

Effect of Orthodontic Forces on Teeth with Compromised Pulpal Status: A Clinical Study

Danish Uz Zama Khan¹, Isukaptla Anusha², Bikash Ranjan Bindhani³,
Manali Prakash Jadhav⁴, MD. Shahbaz Alam⁵, Sanobar Ansari⁶

¹Professor, Department of Dentistry, Era's Lucknow Medical College & Hospital, Lucknow, Uttar Pradesh, India
danish07khan@gmail.com

²Senior Lecturer, Department of Orthodontics & Dentofacial Orthopaedics, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana, India anusha5190dr@gmail.com

³Assistant Professor, Department of Orthodontics & Dentofacial Orthopaedics, Institute of Dental Sciences, Siksha O Anusandhan Deemed to be University, Bhubaneswar, Odisha, India
drbikashranjanbindhani@gmail.com

⁴Assistant Professor, Department of Orthodontics & Dentofacial Orthopaedics, Government Dental College & Hospital, Ahmedabad, Gujarat, India vinzdarla90@gmail.com

⁵Reader, Department of Periodontology, Awadh Dental College & Hospital, Jamshedpur, Jharkhand, India
dr.shahbazalam20nov@gmail.com

⁶Post Graduate, Department of Orthodontics & Dentofacial Orthopaedics, Vananchal Dental College and Hospital, Garwah, Jharkhand, India dr.sanobaransari@gmail.com

Corresponding author: Danish Uz Zama Khan, danish07khan@gmail.com

HOW TO CITE:

Danish Uz Zama Khan, Isukaptla Anusha, Bikash Ranjan Bindhani, Manali Prakash Jadhav, MD. Shahbaz Alam, Sanobar Ansari (2026). Effect of Orthodontic Forces on Teeth with Compromised Pulpal Status: A Clinical Study. International Journal of Special Education, 41(10s), 318-328.

ABSTRACT:

Background: Orthodontic tooth movement is achieved through the application of controlled mechanical forces that trigger adaptive biological changes within the periodontal ligament and surrounding alveolar bone. Nevertheless, the behavior of teeth with compromised pulpal conditions under orthodontic loading remains a clinical concern because of the possible risk of pulpal damage or necrosis.

Aim: To assess the clinical and radiographic response of teeth with compromised pulpal status subjected to orthodontic forces during fixed appliance therapy.

Materials and Methods: This clinical investigation involved 48 patients receiving fixed orthodontic treatment. A total of 72 teeth with compromised pulpal status—including previously traumatized teeth, teeth with extensive restorations, and endodontically treated teeth—were evaluated and compared with 72 contralateral teeth with normal pulp serving as controls. Light continuous orthodontic forces not exceeding 100 g were applied. Periodic assessments were conducted at baseline, 3 months, 6 months, and 12 months using clinical examination, pulp vitality tests, and periapical radiographs. Data analysis was performed using the Independent Student's t-test and Chi-square test, with the level of statistical significance set at $p < 0.05$.

Results: No statistically significant difference was observed in the rate of orthodontic tooth movement between compromised pulp teeth (1.12 ± 0.21 mm per 6 months) and control teeth (1.18 ± 0.24 mm per 6 months)

COPYRIGHT STATEMENT:

Copyright: © 2026 Authors.
Open access publication under the
terms and conditions
of the Creative Commons Attribution
(CC BY)
license (<http://creativecommons.org/licenses/by/4.0/>).

($p = 0.37$). Alterations in pulp vitality were noted in 6.9% of teeth with compromised pulp and 4.2% of control teeth, with no significant intergroup difference ($p = 0.48$). Radiographic findings demonstrated comparable periapical status between both groups ($p = 0.62$). Importantly, no instances of irreversible pulpal necrosis related to orthodontic force application were detected.

Conclusion: Teeth with compromised pulpal status can undergo orthodontic tooth movement safely when light and controlled forces are used. Careful patient selection combined with regular clinical and radiographic follow-up minimizes the risk of unfavorable pulpal or periapical outcomes.

Keywords: Compromised pulp, Orthodontic forces, Orthodontic treatment, Pulpal vitality, Tooth movement.

Introduction

Orthodontic tooth movement represents a biologically driven process that occurs in response to the application of controlled mechanical forces, leading to adaptive changes within the periodontal ligament, alveolar bone, and surrounding structures. These forces initiate a sequence of cellular and molecular reactions that enable tooth displacement within the alveolar housing while maintaining functional integrity of the dentition. In teeth with normal pulpal health, such responses are typically well tolerated, producing only mild and reversible changes in pulpal circulation and sensory perception. Nevertheless, the influence of orthodontic forces on pulpal tissues continues to be an area of active research, particularly with regard to their effects on pulp vitality, microcirculation, and neural function [1].

Teeth exhibiting compromised pulpal status pose distinct biological considerations during orthodontic treatment. Such compromise may arise from dental trauma, extensive caries, deep restorative procedures, or previous endodontic intervention. These conditions can adversely affect pulpal vascular supply, sensory responsiveness, and reparative potential, thereby increasing the susceptibility of the pulp to ischemic or inflammatory insults under orthodontic loading. Traumatized teeth, in particular, may demonstrate disruption of the

neurovascular bundle and subsequent pulp canal obliteration, complicating both the assessment of pulpal health and orthodontic treatment planning [2].

Contemporary clinical studies suggest that teeth with pre-existing pulpal compromise, especially those with a history of trauma, may be more prone to altered pulpal responses during orthodontic therapy. Prospective investigations have reported a greater reduction in pulp vitality in traumatized teeth undergoing fixed orthodontic treatment when compared with non-traumatized counterparts, along with an increased occurrence of pulp necrosis and calcific changes over time [3].

Evidence from systematic reviews further indicates that orthodontic force application is commonly associated with temporary alterations in pulpal blood flow and sensibility. Although these changes are largely reversible in teeth with intact pulp, orthodontic forces have been shown to reduce pulpal perfusion, modify sensibility thresholds, and stimulate the release of inflammatory mediators. Importantly, consistent evidence of irreversible pulpal damage in teeth with healthy pulp remains limited [4].

The pulpal response to orthodontic forces is multifactorial and depends on variables such as force magnitude, direction, duration, and the pre-treatment pulpal condition. Both

experimental and clinical findings suggest that excessive or prolonged force application may intensify circulatory disturbances within the pulp, increasing the likelihood of unfavorable outcomes in biologically vulnerable teeth [5].

Despite growing interest in this area, there is still no clear consensus regarding the extent to which compromised pulpal status influences orthodontic treatment outcomes. A significant proportion of existing research focuses on teeth with healthy pulp and excludes compromised cases, resulting in a lack of robust clinical evidence to guide management strategies. This limitation highlights the necessity for targeted clinical studies addressing orthodontic tooth movement in teeth with altered pulpal health [6].

Accordingly, the present clinical study seeks to evaluate the clinical and radiographic responses of teeth with compromised pulpal status subjected to controlled orthodontic forces, with the aim of contributing evidence that supports safe and effective orthodontic management in such clinical scenarios.

Materials and Methods

Study Design and Sample Selection

This prospective clinical study was conducted on patients undergoing fixed orthodontic therapy. Ethical clearance was obtained from the institutional ethics committee, and written informed consent was secured from all participants prior to enrollment. A total of 48 patients receiving fixed orthodontic treatment were included in the study. From these patients, 72 teeth with compromised pulpal status were identified and evaluated. These teeth were compared with 72 contralateral teeth exhibiting normal pulpal vitality, which served as the control group.

Inclusion and Exclusion Criteria

Patients between 15 and 35 years of age who required orthodontic tooth movement and exhibited teeth with compromised pulpal status were selected for inclusion in the study. Compromised pulpal status was defined by the presence of a previous history of dental trauma,

deep restorative procedures, or teeth that had undergone root canal treatment.

Teeth demonstrating active periapical lesions were excluded from the study. Additionally, patients presenting with systemic conditions known to influence bone metabolism, inadequate oral hygiene, or existing periodontal disease were not considered eligible for participation.

Orthodontic Procedure

All patients were treated using fixed orthodontic appliances. Orthodontic tooth movement was achieved using light and continuous forces not exceeding 100 g, applied through standardized archwire sequences. Special care was taken to avoid excessive force application to minimize stress on the pulp and surrounding periodontal structures.

Clinical and Radiographic Evaluation

Clinical and radiographic assessments were carried out for both compromised pulp teeth and control teeth at baseline, 3 months, 6 months, and 12 months.

Pulp vitality was evaluated using thermal and electric pulp testing methods.

Clinical parameters such as pain, discoloration, and abnormal mobility were recorded at each follow-up visit.

Periapical radiographs were obtained to assess periapical status and detect any evidence of root resorption or pathological changes.

The rate of orthodontic tooth movement was measured and recorded at regular intervals.

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all study variables. Continuous variables were expressed as mean $\pm$ standard deviation (SD), while categorical variables were presented as frequencies and percentages.

The age distribution of study participants and the distribution of teeth according to pulpal status were analyzed using descriptive statistics. The rate of orthodontic tooth movement between compromised pulp teeth and control teeth was compared using the Independent Student's t-test after assessment of data normality.

Changes in pulp vitality during the follow-up period and the comparison of final pulp vitality status between compromised and control teeth were analyzed using the Chi-square test. Radiographic findings related to periapical status were also compared between groups using the Chi-square test.

The association between the type of pulpal compromise (traumatized teeth, deeply restored teeth, and endodontically treated teeth) and vitality outcomes was evaluated using the Chi-square test. All statistical tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant.

The level of significance was set at 95% confidence interval with an alpha error of 5% ($p < 0.05$).

Results

Table 1 & Figure 1 present the age distribution of the 48 study participants. The majority of subjects belonged to the 21–25 years age group, accounting for 16 participants (33.3%), followed by the 15–20 years age group with 14 participants (29.2%). Participants aged 26–30 years constituted 11 subjects (22.9%), while the 31–35 years age group represented the smallest proportion with 7 subjects (14.6%). Overall, the study population was predominantly composed of young adults, with more than half of the participants (62.5%) falling within the 15–25 years age range. This age distribution reflects the common age group seeking orthodontic treatment.

Table 1: Distribution of Study Subjects According to Age

Age Group (Years)	Frequency (n=48)	Percentage (%)
15–20	14	29.2
21–25	16	33.3
26–30	11	22.9
31–35	7	14.6
Total	48	100.0

■ 15–20 ■ 21–25 ■ 26–30 ■ 31–35

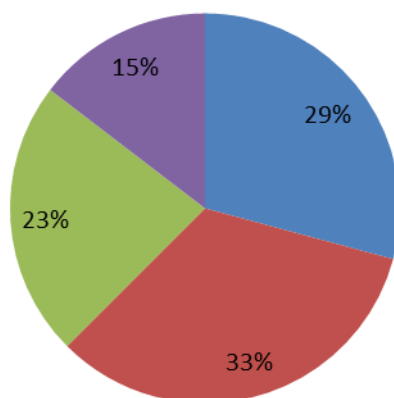


Figure 1: Age Distribution of the Study Participants

Table 2 & Figure 2 present the distribution of the 72 teeth included in the study according to

their pulpal status. Among the compromised teeth, previously traumatized teeth constituted

the largest category, accounting for 28 teeth (38.9%). This was followed by deeply restored teeth, which comprised 24 teeth (33.3%) of the sample. Endodontically treated teeth represented the smallest subgroup, with 20 teeth (27.8%). Overall, traumatized and restored teeth together accounted for more than two-thirds of the compromised teeth evaluated, indicating that these conditions were the most common causes of pulpal compromise among the study subjects.

Table 2: Distribution of Teeth According to Pulpal Status

Type of Tooth	Frequency (n=72)	Percentage (%)
Previously Traumatized Teeth	28	38.9
Deeply Restored Teeth	24	33.3
Endodontically Treated Teeth	20	27.8
Total	72	100.0

■ Previously Traumatized Teeth ■ Deeply Restored Teeth ■ Endodontically Treated Teeth

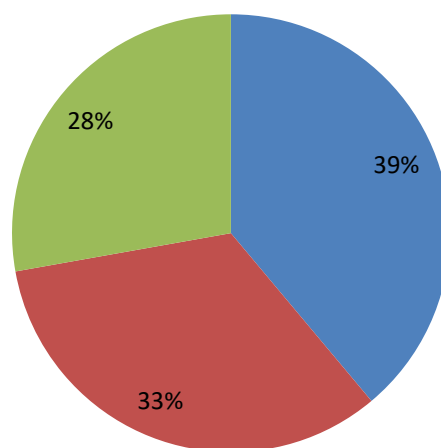


Figure 2: Distribution of Teeth According to Pulpal Status

Table 3 & Figure 3 compare the rate of orthodontic tooth movement between teeth with compromised pulpal status and their corresponding control teeth. The mean orthodontic tooth movement over a 6-month period was 1.12 ± 0.21 mm in the compromised pulp group and 1.18 ± 0.24 mm in the control group. Although the control teeth exhibited a

slightly greater mean tooth movement, the difference between the two groups was not statistically significant ($t = 0.89$, $p = 0.370$). These findings indicate that compromised pulpal status did not adversely affect the rate of orthodontic tooth movement when light and controlled orthodontic forces were applied.

Table 3: Comparison of Orthodontic Tooth Movement Between Study Groups

Group	n	Mean Tooth Movement (mm/6 months)	SD	t-value	p-value
Compromised Pulp Teeth	72	1.12	0.21	0.89	0.370

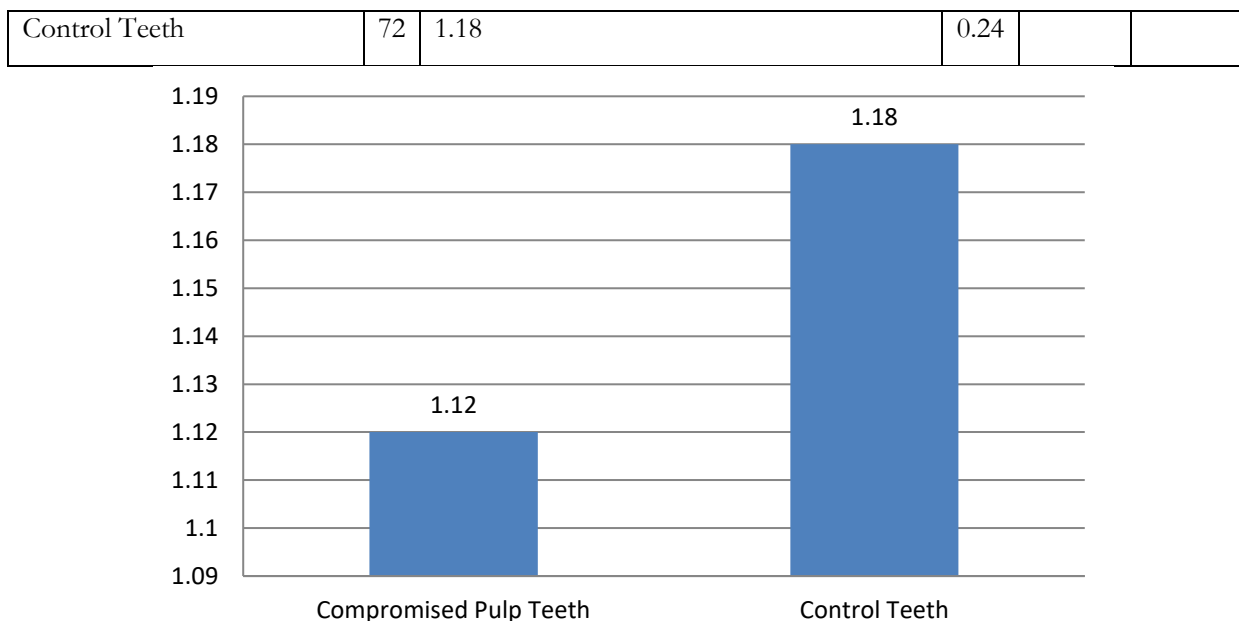


Figure 3: Comparison of Orthodontic Tooth Movement Between Compromised Pulp and Control Teeth (6-Month Evaluation)

Table 4 & Figure 4 present the changes in pulp vitality observed during the follow-up period among compromised pulp teeth and control teeth. At baseline, no teeth in either group exhibited altered vitality, and the comparison showed no difference between groups ($\chi^2 = 0.000$, $p = 1.000$). At the 3-month follow-up, altered vitality was detected in 2 teeth (2.8%) in the compromised pulp group and 1 tooth (1.4%) in the control group; however, the difference was not statistically significant ($\chi^2 = 0.34$, $p = 0.559$). At 6 months, the frequency of altered vitality increased to 4 teeth (5.6%) among compromised pulp teeth and 2 teeth (2.8%) among control teeth, with no significant

intergroup difference ($\chi^2 = 0.70$, $p = 0.403$). By the end of the 12-month follow-up period, altered vitality was observed in 5 teeth (6.9%) in the compromised pulp group and 3 teeth (4.2%) in the control group. The difference remained statistically non-significant ($\chi^2 = 0.50$, $p = 0.480$). Overall, although a gradual increase in altered pulp vitality was noted over time in both groups, no statistically significant differences were observed between compromised pulp teeth and control teeth at any follow-up interval, indicating that the application of controlled orthodontic forces did not adversely affect pulp vitality.

Table 4: Changes in Pulp Vitality During Follow-Up

Follow-up Period	Compromised Pulp Teeth Showing Altered Vitality n (%)	Control Teeth Showing Altered Vitality n (%)	Chi Square value	P value
Baseline	0 (0.0)	0 (0.0)	0.000	1.000
3 Months	2 (2.8)	1 (1.4)	0.34	0.559
6 Months	4 (5.6)	2 (2.8)	0.70	0.403
12 Months	5 (6.9)	3 (4.2)	0.50	0.480

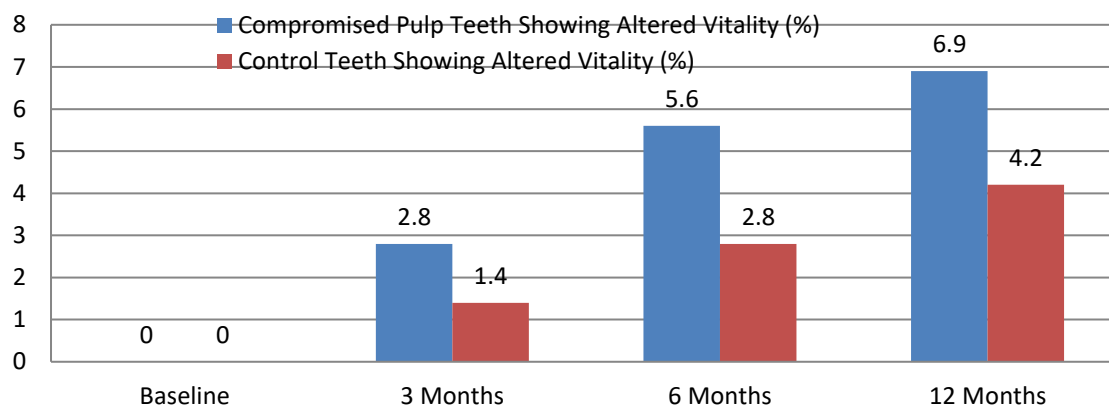


Figure 4: Changes in Pulp Vitality in Compromised Pulp and Control Teeth During the Follow-up Period

Table 5 & Figure 5 compare the final pulp vitality status of compromised teeth and control teeth after 12 months of orthodontic treatment. The majority of teeth in both groups maintained normal pulp vitality throughout the study period. In the compromised pulp group, 67 teeth (93.1%) retained vitality, while 5 teeth (6.9%) exhibited altered vitality. Similarly, among the control teeth, 69 teeth (95.8%) maintained vitality and only 3 teeth (4.2%) showed altered vitality. Statistical analysis

revealed no significant difference between the two groups with respect to pulp vitality status at the end of the study ($\chi^2 = 0.50$, $p = 0.480$). These findings suggest that teeth with compromised pulpal status responded comparably to healthy control teeth during orthodontic treatment and that the application of light, controlled orthodontic forces did not significantly increase the risk of adverse pulpal changes.

Table 5: Comparison of Final Pulp Vitality Status at 12 Months

Vitality Status	Compromised Teeth (n=72)	Control Teeth (n=72)	χ^2 value	p-value
Maintained vitality	67 (93.1%)	69 (95.8%)	0.50	0.480
Altered vitality	5 (6.9%)	3 (4.2%)		

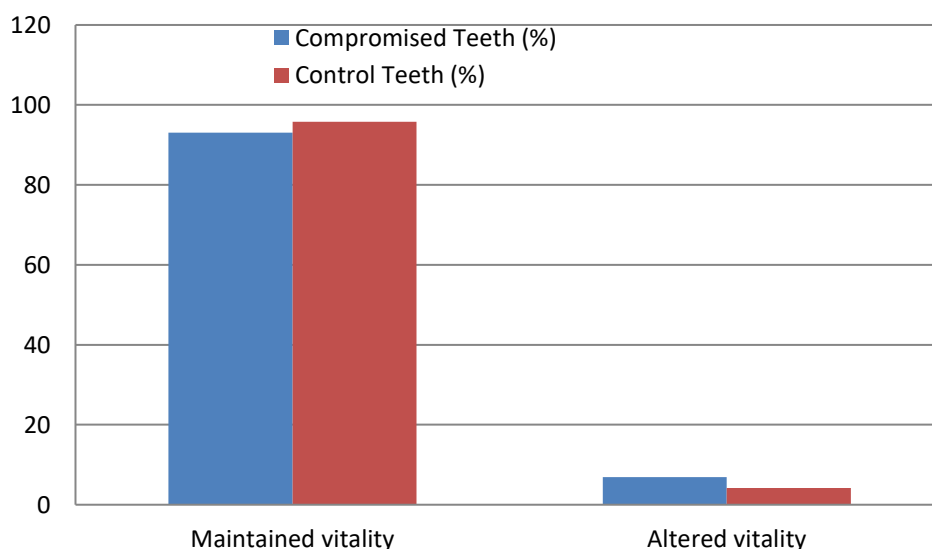


Figure 5: Comparison of Final Pulp Vitality Status Between Compromised and Control Teeth at 12 Months

Table 6 & Figure 6 present the radiographic evaluation of periapical status following orthodontic treatment in both study groups. A normal periapical appearance was observed in the majority of teeth, with 68 compromised teeth (94.4%) and 69 control teeth (95.8%) demonstrating no radiographic abnormalities. Mild widening of the periodontal ligament space was noted in 3 compromised teeth (4.2%) and 2 control teeth (2.8%), while mild periapical radiolucency was detected in 1 tooth (1.4%) in each group. Importantly, no cases of significant

periapical pathology were identified in either group during the study period. Statistical analysis revealed no significant difference in radiographic findings between compromised and control teeth ($\chi^2 = 0.245$, $p = 0.620$). These results indicate that orthodontic treatment using light and controlled forces did not adversely affect the periapical health of teeth with compromised pulpal status and produced radiographic outcomes comparable to those observed in teeth with normal pulp vitality.

Table 6: Radiographic Evaluation of Periapical Status After Orthodontic Treatment

Radiographic Finding	Compromised Teeth (n=72)	Control Teeth (n=72)
Normal periapical appearance	68 (94.4%)	69 (95.8%)
Mild widening of PDL space	3 (4.2%)	2 (2.8%)
Mild periapical radiolucency	1 (1.4%)	1 (1.4%)
Significant pathology	0 (0.0%)	0 (0.0%)

χ^2 value-0.245, p value -0.620

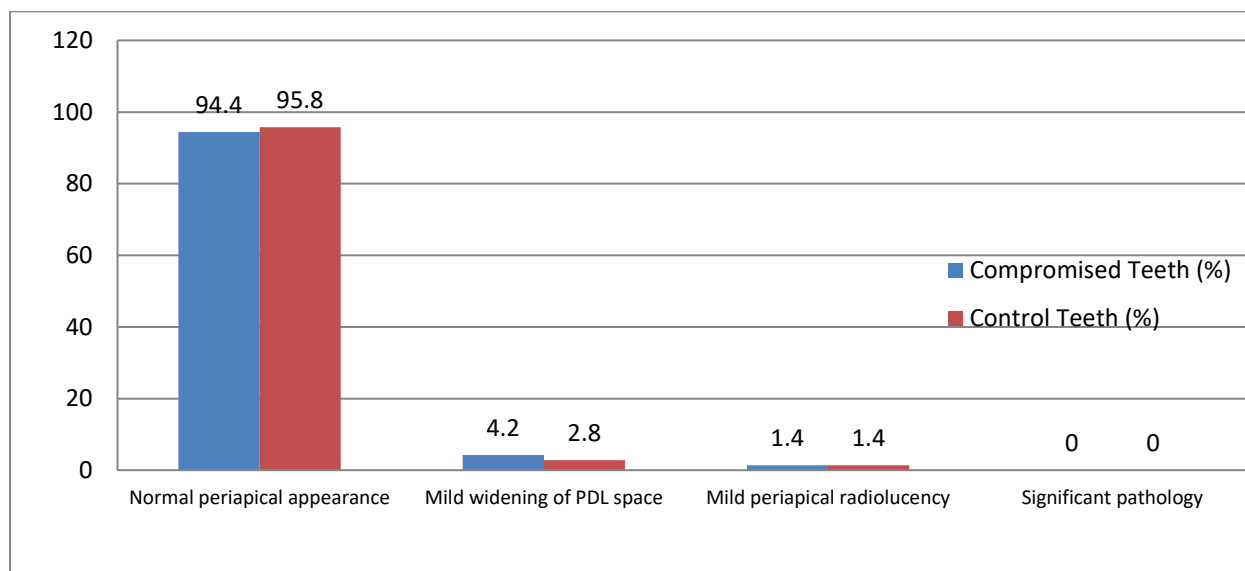


Figure 6: Radiographic Periapical Status of Compromised and Control Teeth After Orthodontic Treatment

Table 7 & Figure 7 present the vitality outcomes of teeth with different types of pulpal compromise following orthodontic treatment. Among the previously traumatized teeth ($n =$

28), 25 teeth (89.3%) maintained vitality, while 3 teeth (10.7%) exhibited altered vitality, representing the highest proportion of vitality changes among the three categories. In the

group of deeply restored teeth ($n = 24$), 23 teeth (95.8%) maintained vitality and only 1 tooth (4.2%) showed altered vitality. Similarly, among the endodontically treated teeth ($n = 20$), 19 teeth (95.0%) demonstrated maintained vitality; whereas 1 tooth (5.0%) exhibited altered vitality. Overall, 67 teeth (93.1%) maintained vitality throughout the study period, while only 5 teeth

(6.9%) showed altered vitality. These findings suggest that the majority of teeth with compromised pulpal status remained clinically stable during orthodontic treatment, with previously traumatized teeth showing a slightly greater tendency toward vitality alterations compared to restored and endodontically treated teeth.

Table 7: Incidence of External Apical Root Resorption

Type of Tooth	Maintained Vitality n (%)	Altered Vitality n (%)
Traumatized teeth (n=28)	25 (89.3)	3 (10.7)
Deep restorations (n=24)	23 (95.8)	1 (4.2)
Endodontically treated teeth (n=20)	19 (95.0)	1 (5.0)
Total	67 (93.1)	5 (6.9)

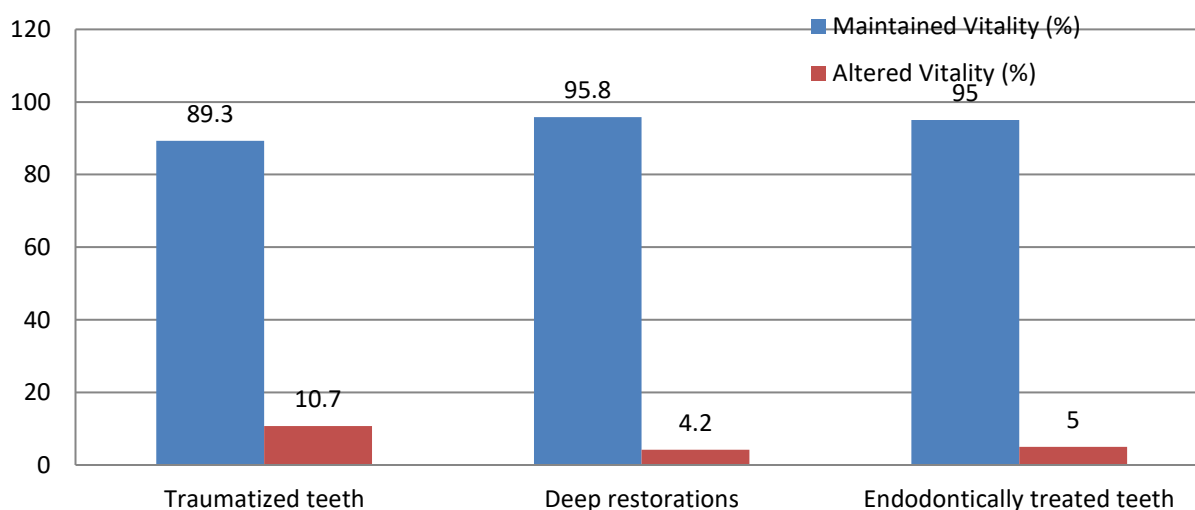


Figure 7: Pulp Vitality Outcomes According to Type of Pulpal Compromise After Orthodontic Treatment

Discussion

The results of the present investigation suggest that orthodontic tooth movement can be carried out safely in teeth with compromised pulpal status when light and carefully regulated forces are applied. These findings reinforce the principle described by McDonald and Pitt Ford (1994) [7], who proposed that pulpal reactions during orthodontic treatment are primarily influenced by the intensity and duration of force application rather than by pulpal condition alone. Comparable observations were reported by Javed et al. (2015) [8], who demonstrated that

orthodontically induced pulpal changes are largely reversible when forces remain within physiological limits.

The temporary pulpal alterations noted in some teeth may be explained by transient disturbances in pulpal microcirculation caused by mechanical compression of the neurovascular structures. Using laser Doppler flowmetry, McDonald and Pitt Ford (1994) [7] documented an initial decrease in pulpal blood flow immediately after orthodontic force application, followed by gradual normalization as adaptive mechanisms ensued. Similar findings were reported by Lam

et al. (2020) [9], who observed temporary reductions in pulpal sensibility during orthodontic expansion without subsequent progression to pulpal necrosis or periapical disease.

Evidence from studies involving teeth with altered pulpal conditions further supports these observations. Hamilton and Gutmann (1999) [10] reported that endodontically treated teeth exhibit orthodontic movement patterns comparable to those of vital teeth, provided that periodontal health is maintained and biomechanical principles are appropriately applied. In addition, Kindelan et al. (2008) [11] found no increased incidence of periapical pathology or external root resorption in root canal-treated teeth subjected to orthodontic forces.

Teeth with a history of dental trauma may demonstrate more variable pulpal responses. Andreasen and Andreasen (2007) [12] noted that traumatized teeth are at greater risk of pulpal alterations during orthodontic movement due to pre-existing compromise of the pulpal microvasculature. Nevertheless, Sandler (2021) [13] reported that orthodontic treatment of traumatized teeth can be undertaken successfully when adequate healing time is allowed prior to force application and when light forces are used. These observations are in agreement with the findings of the present study, in which traumatized teeth did not exhibit irreversible pulpal damage under controlled orthodontic loading.

Recent systematic reviews by Duarte et al. (2023) [14] and Golež et al. (2023) [15] further

substantiate that orthodontic forces may induce transient pulpal inflammation and sensibility alterations but rarely result in permanent pulpal injury, particularly when excessive or prolonged forces are avoided. Additionally, Brezniak and Wasserstein (2002) [16] emphasized that unfavorable biological responses are more commonly associated with heavy or continuous force application rather than with compromised pulpal status itself.

Taken together, the available evidence supports the findings of the present study and highlights the critical role of careful treatment planning when managing teeth with compromised pulpal health. Comprehensive pre-treatment evaluation, including pulp vitality testing and radiographic assessment, along with the use of light, controlled orthodontic forces, is essential. Ongoing clinical and radiographic monitoring throughout treatment is recommended to identify early pulpal or periapical changes and to ensure optimal long-term outcomes.

Limitations

Limitations of this study include the relatively short follow-up period and limited sample size. Long-term studies with larger samples are recommended to further validate these findings.

Conclusion

Orthodontic forces, when applied judiciously, do not adversely affect teeth with compromised pulpal status. Careful diagnosis, light force application, and regular monitoring are essential to ensure favorable outcomes in such cases.

References

- Boruah S, Gill I, Dandiwal N, Sharma MK, Agarwal I, Devi A, Gupta S. Effect of Orthodontic Tooth Movement on Pulp Vitality in Previously Traumatized Teeth: A Prospective Cohort Study. *Cureus*. 2026 Mar 26; 18(3):e105938. doi: 10.7759/cureus.105938. PMID: 42046592; PMCID: PMC13110307.
- Golež A, Ovsenik M, Cankar K. The effect of orthodontic tooth movement on the sensitivity of dental pulp: A systematic review and meta-analysis. *Heliyon*. 2023 Mar 24; 9(4):e14621. doi: 10.1016/j.heliyon.2023.e14621. PMID: 37025792; PMCID: PMC10070381.
- Javed F, Al-Kheraif AA, Romanos EB, Romanos GE. Influence of orthodontic forces on human dental pulp: a systematic review. *Arch Oral Biol*. 2015 Feb; 60(2):347-56. doi: 10.1016/j.archoralbio.2014.11.011. Epub 2014 Nov 24. PMID: 25463910.

- Duarte PHM, Weissheimer T, Michel CHT, Só GB, da Rosa RA, Só MVR. Do orthodontic movements of traumatized teeth induce dental pulp necrosis? A systematic review. *Clin Oral Investig*. 2023 Aug; 27(8):4117-4129. doi: 10.1007/s00784-023-05102-2. Epub 2023 Jun 19. PMID: 37335397.
- Lam R, Goonewardene MS, Naoum S. Pulp blood flow and sensibility in patients with a history of dental trauma undergoing maxillary expansion. *Angle Orthod*. 2020 Sep 1; 90(5):695-701. doi: 10.2319/022520-129.1. PMID: 33378486; PMCID: PMC8032256.
- Vermiglio G, Centofanti A, Matarese G, Militi A, Matarese M, Arco A, Nicita F, Cutroneo G. Human Dental Pulp Tissue during Orthodontic Tooth Movement: An Immunofluorescence Study. *J Funct Morphol Kinesiol*. 2020 Aug 22; 5(3):65. doi: 10.3390/jfmk5030065. PMID: 33467280; PMCID: PMC7739291.
- McDonald F, Pitt Ford TR. Blood flow changes in permanent maxillary canines during retraction. *Eur J Orthod*. 1994 Feb; 16(1):1-9. doi: 10.1093/ejo/16.1.1. PMID: 8181544.
- Javed F, Al-Kheraif AA, Romanos EB, Romanos GE. Influence of orthodontic forces on human dental pulp: a systematic review. *Arch Oral Biol*. 2015 Feb; 60(2):347-56. doi: 10.1016/j.archoralbio.2014.11.011. Epub 2014 Nov 24. PMID: 25463910.
- Lam R, Goonewardene MS, Naoum S. Pulp blood flow and sensibility in patients with a history of dental trauma undergoing maxillary expansion. *Angle Orthod*. 2020 Sep 1; 90(5):695-701. doi: 10.2319/022520-129.1. PMID: 33378486; PMCID: PMC8032256.
- Hamilton RS, Gutmann JL. Endodontic-orthodontic relationships: a review of integrated treatment planning challenges. *Int Endod J*. 1999 Sep; 32(5):343-60. doi: 10.1046/j.1365-2591.1999.00252.x. PMID: 10551108.
- Kindelan SA, Day PF, Kindelan JD, Spencer JR, Duggal MS. Dental trauma: an overview of its influence on the management of orthodontic treatment. Part 1. *J Orthod*. 2008 Jun; 35(2):68-78. doi: 10.1179/146531207225022482. PMID: 18525070.
- Andreasen JO, Andreasen FM. Textbook and color atlas of traumatic injuries to the teeth. 4th ed. Oxford: Blackwell Munksgaard; 2007.
- Sandler C, Al-Musfir T, Barry S, Duggal MS, Kindelan S, Kindelan J, Littlewood S, Nazzal H. Guidelines for the orthodontic management of the traumatised tooth. *J Orthod*. 2021 Mar; 48(1):74-81. doi: 10.1177/1465312520977498. Epub 2020 Dec 16. PMID: 33325314; PMCID: PMC8042518.
- Duarte PHM, Weissheimer T, Michel CHT, Só GB, da Rosa RA, Só MVR. Do orthodontic movements of traumatized teeth induce dental pulp necrosis? A systematic review. *Clin Oral Investig*. 2023 Aug; 27(8):4117-4129. doi: 10.1007/s00784-023-05102-2. Epub 2023 Jun 19. PMID: 37335397.
- Golež A, Ovsenik M, Cankar K. The effect of orthodontic tooth movement on the sensitivity of dental pulp: A systematic review and meta-analysis. *Heliyon*. 2023 Mar 24; 9(4):e14621. doi: 10.1016/j.heliyon.2023.e14621. PMID: 37025792; PMCID: PMC10070381.
- Brezniak N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part I: The basic science aspects. *Angle Orthod*. 2002 Apr; 72(2):175-9. doi: 10.1043/0003-3219(2002)072<0175:OIIRRP>2.0.CO;2. PMID: 11999941.