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MODERN DIAGNOSTIC METHODS OF PERIODONTAL DISEASES

Inoyatova Sofiya Abdusamad qizi

Jabborova Iroda Jasur qizi

Raxmonova Ma`mura Erkin qizi

Yoqubova Sevara Nuriddin qizi

Hamidova Farzona Suhrob qizi

4th year students of the Faculty of Dentistry of the

Tashkent International University of Chemistry

Scientific advisor: Phd. Dotsent **Xatamov Ulug'bek Altibayevich**

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Abstract: This scientific paper analyzes modern diagnostic methods for periodontal diseases. The limitations of conventional clinical and radiographic examinations are outlined, and the clinical significance of molecular-biological (PCR, NGS), immunological biomarkers (aMMP-8, cytokines), genetic testing, as well as artificial intelligence and digital imaging technologies is highlighted. The findings demonstrate that a comprehensive diagnostic approach enables detection of the disease at the preclinical stage, assessment of individual risk, and monitoring of treatment efficacy. The paper is intended for dental practitioners, researchers, and residents.

Keywords: periodontitis, diagnostics, biomarkers, polymerase chain reaction, artificial intelligence, gingival crevicular fluid, genetic testing.

Annotasiya: Ushbu ilmiy ishda parodontal kasalliklarni zamonaviy diagnostika qilish usullari tahlil qilingan. An'anaviy klinik va rentgenologik tekshiruvlarning cheklovlari ko'rsatilib, molekulyar-biologik (PZR, NGS), immunologik biomarkerlar (aMMP-8, sitokinlar), genetik testlash hamda sun'iy intellekt va raqamli tasvirlash texnologiyalarining klinik ahamiyati yoritilgan. Tadqiqot natijalari shuni ko'rsatadiki, kompleks diagnostika yondashuvi kasallikni preklinink bosqichda aniqlash, individual riskni baholash va terapiya samaradorligini monitoring qilish imkonini beradi. Ish stomatolog-shifokorlar, tadqiqotchilar va rezidentlar uchun mo'ljallangan.

Kalit so'zlar: parodontit, diagnostika, biomarkerlar, polimeraza zanjir reaksiyasi, sun'iy intellekt, gingival krevikulyar suyuqlik, genetik testlash.

Аннотация: В данной научной работе проанализированы современные методы диагностики пародонтальных заболеваний. Показаны ограничения традиционных клинических и рентгенологических методов обследования, освещена клиническая значимость молекулярно-биологических (ПЦР, NGS), иммунологических биомаркеров (аММП-8, цитокины), генетического тестирования, а также технологий искусственного интеллекта и цифровой визуализации. Результаты исследования свидетельствуют о том, что комплексный диагностический подход позволяет выявлять заболевание на доклинической

стадии, оценивать индивидуальный риск и мониторить эффективность терапии. Работа предназначена для врачей-стоматологов, исследователей и ординаторов.

Ключевые слова: пародонтит, диагностика, биомаркеры, полимеразная цепная реакция, искусственный интеллект, десневая кревикулярная жидкость, генетическое тестирование.

INTRODUCTION

Periodontal diseases are one of the most common pathologies in dentistry, leading not only to the destruction of the supporting apparatus of the teeth, but also to serious changes in general somatic health. According to the World Health Organization, severe forms of periodontitis occur in 10-15% of cases among adults, and this figure increases with age [1]. Due to the vagueness of clinical signs and the lack of subjective complaints in the early stages of the disease, patients often seek medical attention late, which reduces the effectiveness of treatment.

Although traditional diagnostic methods (probing of periodontal pockets, radiography) have been considered the “gold standard” for many years, they only allow recording destructive changes in the disease that have already occurred. Modern periodontology is aimed at detecting the disease at the preclinical stage, assessing individual risk factors and predicting its prognosis. Today, molecular-biological, immunological, microbiological and digital technologies are radically changing the diagnostic process. The aim of this work is to analyze modern approaches to the diagnosis of periodontal diseases, their advantages and place in clinical practice. Although classical methods for the detection of periodontal diseases have not lost their relevance, their sensitivity and specificity are limited. For example, the results obtained during periodontal probing depend on the experience of the operator, the force applied and the diameter of the probe, and the probability of subjective error is high [2]. Demineralization of bone tissue on the radiograph is visualized only after 30-50% of its loss, that is, this method reflects the history of past damage, and not the active phase of the disease.

Therefore, the modern diagnostic paradigm has moved from static anatomical changes to the assessment of dynamic biological processes. This approach includes the following three main areas:

1. Qualitative and quantitative analysis of periodontal pathogenic microflora;

2. Identification of host response markers (biomarkers);

3. Assessment of genetic and epigenetic predisposition.

Periodontitis is an infection of polymicrobial etiology, in the development of which pathogens such as Porphyromonas gingivalis, Treponema denticola, Tannerella forsythia (red complex) and Aggregatibacter actinomycetemcomitans play a decisive role. Modern microbiological diagnostics is abandoning the traditional bacteriological culture method and is based on molecular genetic methods.

Polymerase chain reaction (PCR) and real-time PCR (qRT-PCR) methods are currently the most sensitive and rapid diagnostic tools. These methods can detect pathogen DNA in a periodontal pocket fluid or biopsy sample within a few hours. PCR not only identifies the type of bacteria, but also accurately indicates their quantity, which is important for justifying antibiotic therapy and

monitoring the effectiveness of treatment [3]. Next-generation sequencing (NGS) technology allows you to study the complete composition of the periodontal microbiome. Detection of non-culturable anaerobic microorganisms and assessment of the degree of dysbiosis are performed using NGS. This method is invaluable in finding the etiological factor, especially in cases of refractory (treatment-resistant) periodontitis. It should be noted that microbiological tests are not recommended in all patients, but only in complex clinical cases, in aggressive periodontitis or in the preparatory phase before implantation.

A promising direction in assessing disease activity is the study of biomarkers in the gingival crevicular fluid (GCF). GCF is a “biological window” that reflects changes in periodontal tissues in real time.

The following biomarker groups are used in modern diagnostics:

Inflammatory mediators: Interleukin-1β (IL-1β), IL-6, TNF-α and prostaglandin E2 levels directly correlate with the intensity of inflammation and the activity of bone resorption.

Tissue destruction markers: Matrix metalloproteinases (in particular, MMP-8 and MMP-9) are the main enzymes of collagen degradation. Express tests designed to detect active MMP-8 (aMMP-8) (for example, PerioSafe®) allow to detect the active phase of periodontitis in the clinic within 5 minutes [4]. This method is characterized by its non-invasiveness and speed.

Bone metabolism markers: The RANKL/OPG ratio indicates the degree of osteoclastogenesis. An increase in the level of sRANKL in GKS indicates a higher risk of bone loss.

Oxidative stress markers: Markers such as 8-hydroxy-deoxyguanosine (8-OHdG) and malondialdehyde are used to assess oxidative damage in tissues.

Biomarker diagnosis is important not only for diagnosis, but also for prognosis and therapy monitoring. A decrease in biomarker levels after treatment can be observed before the improvement of clinical parameters, which helps to early assess the biological effectiveness of therapy.

Susceptibility to periodontal diseases is also associated with hereditary factors. Genetic testing is used to create an individual risk profile for the disease. In particular, polymorphisms of the IL-1 gene cluster (IL-1A +4845, IL-1B +3954) have been shown to be associated with a genetic predisposition to severe periodontitis. Homozygous presence of these alleles increases the risk of developing the disease by 3-7 times [5].

In addition, polymorphisms of the vitamin D receptor (VDR), Fcγ-receptor and MMP genes are also being studied. Genetic tests are performed once and are valid for life, which allows preventive measures to be planned from early childhood. However, genetic tests should not be interpreted in isolation, but in the context of a complex of clinical and microbiological data.

Epigenetic studies (DNA methylation, histone modifications) help to explain how environmental factors (smoking, stress, nutrition) affect gene expression. Although this field is still in its infancy, it will serve to further understand the multifactorial nature of periodontitis in the future.

An integral part of modern diagnostics is digitization. Digital intraoral scanners and CBCT (cone-angle computed tomography) allow the creation of a 3D model of periodontal tissues. CBCT, unlike conventional radiographs, clearly visualizes the morphology of bone defects, furcation damage, and the state of the cortical plate.

Artificial intelligence (AI) and machine learning algorithms are minimizing the human factor in the analysis of radiological images. AI systems have demonstrated high accuracy in automatically detecting bone loss in X-ray and CBCT images, measuring periodontal pocket depth, and classifying disease severity. Studies have shown that deep learning models can have equal or higher sensitivity in diagnosing periodontitis than expert dentists [6].

Telematics and mobile applications are also creating opportunities for monitoring the patient's hygiene status at home and collecting data in real time. This "digital twin" concept is laying the foundation for the formation of a continuous periodontal health management system.

SUMMARY

Modern diagnostic methods for periodontal diseases are based on the integration of traditional clinical examination with molecular, genetic, and digital technologies. Microbiological PCR tests accurately identify the etiological factor, while biomarkers (aMMP-8, cytokines) assess disease activity in real time. Genetic testing helps predict individual risk, and artificial intelligence and CBCT help visualize anatomical changes with high accuracy. Dentists are required to master these innovative methods and adhere to the principles of evidence-based medicine in making clinical decisions. Only the synthesis of modern diagnostic tools is a guarantee of early detection, effective treatment and achievement of stable remission of periodontal diseases.

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