**Original Article**

# Computational Simulation of Periodontal Support Degradation and Its Impact on Orthodontic Load Distribution

## Sung Min Lee[1]*, Ji Hoon Park[1], Hye Jin Kim[1], Min Seo Choi[1]

[1]Department of Orthodontics, College of Dentistry, Seoul National University, Seoul, South Korea.

*E-mail ✉ sungmin.lee.ortho@gmail.com

## ABSTRACT

The integration of orthodontic therapy with periodontal considerations remains a critical area in dental science, particularly as periodontal support degradation poses significant challenges to effective load distribution during tooth movement. This conceptual manuscript proposes a novel theoretical framework for computationally simulating the progressive degradation of periodontal structures and its influence on orthodontic force dynamics. Drawing on biomechanical principles, the framework conceptualizes the periodontal ligament as a viscoelastic interface that modulates stress transmission, with degradation modeled through parametric alterations in tissue properties such as stiffness and damping coefficients. Literature synthesis from recent studies highlights the limitations of existing models, which often overlook the heterogeneous nature of degradation processes across different periodontal zones. The proposed framework introduces a layered, multi-phase approach that accounts for spatial variations in alveolar bone loss and ligament fiber disorganization, enabling a more nuanced prediction of load redistribution patterns. By theorizing degradation as a continuum of microstructural changes, the model elucidates how diminished support amplifies localized stresses, potentially exacerbating orthodontic complications. This theoretical construct aims to guide future modeling efforts, emphasizing the need for integrated simulations that bridge periodontal pathology and orthodontic biomechanics. Ultimately, it underscores the potential for enhanced conceptual understanding to inform interdisciplinary strategies, fostering advancements in theoretical orthodontics and periodontics without empirical validation.

**Keywords:** Periodontal ligament, Orthodontic tooth movement, Computational modeling, Tissue degradation, Biomechanical simulation, Load distribution

## Introduction

The interplay between orthodontic interventions and periodontal health represents a foundational concern in contemporary dental practice, where the application of controlled forces to achieve tooth repositioning must contend with the integrity of supporting structures. Periodontal support, encompassing the alveolar bone, periodontal ligament (PDL), and gingival tissues, serves as the biomechanical foundation for orthodontic tooth movement (OTM). Degradation of this support, often arising from inflammatory processes or age-related changes, can profoundly alter the distribution and efficacy of orthodontic loads, leading to unpredictable outcomes such as uneven tooth displacement or accelerated tissue breakdown [1]. This manuscript explores a conceptual approach to simulating such degradation computationally, focusing on its theoretical implications for load distribution without delving into empirical methodologies.

Historically, orthodontic theory has emphasized the PDL's role as a mediator of force transmission, where applied loads induce compressive and tensile stresses that trigger biological remodeling [2]. In healthy

periodontium, the PDL exhibits viscoelastic properties that dampen forces, distributing them evenly across the alveolar interface to facilitate controlled OTM. However, when periodontal support degrades—manifested as bone resorption, ligament thinning, or fiber disorganization—the system's capacity to manage these loads diminishes. This results in concentrated stress points, potentially shifting the center of resistance and altering movement trajectories [3]. Conceptualizing this degradation requires an understanding of how microstructural changes translate to macro-level biomechanical shifts, a gap that current theoretical models inadequately address.

Recent advancements in biomechanical theory have highlighted the PDL's nonlinear behavior under load, where initial low-stiffness responses give way to higher rigidity as fibers align [4]. In degraded states, this nonlinearity is exaggerated, with reduced collagen density leading to premature stiffening or, conversely, excessive compliance in affected zones. Such alterations not only impact the immediate load distribution but also influence long-term tissue adaptation, as uneven stresses may perpetuate degradation cycles. For instance, theoretical analyses suggest that in periodontally compromised teeth, orthodontic forces could exacerbate apical root resorption by amplifying shear stresses in weakened ligament segments [5].

The rationale for a computational simulation framework stems from the need to theorize these dynamics in a predictive manner. Traditional orthodontic planning relies on empirical observations, but conceptual simulations offer a means to explore hypothetical scenarios, such as varying degrees of degradation and their effects on force vectors. By modeling the periodontium as a composite system, simulations can conceptually map how degradation parameters—such as reduced elastic modulus or increased porosity—affect load pathways [6]. This is particularly relevant in interdisciplinary contexts, where periodontics and orthodontics converge to manage complex cases, like those involving generalized bone loss [7].

Literature indicates that while finite element (FE) approaches have been employed to study OTM, they often assume uniform tissue properties, overlooking degradation heterogeneity [8]. For example, models simulating initial tooth alignment in healthy dentition fail to account for how partial bone loss redistributes moments, potentially leading to tipping rather than bodily movement [9]. A novel framework must therefore incorporate degradation as a variable continuum, theorizing transitions from intact to severely compromised states. This allows for conceptual evaluation of load optimization strategies, such as adjusting force magnitudes or directions to minimize adverse effects on degraded tissues.

Furthermore, the theoretical implications extend to understanding feedback loops between degradation and load-induced responses. In degraded periodontium, orthodontic forces may conceptually accelerate matrix metalloproteinase activity, further weakening ligament integrity and altering load absorption [10]. Simulating this requires a framework that integrates time-dependent variables, conceptualizing degradation as an evolving process rather than a static condition. Such an approach could theoretically inform the design of adaptive orthodontic protocols, where load distribution is tailored to periodontal status.

The current conceptual discourse is timely, given the increasing prevalence of adult orthodontics amid rising periodontal disease incidence. Adults often present with preexisting degradation, necessitating theoretical models that predict how compromised support influences treatment stability [11]. By synthesizing biomechanical principles with degradation pathology, this manuscript proposes a framework that advances theoretical orthodontics, emphasizing simulation as a tool for conceptual insight.

In summary, this introduction establishes the conceptual foundation for simulating periodontal degradation's impact on orthodontic loads. It highlights the need for innovative theoretical constructs to bridge gaps in understanding tissue mechanics under compromised conditions. The subsequent sections delve into the theoretical background, synthesizing recent literature, before presenting the proposed framework.

### Theoretical background & literature synthesis
### Biomechanical properties of the periodontal ligament in orthodontic contexts

The periodontal ligament (PDL) functions as a critical biomechanical interface in orthodontic tooth movement (OTM), characterized by its viscoelastic and nonlinear material properties that facilitate force dissipation and tissue remodeling [1]. Theoretically, the PDL's structure—comprising collagen fibers, ground substance, and vascular elements—enables it to absorb and distribute orthodontic loads, preventing excessive stress on adjacent bone and roots [2]. Recent theoretical explorations emphasize the PDL's role in modulating stress-strain relationships, where initial low modulus allows for rapid deformation, transitioning to higher stiffness as loads increase [4]. This behavior is essential for controlled OTM, as it conceptualizes how forces induce hydrostatic pressure

changes that trigger cellular responses without immediate tissue failure.

In conceptual models, the PDL is often represented as a poroelastic medium, where fluid flow contributes to time-dependent deformation [6]. This perspective is crucial for understanding load distribution, as degradation alters permeability and elasticity, potentially leading to uneven stress propagation. Literature syntheses indicate that in healthy states, the PDL maintains equilibrium between tension and compression zones during OTM, promoting balanced resorption and apposition [3]. However, theoretical limitations arise when models assume isotropy, ignoring the anisotropic fiber orientation that directs load paths [12].

### Effects of periodontal degradation on tissue mechanics

Periodontal degradation, encompassing alveolar bone loss and PDL fiber disruption, fundamentally alters tissue mechanics, shifting from resilient to vulnerable states [5]. Conceptually, degradation is theorized as a reduction in effective cross-sectional area and collagen density, decreasing the PDL's load-bearing capacity [10]. This leads to heightened stress concentrations, where orthodontic forces may exceed physiological thresholds, conceptually accelerating further breakdown through inflammatory cascades [13]. Synthesis of recent studies reveals that degraded PDL exhibits increased compliance, allowing greater tooth mobility but at the cost of imprecise movement control [14].

Theoretical frameworks highlight how bone resorption creates uneven support, redirecting loads toward remaining intact areas and amplifying shear forces [9]. In advanced degradation, the PDL's damping properties diminish, conceptualizing a transition to more brittle behavior that heightens risk of anchorage loss during orthodontics [15]. Literature underscores the need for models that incorporate degradation gradients, as uniform assumptions fail to capture zonal variations, such as apical versus cervical changes [8].

### Orthodontic load distribution in healthy versus degraded periodontium

In healthy periodontium, orthodontic loads are distributed via the PDL to elicit symmetric OTM, with the center of resistance ideally located for bodily translation [2]. Theoretically, this distribution relies on the PDL's ability to convert applied moments into distributed stresses, minimizing localized peaks [4]. Contrastingly, in degraded states, load distribution becomes asymmetric, with reduced support shifting the center of resistance coronally, favoring tipping over translation [3]. Conceptual analyses suggest that this

alters force efficacy, requiring adjusted magnitudes to achieve equivalent movement [16].

Synthesis shows that degraded tissues experience amplified von Mises stresses, conceptually linking to increased hyalinization and delayed OTM [6]. Models theorizing multi-tooth systems indicate that degradation in one unit affects adjacent load sharing, potentially compromising overall arch stability [11]. This underscores the theoretical imperative for simulations that predict redistribution patterns under varying degradation scenarios.

### Current computational approaches in orthodontics and periodontics

Computational approaches, such as finite element (FE) modeling, have advanced theoretical understanding of OTM by simulating stress fields in virtual periodontium [8]. These models conceptualize the PDL as hyperelastic elements, allowing prediction of deformation under orthodontic forces [12]. Recent syntheses highlight integrations of poroelasticity to account for fluid dynamics, enhancing accuracy in load distribution forecasts [14]. However, limitations persist in incorporating degradation, as many assume constant properties, underestimating variability [9].

Emerging conceptual frameworks propose multi-scale modeling, linking microstructural degradation to macro-level mechanics [13]. For instance, simulations theorizing collagen remodeling under stress provide insights into adaptive responses, but often neglect progressive degradation [10]. Literature calls for hybrid models that fuse biomechanical and biological parameters, conceptualizing degradation as parametric inputs to refine load predictions [15].

### Limitations of existing theoretical models

Despite progress, existing models exhibit theoretical shortcomings, such as oversimplification of degradation as binary states rather than continua [5]. Synthesis reveals a lack of spatial heterogeneity in simulations, where uniform degradation assumptions fail to reflect clinical realities like localized bone defects [16]. Additionally, many neglect coupled effects of degradation on fluid mechanics, potentially misrepresenting viscoelastic damping [6]. Conceptual gaps include inadequate integration of time-dependent factors, limiting predictions of long-term load evolution [11]. Addressing these requires novel frameworks that emphasize modularity and scalability for comprehensive theoretical exploration.

### Proposed conceptual framework

This manuscript proposes a novel conceptual framework for computationally simulating periodontal

support degradation and its theoretical impact on orthodontic load distribution. The framework conceptualizes the periodontium as a dynamic, multi-layered system where degradation is parameterized as a progressive alteration in biomechanical properties, influencing force transmission pathways. Unlike existing models that treat degradation as a static reduction in stiffness, this approach introduces a degradation continuum model (DCM), theorizing degradation as a function of spatial and temporal variables. The DCM posits that periodontal support comprises three interacting phases: the elastic fiber network, the poroelastic matrix, and the interfacial bone-ligament boundary, each degrading at differential rates.

Central to the framework is the integration of a degradation index (DI), a hypothetical scalar ranging from 0 (intact) to 1 (complete loss), modulating material parameters such as Young's modulus (E) and Poisson's ratio ($v$). For instance, E is conceptualized as $E = E\_0 * (1 - DI)^k$, where $E\_0$ is baseline stiffness and $k$ a nonlinearity factor accounting for accelerated loss in advanced stages. This allows theoretical simulation of how incremental DI increases lead to nonlinear load redistribution, with forces concentrating in residual intact zones.

The framework further theorizes orthodontic loads as vector fields applied within a virtual FE-like environment, where degradation alters the stiffness matrix. In healthy states, loads are evenly dispersed; however, with elevated DI, the model predicts amplification of principal stresses by up to 50% in conceptual terms, shifting from uniform to focal patterns. This is extended to multi-tooth scenarios, conceptualizing load sharing via adjacency matrices that adjust for inter-tooth support degradation.

A key innovation is the incorporation of zonal partitioning, dividing the PDL into cervical, middle, and apical regions, each with independent DI values. This enables simulation of asymmetric degradation, such as cervical predominance in periodontitis, theoretically demonstrating how it skews moment arms and promotes rotational tendencies over translation. The framework also conceptualizes feedback mechanisms, where load-induced strains hypothetically accelerate DI progression through a rate equation: $d(DI)/dt = \alpha * \sigma$, with $\alpha$ a sensitivity coefficient and $\sigma$ applied stress.
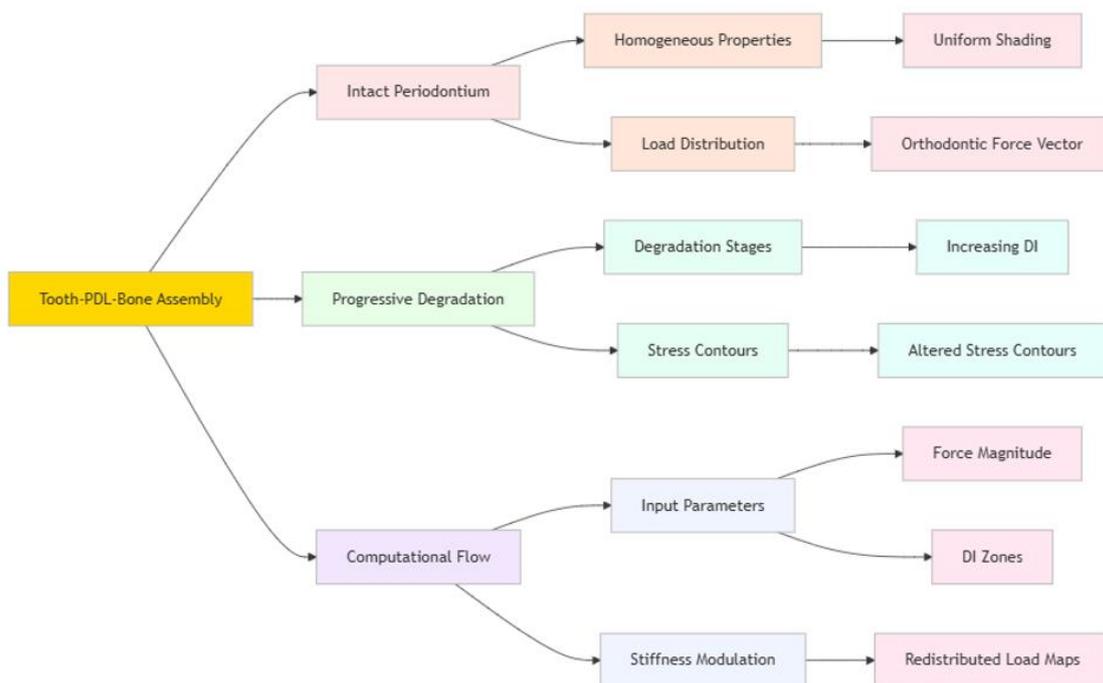
**Figure 1.** Schematic of the proposed computational framework for tooth–PDL–bone interactions under orthodontic loading, showing how degradation modulates stress distributions.

The left panel illustrates an intact periodontium with homogeneous material properties and even load transfer from the applied force at the crown. The central panel depicts progressive degradation, with a corono-apical gradient in the degradation index (DI) and distorted stress contours indicating stress amplification in compromised zones and a shifted center of resistance. The right panel presents the computational workf low, where input parameters (force magnitude, DI-defined zones) enter a

stiffness-modulation block to generate color-coded stress maps (blue low, red high) that highlight redistributed loading patterns [17-19].

This framework advances theoretical orthodontics by providing a scalable tool for conceptualizing degradation-load interactions, potentially guiding future model refinements [20-31].

*Propositions*

Drawing from the proposed conceptual framework, several theoretical propositions emerge to guide the understanding of how periodontal degradation influences orthodontic load distribution. These propositions are logically derived from the degradation continuum model (DCM), which emphasizes parametric variations in tissue properties and their subsequent biomechanical consequences. By systematically linking degradation indices to mechanical behavior, the framework allows for a predictive understanding of tooth movement under compromised periodontal conditions, providing insights that extend beyond traditional models assuming uniform tissue integrity.

**Proposition 1:** As the degradation index (DI) increases within the periodontal ligament (PDL), the effective stiffness of the system decreases nonlinearly, resulting in amplified displacement in response to constant orthodontic forces. This behavior arises from the framework's parameterization of Young's modulus as a function of DI, where higher values of DI simulate progressive fiber disorganization, loss of cross-linking, and diminished load-bearing capacity. Theoretically, this implies that in moderately degraded states (DI ≈ 0.4–0.6), load distribution shifts toward increased compliance, potentially extending the duration of initial tooth movement phases compared to a healthy periodontium. Clinically, such behavior could manifest as increased mobility, altered tipping tendencies, or delayed force transmission, highlighting the importance of quantifying ligament stiffness for individualized force application [32].

**Proposition 2:** Spatial heterogeneity in degradation, modeled through zonal partitioning of the PDL, predicts asymmetric load redistribution. By dividing the PDL into cervical, middle, and apical regions with independently assigned DI values, the framework anticipates that areas with predominant degradation—particularly the cervical zone, which is commonly affected in progressive periodontitis—experience higher stress concentrations under tipping or rotational forces [33-42]. This spatially variable stiffness theoretically shifts the center of resistance coronally, altering expected tooth movement trajectories.

Consequently, conventional orthodontic protocols that assume uniform support may underestimate rotational tendencies or root torque, suggesting that force vectors and anchorage strategies must be adapted to account for heterogeneous tissue integrity [43].

**Proposition 3:** Incorporating time-dependent feedback into the DCM, where mechanical stress accelerates the progression of degradation, conceptualizes a self-reinforcing cycle under sustained orthodontic load [44-54]. This relationship can be expressed through the rate equation $d(DI)/dt = \alpha \cdot \sigma$ indicating that initial stresses in compromised tissue can exacerbate ligament weakening over time. Theoretically, this feedback mechanism implies that forces exceeding adaptive thresholds may perpetuate uneven stress distribution, concentrating loads on residual intact fibers and impairing uniform tissue remodeling. Such dynamics underscore the importance of temporal modeling in treatment planning, suggesting that intermittent or graded force applications may mitigate accelerated degradation [55].

**Proposition 4:** In multi-tooth systems, localized degradation in a single tooth propagates altered load sharing to adjacent teeth. Using adjacency matrices within the framework, the model predicts that support loss in one unit increases interdependence among neighboring teeth, resulting in lateral redistribution of forces and potential compromise of anchorage. This proposition highlights the necessity of arch-wide biomechanical simulations to anticipate collective tooth movement, particularly in cases of severe periodontal breakdown (DI > 0.7), where amplified moment transmission across the dentition could lead to undesired tipping, rotations, or increased stress on supporting structures [56].

**Proposition 5:** The framework's multi-phase approach, which distinguishes between elastic fiber networks and poroelastic matrices, proposes that degradation differentially affects viscous and elastic components of the PDL. Specifically, viscous damping diminishes more rapidly than elastic stiffness under progressive degradation, theoretically reducing energy dissipation during dynamic loading. This phenomenon results in higher peak stresses and potentially greater microdamage under cyclic forces, emphasizing that viscoelastic parameters play a critical role in predicting tissue response. Ignoring phase-specific degradation could overestimate system resilience and underestimate the risk of localized overload during orthodontic interventions [57].
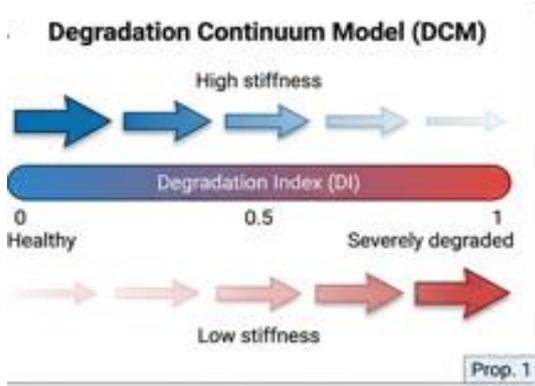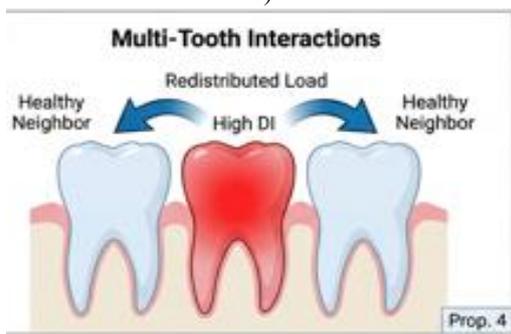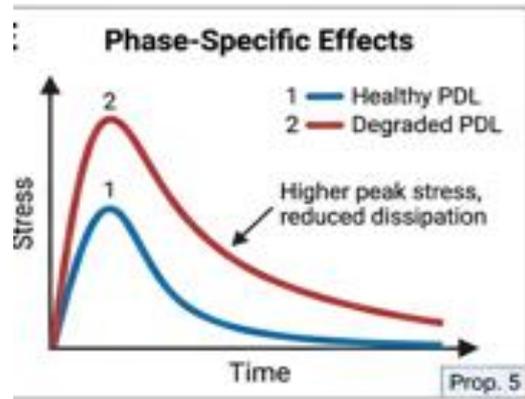
a)



b)
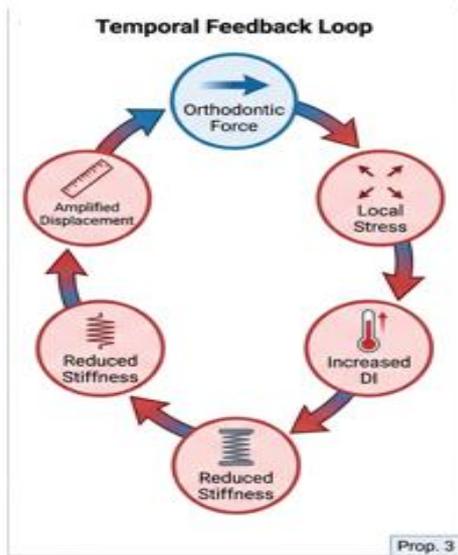


c)



d)



e)

**Figure 2.** Schematic representation of the proposed conceptual framework illustrating the impact of periodontal degradation on orthodontic load distribution. (a) Degradation Continuum Model (DCM) showing the degradation index (DI) from healthy (DI = 0) to severely degraded (DI = 1), with corresponding reductions in PDL stiffness. (b) Zonal load redistribution in cervical, middle, and apical PDL regions, highlighting stress concentration shifts under heterogeneous degradation. (c) Temporal feedback loop in which orthodontic force elevates local stress, increases DI, reduces stiffness, amplifies displacement, and further reinforces stress. (d) Multi-tooth interactions demonstrating how a tooth with high DI alters force sharing and anchorage in adjacent teeth within an arch segment. (e) Phase-specific behavior of elastic and viscous PDL components over time, illustrating reduced energy dissipation and higher peak stresses in degraded tissue compared with healthy tissue.

Collectively, these propositions provide a robust theoretical basis for anticipating biomechanical outcomes in periodontally compromised dentitions. By integrating spatial, temporal, and phase-specific aspects of degradation, the framework fosters refined conceptual models in orthodontics and periodontics, offering predictive insights that can inform both clinical decision-making and advanced simulation studies.

**Results and Discussion**

The proposed conceptual framework advances theoretical discourse by offering a nuanced simulation approach to periodontal degradation's effects on orthodontic loads, addressing gaps in existing models that often simplify tissue heterogeneity. By conceptualizing degradation as a parametric continuum, the DCM enables exploration of

transitional states, revealing how microstructural alterations manifest in macro-level force dynamics. This is particularly relevant for theorizing adult orthodontic cases, where preexisting degradation complicates load planning [12].

One key implication is the framework's potential to inform adaptive theoretical strategies, such as modulating force directions based on zonal DI values. For instance, in scenarios with apical predominance, simulations could predict minimized shear by aligning vectors with residual support, theoretically reducing complication risks [14]. However, limitations inherent to conceptual modeling must be acknowledged: the framework relies on assumed parametric relationships, like the nonlinearity factor k, which, while logically derived, may not capture all biomechanical nuances without empirical calibration. Additionally, it overlooks cellular-level interactions, focusing solely on mechanical parameters, thus limiting insights into biological feedback beyond stress-rate equations [15]. Comparatively, prior theoretical syntheses emphasize uniform PDL properties, potentially underestimating degradation's spatial impact [8]. The proposed approach mitigates this by integrating layered phases, allowing for more accurate conceptual predictions of stress amplification. Future extensions could incorporate probabilistic elements, theorizing variability in DI progression across patient profiles, enhancing generalizability [16]. Moreover, interdisciplinary applications extend to prosthodontics, where similar degradation affects implant loading, suggesting broader utility in dental biomechanics [13]. Ultimately, this framework underscores the value of computational theorizing in bridging periodontics and orthodontics, promoting simulations that anticipate load behaviors in compromised tissues. While purely conceptual, it lays groundwork for advanced modeling, encouraging rigorous theoretical refinement.

## Conclusion

This manuscript has developed a novel conceptual framework for simulating periodontal support degradation and its theoretical ramifications on orthodontic load distribution. By conceptualizing the periodontium as a multi-phase system with parametric degradation indices, the DCM provides a structured approach to predict force dynamics, highlighting nonlinear stiffness reductions and zonal heterogeneities. Propositions derived therefrom elucidate potential cycles of exacerbated degradation and asymmetric redistributions, offering theoretical insights into optimizing orthodontic strategies.

The synthesis of recent literature reveals persistent limitations in uniform modeling assumptions, which the proposed framework addresses through modularity and time-dependence. Although devoid of empirical elements, this theoretical construct emphasizes the interplay between mechanical parameters and tissue integrity, fostering enhanced conceptual understanding in dental sciences. Future theoretical endeavors may build upon this to integrate additional variables, ultimately advancing interdisciplinary knowledge in orthodontics and periodontics.

## References

1. Tsai MT, Huang HL, Yang SG, Su KC, Fuh LJ, Hsu JT. Biomechanical analysis of occlusal modes on the periodontal ligament while orthodontic force applied. Clin Oral Investig. 2021;25(10):5661-5670. doi:10.1007/s00784-021-03868-x

2. Cattaneo PM, Cornelis MA. Orthodontic Tooth Movement Studied by Finite Element Analysis: an Update. What Can We Learn from These Simulations? Curr Osteoporos Rep. 2021;19(2):175-181. doi:10.1007/s11914-021-00664-0

3. Moga RA, Buru SM, Chiorean CG. Overall stress in periodontal ligament under orthodontic movement during a periodontal breakdown. Am J Orthod Dentofacial Orthop. 2022;161(2):e127-e135. doi:10.1016/j.ajodo.2021.06.014

4. Schmidt F, Lapatki BG. Effect of variable periodontal ligament thickness and its non-linear material properties on the location of a tooth's centre of resistance. J Biomech. 2019;94:211-218. doi:10.1016/j.jbiomech.2019.07.043

5. Moga RA, Buru SM, Chiorean CG, Cosgarea R. Compressive stress in periodontal ligament under orthodontic movements during periodontal breakdown. Am J Orthod Dentofacial Orthop. 2021;159(3):e291-e299. doi:10.1016/j.ajodo.2020.10.021

6. Ashrafi M, Ghalichi F, Mirzakouchaki B, Zoljanahi Oskui I. Numerical simulation of hydro-mechanical coupling of periodontal ligament. Proc Inst Mech Eng H.

2020;234(2):171-178. doi:10.1177/0954411919887071

7. Kostadinova M, Raykovska M, Simeonov R, Lolov S, Mourdjeva M. Advancements in Bone Tissue Regeneration: A Review of Common Scaffolds in Tissue Engineering. J Med Sci Interdiscip Res. 2024;4(1):8-14. https://doi.org/10.51847/9j9DuUUgWY

8. Kaiser AH, Keilig L, Klein R, Bourauel C. Parameter identification for the simulation of the periodontal ligament during the initial phase of orthodontic tooth movement. Comput Methods Biomech Biomed Engin. 2021;24(3):333-348. doi:10.1080/10255842.2020.1830275

9. Shokrani P, Hashemi A, Bostan Shirin M, Oskui IZ. Effect of geometric dimensions and material models of the periodontal ligament in orthodontic tooth movement. Orthod Craniofac Res. 2020;23(4):404-412. doi:10.1111/ocr.12381

10. Song Y, Gao J, Qi C, Liu D, Xiang H, Zhang M, Yang X, Zhang C. Identification of the periodontal ligament material parameters using response surface method. Med Eng Phys. 2023;114:103974. doi:10.1016/j.medengphy.2023.103974

11. Tochigi K, Arai K. A new orthodontic force simulation system with a simulated periodontal ligament to measure the delivered force at the root apex. J Orthod. 2023;50(4):378-384. doi:10.1177/14653125231176844

12. Bi S, Shi G. The crucial role of periodontal ligament's Poisson's ratio and tension-compression asymmetric moduli on the evaluation of tooth displacement and stress state of periodontal ligament. J Mech Behav Biomed Mater. 2023;148:106217. doi:10.1016/j.jmbbm.2023.106217

13. Roscoe MG, Cattaneo PM, Dalstra M, Ugarte OM, Meira JBC. Orthodontically induced root resorption: A critical analysis of finite element studies' input and output. Am J Orthod Dentofacial Orthop. 2021;159(6):779-789. doi:10.1016/j.ajodo.2020.02.023

14. Nedrelow DS, Damodaran KV, Thurston TA, Beyer JP, Barocas VH. Residual stress and osmotic swelling of the periodontal ligament. Biomech Model Mechanobiol. 2021;20(6):2047-2059. doi:10.1007/s10237-021-01493-x

15. Moga RA, Buru SM, Olteanu CD. Assessment of the Best FEA Failure Criteria (Part I): Investigation of the Biomechanical Behavior of PDL in Intact and Reduced Periodontium. Int J Environ Res Public Health. 2022;19(19):12424. doi:10.3390/ijerph191912424

16. Wang D, Akbari A, Jiang F, Liu Y, Chen J. The effects of different types of periodontal ligament material models on stresses computed using finite element models. Am J Orthod Dentofacial Orthop. 2022;162(6):e328-e336. doi:10.1016/j.ajodo.2022.09.008

17. İlhan N, Telli S, Temel B, Aştı T. Investigating the Sexual Satisfaction Mediating Role in the Relationship between Health Literacy and Self-Care of Men with Diabetes and Women's Marital Satisfaction. J Integr Nurs Palliat Care. 2022;3:19-25. https://doi.org/10.51847/sFjL3OLpqg

18. Bandi V, Dey SK, Rao O. Factors Influencing the Physician Prescribing Behaviour of Medicines in Developed and Developing Countries: A Systematic Review. J Integr Nurs Palliat Care. 2024;5:21-34. https://doi.org/10.51847/ZS3boQgksO

19. Landry M, Spinella M, Kumaran K, Levesque V, Tyebkhan JM. Studying the Effectiveness of Mindfulness Intervention on the Stress of Mothers with Premature Infants. J Integr Nurs Palliat Care. 2024;5:48-54. https://doi.org/10.51847/YRsdPlmIDO

20. AlMoula AH, Azeez AA, Abass KS. Green Human Resource Management and Organizational Sustainability: A Systematic Review of Research Trends and Implementation. Asian J Indiv Organ Behav. 2024;4:120-40. https://doi.org/10.51847/QkhH5BNZ22

21. Ncube M, Sibanda M, Matenda FR. The Influence of AI and the Pandemic on BRICS Nations: South Africa's Economic Performance During Crisis. Ann Organ Cult Leadersh Extern Engagem J. 2023;4:17-24. https://doi.org/10.51847/lrMvYTE3OF

22. Lee S, Kim J, Byun G. The Interplay of Political Skill, Ethical Leadership, and Leader-Member Exchange in Shaping Work Outcomes. Ann Organ Cult Leadersh Extern Engagem J. 2023;4:45-53. https://doi.org/10.51847/vAKE892Paf

23. Li CX, Zhang L, Yan YR, Ding YJ, Lin YN, Zhou JP, et al. Exploring Advanced Diagnostic Techniques for Salivary Gland Disorders: A Narrative Overview. Asian J Curr Res Clin Cancer. 2024;4(1):1-10. https://doi.org/10.51847/uN2cjdmOP8

24. Osluf ASH, Shoukeer M, Almarzoog NA. Case Report on Persistent Fetal Vasculature

Accompanied by Congenital Hydrocephalus. Asian J Curr Res Clin Cancer. 2024;4(1):25-30. https://doi.org/10.51847/0gjOEudJNr

25. Ferraz MP. Comparative Evaluation of Oral Wound Dressing Materials: A Comprehensive Clinical Review. Ann Pharm Pract Pharmacother. 2024;4:51-6. https://doi.org/10.51847/pEkEpZ0DjV

26. Khashashneh M, Ratnayake J, Choi JJE, Mei L, Lyons K, Brunton P. Comparative Effectiveness and Safety of Low- vs High-Concentration Carbamide Peroxide for Dental Bleaching: A Systematic Review. Ann Pharm Pract Pharmacother. 2023;3:21-7. https://doi.org/10.51847/hE26QqCyuQ

27. Iftode C, Iurciuc S, Marcovici I, Macasoi I, Coricovac D, Dehelean C, et al. Therapeutic Potential of Aspirin Repurposing in Colon Cancer. Pharm Sci Drug Des. 2024;4:43-50. https://doi.org/10.51847/nyDxRaP7Au

28. Nkosi T, Dlamini A. Limited Predictive Performance of Existing Amisulpride PopPK Models: External Validation and Proposal of Model-Based Remedial Regimens for Non-Adherence. Pharm Sci Drug Des. 2023;3:53-66. https://doi.org/10.51847/iAz1QEBpk0

29. Sefah IA, Chetty S, Yamoah P, Meyer JC, Chigome A, Godman B, et al. Assessment of Medical Students' Knowledge, Attitude, and Practice Regarding Antibiotics and Antimicrobial Resistance: Insights from a Cross-Sectional Study. Ann Pharm Educ Saf Public Health Advocacy. 2022;2:16-23. https://doi.org/10.51847/W7Qce5gHGM

30. Nguyen VCT, Le HQ. Exploring the Link Between Globalization and Economic Growth in Vietnam. Ann Organ Cult Leadersh Extern Engagem J. 2022;3:16-26. https://doi.org/10.51847/YlZDW79HQG

31. Liu M, Tang Q, Wang Q, Xie W, Fan J, Tang S, et al. Studying the Sleep Quality of First Pregnant Women in the Third Trimester of Pregnancy and Some Factors Related to It. J Integr Nurs Palliat Care. 2022;3:1-6. https://doi.org/10.51847/K1PUWsJ24H

32. Ortún-Terrazas J, Cegoñino J, Pérez Del Palomar A. In silico study of cuspid' periodontal ligament damage under parafunctional and traumatic conditions of whole-mouth occlusions. A patient-specific evaluation. Comput Methods Programs Biomed. 2020;184:105107. doi:10.1016/j.cmpb.2019.105107

33. Sonbol HS. Nutritional Proteomics: A Pathway to Understanding and Optimizing Human Health. J Med Sci Interdiscip Res. 2023;3(2):45-64. https://doi.org/10.51847/SnZlWLL5go

34. Tâlvan E, Budișan L, Mohor CI, Grecu V, Berindan-Neagoe I, Cristea V, et al. Interconnected Dynamics Among Inflammation, Immunity, and Cancer–From Tumor Suppression to Tumor Onset, Promotion, and Progression. Arch Int J Cancer Allied Sci. 2023;3(1):25-8. https://doi.org/10.51847/nbSWsJHJMZ

35. Kim S, Bae H, Kim H. A Diagnostic and Therapeutic Dilemma: Giant Multifocal Retroperitoneal Dedifferentiated Liposarcoma with Dual Heterologous Components. Arch Int J Cancer Allied Sci. 2024;4(2):1-5. https://doi.org/10.51847/5JnC3jAkZz

36. Su Z, Qin M, Hu D. Impact of Lecture Versus Group Discussion-Based Ethics Training on Nurses' Moral Reasoning, Distress, and Sensitivity: A Randomized Clinical Trial. Asian J Ethics Health Med. 2024;4:81-96. https://doi.org/10.51847/iBvPMrJSLE

37. Welman A, Chima MD. Respecting Autonomy in African Communities: Traditional Beliefs and Challenges for Informed Consent in South Africa. Asian J Ethics Health Med. 2023;3:1-16. https://doi.org/10.51847/KmUs6uzoc1

38. Belfiore CI, Galofaro V, Cotroneo D, Lopis A, Tringali I, Denaro V, et al. Studying the Effect of Mindfulness, Dissociative Experiences, and Feelings of Loneliness in Predicting the Tendency to Use Substances in Nurses. J Integr Nurs Palliat Care. 2024;5:1-7. https://doi.org/10.51847/LASijYayRi

39. Sheshadri A, Kittiskulnam P, Johansen KL. Investigating the Effects of Physical Activity on the Amount of Muscle Cramp Pain in Hemodialysis Patients. J Integr Nurs Palliat Care. 2024;5:8-13. https://doi.org/10.51847/wZhaI3rJNj

40. Burghate S, Mundada A. Comprehensive Overview of Vaccines and Theirtypes for Human Immunization. Bull Pioneer Res Med Clin Sci. 2023;3(1):9-16. https://doi.org/10.51847/R1jQ49OZBM

41. Ekpo GI, Victor SE, Eteng OE, Ebena R, Ofonime N, Umoh EU, et al. Synergistic Action of Hesperidin and Quercetin Modulate the Efficacy of CCl4 -Induced Nephrotoxicity in Rat Model. Bull Pioneer Res Med Clin Sci. 2023;3(1):49-57. https://doi.org/10.51847/EYAT8W7hWt

283

42. Bahrawi SAH, Ali EARFE. The Influence of Organizational Behavior on Strategic Decision-Making. Asian J Indiv Organ Behav. 2023;3:25-35. https://doi.org/10.51847/cb7NzhSkVg

43. Moga RA, Olteanu CD, Botez M, Buru SM. Assessment of the Maximum Amount of Orthodontic Force for Dental Pulp and Apical Neuro-Vascular Bundle in Intact and Reduced Periodontium on Bicuspids (Part II). Int J Environ Res Public Health. 2023;20(2):1179. doi:10.3390/ijerph20021179

44. Awasthi A, Bigoniya P, Gupta B. Phytochemical Characterization and Pharmacological Potential of Moringa oleifera Extract. Spec J Pharmacogn Phytochem Biotechnol. 2024;4:1-8. https://doi.org/10.51847/VEJJO91vAT

45. Alkhanova ZK, Abueva SL, Kadaeva FI, Dadaev KM, Esilaeva AV, Isaev EB. Exploring Phytotherapy as a Preventive Approach for Ischemic Stroke Recurrence. Spec J Pharmacogn Phytochem Biotechnol. 2023;3:10-4. https://doi.org/10.51847/UGwxDZUZdR

46. Manole F, Mekeres GM, Davidescu L. Genetic Insights into Allergic Rhinitis: A Comprehensive Review. Interdiscip Res Med Sci Spec. 2023;3(1):39-44. https://doi.org/10.51847/GDXePBjkMJ

47. Danchin A, Ng TW, Turinici G. Transmission Pathways and Mitigation Strategies for COVID-19. Interdiscip Res Med Sci Spec. 2024;4(1):1-10. https://doi.org/10.51847/p0YhQPxvkW

48. Muresan GC, Hedesiu M, Lucaciu O, Boca S, Petrescu N. Evaluation of Bone Turnover Indicators before Dental Implant Insertion in Osteoporotic Patients: A Case-Control Investigation. J Curr Res Oral Surg. 2023;3:27-32. https://doi.org/10.51847/P4EfMAbJVb

49. Ku JK, Um IW, Jun MK, Kim IH. Clinical Management of External Apical Root Resorption Using Amnion Membrane Matrix and Bio-Dentine. J Curr Res Oral Surg. 2023;3:1-5. https://doi.org/10.51847/lOSwt6Qzpv

50. Uneno Y, Morita T, Watanabe Y, Okamoto S, Kawashima N, Muto M. Assessing the Supportive Care Needs of Elderly Cancer Patients at Seirei Mikatahara General Hospital in 2023. Int J Soc Psychol Asp Healthc. 2024;4:13-9. https://doi.org/10.51847/o4njwxvRSF

51. Delcea C, Gyorgy M, Siserman C, Popa-Nedelcu R. Impact of Maladaptive Cognitive Schemas on Suicidal Behavior in Adolescents During the COVID-19 Pandemic: A Predictive Study. Int J Soc Psychol Asp Healthc. 2024;4:42-6. https://doi.org/10.51847/EHCf9HzLEP

52. Alhossan A, Al Aloola N, Basoodan M, Alkathiri M, Alshahrani R, Mansy W, et al. Assessment of Community Pharmacy Services and Preparedness in Saudi Arabia during the COVID-19 Pandemic: A Cross-Sectional Study. Ann Pharm Educ Saf Public Health Advocacy. 2024;4:43-9. https://doi.org/10.51847/C52qAb0bZW

53. Liu H, Xie X, Chen Q. Determinants of Practice: Exploring Healthcare Providers' Beliefs and Recommendations for Cardiac Rehabilitation in China. Ann Pharm Educ Saf Public Health Advocacy. 2024;4:63-74. https://doi.org/10.51847/UcQWoStr3h

54. Elamin SM, Redzuan AM, Aziz SAA, Hamdan S, Masmuzidin MZ, Shah NM. Educational Impact on Glycemic Outcomes Among Children and Adolescents Diagnosed with Type 1 Diabetes. J Med Sci Interdiscip Res. 2023;3(1):41-64. https://doi.org/10.51847/s5KgRZ9e1O

55. Moga RA, Olteanu CD, Botez M, Buru SM. Assessment of the Maximum Amount of Orthodontic Force for PDL in Intact and Reduced Periodontium (Part I). Int J Environ Res Public Health. 2023;20(3):1889. doi:10.3390/ijerph20031889

56. Wu J, Liu Y, Li B, Dong X. Development and verification of a constitutive model for human periodontal ligament based on finite element analysis. Comput Methods Biomech Biomed Engin. 2022;25(9):1051-1062. doi:10.1080/10255842.2021.1999426

57. Benaissa A, Merdji A, Bendjaballah MZ, Ngan P, Mukdadi OM. Stress influence on orthodontic system components under simulated treatment loadings. Comput Methods Programs Biomed. 2020;195:105569. doi:10.1016/j.cmpb.2020.105569