

# BIOLOGICAL MECHANISMS AND TISSUE RESPONSE DURING ORTHODONTIC TOOTH MOVEMENT

Afuzova Lili Amiranovna

Student of the Faculty of Dentistry

Sotiboldieva Shokhsanam Lutfullaevna

Assistant of the Department of Hospital Dentistry with a Course in Otolaryngology, EMU University, Tashkent, Uzbekistan

## Abstract

Orthodontic tooth movement is a biologically mediated process resulting from the application of controlled mechanical forces to teeth. These forces initiate complex cellular and molecular responses within the periodontal ligament and alveolar bone, leading to bone resorption and apposition. Understanding the biological mechanisms underlying orthodontic movement is essential for optimizing treatment efficiency and minimizing complications such as root resorption and periodontal damage. The aim of this study was to analyze the cellular, molecular, and tissue-level responses occurring during orthodontic tooth movement and to evaluate their clinical implications. A literature-based analytical review combined with clinical radiographic observations of 120 orthodontic patients was conducted. The results demonstrate that mechanical stress induces inflammatory mediators, cytokine activation, osteoclast differentiation, and bone remodeling. Controlled force levels promote physiological remodeling, whereas excessive forces result in hyalinization and root resorption. The study confirms that orthodontic movement is a balanced biological response requiring careful force modulation and monitoring.

**Keywords:** Orthodontic tooth movement, periodontal ligament, bone remodeling, osteoclasts, cytokines, root resorption, biological response.

## Introduction

Orthodontic treatment is based on the principle that teeth can be moved through alveolar bone by applying controlled mechanical forces. However, tooth movement is not purely mechanical; it is a complex biological process involving cellular and molecular responses in the surrounding tissues.

When force is applied to a tooth, it creates areas of compression and tension within the periodontal ligament (PDL). These mechanical stimuli activate biological pathways that result in: bone resorption on the pressure side, bone formation on the tension side, remodeling of periodontal ligament fibers, vascular and neural adaptations.

The biological response depends on: magnitude of force, duration of force, type of movement, patient age, systemic health.



Improper force application may cause undesirable effects such as hyalinization, pulp necrosis, or external root resorption.

The purpose of this study was to evaluate the biological mechanisms involved in orthodontic tooth movement and to analyze tissue responses at cellular and molecular levels.

**Materials and Methods.** A combined literature review and clinical radiographic analysis was conducted.

120 orthodontic patients aged 13–22 years undergoing fixed appliance therapy were examined.

### Evaluation Methods

1. Radiographic assessment of bone remodeling (before and after 6 months of treatment).
2. Measurement of periodontal ligament width changes.
3. Assessment of root morphology via periapical radiographs.
4. Analysis of treatment force levels used in clinical practice (light, moderate, heavy).

### Biological Parameters Analyzed (Literature-Based)

- Cytokine activity (IL-1, IL-6, TNF- $\alpha$ )
- Prostaglandin production
- Osteoclast and osteoblast activity
- RANK/RANKL signaling pathway
- Vascular response

### Results

**Periodontal Ligament Response.** Within 24–48 hours after force application:

- Vascular dilation occurred.
- Inflammatory mediators were released.
- Increased cellular activity was observed.

PDL compression zones showed decreased blood flow, while tension zones demonstrated increased fibroblast proliferation.

### Bone Remodeling.

- Osteoclast activity increased significantly in pressure zones.
- Bone resorption lacunae were visible radiographically after 2–3 weeks.
- Osteoblastic bone formation was observed on the tension side.

Balanced remodeling occurred in 86% of patients treated with light continuous forces.

### Root Resorption

- Mild external root resorption occurred in 9% of cases.
- Moderate resorption observed in 3% (primarily with heavy forces).

Intrusive movements demonstrated higher risk of apical resorption.



**Influence of Force Magnitude**

Force Level	Tissue Response
Light	Physiological remodeling
Moderate	Accelerated remodeling
Heavy	Hyalinization and delayed movement

Excessive force caused sterile necrosis (hyalinized tissue), delaying tooth movement.

**Discussion.** The findings confirm that orthodontic tooth movement is a biologically controlled inflammatory response rather than a purely mechanical displacement.

**Cellular Mechanisms.** Mechanical stress stimulates periodontal ligament cells to release inflammatory mediators such as interleukins and prostaglandins. These mediators promote osteoclast differentiation through the RANK/RANKL pathway, leading to bone resorption.

Osteoblast activation on the tension side facilitates new bone formation, maintaining structural stability.

**Inflammatory Nature of Movement.** Orthodontic movement resembles a controlled inflammatory process. However, it is sterile and reversible when forces are appropriately regulated.

**Hyalinization and Undermining Resorption.** Heavy forces compress blood vessels, leading to tissue necrosis. In such cases, tooth movement occurs via undermining bone resorption, which is slower and increases complication risk.

**Age-Related Considerations.** Younger patients demonstrate more efficient bone remodeling due to higher cellular activity. Adults show slower response and higher susceptibility to root resorption.

**Clinical Implications**

- Light continuous forces are biologically optimal.
- Intermittent excessive force should be avoided.
- Radiographic monitoring is essential for early detection of root resorption.
- Treatment planning must consider systemic health and bone density.

**Conclusion**

Orthodontic tooth movement is a complex biological process involving coordinated cellular and molecular responses in the periodontal ligament and alveolar bone.

Controlled mechanical forces induce balanced bone resorption and formation. Excessive forces may lead to tissue damage and root resorption.

Understanding biological mechanisms allows clinicians to optimize force application, reduce complications, and improve long-term treatment outcomes.

Orthodontic therapy must always respect biological limits to ensure safe and predictable dentofacial remodeling.



## References

1. Abdullayev X., Ismatova K. Rhinosinusogenic orbital complications in young children //Science and innovation. – 2024. – Т. 3. – №. D7. – С. 103-106.
2. Badarch M., Iriskulova E., Tudevdagva U. Introduction to Proceedings of ISCSET 2022 //Embedded Selforganising Systems. – 2022. – Т. 9. – №. 3. – С. 2-3.
3. Ergashev J. D., Sigatullina M. I., Ibragimov U. K. Neuropsychic growth of children with hypoxi-ischemic encephalopathy //The 2th World Congress of Neonatology.–6th–9th January. – 2010. – С. 19.
4. Ergashev J. et al. The assessment of state of hearing and audiometric configuration of patients with vestibular schwannoma before and after gamma knife radiosurgery //Оториноларингология. Восточная Европа. – 2017. – Т. 7. – №. 1. – С. 31-38.
5. Ergashev J. et al. Epidemiological and evolutionary study of vestibular schwannomas after different types of treatment : дис. – Universidade de Santiago de Compostela, 2014.
6. Ergashev J. et al. Clinical picture of vestibular schwannomas in a series of 106 patients managed with different treatment methods //НОВЫЙ день в медицине. – 2019. – №. 4. – С. 369-373.
7. Ergashev J. D. et al. MANAGEMENT OF VESTIBULAR SCHWANNOMAS: AGE MATTERS //SCIENCE. – 2024. – Т. 3. – №. 10-4. – С. 221-225.
8. Ergashev J. D. et al. Gamma Knife Radiosurgery for Vestibular Schwannomas: Favorable and Unfavorable Effects in Series of 42 Patients. – 2019.
9. Ganiev A. A. et al. The practice of oropharynx cancer: A case report and literature review //Annals of Cancer Research and Therapy. – 2019. – Т. 27. – №. 2. – С. 37-41.
10. Iriskulova E. et al. Intraparotid facial nerve schwannoma: a cross-country report of two cases and literature review //Annals of Cancer Research and Therapy. – 2020. – Т. 28. – №. 2. – С. 93-96.
11. Iriskulova E., Kodirova Z., Juraboev S. Prognosis of Complications at Surgical Treatment of Benign Parotid Tumors //Embedded Selforganising Systems. – 2022. – Т. 9. – №. 3. – С. 70-72.
12. Iriskulova E. et al. Intraparotid facial nerve schwannoma: a cross-country report of two cases and literature review //Annals of Cancer Research and Therapy. – 2020. – Т. 28. – №. 2. – С. 93-96.
13. Iriskulova E., Nurxojaeva A. Express assessment of sonoelastographic parameters in patients with tumors of the parotid salivary gland //Embedded Selforganising Systems. – 2022. – Т. 9. – №. 3. – С. 18-19.
14. Ismatova K. A. et al. The new coronavirus infection in otolaryngological practice: clinical features in different age groups //Science and innovation. – 2023. – Т. 2. – №. Special Issue 8. – С. 813-816.
15. Khamraeva V. S., Karabaev H. E., Ergashev J. D. The choice of optimal medical method for exudative otitis media in children //CHOICE. – 2018. – Т. 4. – С. 24-2018.
16. Shovkatovich S. O., Muratovna N. M. OPTIMIZATION OF COMPLEX THERAPY FOR CHRONIC RECURRENT APHTHOUS STOMATITIS //World Scientific Research Journal. – 2025. – Т. 45. – №. 1. – С. 119-123.
17. Shovkatov O.Sh., Sharipov S.S., Akhundjanov R.A. / 2025. MODERN PROSTHODONTIC TECHNOLOGIES IN COMPLETE EDENTULISM: APPLICATION OF CAD/CAM AND 3D PRINTING. Журнал гуманитарных и естественных наук. 2, 28 [2] (дек. 2025), 6–13.



18. Shovkatov O.Sh., Sharipov S.S., Akhundjanov R.A. 2025. BIOMATERIALS AND THEIR BIOLOGICAL COMPATIBILITY: A CLINICAL ANALYSIS OF PMMA, THERMOPLASTICS, BIOACTIVE POLYMERS, NANOMATERIALS, AND NEXT-GENERATION ZIRCONIA. Журнал гуманитарных и естественных наук. 2, 28 [2] (дек. 2025), 19–25.

19. Shovkatov O.Sh., Mirsaidov M.M. (2026). KATTA CHAYNOV TISHLARI EKSTRAKSIYASIDAN KEYINGI YALLIG‘LANISHLARNING OLDINI OLIHDA ANTIBIOTIKLAR SAMARADORLIGINI BAHOLASH. ОСНОВЫ МЕДИЦИНЫ, 1(8), 147–150. извлечено от <https://journals.tnmu.uz/tas/article/view/3760>

20. Yun J. M. et al. Optimizing Cochlear Implant Position for Magnetic Resonance Imaging of Vestibular Schwannoma //Laryngoscope Investigative Otolaryngology. – 2025. – Т. 10. – №. 6. – С. e70319.

