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INNOVATIVE METHODS OF ORAL CAVITY REHABILITATION IN PATIENTS AFTER CHEMOTHERAPY

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Abstract. *Oral mucositis is one of the common complications of chemotherapy. It negatively affects the course of antitumor treatment, nutritional status, and quality of life of patients. The oral mucosa is highly sensitive to the cytotoxic effects of chemotherapy drugs. This is due to rapid cell renewal processes, active metabolism, impaired local immunity, and interaction with the oral microbiome. Lesions have a complex pathogenesis and manifest as mucositis, xerostomia, erosive and ulcerative changes, dysbiotic disorders, and the risk of secondary infections.*

The aim of this study was to determine the characteristics of innovative methods of oral rehabilitation in patients after chemotherapy, taking into account clinical, functional, and biological markers of effectiveness. An analysis of current publications indicates a gradual transition from symptomatic treatment to pathogenetically justified and multidisciplinary rehabilitation strategies. Photobiomodulation therapy demonstrates the highest efficacy, contributing to the reduction of inflammation, activation of reparative processes, and reduction of the severity of oral mucositis. In addition, local pharmacological agents, oral hygiene, and adherence to international clinical recommendations play an important role.

A comprehensive assessment of the effectiveness of rehabilitation using clinical manifestations, salivation indicators, inflammatory markers, and the state of the microbiome allows determining the results of treatment and creates the conditions for a personalized approach to the rehabilitation of patients after chemotherapy.

Keywords: *chemotherapy, oral cavity, oral mucositis, photobiomodulation therapy, rehabilitation, efficacy markers.*

Introduction

Modern anticancer treatments, particularly chemotherapy, have significantly improved survival rates for cancer patients, but their use is accompanied by numerous side effects, among which oral mucositis is one of the most common. The oral mucosa is highly sensitive to the cytotoxic effects of anticancer drugs due to intense cell renewal, active metabolic processes, and constant contact with the microbial environment. In this context, oral mucositis is considered one of the most common and clinically significant complications of chemotherapy, significantly affecting the course of treatment and quality of life of patients [1, 2].

According to current scientific research, chemotherapy-induced oral mucositis is characterized by a multiphase pathogenesis, including direct damage to epithelial cells, activation of pro-inflammatory signaling pathways, development of oxidative stress, and impaired regenerative potential of the mucous membrane [3, 4]. The progression

of these processes is accompanied by the formation of erosive and ulcerative lesions, pain syndrome, dysphagia, and an increased risk of secondary infections, which often necessitates the correction or temporary discontinuation of antitumor therapy [5, 6].

Functional disorders, in particular xerostomia and changes in the composition of saliva, which lead to a decrease in local immune protection and a violation of the barrier function of the mucous membrane, also play an important role in the formation of oral lesions. In this regard, increasing attention is being paid to the role of the microbiome, whose dysbiotic shifts can sustain the inflammatory process and slow down the reparative mechanisms of the mucous membrane after chemotherapy [7]. Thus, oral lesions should be considered as the result of the interaction of cytotoxic, immune, and microbiological factors.

In addition to classic manifestations of mucositis, other pathological changes in the oral cavity have been described in patients receiving chemotherapy, including pigmentation of the mucous membrane, which reflects the systemic toxic effects of antineoplastic drugs [6, 8]. The combination of these changes forms a significant clinical burden that goes beyond dental problems and affects nutritional status, psychological state, and overall treatment tolerance [5].

In this regard, a relevant direction in modern oncology dentistry is the development and implementation of effective preventive and rehabilitative approaches aimed at reducing the frequency and severity of oral cavity lesions. Among them, photobiomodulation therapy, modern local remedies, oral hygiene correction, and multidisciplinary patient management models, whose effectiveness has been confirmed by the results of randomized clinical trials and systematic reviews, attract particular attention [9, 10, 11, 12]. At the same time, despite the existence of international clinical guidelines, the issue of comprehensive assessment and rehabilitation of the oral cavity in patients receiving chemotherapy remains the subject of active scientific debate [13, 14].

The aim of the study is to identify the characteristics of innovative methods of oral rehabilitation in patients after chemotherapy, taking into account clinical, functional, and biological markers of effectiveness.

Results Rehabilitation of the oral cavity in patients after chemotherapy is a multicomponent process that should be based on an understanding of the pathophysiological mechanisms of mucosal damage, the nature of clinical manifestations, and the individual characteristics of the course of antitumor treatment. An analysis of current scientific literature shows a clear trend away from symptomatic treatment of oral complications toward the introduction of innovative, pathogenetically sound rehabilitation approaches [1, 2, 3].

One of the innovative rehabilitation methods is photobiomodulation therapy, which helps to reduce the severity of oral mucositis, accelerates the repair of the mucous membrane, and reduces the intensity of pain syndrome. The main mechanism of action of photobiomodulation is the activation of cell metabolism, reduction of oxidative stress and inflammatory response. This makes photobiomodulation a promising method for both prevention and rehabilitation of oral lesions in patients after chemotherapy [9, 12].

In parallel with this, modern research has paid considerable attention to local pharmacological and bioactive agents aimed at restoring the barrier function of the mucous membrane and reducing inflammation. The use of anti-inflammatory, moisturizing, and protective agents reduces the severity of clinical symptoms and improves the tolerability of chemotherapy [10, 15]. At the same time, the effectiveness of such approaches largely depends on the timeliness of their application and combination with other rehabilitation methods.

In a study by Amin M. et al. [16] found that hygiene correction and patient education on oral care principles play an important role in restoring the normal condition of the oral cavity after chemotherapy. Providing clear hygiene recommendations helps to reduce the frequency of complications and improve the condition of the mucous membrane.

Dysbiotic changes after chemotherapy can hinder the healing of lesions and maintain chronic inflammation [7, 17, 18]. That is why correcting the microbiological balance is considered a promising direction for rehabilitation that can complement standard treatment strategies (Table 1).

Table 1. Innovative methods of oral rehabilitation in patients after chemotherapy

Rehabilitation method	Mechanism of action	Clinical significance	Source
Photobiomodulation therapy	Reduction of inflammation, activation of repair	Reduction in the severity of mucositis, reduction in pain	[9], [12]
Local anti-inflammatory and protective agents	Restoration of mucosal barrier function	Symptom relief, accelerated healing	[10], [15
Correction of oral hygiene	Reduction of microbial load	Prevention of infectious complications	[16], [19]
Microbiome-oriented approaches	Normalization of microflora	Support of reparative processes	[7
Multidisciplinary support	Comprehensive impact on risk factors	Improvement of patients' quality of life	[5], [13]

Source: compiled by the author based on [5, 7, 9, 10, 12, 13, 15, 16, 19]

The most convincing evidence has been obtained for the use of photobiomodulation therapy, which in randomized clinical trials has been associated with a statistically significant reduction in the incidence and severity of oral mucositis [9, 12, 20]. At the same time, other methods, in particular the use of local pharmacological agents and educational hygiene programs, demonstrate moderate but clinically significant efficacy, especially as part of combined rehabilitation strategies (Table 2) [10, 16].

Table 2 Effectiveness of rehabilitation interventions in patients after chemotherapy

Rehabilitation intervention	Main results	Source
Photobiomodulation therapy	Significant reduction in the severity of mucositis, reduction in the duration of lesions	[9], [12]
Local drug therapy	Moderate reduction in symptoms, improved comfort	[10], [15
Hygiene education programs	Reduction in the frequency of complications, improvement in the condition of the oral mucosa	[16
Comprehensive MASCC/ISOO recommendations	Standardization of approaches to rehabilitation	[13], [14]

Source: compiled by the author based on [9, 10, 12, 13, 14, 15, 16]

The effectiveness of innovative methods of oral rehabilitation after chemotherapy can be determined using a number of clinical, biochemical, and functional markers. In modern studies, increasing attention is being paid not only to reducing the clinical manifestations of oral mucositis, but also to the dynamics of markers that reflect the restoration of the mucous membrane at the cellular and molecular levels [1, 21, 22].

One of the key markers of the effectiveness of rehabilitation interventions is a decrease in the level of pro-inflammatory cytokines, in particular TNF-α and IL-6, which play a central role in the pathogenesis of chemotherapy-induced mucosal damage. Data from clinical studies and systematic reviews indicate that the use of photobiomodulation therapy is associated with a decrease in the expression of these inflammatory mediators, which correlates with a reduction in the severity of mucositis and a reduction in the duration of ulcerative lesions [9, 12]. The cytokine profile can be considered one of the most sensitive biological markers of the mucosal response to innovative rehabilitation methods (Table 3).

Table 3. Indicators of the **effectiveness of innovative approaches to oral rehabilitation in patients after chemotherapy**

Group of markers	Specific markers	Direction of change	Clinical significance	Source
Inflammatory	TNF-α, IL-6	Decrease	Reduction in the intensity of the inflammatory process and the severity of mucositis	[1, 3, 9, 12]
Oxidative stress	Active forms of oxygen	Decrease	Improvement of cellular homeostasis, activation of repair	[3, 12]
Functional (saliva)	Salivation rate, IgA secretion	Increase	Restoration of the protective function of the lacrimal membrane of the oral cavity	[15, 16
Microbiological	Level of opportunistic flora (*Candida spp.*, Gram-negative bacteria)	Normalizatio n	Reduced risk of secondary infections	[7

Group of markers	Specific markers	Direction of change	Clinical significance	Source
Clinical	Degree of mucositis, intensity of pain, duration of the ulcerative phase.	Reduction	Improvement in quality of life and tolerability of chemotherapy	[5, 10], [19]
Quality of life	Dysphagia, nutritional disorders	Improvement	Reduction in clinical severity of the disease	[5, 16

Source: compiled by the author based on [1, 3, 5, 7, 9, 10, 12, 15, 16, 19]

An important functional indicator of oral cavity recovery after chemotherapy is the dynamics of salivation and local immunity indicators. An increase in the rate of salivation and an increase in the concentration of secretory immunoglobulin (Ig) A after the implementation of comprehensive rehabilitation programs indicate frequent restoration of the protective function of the mucous membrane [15, 16]. In this context, changes in saliva indicators can be accessible and non-invasive markers of rehabilitation effectiveness.

Contemporary research has paid particular attention to markers of microbiological homeostasis. Restoring the balance of the oral microbiome after chemotherapy is considered an important factor in successful mucosal repair. A decrease in the frequency of colonization by opportunistic microorganisms and a reduction in microbial load are associated with better clinical outcomes and a lower risk of secondary infections [7]. Normalization of the microbiome may be an indirect but clinically significant marker of the effectiveness of rehabilitation interventions. Meanwhile, clinical markers, such as reduced pain intensity, shorter ulcerative phase, and improved swallowing and nutrition, remain important criteria for assessing rehabilitation outcomes. Studies show that the introduction of innovative methods, especially in combination with educational hygiene programs, contributes to a reduction in the clinical severity of the disease and an improvement in the quality of life of patients [5, 16, 17].

Stimulation or replacement of salivation is considered a potential direction for rehabilitation in patients with severe xerostomia after chemotherapy. The use of non-

pharmacological salivary stimulants and artificial saliva substitutes can help improve mucosal hydration, reduce discomfort, and partially restore barrier function. At the same time, available data indicate that these methods are mainly symptomatic and have no direct effect on the inflammatory mechanisms of mucosal damage, which limits their independent effectiveness in rehabilitation [15, 16].

Another area discussed in the context of post-chemotherapy rehabilitation is the use of complementary and nutrition-oriented approaches, in particular dietary correction and the use of biologically active supplements. The results of systematic reviews indicate the potential positive effect of certain nutrients on the condition of the mucous membrane, but the high level of heterogeneity of studies and the lack of standardized protocols do not allow these methods to be considered as independent or universal rehabilitation strategies [5, 16].

Some publications also highlight the potential for regenerative approaches, including bioactive coatings and local healing stimulants. Most of these methods are in the clinical implementation stage, and the evidence base for their effectiveness remains insufficient for inclusion in standard recommendations for oral rehabilitation after chemotherapy. Current scientific research indicates that the effectiveness of innovative rehabilitation must be determined comprehensively and take into account the dynamics of inflammatory, functional, and microbiological markers. This approach allows for the determination of effective intervention outcomes and creates opportunities for the personalization of rehabilitation programs depending on the individual course of mucosal lesions.

Thus, modern oral rehabilitation in patients after chemotherapy has evolved from symptomatic control to pathogenetically sound and multidisciplinary strategies. Lesions of the oral mucosa should be considered not as an isolated side effect, but as a dynamic process resulting from the interaction of cytotoxic damage, inflammatory response, local immune disorders, and changes in the oral microbiome [1, 3]. This approach explains the variability of clinical manifestations and the varying effectiveness of rehabilitation interventions in different patient groups.

One effective method of recovery is photobiomodulation therapy. Its effect is

achieved through the reduction of pro-inflammatory cytokine expression and the activation of reparative processes. At the same time, the results of the analysis show that none of the rehabilitation methods can be considered universal in monotherapy. Local pharmacological agents, oral hygiene correction, and educational programs demonstrate moderate but clinically significant efficacy, especially as part of combined rehabilitation strategies [10, 15, 19]. This emphasizes the advisability of a comprehensive approach aimed at simultaneously reducing inflammation, restoring protective function, and reducing microbial load.

The role of rehabilitation effectiveness markers deserves special attention. Decreased levels of TNF-α and IL-6, normalization of salivation and secretory IgA, and restoration of the microbiological balance of the oral cavity reflect not only clinical improvement but also deeper processes of tissue homeostasis restoration [7, 9, 12]. Such integration of biological and clinical markers into the practice of assessing rehabilitation outcomes creates the prerequisites for personalizing treatment programs.

From a clinical point of view, effective oral rehabilitation has a direct impact on the quality of life of cancer patients, reducing pain, improving nutritional status, and tolerability of chemotherapy [5]. The implementation of MASCC/ISOO international recommendations and their adaptation to the individual needs of patients allow for the standardization of approaches to patient management and minimize the risk of serious complications [13, 14].

It should be noted that additional rehabilitation approaches (correction of salivary function, nutrition-oriented interventions, and experimental regenerative methods) cannot be considered alternatives to the main innovative strategies. Their role is mainly to reduce symptomatic burden and support the mind in restoring the condition of the oral cavity.

Conclusions

Oral rehabilitation in patients after chemotherapy should be based on a combination of innovative methods and evidence-based clinical recommendations, taking into account the pathophysiological mechanisms of damage and the dynamics of recovery markers. Among innovative methods, photobiomodulation therapy

demonstrates the most convincing effectiveness, especially as part of combined rehabilitation programs. The effectiveness of rehabilitation should be assessed using a combination of clinical, functional, and biological markers that reflect a reduction in inflammation and restoration of normal mucosal function. Additional rehabilitation approaches, such as salivary function correction and nutritional support, can be used as adjuncts to individualized programs, but do not yet have sufficient evidence for separate use.

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