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Pyruvate-lactate reaction of the body to combined laser irradiation and transcanal electrophoresis of copper-calcium in patients with type 2 diabetes and periodontitis

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ABSTRACT

***BACKGROUND*:** One of the pressing issues in modern medicine is diabetes mellitus (DM) and its comorbidities, including dental complications associated with it. The potential relationship between inflammatory processes in the oral cavity and the overall state of the body has been discussed for a long time, as DM alters the metabolic components of vital organ systems.

AIM: To improve the clinical effectiveness of dental treatment in patients with type 2 diabetes and periodontitis-periodontal disease by using transcanal copper-calcium electrophoresis and laser irradiation as adjunct therapies.

MATERIALS AND METHODS: A randomized, open-label clinical study was conducted involving 123 patients with type 2 diabetes and verified periodontitis. After obtaining informed consent, the oral cavity of all participants was examined, and additional radiological diagnostics were used to verify periodontitis-periodontal pathology. To assess the acid-base balance in the periodontal and periodontic tissues, the levels of pyruvate and lactate in the blood were measured using Lactate/Peruvat test kits (LOX-PAP, Biocom, Germany), along with blood glucose parameters (Express-Satellite-PKG-0.3 method) before and after combined treatment.

RESULTS: Significant shifts in baseline lactate levels were found in 75 (61.0%) patients, with lactate exceeding the physiological norm by 2.9 times ($p < 0.05$) and pyruvate levels below the physiological norm by 33.6% ($p < 0.01$). After combined treatment, pyruvate levels increased and lactate levels decreased, leading to an improvement in the physiological ratio between lactate and pyruvate from 54.8 [51.7; 57.9] to 31.6 [30.7; 32.6] units ($p < 0.05$), demonstrating correction of hypoxia and acid-base imbalance in the tissues.

Keywords: pyruvate; blood lactate; diabetes mellitus; acid-base imbalance; transcanal copper-calcium electrophoresis; transcanal laser irradiation.

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Пируват-лактатная реакция организма на комбинированное воздействие лазерного излучения и трансканальный электрофорез меди-кальция у пациентов с сахарным диабетом 2-го типа и периодонтитом

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АННОТАЦИЯ

Актуальность. Одной из актуальных проблем современной медицины являются сахарный диабет 2-го типа (СД-2) и коморбидные патологии, в том числе стоматологические осложнения, ассоциируемые с ним. Вопрос о возможной взаимосвязи воспалительных процессов в полости рта и состоянием организма в целом обсуждается очень давно, поскольку при СД меняется метаболическая компонента жизненно важных органно-системных структур.

Цель исследования — повысить клиническую эффективность стоматологического лечения пациентов с СД-2 с пародонто-периодонтитом, используя для вспомогательного лечения трансканальный электрофорез меди-кальция и лазерного излучения (НИЛИ) с учётом критериев оценки лактат-пируватной реакции и стоматологического статуса.

Материалы и методы. Проведено рандомизированное открытое клиническое исследование 123 пациентов с СД-2 с верифицированной пародонто-периодонтальной патологией. После подписания информированного согласия у всех участников осмотрена полость рта, применены дополнительно методы лучевой диагностики для верификации пародонто-периодонтальной патологии. Для оценки кислотно-щелочного равновесия в тканях периодонта и пародонта исследовали уровни пирувата (ПВК) и лактата (ЛК) крови (тест-системы Lactat/ Peruvat [LOX-PAP, Biocom] (Германия), параметры глюкозы крови (метод Экспресс-Сателлит-ПКГ-0,3) до и после комбинированного лечения.

Результаты. Существенные сдвиги в исходных уровнях ЛК выявлены у 75 (61,0%) человек в виде его превышения от физиологической нормы в 2,9 раза (p <0,05) и снижения параметров ПК ниже физиологической нормы на 33,6% (p <0,01). После комбинированного лечения отмечали повышение ПВК и снижение ЛК, что способствовало улучшению физиологического соотношения между ЛК: ПВК с 54,8 [51,7; 57,9] до 31,6 [30,7; 32,6] ед. (p <0,05), демонстрируя коррекцию в тканях явлений гипоксии и кислотно-щелочного дисбаланса.

Заключение. Применение комбинированной физиотерапии у пациентов с СД-2 с пародонто-периодонтальной патологией снижает риски воспалительных осложнений и повышает клиническую эффективность лечения. Устранение в тканях гипоксии и ацидотических явлений усиливает эффективность санационного воздействия в отношении хронических очагов инфекции в ротовой полости, что ориентировано на повышение адаптационных резервов. После проведённого комбинированного лечения у пациентов отмечали уменьшение выраженности дисметаболических и гипоксических явлений в тканях, что подтверждено улучшением физиологического соотношения между ЛК:ПВК.

Ключевые слова: пируват; лактат крови; сахарный диабет; кислотно-щелочной дисбаланс; трансканальный электрофорез меди-кальция; трансканальное лазерное воздействие.

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二型糖尿病患者在激光照射和经皮电泳铜钙联合治疗法下的丙酮酸-乳酸反应伴牙周炎

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摘要

背景。现代医学中的一个紧迫问题是糖尿病及其相关的并发症，包括牙科并发症。口腔炎症过程与全身状况之间的潜在关系已讨论多年，因为糖尿病会改变重要器官系统的代谢成分。

研究目的。 通过使用经皮（通过牙髓管进行的铜钙经皮电泳）电泳铜钙和激光照射联合治疗，改善二型糖尿病患者的牙科治疗效果，特别是针对牙周病和牙周炎患者。

材料与方法。进行了一项随机开放临床研究，研究对象为123名患有二型糖尿病并确诊为牙周病的患者。所有参与者签署知情同意书后，进行了口腔检查，并采用了额外的放射学诊断方法来确认牙周病和牙周炎的病理变化。为了评估牙周和牙周韧带组织的酸碱平衡，使用Lactat/Peruvat检测系统（LOX-PAP，Biocom，德国）测量血液中的丙酮酸和乳酸水平，并在治疗前后监测血糖水平（使用Express-Satellite-PKG-0.3方法）。

结果。在75名（61.0%）参与者中，基线乳酸水平出现显著变化，乳酸值比生理标准高出2.9倍（p <0.05），丙酮酸水平则下降33.6%（p <0.01）。联合治疗后，丙酮酸水平上升，乳酸水平下降，乳酸与丙酮酸的生理比例从54.8 [51.7; 57.9]下降至31.6 [30.7; 32.6]单位（p <0.05），表明组织内缺氧和酸碱失衡现象得到了纠正。

关键词：丙酮酸；血乳酸；糖尿病；酸碱失衡；经皮电泳铜钙；经皮激光照射。

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BACKGROUND

The pandemic of type 2 diabetes mellitus (T2DM) has emerged as a serious public health threat [1–3]. The persistent upward trend in T2DM prevalence is complicated by worsening oral health in these patients, with edentulism rates up to 15 times higher [2]. Increasing evidence indicates that, in addition to glycemic risks, diabetes is associated with comorbidities including dental diseases [1–3]. The concept of "metabolic memory"—where early glycemic exposure causes long-term disruptions in target tissues even after optimal glucose control—underscores the clinical imperative for early risk identification and management of comorbidities. In recent years, various physiotherapy techniques have been increasingly applied to treat conditions such as metabolic syndrome and associated dental diseases [4–9]. However, combined transcanal electrophoresis of copper-calcium and laser irradiation have not previously been used to treat T2DM with endodontic–periodontal lesions.

AIM

This study aimed to improve the clinical efficacy of dental treatment in T2DM patients with endodontic–periodontal lesions by using adjunctive transcanal electrophoresis of copper-calcium and low-level laser irradiation (LLLT), with assessment criteria including lactate–pyruvate response and dental status.

METHODS

A randomized, open-label clinical trial was conducted with 165 T2DM patients; 123 of them were confirmed to have endodontic–periodontal lesions, which is consistent with an average 75% prevalence of dental disease in 40- to 70-year-old T2DM adults [1, 2, 4, 5].

The research was conducted in accordance with the ethical standards of the Declaration of Helsinki (as amended in 2013) under ethical approval No. 24 (2022, Peoples' Friendship University of Russia).

Participants with T2DM (59 men, 47.9%; 64 women, 52.1%) underwent confirmation of endodontic–periodontal lesions via medical and dental history [6, 7], oral examination, and dynamic laboratory assessment of gluconeogenesis metabolites, i.e., blood pyruvate and lactate levels [8–10]. Blood samples were drawn from the antecubital vein, centrifuged for 5 minutes at 1700 g, and analyzed using an enzymatic colorimetric Lactate/Pyruvate assay [LOX-PAP, Biocom, Germany]. The analyte concentrations were measured with a PE-5300VI spectrophotometer. Working length in affected teeth was measured using an electronic apex locator (Dentaport ZX RCM-EX, Japan) [10–12].

Inclusion Criteria: T2DM patients aged 40–70 with confirmed endodontic–periodontal lesions who provided informed consent.

Non-inclusion Criteria: Age < 40 or > 70, severe T2DM complications, intolerance to electrophysiological procedures or copper/calcium or laser irradiation [13–15].

Exclusion Criteria: Non-adherence to the treatment protocol. Before the administration of the medication via transcanal delivery (transcanal electrophoresis [16]) and prior to final obturation, root canals were treated transcanally using laser irradiation (λ = 810 nm) and a 3% sodium hypochlorite solution.

Intervention

The study included 123 patients with T2DM and confirmed endodontic–periodontal lesions. Clinical and laboratory evaluations were conducted at the City Endocrinology Department in Moscow and the rehabilitation unit of the Victoria Sanatorium. Assessments focused on height, weight, body mass index, and consultations with an endocrinologist, dentist, and physiotherapist. Dental status was evaluated by radiographic imaging (panoramic radiography), and laboratory assessment included plasma levels of pyruvate and lactate as potential targets for non-pharmacologic transcanal laser and copper-calcium drug electrophoresis [16]. Before transcanal administration of the drug (endodontic electrophoresis) and final obturation, root canals were treated with transcanal laser irradiation (λ = 810 nm) and 3% sodium hypochlorite. Parameters of transcanal LLLT were: 810 nm wavelength with continuous laser mode; 80–1200 Hz pulse frequency; 30–120 s exposure duration per field, with a power flux density of 15–20 mW/cm^2.

Lactate and pyruvate levels were selected as diagnostic markers and potential targets for combined transcanal laser exposure and electrophoresis of copper-calcium [17].

In all patients, body mass index was calculated and the severity of metabolic disturbances was assessed using plasma levels of lactate (L) and pyruvate (P) (mmol/L). The L:P ratio was also calculated to compare with normal physiologic levels. All T2DM patients with endodontic–periodontal lesions exhibited metabolic disturbances, evidenced by radiologic signs in the periodontium and elevated plasma lactate and glycated methemoglobin (HbA1c) levels, combined with reduced pyruvate values and an altered physiological ratio between them [18–20].

RESULTS

The distribution of patients across the study groups by severity of T2DM and diagnosed endodontic–periodontal lesions (n = 123, abs./% of total) is shown in Table 1.

Significant shifts in baseline lactate levels were found in 75 patients (61.0%), with lactate levels exceeding the normal reference range by 2.9 times ($p < 0.05$) and pyruvate levels falling 33.6% below the lower limit of the reference range ($p < 0.01$) (Table 2).

After combined treatment, pyruvate levels increased and lactate levels decreased, leading to an improvement in

the L:P ratio from 54.8 [51.7; 57.9] to 31.6 [30.7; 32.6] units ($p < 0.05$), demonstrating correction of hypoxia and acid–base imbalance in the tissues. The most pronounced positive changes were observed in group 1 patients who received transcanal laser therapy of the root structures of affected teeth followed by transcanal electrophoresis of copper-calcium. Correction of tissue hypoxia and acidosis enhances the efficacy of decontamination in chronic oral infection foci and improves the adaptive capacity of patients with T2DM.

Participants

The study enrolled 123 patients with T2DM (59 men and 64 women), all diagnosed with endodontic–periodontal lesions. Significant baseline deviations were observed: serum lactate levels were 2.9-fold above the reference range ($p < 0.05$), and pyruvate levels were 33.6% below normal ($p < 0.01$), reflecting pronounced anaerobic shifts amid acid–base imbalance in the tissues. In group 1 (transcanal laser irradiation of affected root structures followed by copper-calcium electrophoresis), the L:P ratio improved significantly from 54.8 [51.7; 57.9] to 31.6 [30.7; 32.6] units ($p < 0.05$), indicating correction of tissue hypoxia and acid–base disturbance.

Significant baseline shifts in blood lactate levels were identified in 75 patients (61.0%), with concentrations exceeding the reference range by 2.9 times ($p < 0.05$) and pyruvate levels decreased by 33.6% below the reference range ($p < 0.01$). In 56.5% of patients with T2DM, manifestations of endodontic–periodontal lesions (exudative, hemorrhagic, and proliferative forms) included marked cyanosis of the gingival margin, friability of the interdental papillae accompanied by granulation tissue protruding from the papillae, and purulent or hemorrhagic exudate. In 30.6% of patients with T2DM, periodontal changes were characterized by gingival collar-like encasement of the tooth necks and bulbous swelling of the interdental papillae, more frequently observed in individuals with severe disease progression. All patients with T2DM in the study exhibited a marked elevation in lactate levels, whereas pyruvate levels were significantly reduced to 33.6% below the reference range ($p < 0.01$), indicating pronounced anaerobic shifts associated with T2DM-related metabolic disturbances. Following combination therapy, an increase in pyruvate concentration and a decrease in lactate levels were observed, contributing to the improvement of the physiological L:P ratio from 54.8 [51.7; 57.9] to 31.6 [30.7; 32.6] units ($p < 0.05$), indicating resolution of tissue hypoxia. Prior to dental treatment, it is essential to conduct a thorough evaluation of patients with T2DM, assessing not only their dental status but also identifying potential targets of metabolic imbalance—specifically pyruvate and lactate levels—to mitigate dental complications and glycemic risks.

Statistical Analysis

Data were processed using Microsoft Excel (2017) and IBM SPSS Statistics 26 (PASW Statistics 2018). Descriptive statistics included mean ± standard deviation, interquartile ranges (Q1; Q3), histograms, and box plots. Normality of distribution was assessed via descriptive metrics and the Shapiro–Wilk test. Changes in glycemic control and HbC% were analyzed using repeated-measures ANOVA (general linear model). Absolute and relative variables were compared using the Student's *t*-test ($p < 0.05$). For comparison of independent

Table 1. Patients with DM-2 and diagnosed periodontal periodontitis

Groups	Sex (abs., %)				Dental disease	
	M	F	T2DM severity		Periodontitis	Periapical periodontitis and caries
Group 1	15 (12.2)	16 (13.0)	Mild	17 (54.8)	17 (13.8)	39 (31.7)
			Moderate	11 (36.6)		
			Severe	1 (3.4)		
Group 2	15 (12.2)	16 (13.0)	Mild	16 (51.6)	16 (13.0)	34 (27.6)
			Moderate	13 (41.9)		
			Severe	2 (6.5)		
Group 3	15 (12.2)	16 (13.0)	Mild	16 (51.6)	15 (12.2)	32 (26.0)
			Moderate	13 (41.9)		
			Severe	2 (6.6)		
Group 4	14 (11.4)	16 (13.0)	Mild	13 (43.3)	17 (13.8)	32 (26.0)
			Moderate	15 (50.0)		
			Severe	3 (10.0)		

Note. All groups are comparable in terms of diabetes mellitus severity, gender ($p > 0.05$), and dental pathology ($p > 0.05$).
DM-2 — diabetes mellitus type 2.

Table 2. Blood lactate and pyruvate levels in DM-2 patients with periodontal pathology before and after physiotherapy treatment (*n*=123)

Parameter	Group 1	Group 2	Group 3	Group 4
		Before treatment		
Lactate, mmol/L	2.97 [2.88; 3.16]	2.8 [2.6; 3.05]	2.89 [2.68; 3.09]	2.86 [2.65; 3.17]
		After treatment		
Lactate, mmol/L	1,9 [1,8; 2,0]$^{\#\#\bullet\bullet}$	2,5 [2,3; 2,75]*	2,4 [2,3; 2,59]*	2,6 [2,5; 2,7]*
		Reference range: 0.95–1.8 mmol/L		
		Before treatment		
Pyruvate, mmol/L	0,04 [0,03; 0,048]	0,0379 [0,028; 0,043]	0,037 [0,03; 0,044]	0,026 [0,02; 0,032]
		After treatment		
Pyruvate, mmol/L	0,058 [0,05; 0,068]$^{\#}$	0,04 [0,038; 0,045]*	0,048 [0,04; 0,053]	0,046 [0,04; 0,052]
		Reference range: 0.05–0.06 mmol/L		
		Before treatment		
L:P (units)	54.8 [51.7; 57.9]	61.8 [60.8; 62.8]	58.4 [57.3; 59.6]	56.8 [54.5; 59.1]
		After treatment		
L:P (units)	31.6 [30.7; 32.6]*	59.8 [58.8; 60.7]**	58.0 [57.3; 58.9]**	55.4 [54.5; 56.4]**
		Reference range: 19.0–20.5 mmol/L		

Note. LC — blood lactate; PVC — blood pyruvate. The data is presented by Me [Q_1; Q_3]. The reliability in each group before and after treatment according to the Wilcoxon criterion: $^{\#}$ — p <0.05; $^{\#\#}$ — p <0.01. The reliability between the groups in relation to the 4th group without physiotherapy after treatment according to the Kraskel–Wallis criterion: $^{\bullet}$ — p <0.05; $^{\bullet\bullet}$ — p <0.01.

groups with non-normal distribution across more than two groups, the Kruskal–Wallis test was used. When comparing two dependent groups, the Wilcoxon signed-rank test was applied. To compare with the control group, the Mann–Whitney *U* test was used. Changes in the studied parameters during treatment were assessed using the Wilcoxon signed-rank test for paired samples with non-normal distribution. Correlations between age (predictor) and the studied parameters (outcomes) were assessed using the Spearman's correlation coefficient for groups with non-normal distributions and the Pearson's correlation coefficient for normally distributed data.

DISCUSSION

The present study highlights the importance of assessing not only the dental status of patients with T2DM but also their acid–base balance markers, specifically blood pyruvate and lactate, which reflect the degree of tissue hypoxia and oxidative stress within the dentoalveolar complex.

In T2DM patients who received adjuvant transcanal laser irradiation of affected tooth root structures followed by transcanal copper-calcium electrophoresis, a more rapid restoration of damaged dental and periodontal tissues was observed. This recovery was associated with normalization of the L:P ratio and a reduction in glycemic risks.

Additionally, this therapeutic protocol enhanced reparative and adaptive responses in the tissues of patients receiving transcanal copper-calcium electrophoresis alone.

It is well established that LLLT provides significant microvascular, antioxidant, and anti-inflammatory benefits [11–18]. Therefore, it may be concluded that laser therapy exerts significant anti-inflammatory and disinfecting effects in the complex root canal systems of affected teeth, supporting enhanced tissue healing, particularly after the administration of a therapeutic copper-calcium depot.

CONCLUSION

In summary, combined physiotherapy in T2DM patients with endodontic–periodontal lesions reduces the risk of inflammatory complications and improves clinical outcomes. The mitigation of tissue hypoxia and acidosis enhances the efficacy of infection control measures for chronic oral foci, ultimately contributing to increased adaptive capacity. Following combination therapy, patients demonstrated reduced severity of metabolic disturbances and hypoxic events, as evidenced by improved physiological L:P ratios.

ADDITIONAL INFORMATION

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Competing interests. The authors declare that they have no competing interests.

Author's contribution. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work. T. Chkheidze — collection of material; A.S. Tkachenko — statistical processing, editorial; N.G. Kulikova — writing, editorial.

Patients' consent. Written consent obtained from all the study participants before the study screening in according to the study protocol approved by the local ethic committee.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

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