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Modern Methods of Diagnosis of Occlusive Imbalance in Patients with Temporomandibular Myofascial Pain Syndrome

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Abstract

Background: In recent years, there has been a growing interest in digital methods for diagnosing occlusive imbalance both in Russia and abroad. The development of technologies in this area opens up new prospects for improving the diagnosis and treatment of dental diseases.
The purpose of this study is to analyze existing digital methods and devices for diagnosing occlusive imbalance, identify their advantages and disadvantages, and assess the prospects for their implementation in clinical practice.
Materials and methods: To achieve this goal, a systematic review of 40 scientific publications covering the period from 2016 to 2024 was conducted. The study includes both domestic and international sources from leading scientific electronic libraries and databases. Data on various types of digital devices such as strain gauges, piezoresistive and piezoelectric transducers, pressure sensors and fiber optic sensors are analyzed. Methods of index evaluation of occlusal contacts have also been studied.
Results: The analysis showed that existing digital technologies for the diagnosis of occlusive imbalance have significant potential to improve the accuracy and effectiveness of diagnosis. Load cells, piezoresistive and piezoelectric transducers, as well as pressure sensors and fiber optic sensors provide various approaches to measuring the occlusion force. Despite their high sensitivity and accuracy, the implementation of these technologies faces challenges such as the complexity of equipping clinics and the insufficient level of digital competencies among doctors.
Conclusion: Digital diagnostic technologies for occlusal imbalance have significant potential to improve dental practice. However, for the successful implementation of these methods, it is necessary to overcome the existing difficulties associated with equipment and training of specialists. Further efforts in the field of digital technology development, process automation and advanced training of dentists can contribute to more effective diagnosis and treatment of occlusion disorders.

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Key words: Occlusion, digital radiography, strain gages, piezoelectric devices, artificial intelligence.

INTRODUCTION

Occlusion disorders are an important risk factor for the development of various diseases of the oral cavity, including dental, periodontal and temporomandibular joint pathologies. Studies have also shown that occlusive imbalance can contribute to the development of endocrine (for example, diabetes mellitus) and cardiovascular diseases, as well as cognitive impairment (1, 2, 3).

A decrease in occlusive strength is one of the diagnostic signs of hypofunction of the oral cavity, which includes an assessment of hygiene, dry mouth, mobility and pressure of the tongue, as well as the functions of chewing and swallowing. The diagnosis is considered positive if there are at least three of these signs (4). The concept of "hypofunction of the oral cavity", originally developed for elderly patients, has recently been recognized as relevant for young people, especially in terms of occlusive strength (5).

Thus, the diagnosis of occlusion disorders has not only dental, but also general medical significance, as it allows us to study the relationship between oral health and the general state of human health.

For dentists, conducting a high-quality, accurate and prompt assessment of the occlusive status of a patient is an important task. In this regard, there is a high need to develop effective and affordable methods for diagnosing occlusive imbalance. Doctors would like to have methods that meet the modern requirements of dental care: they must be effective, accurate, reliable, economical and easy to use. These tasks can be solved through the development of technologies for the diagnosis and correction of occlusive disorders.

One of the promising directions in the assessment of dental status is the digitalization of diagnostic processes. This includes not only the correction of occlusion pathologies, but also the creation of a digital patient profile for monitoring, including telemedicine, as well as for preventive and rehabilitative measures (6). It is also important to update and improve traditional methods of diagnosing occlusive imbalance using computer technology.

Thus, the wide prevalence and diversity of oral diseases arising from occlusion disorders, as well as the limited capabilities of modern diagnostic technologies, emphasize the relevance of analyzing digital methods for diagnosing these disorders.

The purpose of the study is to analyze digital methods and devices used to diagnose disorders of occlusive relationships.

MATERIALS AND METHODS

A systematic analysis of 40 scientific publications devoted to digital methods of diagnosis of occlusive imbalance for the period from 2016 to 2024 was carried out. Of these publications, 9 were indexed in Russian scientific electronic libraries (CyberLeninka and eLibrary), and 31 articles were indexed in international databases (PubMed, Google Scholar, ResearchGate). The search for sources was carried out using combinations of keywords: "occlusive relationships", "occlusion disorders", "digital technologies", "occlusive sensors".

An analysis of the literature has shown that in practice, doctors can use various commercial electronic devices to register the strength of occlusion. These devices operate on the basis of the transformation of mechanical force into electrical energy using various sensors (7, 8). According to the mechanism of action, they can be classified as load cells, piezoelectric and piezoresistive transducers, as well as pressure sensors (9). These devices are used to diagnose various conditions, such as disorders in the temporomandibular joint, fractures of the mandible, malocclusion deformities, as well as to monitor the strength of occlusion during treatment (10). Brief characteristics of these devices are presented in Table 1.

Table 1. Characteristics of devices for determining the force of occlusion

Type (device)	**Composition**	**Advantages**	**Disadvantages**
Load cells («Dentoforce 2», Itlab, «IDD», Kratos)	a metal bite plug covered with rubber or a plastic disc, a digital monitor	high accuracy, wide range of measurements, light weight and size	bite plug thickness is more than 10 mm, interference with occlusion during measurements
Piezoresistive transducers («FSR151», Interlink Electronics, «Flexiforce», Tekscan)	, thermoplastic sheets with built-in conductive electrodes and semiconductor polyethyrimide ink, or an electronic device for detecting changes in sensor resistance	high sensitivity, thin, light weight, inexpensive	is less accurate compared to load
Pressure sensors («GM10», Nagano Keiki «MPX 5700 Motorola», SPS)	occlusal vinyl element or flexible occlusal tube	portable, soft, create uniform force distribution	cells measurement inaccuracies
Piezoelectric sensors («T-scan III», Tekscan)	piezoelectric sensor made of foil	thin (0.1mm) and flexible sensor, quantification of occlusion force	insufficient sensor sensitivity, narrow range

Load cells: Strain gauges measure pressure and control the applied force using a strain gauge, which converts mechanical deformation caused by tooth compression into an electrical signal (11-13). The advantages of load cells include high sensitivity and accuracy, compactness and resistance to external influences. However, their metal surface can cause discomfort in patients, which complicates the registration of the maximum compression force (14).

Piezoresistive transducers: Piezoresistive transducers change resistance when pressure increases and use semiconductor materials. These sensors are characterized by high sensitivity and measurement accuracy, as well as compact dimensions. They are widely used not only in dentistry, but also in other medical fields. Nevertheless, some studies have noted certain inaccuracies in their measurements compared to other types of sensors (15-19).

Pressure sensors: These sensors convert the pressure of a liquid or gas into electrical signals. The advantages of such sensors include the accuracy and repeatability of measurements, the ability to adapt to the anatomy of teeth and comfort for patients. However, they are limited in use with different environments, which can reduce accuracy and reliability (20-21).

Piezoelectric converters: These devices operate on the basis of a piezoelectric effect that converts pressure into an electrical signal. They are characterized by high accuracy and reliability, as well as the ability to create a three-dimensional map of the occlusive force. However, the disadvantage is the limited flexibility of the sensors and the narrow measurement range (22-27).

Fiber-optic sensors: These devices use optical transducers to register the compression force of teeth and transmit data to a computer (Figure 1). They are characterized by their miniature size, independence from electrical energy and resistance to electromagnetic interference, which makes them promising for use in wireless technologies (28-31).

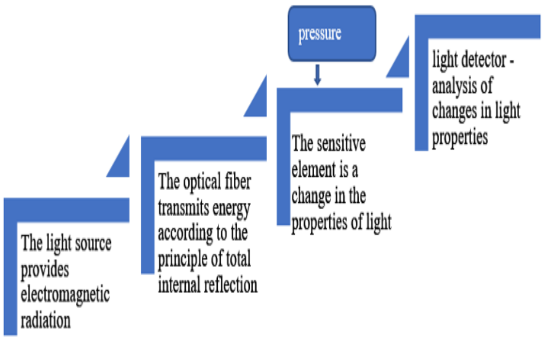

Figure 1: Operating principle of fiber optic pressure sensors.

Methods of index evaluation of occlusal contacts: A number of studies are devoted to the development of methods for the index assessment of occlusal disorders using articulation paper of various thicknesses and colors to identify static and dynamic contacts, followed by photographing and digitizing for computer diagnostics, as well as 3D analysis of occlusal imbalance using dental scans and studying digital models (32, 33). Exponential monitoring makes it possible to identify the severity of trigger factors and their effect on occlusion disorders (34). The point scale of occlusal contacts provides recommendations to the clinician on the choice of a differentiated algorithm: whether to limit oneself to selective grinding of teeth, restoration, or whether orthodontic treatment is necessary (35).

Prospects for the use of occlusive sensors: Modern technologies allow the development of miniature sensors that can be integrated into dentures and other dental devices for continuous monitoring of occlusive strength. This opens up new possibilities for quantitative analysis of occlusive disorders in real time. The use of artificial intelligence for the diagnosis and treatment of occlusive imbalances is also developing, which makes it possible to create more accurate and effective algorithms based on the analysis of large volumes of clinical data (36-40).

RESULTS

The results of a systematic analysis of 40 scientific publications conducted as part of the study showed that for the period from 2016 to 2024, a variety of digital methods and devices for diagnosing occlusive imbalance were presented in the scientific literature. A study of the sources revealed a significant number of commercially available electronic devices used to register the occlusion force. These devices operate on the basis of various sensors such as load cells, piezoresistive and piezoelectric transducers, as well as pressure sensors and fiber optic sensors.

Each type of sensor has its own advantages and disadvantages, which makes their application specific to certain clinical situations. The advantages include high accuracy, sensitivity and ease of use, while the disadvantages are related to limitations in measurement accuracy, difficulties in positioning sensors and patient comfort.

Modern methods of index evaluation of occlusive contacts based on digital technologies allow for a detailed analysis of occlusive disorders, which contributes to a more accurate diagnosis and selection of effective treatment methods.

In addition, the development of artificial intelligence technologies and the miniaturization of sensors open up prospects for continuous monitoring of occlusive strength, which is an important step towards improving the diagnosis and treatment of occlusive disorders.

DISCUSSION

Violations of occlusive relationships in modern dentistry are becoming an increasing problem due to their rather high prevalence, a variety of clinical symptoms, difficulties in diagnosis and treatment, as well as the need for long-term rehabilitation of patients. Currently, the subject of interest of domestic and foreign researchers is the diagnosis, treatment and prevention of occlusion disorders. It should be noted that in recent years, an increase in the frequency of occurrence of these pathologies in clinical practice has been recorded. In addition, occlusive disorders imply characteristic clinical manifestations in the oral cavity and on the face, accompanied by pathologies of the hard tissues of the teeth, periodontal, temporomandibular joint (TMJ), balance of the chewing muscles. Despite the variety of clinical manifestations, it is believed that patients with occlusive disorders represent one of the most difficult groups of patients, since this group of pathologies has a multifactorial etiopathogenetic nature, consisting in the formation of several developmental links: teeth, jaw bone, muscle factor, as well as TMJ. In addition, these patients often have concomitant diseases that exacerbate the course of pathology of the dental system.

In light of the above, occlusive disorders are a subject of considerable interest among researchers, which is confirmed by the abundance of scientific publications on this topic. It is important to note that recent scientific developments are focused on automation of diagnostic processes, data analysis using computer vision and neural networks, which opens up new horizons for the application of these technologies in dentistry and related fields.

The development of new methods and highly sensitive sensors for measuring chewing pressure provides new diagnostic capabilities, allowing the identification of clinical parameters that were previously unavailable for analysis.

Modern hardware technologies and software make it possible to integrate machine vision and neural network analysis algorithms into the practice of doctors, which, based on the analysis of previous clinical cases, can not only evaluate current data, but also predict the risk of developing diseases and possible complications.

CONCLUSION

Thus, our study demonstrates that digital methods for diagnosing occlusal imbalance are currently being actively developed, which will become a priority in dental practice in the future. However, the introduction of these techniques into the daily work of dentists is still limited not only by the difficulties in equipping clinics with the necessary digital equipment, but also by the insufficient level of digital competencies of specialists. Overcoming these obstacles will significantly improve the quality of dental care for patients with occlusive disorders.

Statement of conflict of interest : The authors declare that there is no conflict of interest.

Ethical Statement

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