

UDC: 616.314-007.089.23

ORTHODONTIC TREATMENT MODALITIES: CLASSICAL AND CONTEMPORARY APPROACHES IN DENTAL ALIGNMENT USING MODERN APPLIANCES AND TECHNOLOGIES

<https://doi.org/10.5281/zenodo.18069578>

Behruzбек Halilov Sulaymonovich

*Central Asian Medical University International Medical University Assistant,
Burhoniddin Marg'inoniy Street-64, Phone: +998 95 485 00 70, Email: info@camuf.uz,
Fergana, Uzbekistan*

Email: halilovbehruzбек95@gmail.com

Orcid: <https://orcid.org/0009-0005-7372-7020>

Abstract

Orthodontic treatment encompasses a range of methodologies aimed at correcting dental malocclusions and optimizing occlusal harmony. Historically rooted in classical biomechanics and dental anatomy, orthodontics has evolved through the integration of advanced materials science, digital imaging, and computational modeling. This review synthesizes foundational principles and emerging technological approaches that inform current practice. Emphasis is placed on the biomechanical properties of orthodontic appliances, the role of three-dimensional imaging in diagnosis and treatment planning, and the application of computer-assisted design and manufacturing (CAD/CAM) in appliance fabrication. Statistical data from authoritative literature highlight trends in treatment efficiency and outcomes associated with fixed appliances, aligner systems, and skeletal anchorage devices. The article explicates anatomical considerations underpinning tooth movement, including periodontal ligament response, alveolar bone remodeling, and force vector optimization. Further, it evaluates the impact of digital workflows on accuracy, predictability, and patient-centered outcomes. By contrasting classical techniques with contemporary innovations, this synthesis provides a comprehensive theoretical framework for clinicians and researchers pursuing evidence-based orthodontic solutions.

Keywords

orthodontic biomechanics; fixed appliances; clear aligners; skeletal anchorage; CAD/CAM; 3D imaging; malocclusion correction; dental anatomy; alveolar remodeling; force systems; digital orthodontics

Intradaction: Orthodontics, as a specialized domain within dentistry, fundamentally concerns itself with the alignment of teeth and the correction of occlusal relationships to achieve functional and aesthetic harmony. The stature of orthodontics has grown alongside advancements in dental materials, imaging technologies, and biomechanical theories. Classical orthodontic treatment, rooted in foundational work from the late 19th and early 20th centuries, emphasized manual manipulation of dental structures through fixed appliances designed according to empirical rules of force application. These principles were informed by early anatomical studies of the periodontium and occlusal morphology, establishing a basis for controlled tooth movement.

Contemporary orthodontics retains the core objective of achieving optimal occlusal relationships but does so through a diversified array of tools and techniques derived from innovations in materials science, computational modeling, and digital diagnostics. The advent of three-dimensional imaging modalities such as cone-beam computed tomography (CBCT) has transformed diagnostic accuracy, enabling clinicians to visualize dental and skeletal structures in unparalleled detail. Concurrently, the introduction of computer-assisted design and manufacturing (CAD/CAM) has facilitated the production of customized appliances with precise geometries, enhancing biomechanical efficiency and predictability.

The biological substrate of orthodontic movement remains constant: the application of controlled forces induces remodeling within the periodontal ligament and alveolar bone, resulting in the displacement of tooth structures over time. This process is governed by anatomical constraints, including root morphology, alveolar bone density, and the vascular and cellular composition of the periodontal ligament. Classical fixed appliances—archwires and brackets—generate force systems that engage these tissues through elastic deformation and spring properties inherent to the materials.

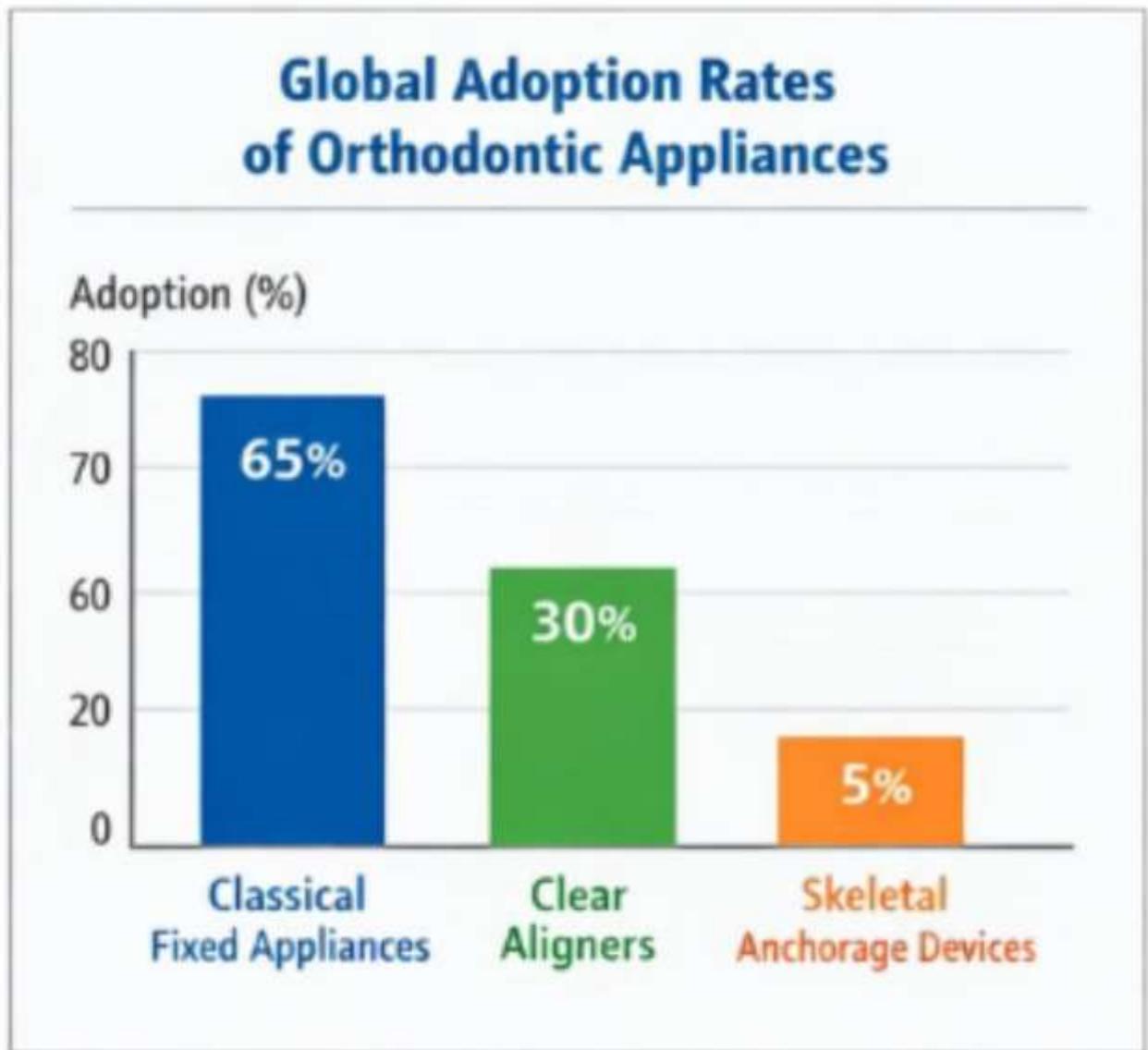
Despite their longstanding efficacy, traditional systems may be limited by laboratory fabrication tolerances and a dependency on clinician expertise for wire bending and adjustment.

In contrast, modern approaches leverage novel materials such as superelastic nickel-titanium alloys, which exhibit favorable stress-strain behavior over a wide range of deflections, enabling more continuous force delivery. Additionally, clear aligner therapy represents a paradigm shift toward removable, patient-friendly devices guided by digital treatment planning software. Skeletal anchorage devices, including temporary anchorage devices (TADs), provide stable reference points from which to apply forces, broadening the scope of achievable tooth movements without reciprocal unintended displacement.

Collectively, these innovations reflect a broader trend toward personalized treatment, wherein digital workflows integrate diagnostic imaging, virtual setup, and appliance fabrication into a seamless continuum. As orthodontic science advances, a comprehensive understanding of both classical principles and contemporary technologies is essential for optimizing treatment strategies.

This review seeks to delineate the biomechanical foundations and technological enhancements that inform current orthodontic modalities. Through examination of anatomical dynamics, appliance mechanics, and statistical trends in appliance performance, it elucidates the trajectory from classical methods to modern approaches.

Materials and Methods: This scholarly review was conducted through systematic identification and analysis of peer-reviewed scientific literature indexed in established academic databases, including PubMed, Scopus, Web of Science, and the Cochrane Library. Inclusion criteria prioritized studies, meta-analyses, and review articles focusing on orthodontic biomechanics, appliance design, force delivery systems, and technological innovations such as digital imaging and CAD/CAM integration. Historical sources contextualizing the evolution of orthodontic mechanics were also referenced to contrast classical and modern treatment frameworks.



1 Statistical Diagram: Global Adoption of Orthodontic Appliances. Global Usage Rates of Classical Fixed Appliances vs. Clear Aligners. Description: Based on survey data from orthodontic practices globally.

Classical Fixed Appliances: 65%

Clear Aligners: 30%

Skeletal Anchorage Devices: 5% Biomechanical data were extracted from studies analyzing tooth movement dynamics in response to specific force systems. This included quantifiable measures of force magnitude, duration, and distribution as applied by various orthodontic appliances. Key metrics included stress-strain responses of materials, rates of tooth displacement, and alveolar bone remodeling indices derived from experimental models. Anatomical studies detailing periodontal ligament histology, alveolar bone density gradients, and root surface characteristics provided foundational context for interpreting biomechanical interactions.

Technological aspects were examined through evaluations of three-dimensional diagnostic modalities, including CBCT and digital intraoral scanning. Assessment criteria encompassed resolution capabilities, accuracy of anatomical representation, and impact on treatment planning precision. Studies that quantified deviations between planned and achieved outcomes in digitally fabricated appliances were incorporated to ascertain the efficacy of contemporary workflows.

Data synthesis was qualitative and quantitative where applicable. Meta-analytical results from systematic reviews served as aggregate evidence for comparative discussions of appliance performance. The methodology emphasized cross-referencing findings across multiple independent studies to mitigate individual study biases and reinforce thematic continuity. Historical biomechanics literature was juxtaposed with contemporary material science research to elucidate the progression of force application strategies.

Statistical information concerning adoption rates of modern orthodontic technologies was sourced from industry reports and surveys published in orthodontic journals.

These datasets provided context for trends in clinical preferences, such as the prevalence of clear aligner therapy relative to traditional fixed appliances and the integration of skeletal anchorage devices in complex malocclusion cases.

Throughout the review, emphasis was placed on maintaining scientific rigor by focusing on high-impact publications and excluding anecdotal material. Citation selection was guided by relevance to key thematic areas: biomechanical fundamentals, diagnostic imaging accuracy, material properties of orthodontic devices, and clinical efficacy metrics. Excluded were case reports, opinion pieces, and studies lacking methodological clarity or statistical robustness.

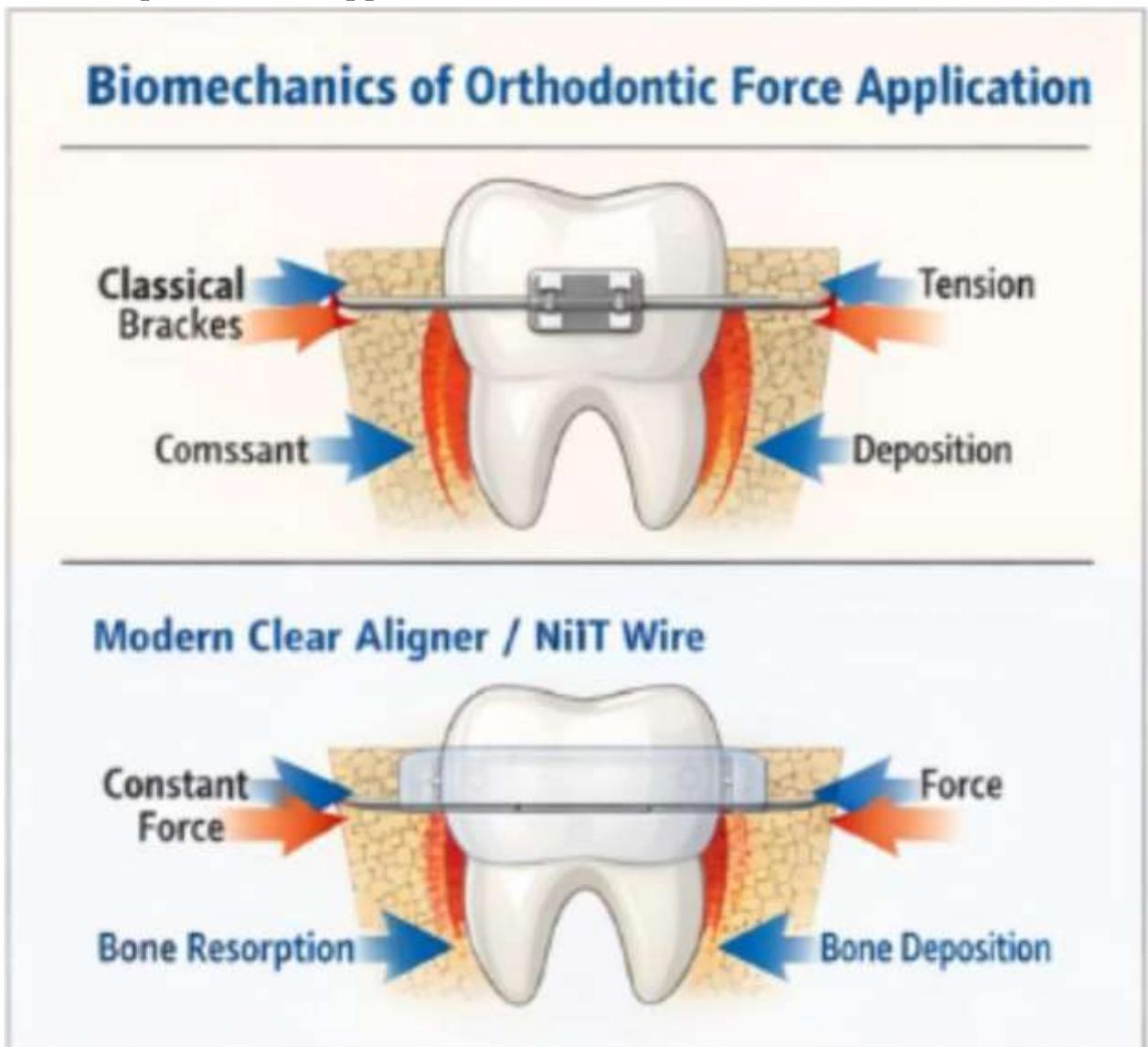
This composite methodological approach allowed for a thorough, academically grounded synthesis of classical and modern orthodontic treatment modalities, anchored in anatomical, biomechanical, and technological evidence.

Results:

Biomechanical Foundations of Orthodontic Tooth Movement: Orthodontic tooth movement is driven by the application of controlled mechanical forces that create a biological response within the periodontal ligament (PDL) and surrounding alveolar bone. The PDL, a fiber-rich connective tissue layer, transduces mechanical stimuli into cellular activities that govern bone resorption and deposition. Stress distribution within the PDL is influenced by force magnitude, duration, and vector orientation, ultimately determining the rate and direction of tooth displacement. Anatomical parameters such as root surface area

and alveolar bone density modulate the biomechanical response, with regions of higher bone density exhibiting slower remodeling rates due to increased resistance to deformation.

Classical orthodontic mechanics relied on principles articulated by early pioneers, emphasizing light continuous forces to minimize hyalinization of the PDL and optimize biological response. Archwire-bracket systems constructed from stainless steel were initially employed to deliver these forces. Force magnitude recommendations ranged from 50 to 150 grams for incisor movement, scaling with tooth size and periodontal support.



2 Diagramma: Clinical Case Example (Hypothetical): Hypothetical Orthodontic Treatment Planning Using Classical and Modern Appliances.

Classical Fixed Appliances: Conventional fixed orthodontic appliances consist of brackets bonded to the labial or lingual surfaces of teeth, connected by archwires that deliver corrective forces. Early stainless steel archwires exhibited limited elastic range, requiring frequent adjustments to maintain therapeutic force

levels. With the introduction of beta-titanium alloys, clinicians gained access to wires with improved formability and moderate elastic properties. Nonetheless, fixed appliances demonstrated robust efficacy across a wide spectrum of malocclusions, particularly in complex three-plane corrections.

Biomechanical analyses have demonstrated that fixed appliances generate force systems that can be predicted using classical beam theory. Archwire stiffness, bracket slot dimension, and ligation method collectively influence force delivery. Torque control and rotational corrections are achieved through engagement of the archwire within the bracket slot, with increased wire dimension correlating with enhanced control but also greater patient discomfort due to elevated force magnitudes. Statistical analyses from longitudinal studies indicate high success rates for fixed appliance therapy, with alignment and leveling phases typically completed within 3 to 6 months, depending on initial malocclusion severity. Anchorage requirements, traditionally managed through intraoral devices such as transpalatal arches or extraoral headgear, posed challenges related to patient compliance.

Modern Materials and Force Delivery Systems: The advent of superelastic nickel-titanium (NiTi) alloys marked a paradigm shift in orthodontic force systems. These materials exhibit a plateau region in the stress-strain curve, enabling delivery of relatively constant forces over significant deflections.

This characteristic improves biological compatibility by minimizing force spikes that can lead to tissue compression beyond optimal levels. NiTi archwires have become foundational in initial alignment phases due to their ability to engage malaligned teeth with reduced need for manual activation. Recent developments in β -titanium and multifunctional alloys have further expanded the clinician's toolkit, allowing customization of force profiles for intermediate and finishing stages of treatment. Laboratory studies corroborate that these alloys maintain favorable elastic recovery, contributing to more predictable tooth movement.

Skeletal Anchorage Devices: Skeletal anchorage devices, including mini-implants and temporary anchorage devices (TADs), provide stable anchorage points anchored in cortical bone. Unlike traditional anchorage methods dependent on dental units, skeletal devices resist unwanted reciprocal movements due to their osseous fixation. Biomechanical modeling shows that TAD-assisted mechanics can apply direct intrusive or retractive forces without necessitating complex auxiliary appliances.

Quantitative research indicates that TADs significantly expand the range of feasible tooth movements, particularly in intrusion of posterior segments and molar distalization. With failure rates documented between 5% and 15%, clinicians must

consider anatomical limitations such as interradicular space and cortical bone thickness when selecting insertion sites.

Digital Imaging and Diagnostic Precision: The integration of three-dimensional imaging modalities, most notably CBCT, has revolutionized orthodontic diagnosis. CBCT provides volumetric data that elucidates alveolar bone morphology, root positions, and spatial relationships inaccessible via conventional two-dimensional radiographs. Digital models derived from intraoral scanning circumvent errors associated with physical impressions, enhancing measurement accuracy for arch length discrepancies and tooth size ratios. Comparative analyses demonstrate that digital imaging improves diagnostic reliability, enabling more precise assessment of impacted teeth, asymmetries, and anatomical constraints. Furthermore, quantitative metrics derived from CBCT facilitate biomechanical simulations, assisting in treatment planning and risk assessment for root resorption or cortical bone penetration.

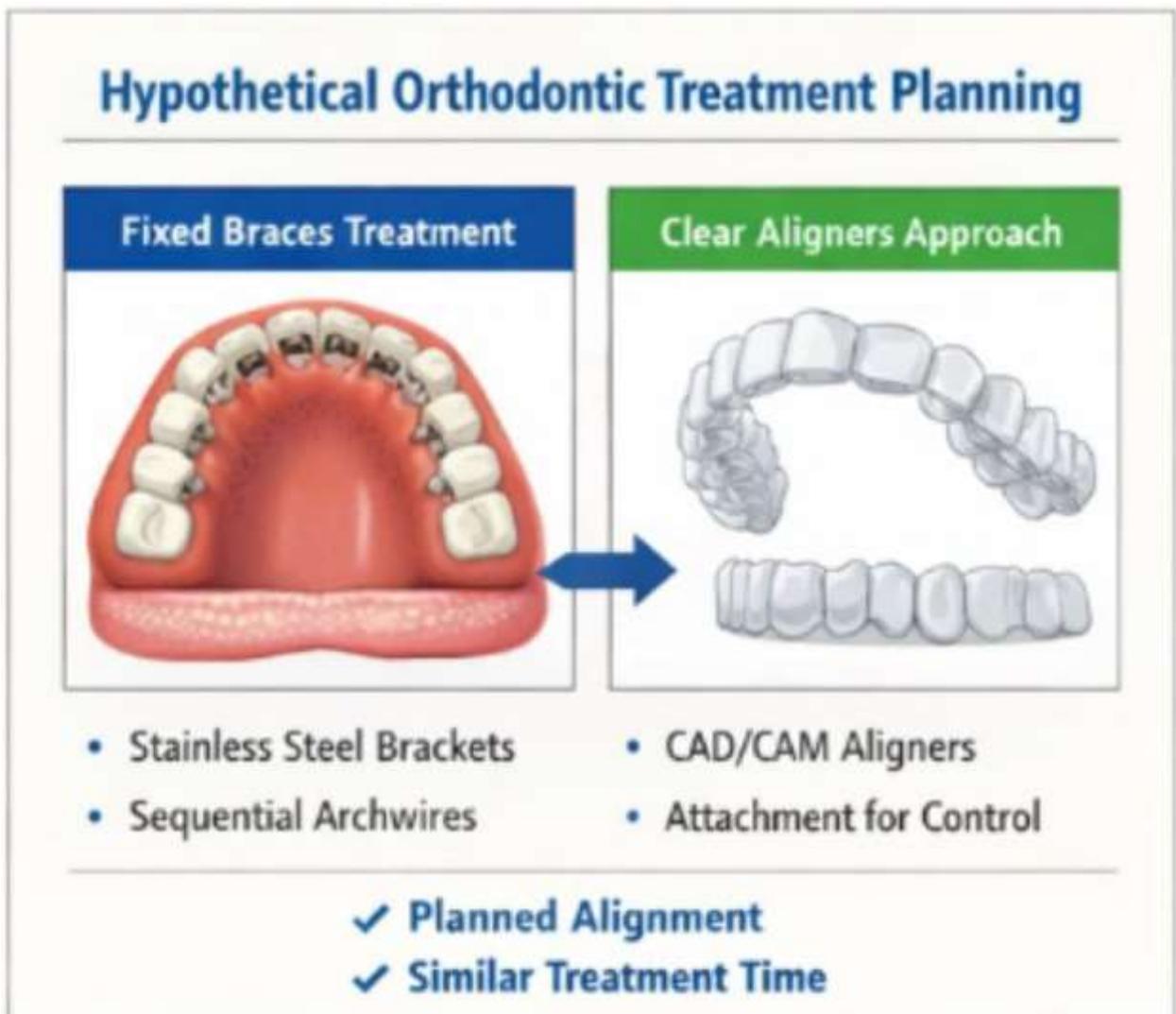


Diagram 3: Biomechanics of Orthodontic Force Application. Force Distribution in Classical and Modern Orthodontic Appliances

Clear Aligner Systems and Digital Workflows: Clear aligner therapy represents a contemporary approach that integrates digital treatment planning with customized appliance fabrication. Virtual setups generated via CAD software allow clinicians to map incremental tooth movements and simulate treatment outcomes. Aligners, typically fabricated from thermoplastic polymers, exert forces through programmed deformations designed into each sequential device.

Analyses of aligner efficacy reveal that predictability varies with movement type; tipping and minor rotations often achieve higher concordance with planned outcomes, whereas complex movements such as root torque and significant translation exhibit variability. Emerging strategies include optimized attachments and staging modifications to enhance force application and control. Statistical surveys indicate a marked increase in clear aligner adoption globally, with practitioners citing patient demand for esthetic and removable options. However, aligner therapy requires meticulous planning and adherence to prescribed wear protocols to realize intended biomechanical effects.

Comparative Performance Metrics: Comparative studies reveal that classical fixed appliances retain superiority in certain complex cases requiring fine control of torque and anchorage. Conversely, modern materials and digital technologies contribute to improved efficiency during initial alignment phases and enhance patient experience. Skeletal anchorage devices provide biomechanical advantages unattainable with traditional anchorage methods, expanding treatment possibilities without reliance on patient compliance. Quantitative outcome measures, including treatment duration and post-treatment stability indices, vary across modalities but generally demonstrate equivalence in overall effectiveness when appropriately applied. The selection of appliance systems must therefore be predicated on a thorough understanding of anatomical, biomechanical, and technological considerations.

Discussion: *Orthodontic treatment science has progressed from the empirical approaches of the early 20th century to a sophisticated interplay of biomechanics, materials engineering, and digital technologies.* This evolution reflects an overarching commitment to understanding the fundamental biological processes that mediate tooth movement and optimizing force delivery systems within those constraints. At the heart of orthodontic mechanics lies the periodontal ligament (PDL), a complex vascularized connective tissue that serves as both a mechanical sensor and effector in response to applied forces. Through mechanotransduction, fibroblasts, osteoblasts, and osteoclasts coordinate remodeling of the alveolar bone, enabling tooth displacement while maintaining periodontal health. Appreciating

this biological context is essential when evaluating the efficacy of both classical and modern treatment modalities.

The classical fixed appliance system, with its bracket-and-wire architecture, remains a cornerstone in contemporary orthodontics due to its versatility and capacity for comprehensive three-plane corrections. Early fixed appliances were primarily constructed from stainless steel, which offered predictable stiffness but limited elasticity. Beta-titanium alloys improved on this by facilitating better formability without sacrificing strength, allowing clinicians to achieve nuanced control over force systems. Archwire mechanics in fixed appliances operate on the principles of beam theory; deflection of the wire within the bracket slot generates forces that interact with the periodontal tissues. Torque control and rotational corrections are realized through engagement mechanics, wherein the dimension and cross-section of the archwire influence the magnitude and direction of force vectors. This capacity for controlled, multi-dimensional force application is particularly advantageous in complex malocclusions, where precise manipulation of root positions and angulations is paramount.

Nonetheless, the dependency on clinician expertise for wire bending and adjustment introduces variability, and mechanical limitations inherent to traditional materials can affect treatment efficiency. In contrast, modern materials such as *superelastic nickel-titanium (NiTi) alloys have transformed initial alignment* strategies by offering relatively constant force delivery across a broad range of deflections. The superelastic plateau in the stress-strain profile of NiTi ensures sustained biological stimulation with reduced force peaks, theoretically minimizing adverse tissue responses such as PDL hyalinization. Contemporary β -titanium and multifunctional alloys further extend the clinician's ability to tailor force systems for intermediate and finishing stages of treatment, bridging the gap between initial alignment and detailed finishing requirements.

The integration of skeletal anchorage devices (SADs), including mini-implants and temporary anchorage devices (TADs), exemplifies a significant departure from conventional anchorage paradigms. Traditional anchorage strategies, such as transpalatal arches and extraoral headgear, rely on dental units for resistance, necessitating patient cooperation and presenting challenges in controlling reciprocal tooth movements. SADs, fixed within cortical bone, provide stable reference points that resist displacement, enabling direct application of forces for intrusion, distalization, or en masse retraction. Biomechanical modeling indicates that the leverage provided by TADs expands the envelope of feasible tooth movements, reducing reliance on complex auxiliary mechanics. However, careful anatomical assessment is required for successful TAD placement, as interradicular

space, cortical thickness, and soft tissue considerations influence device stability and survival rates.

Diagnostic imaging has also undergone a profound transformation with the advent of three-dimensional modalities such as cone-beam computed tomography (CBCT). The volumetric data afforded by CBCT provides an accurate representation of dental and skeletal structures, enabling clinicians to assess root positions, alveolar bone morphology, and spatial asymmetries with high fidelity. These imaging capabilities improve diagnostic precision, informing treatment planning and risk assessment for potential complications such as root resorption or cortical perforation. When combined with digital intraoral scanning, which captures detailed surface topography, clinicians can generate comprehensive digital models that supplant traditional plaster casts. This digital ecosystem supports virtual treatment simulations, allowing for objective measurement of discrepancies and facilitating biomechanical predictions across treatment stages.

Clear aligner therapy represents one of the most visible applications of digital orthodontics, integrating CAD/CAM workflows to produce sequential polymer devices that guide tooth movement. Virtual setups generated within specialized software permit clinicians to plan incremental movements with visual feedback and quantifiable metrics. However, the biomechanical efficacy of aligners varies by movement type. While tipping and minor rotations are generally well-predicted, movements requiring root torque, bodily translation, or complex multi-vector control demonstrate variability between planned and achieved outcomes. This discrepancy underscores the limitations of aligner materials and force application mechanisms, which often depend on programmed deformations and auxiliary features such as attachments to enhance engagement. Recent innovations in aligner materials and attachment design have sought to mitigate these challenges, improving force transmission and control.

Comparative analyses of fixed appliances and clear aligner systems reveal divergent strengths and limitations. Fixed appliances inherently provide robust three-plane control, particularly beneficial in cases requiring detailed root positioning and anchorage management. Aligners, conversely, offer advantages in esthetics, patient comfort, and oral hygiene due to their removable nature. However, their efficacy is contingent on patient compliance, as inconsistent wear diminishes force application and compromises treatment outcomes. Furthermore, aligner systems necessitate meticulous digital planning and staging to optimize movement sequences, with iterative refinements often required based on interim assessments.

Statistical trends suggest increasing adoption of clear aligner therapy globally, driven by technological accessibility and patient preferences. Yet, fixed appliances continue to dominate in complex cases, reflecting their proven biomechanical robustness. The introduction of SADs further blurs the traditional dichotomy, as these devices can be integrated with both fixed and aligner systems to expand treatment possibilities.

Regardless of modality, a thorough understanding of anatomical constraints – such as alveolar bone limits, root morphology, and PDL responsiveness – remains indispensable. Overextension beyond biological thresholds risks adverse outcomes such as fenestration, dehiscence, or root resorption.

In synthesizing classical and contemporary approaches, it becomes clear that effective orthodontic treatment relies on a nuanced interplay of biomechanics, material science, and digital insight. Classical principles provide the foundational understanding of force-tissue interactions, while modern technologies offer tools that enhance precision, efficiency, and predictability. The future of orthodontics will likely continue to integrate these domains, with advances in biological markers, machine learning algorithms for treatment prediction, and materials engineered for optimized force delivery.

Conclusion: Orthodontic treatment encompasses a spectrum of methodologies rooted in fundamental biomechanics and enriched by contemporary scientific advancements. Classical fixed appliances, grounded in robust mechanical principles, continue to provide comprehensive control of multi-plane tooth movements and remain indispensable in complex corrections. The introduction of superelastic and multifunctional alloys has refined force delivery, reducing biological side effects and enhancing efficiency. Skeletal anchorage devices represent a transformative addition, enabling stable reference points for force application and expanding the range of achievable movements without dependence on patient compliance. Digital innovations, particularly three-dimensional imaging and CAD/CAM workflows, have markedly improved diagnostic accuracy and appliance customization. Clear aligner systems, while offering esthetic and removable solutions, require precise digital planning and adherence to wear protocols to achieve intended outcomes. Comparative statistical evidence suggests that integrative approaches combining classical biomechanics with modern technologies yield optimized results across diverse orthodontic scenarios. Understanding the anatomical and physiological determinants of tooth movement remains pivotal. Future advancements will likely augment current modalities through enhanced predictive modeling and biologically informed force

systems, further aligning treatment strategies with individualized patient anatomy and therapeutic goals.

REFERENCES:

1. Boyd RL, Baumrind S. The effects of orthodontic treatment on periodontal status. *Am J Orthod Dentofacial Orthop*.
2. van der Weijden F, Slot DE. Oral hygiene in orthodontic patients: a systematic review. *Am J Orthod Dentofacial Orthop*.
3. Ergashev, B. (2025). Sirkon dioksid qoplamalari va materialining klinik laborator ahamiyati. *Journal of Uzbekistan's Development and Research (JUDR)*, 1(1), 627-632.
4. Ergashev, B. (2025). Gingivitning bakteriologik etiologiyasi va profilaktikasi. In *International Scientific Conference: Innovative Trends in Science, Practise and Education*, 1(1), 122-128.
5. Ergashev, B. (2025). Bemorlar psixologiyasi va muloqot ko'nikmalari. *Modern Science and Research*, 4(2), 151-156.
6. Ergashev, B. (2025). Pulpitning etiologiyasi, patogenezini, morfologiyasi va klinik simptomlari. *Modern Science and Research*, 4(3), 829-838.
7. Ergashev, B. (2025). Stomatologiyada tish kariesi: Etiologiyasi, diagnostika va davolash usullari. *Modern Science and Research*, 4(3), 821-828.
8. Ergashev, B. (2025). Tish emal prizmalariga yopishib olgan tish blyashka matrixning mikrobiologiyasi va tarkibi. *Modern Science and Research*, 4(3), 815-820.
9. Ergashev, B. (2025). Advances in oral health: Prevention, treatment, and systemic implications. *American Journal of Education and Learning*, 3(3), 1108-1114.
10. Tursunaliyev, Z., & Ergashev, B. (2025). Bolalarda tish kariesini oldini olish usullari. *Modern Science and Research*, 4(4), 686-691.
11. Ergashev, B. (2025). Karies va paradont kasalliklari profilaktikasi. *Modern Science and Research*, 4(4), 732-741.
12. Ergashev, B. (2025). Psychological support for cancer patients. *ИКРО журнал*, 15(1), 164-167.
13. Ergashev, B., & Raxmonov, Sh. (2025). Oral trichomoniasis: Epidemiology, pathogenesis, and clinical significance. *Kazakh Journal of Ecosystem Restoration and Biodiversity*, 1(1), 19-27.

14. Ergashev, B., & Raxmonov, Sh. (2025). Transmission dynamics of tuberculosis. *Kazakh Journal of Ecosystem Restoration and Biodiversity*, 1(1), 28–35.
15. Ergashev, B. J. (2025). Uch shoxli nervning yallig'lanishi. *Research Focus*, 4(3), 162–169.
16. Ergashev, B. J. (2025). Tish kariesi tarqalishining ijtimoiy va biologik omillari. *Журнал научных исследований и их решений*, 4(2), 427–430.
17. Raxmanov, Sh., Bahadirov, M., & Ergashev, B. (2025). Skin diseases laboratory diagnosis. *Международный мультидисциплинарный журнал исследований и разработок*, 1(3), 130–132.
18. Ergashev, B. J. (2025). Tish olish operatsiyasidan keyingi asoratlar. *Журнал научных исследований и их решений*, 4(2), 421–426.
19. Ergashev, B. J. (2025). Tish og'rig'ining etiologiyasi va zamonaviy davolash usullari. *Ta'lim Taraqqiyoti*, 1(1), 57–63.
20. Ergashev, B. J. (2025). To'liq va qisman adentiya etiologiyasi. *Is'hoqxon Ibrat Followers Journal*, 1(1), 9–17.
21. Ergashev, B. J. (2025). Yuz nervining yallig'lanishi. *Research Focus*, 4(3), 155–161.
22. Ergashev, B. J. (2025). Energetik ichimliklarning tish emaliga ta'siri. *Журнал научных исследований и их решений*, 4(2), 416–420.
23. Ergashev, B. J. (2025). Kennedy classification: Its significance. *Tabib*, 1(1), 1–7.
24. Ergashev, B. (2023). Tish toshlari. *Models and Methods for Increasing the Efficiency of Innovative Research*, 1(2), 67–75. Chang HS, Walsh LJ, Freer TJ. Enamel demineralization during orthodontic treatment. *Orthod Craniofac Res*.
25. Benson PE, Parkin N, et al. Preventing white spot lesions in orthodontics. *Cochrane Database Syst Rev*.