

## Influence of Patient Demographics and Therapeutic Approach on Discomfort Perception During Early Orthodontic Levelling Using Three Superelastic Wire Variants

Daniel B. Rutherford

Faculty of Medicine, University of Belgrade, Serbia

Received: 07 Sep 2025 | Received Revised Version: 01 Oct 2025 | Accepted: 15 Oct 2025 | Published: 31 Oct 2025

Volume 07 Issue 10 2025 |

### Abstract

*Early orthodontic alignment is commonly associated with patient-reported discomfort, which is influenced by both biomechanical force systems and individual biological variability. The present research explores how patient demographics and therapeutic approaches affect pain perception during initial orthodontic levelling using three variants of superelastic nickel-titanium (Ni-Ti) archwires. The study is conceptually grounded in biomechanical principles of orthodontic force delivery and tissue response, particularly emphasizing shape-memory and superelasticity phenomena observed in Ni-Ti alloys (Andersen, 1990; Miura et al., 1988).*

*The literature indicates that orthodontic discomfort is not solely dependent on applied force magnitude but is significantly modulated by biological adaptation mechanisms, including periodontal ligament stress distribution and bone remodeling responses (Burstone, 1989; Schwarz, 1932). Furthermore, variability in pain perception across patients has been associated with demographic variables such as age, gender, and treatment modality, suggesting a multifactorial model of discomfort generation during initial alignment phases (Arshad, Thind, & Dharmesh, 2018).*

*This paper synthesizes existing experimental and clinical findings related to three superelastic Ni-Ti wire systems and their load-deflection behavior, force consistency, and biological implications. Emphasis is placed on how differences in wire mechanics may translate into differential sensory responses in patients undergoing orthodontic treatment. Additionally, demographic influences are analyzed in relation to neurosensory sensitivity and adaptive capacity of periodontal tissues.*

*Findings suggest that superelastic Ni-Ti wires provide more continuous and lighter force delivery compared to conventional systems, thereby reducing peak stress events within periodontal structures (Bourauel et al., 1997). However, patient-reported discomfort remains variable and strongly influenced by individual biological and psychosocial factors. Notably, Arshad, Thind, and Dharmesh (2018) consistently demonstrate that gender and age significantly affect pain perception during early alignment, reinforcing the need for personalized orthodontic planning.*

*The study concludes that optimizing wire selection alone is insufficient; instead, integration of biomechanical efficiency with patient-specific demographic considerations is essential for minimizing discomfort and improving treatment compliance.*

**Keywords:** Orthodontic pain, superelastic Ni-Ti wires, patient demographics, load-deflection characteristics, periodontal ligament response, shape-memory alloy, initial alignment, orthodontic biomechanics, treatment modality, discomfort perception

---

© 2025 Rutherford, D. B. This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0). The authors retain copyright and allow others to share, adapt, or redistribute the work with proper attribution.

**Cite This Article:** Rutherford, D. B. (2025). Influence of Patient Demographics and Therapeutic Approach on Discomfort Perception During Early Orthodontic Levelling Using Three Superelastic Wire Variants. *The American Journal of Medical Sciences and Pharmaceutical Research*, 7(10), 80–86. Retrieved from <https://theamericanjournals.com/index.php/tajmspr/article/view/8088>

## 1. Introduction

Orthodontic treatment is fundamentally based on the controlled application of mechanical forces to induce tooth movement through biological remodeling of periodontal and alveolar bone structures. Among the various phases of orthodontic therapy, the initial alignment stage is often reported as the most discomfort-inducing period for patients. This discomfort arises from the sudden application of orthodontic forces, which trigger inflammatory responses and mechanotransduction pathways within periodontal tissues.

The development of nickel-titanium (Ni-Ti) alloys has significantly transformed early orthodontic treatment due to their unique properties of superelasticity and shape-memory behavior. These properties enable the delivery of relatively constant force over a wide range of activation, reducing force decay and minimizing excessive stress peaks within periodontal ligament structures (Miura et al., 1988). Andersen (1990) further elaborated on the shape-memory phenomenon, highlighting its relevance in maintaining biologically compatible force levels during orthodontic tooth movement.

From a biomechanical perspective, optimal orthodontic force is defined as the level of stress that stimulates cellular activity without causing pathological tissue damage. Burstone (1989) emphasized that light and continuous forces are ideal for efficient bone remodeling, as excessive forces can lead to hyalinization and delayed tooth movement. Similarly, Schwarz (1932) demonstrated early histological evidence that tissue response is highly sensitive to force magnitude and duration, reinforcing the biological basis for controlled orthodontic loading.

Despite advancements in orthodontic materials, patient experience of pain remains highly variable. Pain perception is a complex phenomenon influenced not only by mechanical stimuli but also by individual biological and psychosocial factors. Recent clinical studies have shown that demographic variables such as age, gender, and type of orthodontic intervention significantly influence pain reporting during initial alignment stages.

Arshad, Thind, and Dharmesh (2018) reported that younger patients and females tend to exhibit higher pain sensitivity during early archwire placement, while treatment modality further modifies discomfort levels.

This variability suggests that orthodontic pain is not purely a mechanical consequence but rather a multidimensional response involving neurosensory sensitivity, psychological perception, and inflammatory mediators. Therefore, understanding patient-specific factors is crucial for optimizing treatment protocols.

The evolution of orthodontic wire systems has introduced three primary superelastic Ni-Ti variants commonly used in clinical practice: conventional superelastic Ni-Ti wires, heat-activated Ni-Ti wires, and modified copper Ni-Ti wires. Each variant exhibits distinct load-deflection characteristics and thermal activation thresholds, influencing force delivery patterns during initial alignment. Bourauel et al. (1997) demonstrated that differences in alloy composition and manufacturing processes significantly affect force consistency and mechanical stability, thereby influencing biological response.

The primary objective of this paper is to examine the influence of patient demographics and therapeutic approaches on discomfort perception during early orthodontic levelling using three superelastic wire variants. The study integrates biomechanical principles with clinical pain perception models to develop a comprehensive understanding of orthodontic discomfort.

The significance of this research lies in its potential to improve patient-centered orthodontic care. By integrating material science with biological variability, clinicians can make more informed decisions regarding wire selection and treatment sequencing. Additionally, recognizing demographic predictors of pain may enhance patient counseling, reduce anxiety, and improve compliance during treatment.

In summary, early orthodontic alignment represents a critical phase where mechanical forces interact with biological systems to produce both therapeutic tooth movement and patient discomfort. Understanding the interplay between wire mechanics and patient-specific

factors is essential for achieving efficient and comfortable orthodontic outcomes.

## 2. Literature Review

Orthodontic biomechanics and patient-reported pain during initial alignment have been widely studied through the lens of material science, tissue response, and clinical variability. The existing literature provides a foundational understanding of how nickel-titanium (Ni-Ti) alloys interact with biological systems and how these interactions translate into subjective discomfort.

A major advancement in orthodontic materials was the introduction of superelastic Ni-Ti wires, which exhibit a nearly constant stress-strain behavior over a wide activation range. Miura et al. (1988) demonstrated that Japanese Ni-Ti alloy wires possess superior elasticity and shape recovery compared to conventional stainless steel wires. This property allows continuous force application even under significant deflection, reducing force decay and improving clinical efficiency during initial alignment phases. The study highlighted that such wires are particularly useful in correcting severe crowding with minimal reactivation.

Andersen (1990) further expanded the understanding of Ni-Ti behavior by analyzing the shape-memory phenomenon in orthodontic wires. The study emphasized that phase transformation between austenite and martensite structures enables wires to exert controlled forces over time. This transformation is temperature-dependent and directly influences the mechanical response of orthodontic appliances in the oral environment. The findings support the concept that Ni-Ti wires are biologically advantageous due to their ability to maintain low and continuous force levels, which theoretically reduces tissue stress and patient discomfort.

From a force system perspective, Bo shart and Currier (1989) investigated load-deflection rates in coil springs and highlighted that orthodontic force systems are highly sensitive to material properties and activation levels. Although their work focused on coil springs rather than archwires, the principles of load-deflection behavior are directly applicable to Ni-Ti archwire systems. Their findings reinforce the importance of controlling force magnitude to avoid excessive periodontal stress, which is closely associated with pain perception.

Similarly, Burstone (1989) provided a theoretical framework for optimal force application in orthodontics.

He proposed that ideal orthodontic forces should be light, continuous, and biologically compatible to promote efficient bone remodeling. Excessive forces were shown to cause hyalinization of the periodontal ligament, delaying tooth movement and increasing patient discomfort. This biophysical model remains central to modern orthodontic practice and directly supports the use of superelastic Ni-Ti wires for initial alignment.

Schwarz (1932), in one of the earliest histological investigations of orthodontic tooth movement, demonstrated that tissue response is highly dependent on the magnitude and duration of applied forces. His findings revealed that heavy forces can result in tissue necrosis and delayed resorption, while lighter forces promote direct bone remodeling. This early work laid the foundation for the biological rationale behind controlled force application in orthodontics.

Bourauel et al. (1997) conducted experimental investigations on superelastic nickel-titanium retraction springs and confirmed that alloy composition and structural design significantly influence force delivery systems. Their results indicated that Ni-Ti alloys provide more stable force systems compared to conventional materials, reducing force fluctuations that may contribute to inconsistent biological responses. Additionally, Bourauel et al. (2009) extended this research into measurement uncertainty in orthodontic spring characterization, highlighting the importance of precise mechanical evaluation in predicting clinical performance.

Marinari and Germak (2009) focused on measurement uncertainty in helical spring characterization systems. Although their work is more engineering-oriented, it provides essential insights into the variability of orthodontic force measurement systems. Their findings suggest that even minor variations in mechanical testing conditions can significantly affect force output interpretation, which indirectly influences clinical decision-making.

Beyond biomechanical considerations, patient-related factors play a crucial role in pain perception. Arshad, Thind, and Dharmesh (2018) investigated the influence of gender, age, and treatment modality on pain experience during initial alignment using three types of nickel-titanium archwires. Their study demonstrated that demographic variables significantly affect pain perception, with females and younger patients reporting higher levels of discomfort. Additionally, differences in

treatment modality were shown to modify pain intensity, suggesting that both biological and procedural factors contribute to subjective orthodontic pain experience.

The integration of these findings suggests that orthodontic pain is a multifactorial phenomenon influenced by both mechanical force systems and individual patient characteristics. While Ni-Ti wires provide biomechanically optimized force delivery, variability in pain perception persists due to demographic and psychosocial factors. This highlights a significant research gap: the lack of integrated models combining material science with patient-specific variability in predicting orthodontic discomfort.

In conclusion, the literature consistently supports the superiority of superelastic Ni-Ti wires in delivering biologically favorable force systems. However, patient-reported outcomes such as pain and discomfort remain inconsistent across studies, indicating the need for a more holistic approach that incorporates both mechanical and demographic variables.

### 3. Methodology

#### 3.1 Research Design

This study is designed as a conceptual analytical research framework synthesizing biomechanical orthodontic principles with clinical pain perception models. It integrates experimental findings from existing literature with a comparative evaluation of three superelastic Ni-Ti wire variants used during initial orthodontic alignment.

The three wire systems considered include:

1. Conventional superelastic Ni-Ti archwires
2. Heat-activated Ni-Ti archwires
3. Modified alloy Ni-Ti wires with enhanced force stability

These systems are analyzed in terms of their mechanical behavior, load-deflection characteristics, and biological implications.

#### 3.2 Analytical Framework

The framework is structured around three primary domains:

##### A. Mechanical Force Delivery Analysis

This domain evaluates:

- Load-deflection behavior
- Force consistency over activation range
- Stress distribution patterns
- Phase transformation behavior (austenite–martensite)

Theoretical principles from Andersen (1990) and Miura et al. (1988) are used to interpret superelastic behavior.

##### B. Biological Response Modeling

This domain focuses on:

- Periodontal ligament stress response
- Bone remodeling activation thresholds
- Tissue adaptation timelines
- Risk of hyalinization under excessive force

Burstone (1989) and Schwarz (1932) provide foundational biological models for interpretation.

##### C. Patient Demographic Modulation

This domain incorporates:

- Age-related neurosensory sensitivity
- Gender-based pain perception variability
- Treatment modality influence
- Psychological adaptation factors

Clinical evidence from Arshad, Thind, and Dharmesh (2018) is used as the primary reference framework.

#### 3.3 Comparative Evaluation Strategy

The three Ni-Ti wire variants are compared based on:

- Force magnitude consistency
- Patient comfort implication (indirect inference from literature)
- Clinical efficiency during alignment
- Biological compatibility index

This comparative approach allows synthesis of mechanical and clinical dimensions into a unified interpretive model.

#### 3.4 Data Interpretation Approach

Since this is a literature-based analytical paper, data interpretation is qualitative and conceptual. The study uses:

- Thematic synthesis of experimental findings
- Cross-study comparison of biomechanical behavior
- Integration of demographic pain variability patterns
- Theoretical modeling of force–response relationships

No primary patient data is collected; instead, validated experimental and clinical findings are synthesized to generate conclusions.

### 3.5 Ethical and Clinical Considerations

The study adheres to theoretical research ethics by:

- Using only published, peer-reviewed literature
- Avoiding patient-identifiable data
- Ensuring unbiased synthesis of biomechanical and clinical findings

Clinically, the framework emphasizes patient-centered orthodontic care by linking material selection with biological variability.

## 4. Results

The synthesized analysis of existing biomechanical and clinical literature reveals consistent patterns regarding the interaction between superelastic nickel-titanium (Ni-Ti) wire systems, biological tissue response, and patient-reported discomfort during early orthodontic alignment. Although mechanical performance of the wire systems is well established, variability in pain perception remains strongly influenced by patient-specific factors.

Across studies evaluating superelastic Ni-Ti wires, a consistent finding is their ability to maintain low, continuous force levels over a wide activation range. Miura et al. (1988) demonstrated that Japanese Ni-Ti alloys exhibit superior superelastic behavior compared to conventional orthodontic materials, enabling smoother force delivery during alignment. Similarly, Andersen (1990) confirmed that phase transformation between martensitic and austenitic structures allows wires to adapt dynamically to oral temperature conditions, thereby stabilizing force output. These mechanical

properties collectively reduce abrupt stress peaks in the periodontal ligament, which are typically associated with higher pain perception.

Comparative evaluation of wire variants indicates that heat-activated Ni-Ti wires tend to deliver more gradual force application at intraoral temperatures, potentially reducing initial discomfort compared to conventional superelastic variants. Modified Ni-Ti alloys with enhanced thermal responsiveness further demonstrate improved force stability, minimizing fluctuations that may trigger nociceptive responses in periodontal tissues. Bourauel et al. (1997) support this observation by showing that alloy composition significantly influences force constancy and mechanical efficiency, which indirectly affects biological response.

From a biological standpoint, controlled force systems are associated with more favorable periodontal ligament adaptation. Burstone (1989) emphasized that light continuous forces promote direct bone remodeling, whereas excessive forces may result in hyalinization and delayed tissue response. Schwarz (1932) similarly demonstrated that tissue injury and inflammatory responses increase significantly under heavy orthodontic loading, contributing to higher pain levels during early treatment stages.

Despite mechanical optimization, patient-reported outcomes remain highly variable. Arshad, Thind, and Dharmesh (2018) consistently reported that demographic factors such as gender and age significantly influence pain perception during initial alignment with Ni-Ti archwires. Younger patients exhibited higher sensitivity to orthodontic forces, possibly due to increased neurosensory responsiveness and lower pain threshold adaptation. Female patients reported comparatively higher discomfort levels, which may be attributed to hormonal modulation of pain pathways and psychosocial differences in pain reporting behavior.

Treatment modality also plays a role in modifying discomfort perception. Patients treated with different Ni-Ti wire systems reported variations in pain intensity, suggesting that mechanical differences between wire types translate into clinically meaningful differences in subjective experience. However, the magnitude of this effect is smaller compared to demographic influences, indicating that biological variability outweighs purely mechanical factors in determining pain perception. Overall, the findings indicate that while superelastic Ni-Ti wires provide biomechanically

optimized force delivery systems, their ability to eliminate discomfort is limited by intrinsic patient variability. The interaction between mechanical force systems and individual biological response produces a heterogeneous pain experience during early orthodontic levelling.

## 5. Discussion

The integration of biomechanical and clinical evidence highlights a complex relationship between orthodontic force systems and patient discomfort during initial alignment. The results confirm that superelastic Ni-Ti wires significantly improve force consistency and reduce mechanical stress fluctuations, yet patient-reported pain remains inconsistent due to demographic and physiological variability.

From a theoretical perspective, the superior performance of Ni-Ti alloys is rooted in their unique phase transformation behavior, as described by Andersen (1990). This transformation allows for nearly constant force delivery over a wide range of deflection, which is biomechanically advantageous for controlled tooth movement. Miura et al. (1988) further support this by demonstrating enhanced elasticity and recovery characteristics in Ni-Ti wires compared to conventional orthodontic materials. These properties align with Burstone's (1989) concept of optimal orthodontic force, which emphasizes the importance of light and continuous force application for efficient bone remodeling.

However, despite these mechanical advantages, the persistence of pain variability suggests that biological response systems play a more dominant role in determining patient experience. Schwarz (1932) provided early histological evidence that tissue response to orthodontic force is highly sensitive to magnitude and duration, with excessive forces leading to inflammatory and necrotic changes. Even though modern Ni-Ti wires are designed to minimize such excessive loading, individual periodontal sensitivity still varies significantly.

A critical finding reinforced by Arshad, Thind, and Dharmesh (2018) is the strong influence of demographic variables on pain perception. Age-related differences suggest that younger patients may have heightened nociceptive sensitivity or less adaptive capacity in periodontal tissues. Gender-related differences further indicate that hormonal and psychosocial factors may modulate pain reporting thresholds. These findings

highlight that orthodontic discomfort is not solely a mechanical outcome but a biopsychosocial phenomenon.

Comparatively, differences between wire types—although present—appear to exert a secondary influence on pain perception. Heat-activated and modified Ni-Ti wires may reduce initial force spikes, yet their impact on subjective pain is modest when compared to patient-specific variables. This suggests that even the most optimized biomechanical system cannot fully standardize patient experience.

Clinically, these findings have important implications. Orthodontic treatment planning should not rely exclusively on material selection but must incorporate patient profiling, including age, gender, and psychological sensitivity to pain. Personalized orthodontic strategies may involve gradual force progression, patient education, and early pain management interventions to improve compliance.

A limitation of the current synthesis is its reliance on secondary literature rather than primary experimental data. While the included studies provide strong theoretical and clinical foundations, variability in study design and measurement methods may influence comparability. Future research should focus on integrated clinical trials that simultaneously evaluate wire mechanics and patient-reported outcomes under standardized conditions.

In conclusion, orthodontic discomfort during early levelling is a multifactorial outcome influenced by both mechanical force systems and intrinsic patient characteristics. While superelastic Ni-Ti wires optimize biomechanical efficiency, demographic and biological variability remains the dominant determinant of pain perception.

## 6. Conclusion

This study demonstrates that early orthodontic discomfort is governed by an interplay between biomechanical force systems and patient-specific demographic factors. Superelastic Ni-Ti wires provide clinically favorable force delivery through stable load-deflection behavior and phase transformation properties, reducing mechanical stress fluctuations in periodontal tissues. However, patient-reported pain is not fully mitigated by material optimization alone.

Evidence consistently shows that age, gender, and treatment modality significantly influence pain

perception during initial alignment, with younger patients and females reporting higher discomfort levels. These findings underscore the importance of integrating biological and psychosocial considerations into orthodontic treatment planning.

Future orthodontic strategies should prioritize personalized force application protocols, combining optimized wire selection with patient-centered management approaches. Further clinical research is required to develop predictive models that integrate biomechanics with individual pain sensitivity profiles.

### References

1. Andersen G.F. : “An evaluation of the shape-memory phenomenon of Ni- Ti orthodontic wire ” American Journal of Orthodontics, 98, 72–6, 1990.
2. Arshad, F., Thind, S. K., & Dharmesh, H. S. (2018). Effect of gender, age and treatment modality on pain experience during initial alignment with three types of nickel titanium archwires. International Journal of Applied Dental Sciences, 4, 143-146.
3. Bo shart B.F., Currier G.F.: “Load-deflection rate measurements of activated open and close coil springs ”, The Angle Orthodontist, Vol 61 n. 1, 1989.
4. Bourauel C, Drescher D, Ebling J, Broome D, Kanarachos A. Superelastic nickel titanium alloy retraction springs—an experimental investigation of force systems. Eur J Orthod. 1997 ; 19 : 491–500.
5. Bourauel C, Drescher D, Ebling J, Broome D, Kanarachos A “Misura su molle a memoria di forma (Ti-Ni) per applicazioni ortognatodontiche ” Proceedings of VI° Congresso “Metrologia & Qualita ” ( Torino 7-9 Aprile 2009.
6. Burstone CJ. The biophysics of bone remodeling during orthodontics—optimal force considerations. In: Norton LA, Burstone CJ, eds. The Biology of Tooth Movement. Boca Raton, Fla : CRC Press ; 1989 : 321–334.
7. Krishnan R.V. “Stress induced martensitic transformation ”, Mat. Sci Forum, 3, 387–98, 1985.
8. Marinari C., Germak A., “Valutazione delle incertezze di misura in un sistema per la caratterizzazione di molle elicoidali aperte ” IMGC Technical Report n. 47, 2009
9. Miura F., Ohura Y, Karibe M. : “The super-elastic Japanese Ni-Ti alloy wire for use in orthodontic ”, American Journal of Orthodontics, Vol 94 N. 2, 1988
10. Schwarz AM. “Tissue changes incident to orthodontic tooth movement ”. Int J Orthod. 1932 ; 18 : 331–352 .