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EFFECTS OF ORTHODONTIC APPLIANCES ON PERIODONTAL HEALTH: BIOLOGICAL AND MORPHOLOGICAL CHANGES, CLINICAL COMPLICATIONS AND ORAL MICROBIAL BALANCE

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Abstract: The investigation of the biomechanical properties of orthodontic appliances, their influence on periodontal tissues, and the dentoalveolar system as a whole during the management of dentofacial anomalies, alongside the prevention of treatment-related complications, constitutes a critical area of contemporary dentistry. This study delineates the morphophysiological modifications in periodontal tissues and the concomitant alterations in the oral microbiome induced by the application of orthodontic devices.

Keywords: changes in periodontal tissues, effects of orthodontic appliances on the periodontium, oral microbiome changes induced by orthodontic devices, post-orthodontic treatment complications.

Relevance: Nowadays, dental anomalies are prevalent, according to statistics they occur in about 82% of adults. [1,5] As a result, orthodontic and orthopedic procedures are most often required among adults between the ages of 18 and 45. One of the reasons for this is the deformation of the teeth and the high pressure on the periodontal ligament (PDL) caused by secondary adentia.

Both removable and fixed orthodontic appliances are extensively applied for the management of dentofacial anomalies and deformities, with the aim of restoring the functional harmony of the dentoalveolar and stomatognathic system, optimizing occlusal relationships, promoting periodontal health, enhancing dental and facial aesthetics, and ultimately improving patients' oral health–related quality of life.

One of the main aims of orthodontic treatment is to achieve an even allocation of mechanical load within the periodontal tissues. However, alongside this aim, several adverse factors—most notably a reduction in the oral hygiene index—may contribute to the development of periodontal diseases, including catarrhal and hypertrophic gingivitis. Under the influence of orthodontic appliances, pathological changes in the periodontal tissues may be not only secondary but also primary in nature, resulting from unaccustomed functional loading imposed on the periodontium of teeth undergoing orthodontic movement. Clinical examination revealed complicated periodontal conditions in 32.32% of patients, reversible complications in 18.77%, and irreversible pathological changes in 13.54% of cases.

Tooth movement induced by orthodontic forces may lead to the development of pathological changes in periodontal tissues. The primary mechanism underlying these changes is the formation of compression and tension zones within the periodontium during tooth displacement. Under the influence of loading on the tooth crown, bending of the tooth occurs, resulting in the formation of a compression zone at the cervical region with a reduction of the periodontal ligament space, while a corresponding tension zone develops on the opposite side.

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Consequently, blood and lymphatic vessels, periodontal fibers, cellular elements, and nerve endings are subjected to compression.[20]

Orthodontic pressure (the mechanical force applied to teeth) may induce a tissue response in the periodontal tissues. This represents a necessary physiological reaction to tooth movement. Therefore, one of the key goals of orthodontic treatment is to select a therapeutic approach and orthodontic appliance that do not exert detrimental effects on the tooth root or the surrounding periodontal tissues.

According to research, the frequency of periodontal complications associated with the use of fixed orthodontic appliances ranges from 20 to 38% [4]. During the first month of mechanical loading in orthodontic treatment with braces, orthodontic forces compress the periodontal ligaments. This results in altered blood circulation within the alveolar bone and triggers bone resorption around the teeth. The resulting tissue hypoxia stimulates the production of a high concentration of angiogenic factors in the gingival crevicular fluid, which facilitates the remodeling of the tissues surrounding the teeth. The gingival fluid shows increased levels of neutrophilic leukocytes, epithelial cell degeneration, and elevated concentrations of osteogenic cytokines and angiogenic factors, provoking a tissue response that promotes the formation of new blood vessels and connective tissue.

Compression of the periodontal ligaments also induces a hyalinization process [2,6,7]. During this process, the volume of the compressed cell nucleus decreases or undergoes atrophy, leading to the transformation of collagen fibers into an amorphous mass. This is a temporary phenomenon, and once metabolism and blood circulation slow and the pressure is relieved, the tissue returns to its baseline state, indicating regeneration. These changes represent a protective physiological response, highlighting the importance of applying controlled, evenly distributed forces in small doses during orthodontic treatment.

The described process can also be explained by the development of immunodeficiency, which is manifested by a reduction in CD3+ lymphocyte levels, immunoglobulin A, and the immunoregulatory index, subsequently leading to alterations in periodontal tissues. During orthodontic treatment, a decrease in local oral immunity, reduced salivary lysozyme levels, and the presence of microorganisms such as *Actinobacillus actinomycetemcomitans*, *Prevotella intermedia*, and *Porphyromonas gingivalis* indicate a compromised periodontal status [10,11].

As previously mentioned, the use of various orthodontic appliances inevitably affects the clinical, functional, and hygienic status of the oral cavity. During orthodontic treatment, fixed appliances may remain in the oral cavity for prolonged periods, potentially disrupting periodontal homeostasis and contributing to adverse factors. It is important to consider that the accumulation of dental plaque on these appliances is accompanied by alterations in the oral microbiota and an increase in the number of pathogenic microorganisms. This condition primarily manifests as a tissue response characterized by inflammation of the periodontal tissues. Studies have demonstrated that quantitative and qualitative changes in the oral microbiota induced by orthodontic appliances promote the development of diseases affecting both hard and soft oral tissues, due to shifts in microbial composition, a decrease in pH toward acidic values, and an increase in various pathogenic microorganisms [11,18,22].

Microbiological studies conducted by several researchers have demonstrated that the number of pathogenic microorganisms in the oral cavity of orthodontic patients increases to some extent. Among aerobic bacteria, 70% were Gram-positive cocci (*Streptococcus viridans* – 31%, *Streptococcus* spp. – 25%, *Staphylococcus epidermidis* – 6%, *Enterococcus* spp. – 4%, *Streptococcus oralis* – 4%), 12% were Gram-negative cocci (*Neisseria* spp.), 10% were *Candida* *albicans*, and 8% were *Corynebacterium* spp. Among anaerobic microorganisms, Gram-positive cocci (*Peptostreptococcus* spp.) were detected in 19% of cases, Gram-positive rods in 30% (*Lactobacillus* spp., *Propionibacterium* spp., *Actinomyces* spp.), Gram-negative rods in 15% (*Fusobacterium* spp.), and Gram-negative cocci in 36% (*Veillonella* spp.) [7,10,13,22].

Zharmgambekova A.G. and Tuleuatova S.T. [29,31,40] investigated the oral microbiota of 12-year-old children with fixed orthodontic appliances using microbiological analysis. The study included 200 schoolchildren, and observations covered all stages of orthodontic treatment. Both obligate and facultative microorganisms present in dental plaque were examined. Microorganism identification was performed using bacteriological methods. The results demonstrated that during the active phase of orthodontic treatment, the levels of certain microorganisms increased sharply. In patients with removable appliances, *Streptococcus* spp. and *Staphylococcus* spp. were consistently detected, whereas *Candida albicans* and *Staphylococcus aureus* exhibited variable prevalence, being present in a small number of children [23,26]. In patients with fixed appliances, the detection frequency of these microorganisms was 1.5 times higher [27]. Furthermore, *Streptococcus pyogenes* and *Neisseria* were identified in patients with plate-type appliances. After completion of orthodontic treatment, a reduction in microbial symbiosis and an improvement in oral hygiene were observed [28,33]. Thus, during orthodontic treatment, the oral cavities of the examined children exhibited a microbial combination including lactobacilli, various species of streptococci, staphylococci, and fungi. Among the dominant bacteria, *Streptococcus mutans*, *Lactobacillus* spp., and *Staphylococcus aureus* were detected, the latter being one of the factors contributing to the development of dental caries [35].

The cause of periodontal tissue diseases during orthodontic treatment is influenced not only by oral hygiene but also by changes in the composition of gingival crevicular fluid (GCF). To determine markers of pathological processes and biochemical reactions in periodontal tissues during orthodontic treatment, GCF is most commonly analyzed. The composition of GCF reflects the course of immune responses and inflammatory processes in a host–parasite type reaction, as well as biomechanical changes. For this reason, as demonstrated by numerous studies, components of GCF, including microbial constituents, can be utilized to assess periodontal status during inflammation or orthodontic tooth movement [Khalid S. Hasan et al.].

As a result of research, inflammatory responses of the organism can lead to tissue remodeling, thereby enabling tooth movement. Uematsu et al. (1996) showed that during orthodontic treatment, levels of various inflammatory mediators, such as interleukin-1β (IL-1β), interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), epidermal growth factor, and β2-microglobulin, can increase significantly. Furthermore, Grieve et al. reported similar findings for prostaglandin E and IL-1β, while Lowney et al. described elevated TNF-α levels in the gingival crevicular fluid of teeth undergoing orthodontic treatment. Additionally, Griffiths et al. observed increased levels of osteocalcin and collagen pyridinoline cross-links in the gingival crevicular fluid of teeth during orthodontic treatment.

In recent studies, Surlin et al. [9] observed the development of hypertrophic gingivitis during orthodontic treatment, even in patients with good oral hygiene indices. This was determined by the production of matrix metalloproteinase-8 (MMP-8) and matrix metalloproteinase-9 (MMP-9) in the gingival crevicular fluid of these patients. The condition manifests as increased mechanical pressure on the periodontal tissues.

Alkaline phosphatase (ALP) is a key enzyme involved in bone tissue remodeling through the hydrolysis of inorganic pyrophosphate, a potent inhibitor of the mineralization process. Alkaline phosphatase activity is observed in periodontal ligament fibroblasts and alveolar bone osteoblasts.

Aspartate aminotransferase (AST), in turn, is an intracellular cytoplasmic enzyme that is released into the extracellular space following cell death; therefore, its activity in the extracellular environment can be considered an indicator of cellular necrosis. Nevertheless, a certain level of AST in the extracellular environment may reflect physiological processes within the tissues. Both AST and ALP are also present in gingival crevicular fluid, and their quantitative levels serve as indicators of periodontal tissue status.

According to the research by Khalid S. Hasan et al., AST enzymatic activity was higher in areas where ligature systems were applied. Additionally, the microbial flora was examined following the use of ligature braces and self-ligating braces at different observation periods. At the initial stages of the study, no significant differences in bacterial parameters were observed between the groups. Subsequently, throughout the observation period, all microbial parameters in Group GII (ligature braces) were slightly higher than in Group GI (self-ligating braces). Moreover, at all time points, bacterial parameters (total bacterial count, *S. mutans*, aerobic and anaerobic forms of lactobacilli) were significantly higher in both experimental groups compared to the control group [Khalid S. Hasan et al.]. In addition, compared with self-ligating braces, the depth of gingival pockets was increased with ligature braces, and more pronounced changes in clinical attachment levels were observed.

Analysis of the reviewed literature indicates that the occurrence of gingival recession during orthodontic treatment remains a subject of debate. Some researchers suggest that gingival recession is caused by mechanical trauma during tooth brushing; however, Matthews and Rajapakse [17,20] emphasized that this process is not directly related, but rather influenced by anatomical and morphological factors of the periodontium. When anatomical parameters such as bone thickness, tooth positioning, and the condition of the alveolar ridge are properly considered during orthodontic treatment, the risk of gingival recession can be minimized.

According to statistics, gingival recession has been observed in 10–12% of patients undergoing orthodontic treatment [reference]. This condition may lead to a range of complications, including dental hypersensitivity, compromised aesthetics, and increased susceptibility to caries. Therefore, it is essential to approach each patient individually, rather than relying on a single treatment protocol. Orthodontic treatment should be tailored to the patient's periodontal anatomy, appliance type, oral hygiene, direction of tooth movement, and results of specialized examinations, with appropriate therapeutic measures implemented to prevent potential complications.

During stages of orthodontic treatment, particularly with the placement of fixed braces, procedural errors can lead to serious complications. Examples include changes in enamel color, the appearance of white spots and defects, dental hypersensitivity, gingivitis, and periodontitis. Improperly selected archwires or incorrect bracket positioning can result in excessive force, contributing to the development of root resorption. According to the literature, the prevalence of root resorption in adults ranges from 17% to 45% [Goldin B., 1989].

One of the most common complications of orthodontic treatment with fixed braces is enamel demineralization. According to statistical data, its prevalence ranges from 15% to 85% of patients [Artyukhova E.K., Kuklyova M.P., 2002]. In contemporary dentistry, these changes have been confirmed using acoustic microscopy. In studies, a microstructural assessment of enamel was performed on 34 teeth extracted for various indications.

Z.V. Gasimova [36,44] divided the extracted teeth into two parts, performing a perpendicular section along the longitudinal axis of the tooth (diamond bur, 1500 rpm). Under the microscope, two main areas were examined: the region around the sealer and the surface to which the bracket had been attached. According to the study results, following bracket placement, physical and mechanical changes in the enamel were observed in some cases, including microcracks, porosity between enamel prisms, and other structural alterations. In the other group of teeth, no such changes were detected, and the microstructural features of the enamel remained nearly unchanged over a period of up to one year.

It has been established that individual structural characteristics of enamel, the overall health status of the patient, and oral hygiene levels significantly influence the nature of changes occurring during orthodontic treatment with fixed braces. Adherence to established bracket placement protocols contributes to the prevention of complications that may arise following orthodontic treatment.

According to research by Banks P.A., among patients with orthodontic appliances, 26.3% exhibited enamel destruction, 31.6% showed erosion and necrosis, and 42.1% presented with localized demineralization [17,11,13]. The structural components of braces—brackets, springs, archwires, clamps, and other elements—create retention sites for microbial accumulation. As a result, patients encounter considerable challenges in maintaining proper oral hygiene.

Failure to maintain regular and adequate oral hygiene often leads to the onset and progression of periodontal diseases [23,25,30,32]. This promotes the accumulation of dental plaque on tooth surfaces, its subsequent mineralization, and calculus formation.

Studies evaluating oral hygiene indices in patients with braces (Karakov K.G. et al.) showed that prior to the initiation of orthodontic treatment, the OHI-s index in all patients did not exceed 0.3, indicating good oral hygiene, while the PMA index was close to zero. One month after the start of treatment, patients exhibited OHI-s values of 1.45 ± 0.35 and a PMA index of 13.2%, indicating difficulties in maintaining oral hygiene and the initial manifestations of gingivitis in patients using fixed orthodontic appliances.

Under the influence of these local factors, the gingival tissues surrounding the teeth become inflamed. When subjected to excessive orthodontic forces, blood circulation in the peripheral vessels of the periodontium is disrupted, and tissue trophism is altered, which may, in turn, lead to resorption of the alveolar bone septa as well as root resorption [21].

Conclusion. Orthodontic appliances are commonly used in the treatment of morpho-functional disorders of the dentoalveolar system, as well as to improve occlusion and aesthetics. However, all types of orthodontic forces exert direct or indirect effects on the periodontal tissues surrounding the teeth. During treatment, it is essential to consider the periodontal biotype, bone tissue structure, and the patient's oral hygiene status. When using fixed braces, monitoring the patient's overall health and local clinical manifestations is necessary. The presence of concomitant conditions—such as hypertension, endocrine disorders, gastrointestinal diseases—as well as local factors, including inadequate oral hygiene, carious lesions, and gingival recession, increases the risk of various complications [37,4,56].

Furthermore, proper distribution of orthodontic forces on the periodontal tissues is of critical importance. The application of optimal and evenly distributed forces, along with a gradual increase in load, helps prevent the development of apical root resorption [27,31,45]. During treatment, it is advisable to develop an individualized orthodontic treatment plan for each patient. Gradual force application reduces the load on the periodontal tissues and helps prevent root resorption [41]. Therefore, the quantitative characteristics and structural organization of the periodontium hold significant clinical relevance. In this context, joint diagnostics, coordinated

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treatment planning by the orthodontist and periodontist, assessment of potential complications, and implementation of preventive measures are highly important.

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