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# Patient-Reported Pain During Initial Leveling with Three Types of Nickel–Titanium Orthodontic Archwires: A Single-Blinded Comparative Study

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### Featured Application

Reducing pain at the start of orthodontic treatment can significantly improve patient satisfaction and compliance. This study highlights the clinical potential of advanced multiforce archwires to transform early orthodontic experiences—offering not only biomechanical efficiency, but also greater comfort from day one.

### Abstract

Background: Patient discomfort during the initial phase of orthodontic treatment is a common concern and may influence compliance. Archwire selection plays a critical role in modulating pain perception. This study aimed to compare immediate and dynamic pain perception among patients undergoing initial orthodontic leveling using three types of nickel–titanium archwires with different mechanical properties and cross-sectional dimensions. Methods: Forty-eight patients undergoing fixed appliance therapy were enrolled in a single-blind comparative clinical study. Participants completed a two-part, pilot-tested questionnaire assessing immediate (Day 4) and dynamic (Day 8) pain after the first archwire placement. Group differences were analyzed with Kruskal–Wallis and Bonferroni-adjusted Mann–Whitney U tests ($\alpha = 0.05$). Results: TriTanium® was consistently associated with lower pain across functional tasks and had significantly lower overall pain than both Bio-Active® and 0.014-inch single-force round Ni-Ti (Bonferroni-adjusted). Bio-Active® was intermediate and did not differ from 0.014-inch round; its reduction relative to the round wire showed a non-significant trend. No correlation was found between archwire size and pain intensity. Conclusions: The type and mechanical behavior of the archwire, rather than its cross-sectional dimension, influence patient discomfort during the initial leveling phase. Multiforce shape-memory archwires such as TriTanium® may offer improved comfort and should be considered when planning early-stage orthodontic treatment.

**Keywords:** orthodontic pain; Ni-Ti archwires; multiforce wires; initial leveling; patient-reported outcome



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## 1. Introduction

Orthodontic treatment aims to align dental arches and achieve ideal occlusal relationships. For initial leveling, nickel–titanium (Ni-Ti) archwires, like Bio-Active® and Tritanium®, are ideal due to their shape memory and progressive force from the midline to the posterior sectors [1–4]. Gentle, consistent force ensures controlled tooth movement,

minimizing harm to biological structures, root resorption, and pain [5,6]. Patients expect aesthetic smiles, rapid tooth movement, and no discomfort during orthodontic treatment. Pain levels vary due to psychological, genetic, social, and individual factors, as well as applied force and alveolar bone condition. Usually, pain starts 12 h after applying orthodontic force [7], reaches a peak on day 1 (24 h), starts to decrease on day 3 (72 h), and disappears after 6–7 days. More than 70% percent of orthodontic patients report pain during orthodontic treatment [8–11], describing feelings of pressure, tension, and soreness of the teeth after placement of the brackets [11–14]. The appearance of discomfort instigates some of the patients to discontinue orthodontic treatment. In this regard, researchers are investigating mechanisms and devices in pain management in fixed orthodontic treatment [15]. The orthodontic tooth movements cause reactions in the periodontium and the alveolar bone, which stimulate the release of various biochemical mediators. They cause the sensation of pain [11,16–19]. The pain experienced due to orthodontic appliances has been found to escalate with increased activity in the masticatory system, such as chewing or biting, as opposed to instances of spontaneous discomfort. Furthermore, fitting the posterior or anterior teeth together also heightens the discomfort, albeit to a lesser extent than chewing or biting [20]. Some studies have indicated that the male tolerates pain easily, considering the female gender more fragile and sensitive to the perception of the pain sensation caused by fixed orthodontic appliances [21] or larger diameter of the archwires [22]; other studies show no statistically significant difference between the two sexes [23]. Pain evaluation is crucial in orthodontics. Methods include questionnaires or Visual Analogue Scales (VAS), first used by Hayes and Petterson in 1921 and which continues to be used today [24,25]. VAS is easy, reliable, and understandable but mainly measures pain intensity, not providing information such as pain quality, location, or emotional impact. Ngan et al. and Joshi et al. combined self-developed questionnaires with VAS for more comprehensive assessments [12,26].

**Rationale for cross-sectional selection:** In everyday orthodontic practice, archwire geometry is chosen to balance force delivery and patient comfort. Rectangular multiforce wires (0.016 × 0.022 inch) are known to provide more consistent, gentle forces over a wider deflection range—helping control tooth movement and torque—whereas round single-force wires (0.014 inch) offer greater flexibility and tend to cause less initial discomfort. By comparing these two cross-sections, our study isolates how the material's superelastic properties affect pain perception, while still reflecting the real-world choices clinicians make during initial leveling. Based on the current literature and clinical observations, we formulated the following null hypothesis ($H_0$): there is no statistically significant difference in patient-reported pain levels during the initial leveling phase of orthodontic treatment when using TriTanium®, Bio-Active®, or conventional single-force superelastic Ni-Ti archwires. The aim of this single-blinded clinical study was to evaluate and compare immediate and dynamic pain perception among patients undergoing initial orthodontic leveling using three types of nickel–titanium archwires with different mechanical properties and cross-sectional dimensions.

## 2. Materials and Methods

### 2.1. Ethics Statement

The clinical procedures were carried out according to the guidelines of the World Medical Association's Declaration of Helsinki and the Ministry of Health for Good Clinical Practice. Patients were treated in the Faculty of Dental Medicine after acceptance of the orthodontic treatment plan and signed an informed consent form. The protocol was approved by the Research Ethic Committee of Medical University Sofia (KENIMUS) with approval code: N3/BK-167/31.01.2019 and approval date: N3/18.02.2019.

### 2.2. Material

A year since the start of the postgraduate specialization internship in the Department of Orthodontics at the Faculty of Dental Medicine, Medical University of Sofia, 50 patients were accepted for treatment. Of these, 48 patients (mean age: 21.57 years) were selected for inclusion after the placement of the initial archwire.

A summary of patient distribution by archwire type, age, and gender is presented in Table 1.

**Table 1.** Patient demographic characteristics by archwire group.

| Archwire Type | N | Mean Age ± SD | Female (n, %) | Male (n, %) |
|---|---|---|---|---|
| Conventional superelastic Ni–Ti (0.014″) | 15 | 16.8 ± 3.7 | 9 (60.0%) | 6 (40.0%) |
| Multiforce Bio-Active® (0.016 × 0.022″) | 10 | 19.5 ± 10.4 | 5 (50.0%) | 5 (50.0%) |
| Multiforce TriTanium® (0.016 × 0.022″) | 23 | 24.9 ± 9.3 | 12 (52.2%) | 11 (47.8%) |

A sensitivity power analysis was conducted in G*Power 3.1.9.7 (F tests → ANOVA: $\alpha = 0.05$; $1-\beta = 0.80$; three groups; total N = 48), which showed that the study could detect a large effect size of f = 0.46 ($\eta^2 \approx 0.18$). Inclusion criteria were (a) permanent dentition, (b) initial multiforce archwires (0.016 × 0.022 inches) and superelastic archwires (0.014 inches), and (c) non-extraction treatment. Exclusion criteria included (a) mixed dentition, (b) initial 0.012-inch superelastic archwires, (c) daily intake of analgesics, (d) extraction treatment, and (e) painful dental conditions.

Orthodontic archwires used in the leveling phase were (1) conventional 0.014-inch superelastic Ni-Ti (American Orthodontics, Sheboygan, WI, USA)—15 pcs; (2) multiforce Bio-active® (TOMY Inc., Tokyo, Japan)—10 pcs; and (3) multiforce TriTanium® (American Orthodontics)—23 pcs, both 0.016 × 0.022 inches. Treatment included MBT 0.022 × 0.028-inch slot, self-ligating brackets with bands on first molars. The distribution of archwires into the three groups followed the natural patient flow, based on real-world clinical availability and individual treatment needs, rather than random allocation.

### 2.3. Method

Research objectives were clarified, and a literature review was conducted. A pilot-tested questionnaire was developed. A testing phase was implemented to identify potential errors, involving a small cohort of representative patients. The survey had two parts:

1. Seven questions assessing moment pain after archwire placement during chewing, biting, intentional meeting of the front and back teeth, changes in speech, joint pain, and ear pain, graded on three levels (no discomfort, mild discomfort, severe discomfort).
2. Six questions studying pain dynamics, including onset and duration of pain, location (front or back teeth), need for painkillers, and interference with daily life.

The questionnaire was completed in two parts: on Day 4 (immediate pain response) and Day 8 (dynamic pain response) post archwires placement. This was a participant-blinded study. Patients were unaware of the archwire brand and size and pain outcomes were self-reported. The statistician was blinded to treatment allocation and wire characteristics and analyzed a de-identified dataset with groups labeled A, B, and C; unblinding occurred only after all analyses were locked.

Although validated instruments such as the Visual Analogue Scale (VAS) are widely used in orthodontic pain studies, we opted for a structured, self-developed questionnaire tailored to the clinical context. This design allowed us to assess not only the intensity but also the functional context, onset, duration, and patient behavior in response to pain. The format was simplified to ensure clarity and patient compliance, particularly for younger participants.

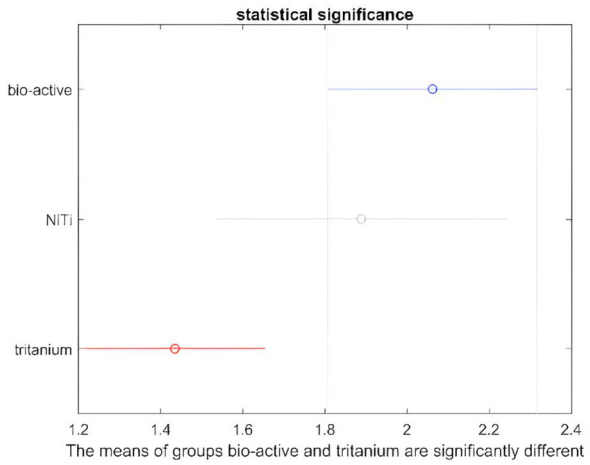
### *2.4. Statistical Methods*

Data were analyzed in MATLAB® R2020a. For the overall comparison among the three groups, we used the Kruskal–Wallis test; when the result was significant, we performed pairwise Mann–Whitney U tests with Bonferroni correction. Results are reported as median with Bonferroni-adjusted $p$-values; $\alpha = 0.05$ (two-sided). Analyses were performed on a de-identified dataset with groups coded A/B/C.

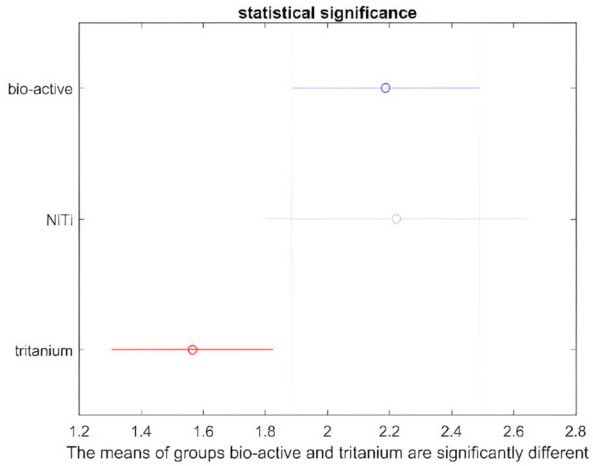
## 3. Results

### *3.1. Immediate Pain Response*

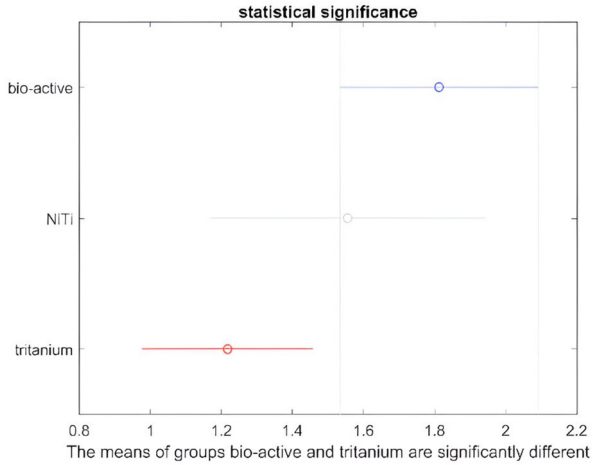
Pain perception during specific oral functions—chewing, biting, and posterior tooth contact—was assessed across the three archwire groups. As shown in Figure 1, the X-axis represents reported pain levels, while the Y-axis displays the compared groups, TriTanium®, Bio-Active®, and conventional single-force Ni-Ti. The analysis revealed function-specific differences in reported pain, with TriTanium® consistently associated with lower pain scores. The means of the groups are considered different if their intervals are disjoint and they are not considered different if their intervals overlap.




(**A**)
When chewing




(**B**)
When biting




(**C**)
Meeting the teeth back

**Figure 1.** Immediate pain levels across archwire groups during chewing (**A**), biting (**B**), and meeting of the posterior teeth (**C**). Group means are depicted by symbols (ring), comparison intervals are indicated with horizontal lines blue for Bio-Active®, grey for Ni-Ti and red for TriTanium® archwires.

These findings are supported by the corresponding ANOVA results summarized in Table 2.

**Table 2.** One-way ANOVA results for pain levels during specific oral functions across archwire groups.

| Function | F-Value | df | *p*-Value |
|---|---|---|---|
| Biting | 5.02 | 2.45 | 0.011 |
| Chewing | 5.82 | 2.45 | 0.0057 |
| Meeting posterior teeth | 4.13 | 2.45 | 0.0226 |

For biting, a one-way ANOVA showed a significant difference between groups (F (2, 45) = 5.02, $p$ = 0.011), with the TriTanium® group reporting the lowest pain intensity. For chewing, a stronger group difference was found (F (2, 45) = 5.82, $p$ = 0.0057), again favoring the TriTanium® group. Pain reported during meeting the back teeth was also significantly different between groups (F (2, 45) = 4.13, $p$ = 0.0226), though the difference was less pronounced than in the other two activities.

In all three conditions, patients treated with TriTanium® archwires consistently reported lower pain scores compared to those in the control group using conventional 0.014-inch single-force Ni-Ti archwires. The Bio-Active® group showed intermediate values but did not significantly differ from the control group. These findings suggest that multiforce archwires, particularly TriTanium®, are associated with reduced pain during everyday functional activities in the initial stages of orthodontic treatment.

### *3.2. Dynamic Pain Response*

Dynamic pain perception—reflecting overall discomfort and painkiller use over time—was evaluated for each archwire group. Patients treated with TriTanium® archwires reported the lowest cumulative pain scores and required fewer analgesics compared to those in the control group, which received conventional 0.014-inch single-force superelastic Ni-Ti archwires. As shown in Figure 2, the TriTanium® group demonstrated the most favorable pain response. The Bio-Active® group showed a moderate reduction in dynamic pain and analgesic use; however, these differences were not statistically significant. Among the multiforce archwires, only TriTanium® produced a consistent and statistically validated reduction in discomfort, supporting its potential clinical advantage during the early phase of orthodontic treatment.

A one-way ANOVA confirmed that the differences in dynamic pain among the three groups were statistically significant (F (2, 45) = 5.03, $p$ = 0.011), indicating that archwire type had a meaningful effect on perceived pain intensity over time. The statistical summary of dynamic pain scores and analgesic use are provided in Table 3.

**Table 3.** One-way ANOVA results for comparison of dynamic pain intensity and analgesic use among the three archwire groups.

| ANOVA Table | | | | | |
|---|---|---|---|---|---|
| Source | SS | df | MS | F | Prob > F |
| Groups | 2.3705 | 2 | 1.1852 | 5.0275 | 0.010699 |
| Error | 10.6087 | 45 | 0.23575 | | |
| Total | 12.9792 | 47 | | | |

In the second part of the pain assessment, based on patient responses, initial pain was felt by 44 out of 48 respondents, with varying durations: 15 felt it for up to 2 h, 17 up to

6 h, 11 after 1 day, 1 after 2 days, and 4 after 5 days. Continuing pain was reported by 44 respondents, with durations ranging from up to 1 week to over 1 week. In total, 91.7% of patients experienced significant pain, while 8.3% did not report significant pain.

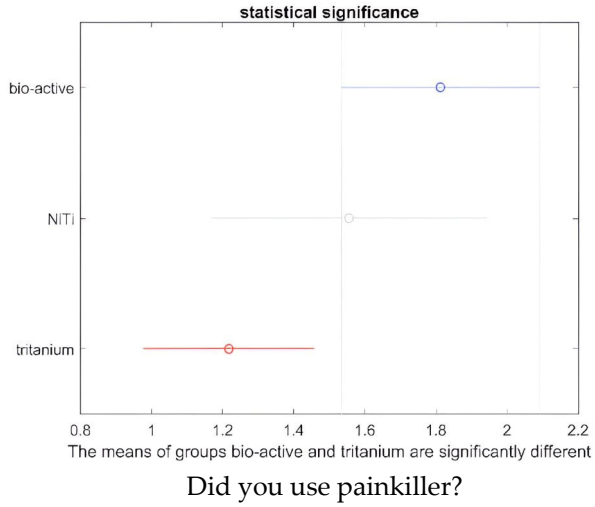



**Figure 2.** Mean dynamic pain scores across archwire types based on patient-reported pain intensity and painkiller use. Group means are depicted by symbols (ring), comparison intervals are indicated with horizontal lines: blue for Bio-Active®, grey for Ni-Ti and red for TriTanium® archwires. A one-way ANOVA revealed a statistically significant difference between groups (F (2, 45) = 5.03, $p = 0.011$), with TriTanium® associated with the lowest pain scores.

### *3.3. Group Statistics*

To assess the overall differences in pain perception across the three archwire types, group-level analysis was conducted. Figure 3 presents the distribution of mean pain levels for each archwire group, plotted against archwire type and cross-sectional size.

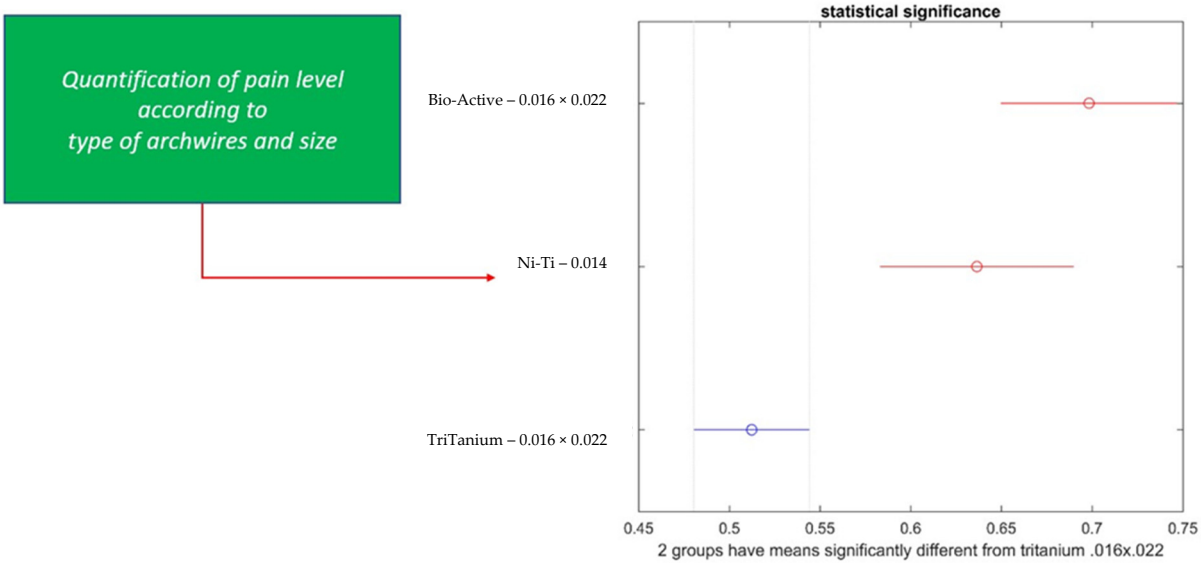



**Figure 3.** Mean patient-reported pain levels during initial orthodontic treatment according to archwire type and size. Group means are depicted by symbols (ring), comparison intervals are indicated with horizontal lines: red for Bio-Active® and Ni-Ti and blue for TriTanium® archwires.

A one-way analysis of variance (ANOVA) revealed a statistically significant difference in pain perception between the groups (F (2, 30) = 19.87, $p < 0.0001$), indicating that the type of archwire significantly influenced patient-reported discomfort (Table 4).

**Table 4.** One-way ANOVA results comparing mean pain levels between the three archwire groups.

| ANOVA Table | | | | | |
|---|---|---|---|---|---|
| Source | SS | df | MS | F | Prob > F |
| Groups | 0.20777 | 2 | 0.10388 | 19.8738 | $3.19 \times 10^{-6}$ |
| Error | 0.15682 | 30 | 0.0052272 | | |
| Total | 0.36458 | 32 | | | |

Bonferroni-adjusted comparisons indicated TriTanium® 0.016 × 0.022-inch multiforce rectangular archwires had significantly lower pain than Bio-Active® 0.016 × 0.022-inch multiforce rectangular (adjusted $p < 0.05$) and conventional 0.014-inch single-force round Ni-Ti archwires (adjusted $p < 0.001$). Bio-Active® vs 0.014-inch round Ni-Ti was not significant (adjusted $p > 0.05$). Thus, TriTanium® had the lowest mean pain; Bio-Active® was numerically lower than 0.014-inch round Ni-Ti but not significantly so.

These findings suggest that the biomechanical behavior and force delivery characteristics of the archwires are more influential in determining patient discomfort than wire dimension alone. Specifically, the round 0.014-inch single-force Ni-Ti archwires was associated with greater pain than both rectangular multiforce shape-memory archwires.

## 4. Discussion

### *4.1. Overview and Study Novelty*

This study evaluated patient-reported pain perception during the initial leveling phase of orthodontic treatment, comparing two multiforce rectangular Ni-Ti archwires (TriTanium® and Bio-Active®, 0.016 × 0.022-inch) to a conventional single-force round Ni-Ti archwire (0.014-inch). Pain was assessed using a detailed, custom-developed questionnaire, which captured both functional immediate response and dynamic pain dimensions. No previous studies were identified evaluating these specific archwires as initial wires, making this investigation a pilot clinical comparison. Based on Wang et al.'s [5] literature review, four studies utilized a 100 mm visual assessment scale to measure pain intensity daily for seven days post-archwire placement. These studies compared various round wires, except for Evans et al. [27] who examined 0.016 × 0.022-inch wires and concluded that thermodynamic Ni-Ti archwires consistently resulted in greater tooth movement compared to stainless steel archwires. The use of a custom-designed questionnaire instead of a validated scale such as the VAS represents a methodological limitation. While our tool was structured to capture multidimensional pain experiences, including specific functional triggers and dynamic progression, it does not allow for direct comparison with previous studies using standardized instruments.

### *4.2. Comparison of Archwire Types and Pain Levels*

Based on the results, the null hypothesis was rejected. Statistically significant differences in pain perception were observed between the three archwire groups, particularly with TriTanium® showing the lowest pain levels during both function-specific and dynamic assessments. It is found that the experienced pain is stronger in patients treated with conventional Ni-Ti archwires, compared to thermally graduated archwires, in four indicators (chewing, meeting of the teeth at the back, biting, and taking painkillers), which coincides with the results obtained in the studies of Cioffi et al. [28], which, however, are not so detailed. Other studies have found no statistically significant differences between heat-activated and conventional archwires, possibly due to small wire sizes and inadequate pain questionnaires [28,29].

### 4.3. Material Properties and Their Impact on Pain

Several researchers have explored how archwire material affects pain levels [21,30,31]. Superelastic Ni-Ti wires have been associated with higher pain levels compared to multistrand stainless steel archwires [32–34]. A study comparing archwires found that a 0.012 stainless steel wire caused less pain than a 0.014 superelastic Ni-Ti wire during initial treatment [34]. Papageorgiou et al. [35] reported that heat-activated Ni-Ti wires led to more pain shortly after archwire placement (from the 4th hour to 1 day) and were not as effective in speeding up leveling compared to conventional Ni-Ti. The research of Andriniaina et al. [36] indicated a trend where pain tends to diminish as the initial archwire diameter increases. In contrast to some of these dimensional and thermal activation effects, our data indicate that the intrinsic superelastic plateau and shape-memory behavior of the alloy is the primary determinant of patient comfort. In our cohort, there was no significant relationship between wire cross-sectional area and reported pain intensity. Instead, the multiforce Ni–Ti wires yielded the lowest pain scores, suggesting that their more uniform force delivery profile—rather than simply being rectangular—accounts for improved patient experience.

These observations underscore the need to consider material design (e.g., superelastic plateau width, transformation temperatures, force gradients) as key variables in future pain-focused wire comparisons, rather than relying on cross-sectional geometry alone.

### 4.4. Pain Dynamics, Gender Differences, and Patient Experience

In our cohort, 91.7% of patients reported pain in the first days of treatment, consistent with Johal et al.'s description of elevated pain lasting 1–3 days [37]. During this period, 37.5% used analgesics. Analgesic use was treated as an outcome rather than a protocolized co-intervention; no prophylactic recommendations were given, and type/timing/dose were not standardized by design. Identical non-directive instructions were applied across groups; consequently, any measurement imprecision is expected to be nondifferential and therefore conservative. Analgesic use incidence was analyzed as a secondary, behavioral endpoint, separate from pain scores.

Pain perception and medication use can vary with personality and social/professional context [38]. We observed that women reported higher pain, used analgesics more frequently, and experienced more posterior-arch pain—findings that align with Scheurer et al. [23], though other studies report no gender association [21,25,37] or greater pain among men [10,39]. Because groups were not stratified by gender and the sample size was limited, these observations are exploratory. Larger, gender-balanced studies with pre-specified interaction testing are warranted. Finally, consistent with Montebugnoli et al. [30], providing clear verbal and written information may reduce perceived pain and the need for medication.

### 4.5. Reevaluating Clinical Assumptions and Archwire Strategy

The belief that round archwires cause less pain than rectangular ones is challenged. Using a single multiforce archwire for initial leveling may be more efficient and cost-effective than multiple round archwires, potentially reducing side effects and unnecessary tooth movement. However, there is limited research comparing pain levels between new multiforce archwires and single-force superelastic Ni-Ti archwires.

### 4.6. Study Limitations and Future Directions

Our study has several limitations. The sample size was relatively small and uneven across groups, and archwire selection was based on clinical discretion rather than randomization, which may introduce selection bias. By comparing commonly used configurations

instead of standardizing cross-sections, we prioritized real-world relevance over strict experimental control, but this may affect isolation of material effects. Pain reporting is inherently subjective, and we used a custom questionnaire rather than a validated tool such as the Visual Analogue Scale (VAS). Future studies should use randomized allocation, balanced group sizes, standardized wire dimensions, and combine validated scales with context-specific tools to improve comparability.

Despite these limitations, this study reflects real-world orthodontic practice and provides valuable insights into pain perception during the initial leveling phase, highlighting the need for further research to optimize patient-centered treatment strategies. Understanding how the built-in properties of multiforce and superelastic Ni-Ti archwires affect the forces applied to teeth, and how these forces influence patient comfort, is key to linking material science with everyday clinical decisions.

## 5. Conclusions

Pain during the initial leveling phase was common. Within the limitations of this study, it can be concluded that pain perception during the initial leveling phase of orthodontic treatment is significantly influenced by the type of Ni-Ti archwire used, rather than its cross-sectional size. Across function-specific tasks (chewing, biting, posterior contact) and in the overall comparison, TriTanium® 0.016 × 0.022-inch multiforce rectangular Ni-Ti consistently showed the lowest pain. In the group analysis, Bonferroni-adjusted tests confirmed that TriTanium® had significantly lower overall pain than both Bio-Active® 0.016 × 0.022-inch multiforce rectangular Ni-Ti and conventional 0.014-inch single-force round Ni-Ti, while Bio-Active® showed a probable trend toward lower pain relative to the 0.014-inch round wire that did not reach statistical significance. Overall, TriTanium® demonstrated the most favorable pain profile in early treatment. These findings suggest that multiforce shape-memory archwires may offer advantages in terms of patient comfort during early treatment stages. Further randomized studies with larger, balanced groups are recommended to confirm these results and guide optimal archwire selection.

**Author Contributions:** Conceptualization, M.G.; methodology, M.G. and L.A.; resources, M.G., L.A. and V.P.; writing—original draft preparation M.G.; writing—review and editing, L.A. and V.P.; visualization, V.P.; supervision, V.P.; project administration, V.P. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** The protocol was approved by the Research Ethic Committee of Medical University Sofia (KENIMUS) with approval Code: N3/BK-167./18.02.2019.

**Informed Consent Statement:** Clinical procedures followed the guidelines of the World Medical Association's Declaration of Helsinki and the Ministry of Health for Good Clinical Practice. Patients were treated in the Faculty of Dental Medicine after acceptance of the orthodontic treatment plan and signed an informed consent form for treatment with multiforce archwires. Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The datasets used and analyzed during the current study are available from the authors upon reasonable request.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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