARNESSING THE POWER OF LASER DOPPLER FLOWMETRY OF TOOTH PULP AND DENSITOMETRY AT DENTAL CARIES

Satsita Supyanovna Maskaeva[1], Mizan Suleymanovna Yusupova[1], Rustam Vakhidovich Kagaev[1], Liana Tahuzovna Ahmadova[1], Karina Ruslanovna Kushkarova[1], Adam Uddievich Dashaev[1], Polina Aleksandrovna Shchetinina[2], Asker Aslanovich Akkuev[3*]

[1]Department of Therapy, Faculty of Medicine, North Ossetian State Medical Academy, Vladikavkaz, Republic of North Ossetia-Alania, Russia.
[2]Department of Therapy, Faculty of Medicine, Stavropol State Medical University, Stavropol, Russia.
[3]Department of Dentistry, Institute of Dentistry and Maxillofacial Surgery, Kabardino-Balkarian State University named after H.M. Berbekov, Nalchik, Republic of Kabardino-Balkaria, Russia. bucky99@yandex.ru

ABSTRACT

The article reveals the indicators of Laser Doppler Flowmetry of the tooth pulp and densitometry in young people aged 20-30, with dentine caries. 106 teeth of the chewing group of the upper and lower jaw were examined (30 intact teeth and 86 teeth with dentin caries). The indicators of Laser Doppler Flowmetry of the tooth pulp and densitometry of teeth affected by dentine caries (class II according to Black) were determined. A significant decrease in the densitometric parameters of the dentin of teeth affected by caries, as well as a significant increase in the parameters of Laser Doppler Flowmetry of the tooth pulp in dentin caries, was determined. According to the data of Laser Doppler Flowmetry of the tooth pulp, an improvement in blood circulation parameters was determined in both groups. However, in group 1, the indicators were unreliable, and in group 2, after 12 months, the level of capillary blood flow (M) improved by 1.3 times, the intensity of blood flow (σ) increased by 1.5 times, the vasomotor activity of microvessels (KV) - by 1.9 times, and also approached the norm.

Key words: Caries of dentin, Densitometry, Optical density, Radiovisiography, Laser Doppler Flowmetry.

Introduction

Currently, dental caries affects almost the entire population of the planet, which determines its not only clinical but also social significance [1-3]. In Russia, the prevalence of caries among the adult population, depending on the region, ranges from 80% to 100% [4]. Despite the successes achieved in the treatment and prevention of caries, the percentage of its complications remains high [5, 6]. The treatment of caries depends on the nature of changes in the hard tissues of the tooth and pulp. Currently, the problem of dental caries treatment has not been completely solved [7].

The use of classical forms of caries diagnosis is not always effective and informative enough. Various methods are used for additional diagnosis of caries: X-ray, electrodontometric, transilluminative, densitometric, and others [8-11].

X-ray examination is an important additional method of diagnosing caries and its complications [12, 13]. In some cases, an X-ray image can reveal a carious lesion in the complete absence of its clinical manifestations [14]. The carious lesion of dentin on the X-ray looks like an area of enlightenment in the corresponding area of the tooth crown [15, 16]. The absence of a defect in the hard tissues of the tooth on the X-ray is not a 100% guarantee that there is no carious lesion in this tooth [14]. This is because the diagnostic information content of X-ray (including radiovisiographic) examination is limited in some cases [17,

18]. This method does not allow for the identification of carious lesions of the enamel, in addition, difficulties may arise with carious lesions of the surface layers of the dentin of the tooth, as well as when superimposing images of teeth on each other [19, 20].

Another method of diagnosing latent caries is transillumination – the translucence of the tooth crown with a bright light stream [21, 22]. In this case, the foci of carious lesions form a shadow visible when examining the tooth from the opposite side [23, 24]. The most effective use of this technique in the study of the frontal group of teeth makes it possible to identify enamel cracks and assess the condition of tooth tissues around previously applied fillings, but if caries affects the lateral teeth, transillumination is not so effective [25, 26].

The method of objective analysis of the optical density of tooth tissues for the diagnosis of hidden foci of carious lesions is based on the analysis of the optical properties of tooth tissues when irradiated with pulsed laser radiation [27, 28]. The detection of foci of carious lesions is based on the fact that in these areas there is a change in the optical properties of tooth tissues. The device allows to assessment of the condition of tooth tissues that are inaccessible during probing and visual examination [29]. It allows you to diagnose latent fissure and approximal caries, recurrent caries along the edge of the filling, as well as identify and control the dynamics of foci of enamel demineralization.

The disadvantage of the method is the high cost of the device [30-35].

Electrodontometry is also used to diagnose caries, based on determining the threshold of pulp sensitivity to electric current [36]. The disadvantage of the method is that the digital indicators of the result depend on the patient's age, his mental state, the excitability of his nervous system; on strict observance of the basics of electrometric research. Electrodontometry allows for a quantitative assessment but is not an objective method [37-41].

An important diagnostic method is the densitometric method, which combines various methods of image acquisition, its quantitative analysis, the main task of which is to determine the mineral density of the bone tissue of the object [42]. The advantages of densitometric radiovisiography are high sensitivity, computer data processing, fast image acquisition on the monitor, and the ability to identify and isolate tissues of the same density using color saturation [43]. Optical densitometry provides an objective assessment of the results and effectiveness of the treatment [44]. To analyze the data of densitometry of dental tissues affected by caries, it is necessary to have comparative indicators of the norm that we determined earlier [45].

In recent years, with the introduction of new technologies, it has become possible to assess the hemodynamics of blood flow in tissues, including in the tooth pulp by Laser Doppler Flowmetry (LDF) [46]. Laser Doppler Flowmetry provides a detailed analysis of the state of microcirculation in the area of the pathological focus, based on the isolation of rhythmic components of hemodynamic flows in tissues [47]. This method allows us to obtain maximum information about violations of the regulatory mechanisms of blood flow in the microcirculatory bed, which are subject to correction [48]. Having a high sensitivity to changes in microhemodynamics, the Laser Doppler Flowmetry method has an undeniable advantage over other methods of studying microcirculation, since it allows us to assess the state of functioning of blood flow control mechanisms [49]. In this regard, the study of Laser Doppler Flowmetry indicators of dental pulp is an urgent problem in practical dentistry [50-55].

The purpose of the study. Determination of the parameters of Laser Doppler Flowmetry of the tooth pulp and densitometry in young people with dentine caries.

Materials and Methods

The study was conducted on young patients aged 21-30 years who applied to the state budgetary healthcare institution Dental Polyclinic in Nalchik (Republic of Kabardino-Balkaria, Russia), with dentine caries, grade II in Black and a low caries prevalence index [56, 57].

Based on the clinical examination, two groups were formed: a control group, where the dentin of 30 intact teeth was examined, and a main group, in which 86 teeth with dentin caries were examined [58-68].

Densitometric studies were performed on RVG images. The densitometric parameters of intact teeth were determined at points A and B. Point A is located at the intersection of a straight line d passing 1.5 mm above the tops of the pulp horns perpendicular to the axis of the tooth and a straight line passing vertically along the top of the pulp horn [69]. Point B is located at the intersection of a straight line with a parallel straight-line d 1.5 mm below the vertices of the pulp horns and a straight line b running perpendicular to the straight line c between the straight line a and point E, which is the border of the tooth (**Figure 1**). The data of the densitometric indicators at point A were 132.5 ± 3.7 conventional units at point B 136.8 ± 4.4 conventional units, which we took as normal indicators.
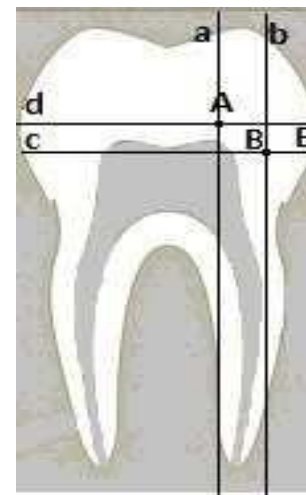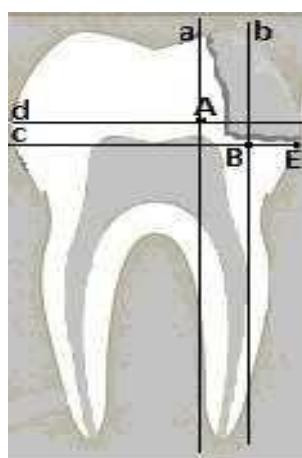

Figure 1. Image of schematic points of dentin density of intact teeth

The microcirculation of the tooth pulp was studied using a computerized laser analyzer of capillary blood flow LAKK-02 (Russia). Before examining the microcirculation of the tooth pulp, hardware compensation of the signal level due to the color of the tooth and affecting the magnitude of the signal received directly from the pulp was performed. To do this, a light guide in a black elastic nozzle was installed in the upper third of the crown of the tooth under study and a biological zero was obtained in the device by automatic subtraction [70, 71]. After that, the light guide probe was installed perpendicular to the buccal surface of the tooth in the cervical region 2 mm above the gingival margin in the zone of the crown part of the pulp [67, 72, 73]. The installation of a light guide probe was carried out without pronounced pressure on the tooth to avoid the reaction of periodontal vessels closely related to the vascular system of the tooth pulp. A useful signal of fluctuations in blood flow in the microcirculatory bed of the pulp was found, an LDF gram was recorded for 3-5 minutes and its subsequent processing was carried out automatically. After registering the LDF-grams, the average statistical values of the

flowmetry (signal amplitudes at the output of the device) are displayed on the monitor: the value of the average blood perfusion flow (M) in the registration time interval, the standard deviation (σ) and the integral index of variations (KV) of this process. Statistical processing was performed in the Statistica v.12.0 software package.

Results and Discussion

Densitometric indicators of teeth affected by dentin caries, according to class II, were also determined at points A and B (**Figure 2**). At point A, the indicators were 98.9 ± 1.6 conventional units, and at point B - 95.8± 2.0 conventional units (**Figure 3**). The data obtained indicate a significant decrease in densitometric parameters in dental caries compared with normal values (p 0.01).

Figure 2. Image of schematic points of dentine density of teeth affected by caries
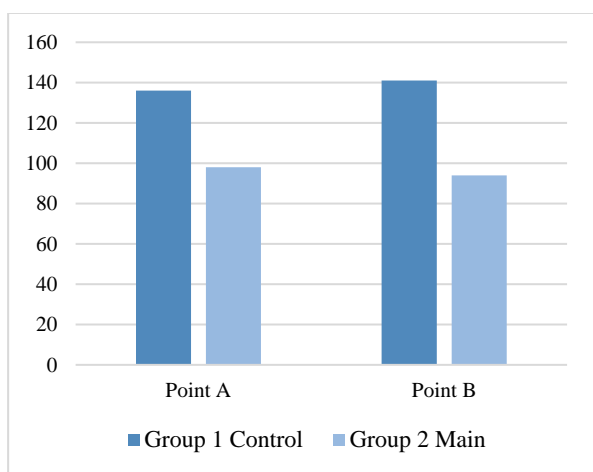
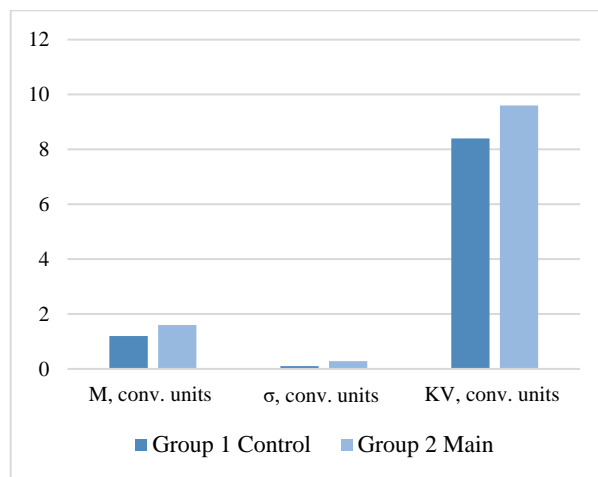**Figure 3.** Indicators of dentin densitometry of teeth affected by caries

The indicators of microcirculation and rhythmic components of the amplitude-frequency spectrum of LDF-grams are shown in **Table 1**.

Table 1. Indicators of microcirculation and rhythmic components of the amplitude-frequency spectrum of LDF-grams

Patient groups	LDF-gram indicators (conditional units)	
Control	M	1.3±0.07
	σ	0.11±0.03
	KV	5.7±0.12
Main	M	1.78±0.42*
	σ	0.16±0.03*
	KV	8.13±1.23*

Note: The reliability of the differences about the norm was p*<0.05; <0.01.

According to the table, it can be seen that in dentin caries, the level of capillary blood flow (M), blood flow intensity (σ), and vasomotor activity of microvessels (KV) is significantly higher compared with the indicators of intact teeth (**Figure 4**) [74, 75].

Figure 4. Indicators of microcirculation and rhythmic components of the amplitude-frequency spectrum of LDF-grams

The examined patients had carious cavities with localization of cavities according to the II Black class. Short-term pain from mechanical and thermal stimuli was observed, which quickly passed after its elimination [76]. When probing, the soreness was noted throughout the bottom of the carious cavity, percussion was painless. The indicator of electrodontodiagnostics from the bottom of the carious cavity on the examined teeth with dentin caries was on average 11.8± 0.8 µA. Next, a densitometric study was performed. The criteria previously developed by us were taken as indicators of the norm, at point A – 132.5 ± 3.7 conventional units, and at point B – 136.8 ±4.4 conventional units. The dynamics of densitometric parameters of patients with dentin caries, depending on the treatment method, are shown in **Table 2**.

Table 2. Dynamics of dentin densitometric parameters in patients of groups 1 and 2, depending on the treatment method

Treatment status	Normal indicators, conventional units		Group 1 Control, conventional units		Group 2 Main, conventional units	
	Point A	Point B	Point A	Point B	Point A	Point B
Before treatment	132.5±3.7	136.8±4.4	96.6±3.1*	95.7±2.2*	96.8±3.3*	95.8±2.0*
6 months after treatment	132.5±3.7	136.8±4.4	98.9±1.2**	103.1±1.4**	113.5±4.0**	112.6±2.7**
12 months after treatment	132.5±3.7	136.8±4.4	103.1±1.4***	102.9±2.9***	130.5±4.1***	129.9±3.5***

Note: Reliability in relation to the indicators of the norm ($p^* > 0.05$). The reliability of the indicators compared with the initial data after treatment after 6 months ($p^{**} < 0.05$), and after 12 months ($p^{***} < 0.01$).

According to **Table 2**, it can be seen that in group 1, after 6 and 12 months, the densitometric parameters at points A and B changed slightly [77]. In group 2, there were significant changes in densitometric indicators: after 6 months at point A, they improved by 16.7±0.7 conventional units, at point B – by 16.8±0.7 conventional units; after 12 months at point A – by 33.7 ±0.8 conventional units, at point B – by 34.1 ±1.5 conventional units (p0.05; 0.01) and approached the indicators of the norm.

The dynamics of microcirculation and rhythmic components of the amplitude-frequency spectrum of LDF-grams in patients with dentin caries, depending on the treatment method, are reflected in **Table 3** [78-82]. The following indicators were taken as normal: the level of capillary blood flow (M) within 1.31±0.07 conventional units, the intensity of blood flow (σ) – 0.11±0.03 conventional units, the vasomotor activity of microvessels (KV) within 5.71±0.12 conventional units [12, 13, 82-84]. According to **Table 3**, it can be seen that in group 1, changes in relation to the norm occur less pronounced than in group 2 – a significant improvement in Laser Doppler Flowmetry was determined after 12 months (p0.01).

Table 3. Indicators of microcirculation and rhythmic components of the amplitude-frequency spectrum of LDF-grams in patients with dentin caries of groups 1 and 2, depending on the treatment method

Treatment status	Normal indicators			Group 1 Control			Group 2 Main		
	M	σ	KV	M	σ	KV	M	σ	KV
Before treatment	1.31±0.07	0.11±0.03	5.71±0.12	1.76±0.41*	0.16±0.03*	8.13±1.23*	1.78±0.43*	0.17±0.03*	8.19±1.12*
6 months after treatment	1.31±0.07	0.11±0.03	5.71±0.12	1.63±0.17**	0.15±0.05**	7.22±1.11**	1.51±0.03**	0.13±0.07**	6.37±0.13**
12 months after treatment	1.31±0.07	0.11±0.03	5.71±0.12	1.52±0.12***	0.14±0.06***	6.26±1.12***	1.36±0.06***	0.11±0.11***	4.31±0.09***

Note: Reliability in relation to the indicators of the norm ($p^* > 0.05$). The reliability of the indicators compared with the initial data after treatment after 6 months ($p^{**} < 0.05$), and after 12 months ($p^{***} < 0.01$).

According to the data of densitometric analysis using the method of radiovisiography, a decrease in indicators at point A was determined by 1.3 times, at point B by 1.4 times, which indicates a significant decrease in the density of dentin of teeth affected by caries [13, 15-17]. According to the LDF data, a significant increase in indicators was obtained by 1.4 times, which indicated an increase in tissue perfusion with blood and a violation in the microcirculatory bed of the tooth pulp [18, 23, 24]. The data obtained should be taken into account when choosing a treatment method and monitoring the therapy.

Conclusion

Based on the data of densitometric analysis, the improvement of indicators in both groups was determined.

However, in group 1, the densitometric indicators increased unreliably, in group 2, after 6 months at points A and B, they increased by 1.2 times; after 12 months at points A and B, they increased by about 1.3 times and approached the norm. According to the data of Laser Doppler Flowmetry of the tooth pulp, an improvement in blood circulation parameters was determined in both groups. However, in group 1, the indicators were unreliable, and in group 2, after 12 months, the level of capillary blood flow (M) improved by 1.3 times, the intensity of blood flow (σ) increased by 1.5 times, the vasomotor activity of microvessels (KV) – by 1.9 times, and also approached the norm. Thus, the complex treatment of dentin caries using a preparation from brown algae and low-intensity laser radiation is effective, which is confirmed by the data of dentin densitometry and Laser Doppler Flowmetry of the tooth pulp.

References

1. Uribe SE, Innes N, Maldupa I. The global prevalence of early childhood caries: A systematic review with meta-analysis using the WHO diagnostic criteria. Int J Paediatr Dent. 2021;31(6):817-30. doi:10.1111/ipd.12783

2. Borg-Bartolo R, Roccuzzo A, Molinero-Mourelle P, Schimmel M, Gambetta-Tessini K, Chaurasia A, et al. Global prevalence of edentulism and dental caries in middle-aged and elderly persons: A systematic review and meta-analysis. J Dent. 2022;127:104335. doi:10.1016/j.jdent.2022.104335

3. Pelevin SI, Taubaev BD, Baklanov IS. Problem of technogenic society dynamics under the conditions of contemporaneity. Int J Civ Eng Technol. 2018;9(11):2437-43.

4. Kalashnikova NP, Avraamova OG, Kulajenko TV, Goryacheva VV, Khokhlova SV. Modern instrumental methods for early diagnosis of dental caries. Stomatologiia (Mosk). 2022;101(1):89-95. [Russian]. doi:10.17116/stomat202210101189

5. Askar H, Krois J, Göstemeyer G, Bottenberg P, Zero D, Banerjee A, et al. Secondary caries: What is it, and how it can be controlled, detected, and managed? Clin Oral Investig. 2020;24(5):1869-76. doi:10.1007/s00784-020-03268-7

6. Clark D, Levin L. In the dental implant era, why do we still bother saving teeth? Dent Traumatol. 2019;35(6):368-75. doi:10.1111/edt.12492

7. Cheng L, Zhang L, Yue L, Ling J, Fan M, Yang D, et al. Expert consensus on dental caries management. Int J Oral Sci. 2022;14(1):17. doi:10.1038/s41368-022-00167-3

8. Warreth A. Dental caries and its management. Int J Dent. 2023;2023(1):9365845. doi:10.1155/2023/9365845

9. Lin WS, Alfaraj A, Lippert F, Yang CC. Performance of the caries diagnosis feature of intraoral scanners and near-infrared imaging technology-A narrative review. J Prosthodont. 2023;32(S2):114-24. doi:10.1111/jopr.13770

10. Abdelaziz M. Detection, diagnosis, and monitoring of early caries: The future of individualized dental care. Diagnostics (Basel). 2023;13(24):3649. doi:10.3390/diagnostics13243649

11. Esiev RK, Samvelyan AA, Kliukina EI, Gazaryants VA, Abdurakhmanova BS, Garibyan VS, et al. Investigation of the effectiveness of nano impregnation of dentine tubules with a molecular complex of copper hydroxyapatite. J Med Pharm Chem Res. 2024;7(1):42-50. doi:10.48309/jmpcr.2025.457568.1244

12. Alharthi NS. Endocannabinoid system components: A crucial role in the regulation of disease. J Adv Pharm Educ Res. 2022;12(3-2022):72-81.

13. Lee JH. Factors affecting the academic performance of low-and high-performing dental students: Evidence from Japan. J Adv Pharm Educ Res. 2022;12(3-2022):82-6.

14. Wenzel A. Radiographic modalities for diagnosis of caries in a historical perspective: From film to machine-intelligence supported systems. Dentomaxillofac Radiol. 2021;50(5):20210010. doi:10.1259/dmfr.20210010

15. malki G, Rabah S, Al-Faifi Z, Alharbi A, Sharma M. Phytochemistry screening, antioxidant and antimicrobial activities of euphorbia inarticulata schweinf plant extract. Pharmacophore. 2022;13(1-2022):91-9.

16. Attavar S. An overview of the antimicrobial effect of natural irrigants in disinfection of root canal system. Pharmacophore. 2022;13(1-2022):79-82.

17. Nabavi SS, Gholizadeh B. Evaluation of the quality of life of the patients with heart failure in Ahvaz teaching hospitals. Entomol Appl Sci Lett. 2022;9(1-2022):26-30.

18. Alsubeie MS. Morphology and molecular study of Cassia angustifolia Vahl. in Saudi Arabia using RAPD technique. Entomol Appl Sci Lett. 2022;9(2-2022):11-6.

19. Vanella V, Castagnola R, Marigo L, Grande NM, Plotino G. A comparison of near-infrared imaging with other diagnostic tools for dental caries. Minerva Dent Oral Sci. 2021;70(5):214-22. doi:10.23736/S2724-6329.21.04527-7

20. Dzugutova K, Kozyreva Z, Mekhtieva K, Bertaev B, Agkatsev A, Zaseev R, et al. Experimental in vivo evaluation of the activity of hydroxyapatite modified with selenium nanoparticles against caries in laboratory animals. J Med Pharm Chem Res. 2024;7(1):89-97. doi:10.48309/jmpcr.2025.457522.1243

21. Blinov AV, Siddiqui SA, Blinova AA, Khramtsov AG, Oboturova NP, Nagdalian AA, et al. Analysis of the dispersed composition of milk using photon correlation spectroscopy. J Food Compos Anal. 2022;108:104414. doi:10.1016/j.jfca.2022.104414

22. Adams SJ, Henderson RDE, Yi X, Babyn P. Artificial intelligence solutions for analysis of X-ray images. Can Assoc Radiol J. 2021;72(1):60-72. doi:10.1177/0846537120941671

23. Saif A, Khan TM, Bukhsh A, Alsultan SM, Saif A, Baig MR, et al. Prevalence and associated factors of

self-medication with antibiotics worldwide: A systematic review. Arch Pharm Pract. 2024;15(4):25-38.

24. Usmaev BV, Kagermanov AT, Al-Rawashdeh MB, Shuaipova MM, Bestaeva KA, Arshieva VA, et al. Investigation of pharmacological and wound-healing properties of zinc oxide nanoparticles. Arch Pharm Pract. 2024;15(4):10-4.

25. Maddalena L, Pozzi P, Ceffa NG, Hoeven BVD, Carroll EC. Optogenetics and light-sheet microscopy. 2023 Feb 21. In: Papagiakoumou E, editor. All-Optical Methods to Study Neuronal Function [Internet]. New York: Humana; 2023. Chapter 8.

26. Perdigão J, Araujo E, Ramos RQ, Gomes G, Pizzolotto L. Adhesive dentistry: Current concepts and clinical considerations. J Esthet Restor Dent. 2021;33(1):51-68. doi:10.1111/jerd.12692

27. Marmaneu-Menero A, Iranzo-Cortés JE, Almerich-Torres T, Ortolá-Síscar JC, Montiel-Company JM, Almerich-Silla JM. Diagnostic validity of digital imaging fiber-optic transillumination (DIFOTI) and near-infrared light transillumination (NILT) for caries in dentine. J Clin Med. 2020;9(2):420. doi:10.3390/jcm9020420

28. Lavrenyuk EA, Wagner VD, Voitsekhovskaya OS. The impact of laser radiation on the effectiveness of therapeutic treatment of dental patients. Stomatologiia (Mosk). 2024;103(2):86-90. [Russian]. doi:10.17116/stomat202410302186

29. Yoon S, Jung HJ, Knowles JC, Lee HH. Digital image correlation in dental materials and related research: A review. Dent Mater. 2021;37(5):758-71. doi:10.1016/j.dental.2021.02.024

30. Omondi EA, Kegode AA. The role of physicochemical pretreatment in lignocellulosic biomass energy valorisation–A review. World J Environ Biosci. 2023;12(3):7-19.

31. Padma KR, Don KR, Dinesh B, Karthikeyan D. Antibiotics are current approaches to improve productivity using soil microbiome. World J Environ Biosci. 2023;12(3):33-9.

32. Bate GB, Adeleye AO, Ijanu EM, Olalere EO, Amoo AO, Asaju CI, et al. Quality assessment of wastewater: Physicochemical and bacteriological evidence from dutse abattoir, North-West Nigeria. World J Environ Biosci. 2023;12(3):58-66.

33. Obisesan OO, Egbetokun OA. Climate change impacts, food security, intra-africa trade and sustainable land governance on food systems in Africa. World J Environ Biosci. 2024;13(3):39-50.

34. Nagdalian A, Askerova A, Blinov A, Shariati MA. Evaluation of the toxicity of copper oxide nanoparticles toward pea seeds. World J Environ Biosci. 2024;13(3):23-30.

35. Ewuzie SR, Chuks-Aginam NC, Uronnachi EM. Evaluation of anti-inflammatory activity of a topical cream containing ocimum gratissimum and cucurbita seed oil. World J Environ Biosci. 2024;13(3):16-22.

36. Patro S, Meto A, Mohanty A, Chopra V, Miglani S, Das A, et al. Diagnostic accuracy of pulp vitality tests and pulp sensibility tests for assessing pulpal health in permanent teeth: A systematic review and meta-analysis. Int J Environ Res Public Health. 2022;19(15):9599. doi:10.3390/ijerph19159599

37. Chandra S, Meel RK. A systematic comparative study of morinda tinctoria and vitex negundo for their anti-ulcerogenic potential. World J Environ Biosci. 2022;11(1):45-52.

38. Shehata MA, AlDawsari AA, Saeedi AH, lbrahim AlAyshan M, Saleh MA, Koshak HA, et al. Acute coronary syndrome diagnosis & management approach in emergency department: Literature review. World J Environ Biosci. 2022;11(2):61-4.

39. Das SK, Karan S, Sen K. Biodiversity of avifauna in Chilkigarh, Jhargram, West Bengal, India. World J Environ Biosci. 2022;11(3):8-13.

40. Elsayed A, Humaidan MF, Hawsawi AO, Muammar MF, AlZahrani AA, Albarrak BA, AlJarrash YR, ALZahrani SM, AlZahrani OM, AlYateem SN, AlAzmi MA. Review on pulmonary embolism diagnosis and management approach. World J Environ Biosci. 2022;11(3):45-9.

41. Naseri B, Safaee D. Rust, weather & wheat yield yellow rust, wheat cultivar, and weather conditions are influencing crop yield. World J Environ Biosci. 2023;12(3):20-6.

42. Gazzotti S, Aparisi Gómez MP, Schileo E, Taddei F, Sangiorgi L, Fusaro M, et al. High-resolution peripheral quantitative computed tomography: Research or clinical practice? Br J Radiol. 2023;96(1150):20221016. doi:10.1259/bjr.20221016

43. Rzhepakovsky I, Piskov S, Avanesyan S, Shakhbanov M, Sizonenko M, Timchenko L, et al. High-performance microcomputing tomography of chick embryo in the early stages of embryogenesis. Appl Sci. 2023;13(19):10642. doi:10.3390/app131910642

44. Gani LU, Sritara C, Blank RD, Chen W, Gilmour J, Dhaliwal R, et al. Follow-up bone mineral density testing: 2023 Official positions of the international society for clinical densitometry. J Clin Densitom. 2024;27(1):101440. doi:10.1016/j.jocd.2023.101440

45. Ulivieri FM, Rinaudo L. Beyond bone mineral density: A new dual X-Ray absorptiometry index of bone strength to predict fragility fractures, the bone strain index. Front Med (Lausanne). 2021;7:590139. doi:10.3389/fmed.2020.590139

46. Afkhami F, Wright PP, Chien PY, Xu C, Walsh LJ, Peters OA. Exploring approaches to pulp vitality assessment: A scoping review of nontraditional methods. Int Endod J. 2024;57(8):1065-98. doi:10.1111/iej.14073

47. Schraven SP, Dohr D, Weiss NM, Mlynski R, Dalhoff E. Laser Doppler vibrometric measurements on human temporal bones. HNO. 2021;69(6):491-500. [German]. doi:10.1007/s00106-021-00995-5

48. Schonberger ZG, Huang SJY, Thakkar RN, Mamone AA, Khan DI, Chow NLY, et al. Assessments of perfusion, blood flow, and vascular structure in ambulatory subjects: Guidance for translational research scientists. J Vasc Res. 2023;60(1):12-68. doi:10.1159/000527765

49. Herrick AL, Dinsdale G, Murray A. New perspectives in the imaging of Raynaud's phenomenon. Eur J Rheumatol. 2020;7(Suppl 3):S212-21. doi:10.5152/eurjrheum.2020.19124

50. Alshehri FS, Alotaibi FF, Alghanim NS, Almutairi FT, Alsuwailem HS, Darwish EG, et al. Status epilepticus diagnostic and management approach in emergency department. World J Environ Biosci. 2022;11(1):30-3.

51. Alsayed MA, Alhassan OM, Alzahrany AM, Mutanbak HI, Alamoudi AA, Eid SM, et al. An overview on lumbar disc herniation on surgical management approach. World J Environ Biosci. 2022;11(1):24-9.

52. Alqurashi AM, Jawmin SA, Althobaiti TA, Aladwani MN, Almuebid AM, Alharbi JF, et al. An overview on nasal polyps' diagnosis and management approach. World J Environ Biosci. 2022;11(1):13-6.

53. Kunder H, Gurusiddappa LH, Hanumanthappa BS, Kalikeri S. Antimicrobial activity and phytochemical analysis of solvent extraction of citrus reticulata peels. World J Environ Biosci. 2022;11(2):20-5.

54. Madhukar CV. Production of potential bio-compost from household and market waste vegetables for the improvement of plant growth. World J Environ Biosci. 2022;11(2):15-9.

55. Natarajan GP, Venkataraman SM, Pitchamuthu S, Rengaraj M. Impact of silicon seed priming on osmoregulants, antioxidants, and seedling growth of maize grown under chemo-stress. World J Environ Biosci. 2022;11(2):1-7.

56. Jablonski-Momeni A, Korbmacher-Steiner H. Assessment of carious dental lesions and treatment options: Comparison of the knowledge of dental students and orthodontic assistants. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2023;66(12):1389-96. [German]. doi:10.1007/s00103-023-03799-w

57. Warreth A, Abuhijleh E, Almaghribi MA, Mahwal G, Ashawish A. Tooth surface loss: A review of literature. Saudi Dent J. 2020;32(2):53-60. doi:10.1016/j.sdentj.2019.09.004

58. Moses MP. CHATGPT4 (AI) shaping the future of medical laboratory sciences by improving teaching, learning, and assessment. J Adv Pharm Educ Res. 2024;14(1):52-5.

59. Husein N, Qaralleh H, Al-Tarawneh A, AlSarayreh A, Al Qaisi Y, Al-limoun M, et al. Modeling phenol biodegradation with Pantoea agglomerans as plant-growth-promoting bacteria. J Adv Pharm Educ Res. 2024;14(2):63-71.

60. Aldossary KM. Awareness and attitude towards premenstrual syndrome among foundation year students at princess nourah university: Cross-sectional study. J Adv Pharm Educ Res. 2024;14(2):97-102.

61. Molas-Tuneu M, Briones-Buixassa L, Díaz L, Pérez H, Berrocoso S, Naudó-Molist J, et al. Perception of care and emotional impact of perinatal women during COVID-19: A multicenter study. J Adv Pharm Educ Res. 2024;14(2):1-0.

62. Saliev T, Tanabayeva S, Ussebayeva N, Izmailova S, Umbayev B, Akhanov G, et al. In vitro cytotoxicity and antiviral activity of aminocaproic acid against SARS-CoV-2. J Adv Pharm Educ Res. 2024;14(3):1-8.

63. Sayuti NA, Rusita YD. Traditional medicinal herbs for healthiness and fitness during the Covid-19 pandemic in Indonesia: Literature review. J Adv Pharm Educ Res. 2023;13(1):80-92.

64. Salih OS, Al-Akkam EJ. Pharmacokinetic parameters of ondansetron in rats after oral solution and transdermal invasomes gel: A comparison study. J Adv Pharm Educ Res. 2023;13(1):116-21.

65. Nguyen TD, Khuu LM, Nguyen TK, Nguyen TD. Research on the treatment of settling sediments in the production process of Ich mau extracts. J Adv Pharm Educ Res. 2023;13(1):134-41.

66. Kusumawardani LA, Andrajati R, Lathifatuzahra F, Yusuf RA, Azzahrini FL, Ardhianti IF. Prescribing and patient care indicators for drug use evaluation at primary healthcare centers in Indonesia. J Adv Pharm Educ Res. 2023;13(2):53-8.

67. Kokoeva LM, Kumacheva DD, Dzhalagonia TB, Mikhailova AI, Kamyshova AA, Moiseenko MP, et al. Analysis of the effectiveness of complex pharmacotherapy using antibacterial agents and immunomodulators for bronchial pneumonia. J Adv Pharm Educ Res. 2023;13(2):99-106.

68. Cahyaningsih I, Hikmah N, Maziyyah N. Drug-related problems in elderly patients with diabetes: A study in primary health care setting. J Adv Pharm Educ Res. 2023;13(2):29-34.

69. Abbott PV, Lin S. Tooth resorption-Part 2: A clinical classification. Dent Traumatol. 2022;38(4):267-85. doi:10.1111/edt.12762

70. Yan L, Yu Y, Yang B, Fu W, Zhang Z, Jia B, et al. Semi-automatic computed tomography angiography quantification assessment is an alternative method to digital subtraction angiography in intracranial stenosis: A multicenter study. Quant Imaging Med Surg. 2024;14(6):3970-82. doi:10.21037/qims-23-1343

71. Podgorsak AR, Rava RA, Shiraz Bhurwani MM, Chandra AR, Davies JM, Siddiqui AH, et al. Automatic radiomic feature extraction using deep learning for angiographic parametric imaging of intracranial aneurysms. J Neurointerv Surg. 2020;12(4):417-21. doi:10.1136/neurintsurg-2019-015214

72. Sari CP, Hanifah S, Yulianto Y, Medisa D, Nafiah Z, Lutfi MA. Improvement in knowledge and perception about the controlling of COVID-19: Best practice of

apothecary student. J Adv Pharm Educ Res. 2023;13(2):6-11.

73. Aldhairyan AH, Alyami SS, Alsaad AM, Al Shuqayfah NI, Alotaibi NA, Mujammami NM, et al. Gastroesophageal reflux disease: Diagnosis and management approach, literature review. World J Environ Biosci. 2022;11(1):1-3.

74. AlMogbel AA, Albarrak MI, AlNumair SF. Ozone therapy in the management and prevention of caries. Cureus. 2023;15(4):e37510. doi:10.7759/cureus.37510

75. Tregub PP, Averchuk AS, Baranich TI, Ryazanova MV, Salmina AB. Physiological and pathological remodeling of cerebral microvessels. Int J Mol Sci. 2022;23(20):12683. doi:10.3390/ijms232012683

76. Malcangi G, Patano A, Guglielmo M, Sardano R, Palmieri G, Di Pede C, et al. Precision medicine in oral health and diseases: A systematic review. J Pers Med. 2023;13(5):725. doi:10.3390/jpm13050725

77. Chandran M, Bilezikian JP, Lau J, Rajeev R, Yang SP, Samuel M, et al. The efficacy and safety of cinacalcet in primary hyperparathyroidism: A systematic review and meta-analysis of randomized controlled trials and cohort studies. Rev Endocr Metab Disord. 2022;23(3):485-501. doi:10.1007/s11154-021-09694-6

78. Chandler NP, Pitt Ford TR, Monteith BD. Laser light passage through restored and carious posterior teeth. J Oral Rehabil. 2014;41(8):630-4. doi:10.1111/joor.12173

79. Chandler NP, Pitt Ford TR, Watson TF. Pattern of transmission of laser light through carious molar teeth. Int Endod J. 2001;34(7):526-32. doi:10.1046/j.1365-2591.2001.00428.x

80. Mendelson AA, Ho E, Scott S, Vijay R, Hunter T, Milkovich S, et al. Capillary module haemodynamics and mechanisms of blood flow regulation in skeletal muscle capillary networks: Experimental and computational analysis. J Physiol. 2022;600(8):1867-88. doi:10.1113/JP282342

81. Moga RA, Cosgarea R, Buru SM, Chiorean CG. Finite element analysis of the dental pulp under orthodontic forces. Am J Orthod Dentofacial Orthop. 2019;155(4):543-51. doi:10.1016/j.ajodo.2018.05.018

82. Belcheva A, Shindova M, Hanna R. Efficacy of laser doppler flowmetry, as a diagnostic tool in assessing pulp vitality of traumatised teeth: A split mouth clinical study. J Pers Med. 2021;11(8):801. doi:10.3390/jpm11080801

83. Neves-Silva R, Alves FA, Antunes A, Goes MF, Giannini M, Tenório MD, et al. Decreased dentin tubules density and reduced thickness of peritubular dentin in hyperbilirubinemia-related green teeth. J Clin Exp Dent. 2017;9(5):e622-8. doi:10.4317/jced.53490

84. Krechina EK, Maslova VV, Rassadina AV, Liashchenko AV, Lobova AS. Dental pulp microvascular reaction in cases of dentine caries treatment by modern nanocomposite materials. Stomatologiia (Mosk). 2009;88(2):27-8. [Russian].