Original Article

Success rate, treatment duration, and pain perception in the management of palatally impacted canines using the K9 and Ballista spring: a randomized clinical trial

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ABSTRACT

Objectives: To evaluate the success rate, treatment duration, and pain perceived during forced eruption of maxillary palatally impacted canines using the K9 and Ballista springs.

Materials and Methods: Thirty unilateral palatal canine impactions of moderate and difficult category as determined by KPG index (score between 10 and 19) were enrolled. Group 1 comprised canine impactions managed with K9 springs, and Group 2 comprised Ballista springs. Block randomization and opaque sealed envelopes were used for allocation. The success rate and treatment duration (application of force to ligation of the impacted canine into the initial alignment archwire) were recorded. Pain perception was evaluated on a 10-point visual analogue scale (VAS) and modified McGill Pain Questionnaire. Chi-square test and Mann-Whitney *U*-test were used to compare the groups.

Results: The success rate for eruption of palatally impacted canines was 100%. The average treatment duration was 296.13 $\pm$ 96.45 days and 311.93 $\pm$ 94.34 days, respectively for Group 1 and Group 2. VAS scale scores for pain were greater for Group 2 compared to Group1, and the differences were statistically significant at all time intervals except at T1. The frequency of none and mild pain was significantly greater at all time intervals in both groups.

Conclusions: The impacted canines of moderate and difficult category were erupted with a 100% success rate and similar treatment duration with both interventions. The pain scores of Ballista springs were greater after 24 hours of force application. (*Angle Orthod.* 2022;93:33–40.)

KEY WORDS: K9 spring; Ballista spring; Palatally impacted canines

INTRODUCTION

An unerupted tooth that exhibits complete root development while its analogous contralateral tooth has been erupted for at least 6 months is defined as an impacted tooth.[1] Disturbances in the eruption of permanent maxillary canines are relatively common because they have a long period of development and follow a long and tortuous path from development lateral to the piriform fossa to erupt into the oral cavity.[2] Maxillary canines are the second most frequently impacted teeth after third molars, with a prevalence of 0.9 to 2.2%.[3,4] The prevalence of maxillary canine impaction is double in females compared to males. The ratio of the prevalence of palatal to buccal impacted canines is 3:1.[5,6] Peck et al.[7] suggested that palatally impacted canines were a dental anomaly of genetic theory, whereas Becker[8] explained guidance theory and discussed the presence of other dental anomalies and environmental factors as etiologic factors for palatal impaction. Palatally impacted canines are often associated with abnormally sized roots and crowns, absence of lateral incisors, and as having sufficient space for eruption.[9]

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The early identification of impacted canines should be based on clinical examination followed by localization using routine radiography.[10] The presence of a palatal bulge at the age of 11 years on palpation may indicate palatal canine impaction.[11] The accurate location of the impacted canine can be determined routinely using periapical radiographs, panoramic-radiographs, lateral cephalograms, and occlusal views.[12,13] The cone shift technique is helpful to estimate the buccolingual position of the tooth.[10,13] Cone beam computed tomography (CBCT) is used for better localization in complicated impactions. With early diagnosis and timely interception, impacted canines may erupt in the correct position within the dental arch. Early removal of deciduous canines, if the canine bulge is not palpable, is indicated to encourage normal eruption of unfavorably located canines.[14] The management of impacted canines that do not respond to interceptive orthodontics involves surgical exposure of the palatal canine generally with gingivectomy because there is abundant attached gingiva in the palatal mucosa, and extrusion into the oral cavity. Two commonly used springs for the eruption of palatal canines are the K9[15] and Ballista spring.[16]

There is a lack of good evidence comparing the treatment effects and success rate of the K9 spring and the Ballista spring. Therefore, the present trial compared the success rate, time required for eruption, and pain perceived during the forced eruption of maxillary palatally impacted canines using the K9 and Ballista spring.

MATERIALS AND METHODS

The present randomized clinical trial was conducted following the guidelines of the Declaration of Helsinki with prior approval from the Institutional Ethics committee (NK/4544/study) at Unit of Orthodontics, Oral Health Sciences Centre, Post Graduate Institute of Medical Education and Research, Chandigarh, India. This trial was registered with Clinical Trials Registry–India (http://www.ctri.nic.in) vide trial CTRI/2018/10/16062. Sample size was calculated based on a pilot study. Five palatally impacted canines were managed with the K9 spring and the Ballista spring. Mean $\pm$ standard deviation of pain scores after 24 hours were used for sample size calculations. A total sample size of 26 was obtained with a confidence interval of 95% and power of 80%.

A total of 30 unilateral palatally impacted canines among 30 subjects (age range: 14–25 years) with moderate and difficult categorization as determined by a KPG index[17] score between 10 and 19, were included. The exclusion criteria were age $>$25 years, buccal and bilateral impactions, cleft lip/palate and syndromic patients, multiple missing teeth, or a history of systemic disease.

Assessment Plane	Score	Assessment
X-axis	0-5	Mesiodistal Location of canine cusp tip/ root tip from actual position to Midline
Y-axis	0-5	Vertical Location of canine crown tip/root tip in relation to crown and root of adjacent tooth
Z-axis	0-5	Buccolingual location of canine crown tip/root tip in relation occlusal arch

The summation of x, y and z axis score is total KPG score(0-30)

Grade of Severity	Score
Easy	0-9
Moderate	10-14
Difficult	15-19
Extremely Difficult	>20

Figure 1. KPG Index.

The patients were divided into two groups based on the type of intervention: Group 1 comprised patients managed with the K9 spring, and Group 2 was managed with the Ballista spring.

Fabrication of K9 and Ballista Springs

The K9 spring was made of 0.017 $\times$ 0.025-inch titanium molybdenum alloy (TMA) wire with advantages of a wide range of action and low continuous forces. The Ballista spring was fabricated using 0.016-inch round stainless steel (SS) wire, which accumulates its energy by being twisted on its long axis. The distal end of the Ballista spring is usually ligated in the headgear tube or buccal tube of the first or second maxillary molar.

Methodology

The KPG index[17] was used to assess the location and severity of each impacted canine using CBCT scans (Figure 1). All the impacted canines were exposed with an open technique, making a window with cautery, removing the palatal tissue with attached gingiva covering the tooth. An orthodontic attachment (lingual bonded button) was bonded on the labial surface as close to the canine cusp tip as possible (Figure 2). An orthodontic force of 60 grams (2 oz) as measured with a Dontrix force gauge (Dentauram, Ispringen, Germany) was applied through a bonded attachment using the K9 and Ballista springs for eruption. A transpalatal arch (TPA) of 0.036-inch stainless steel wire was placed between contralateral

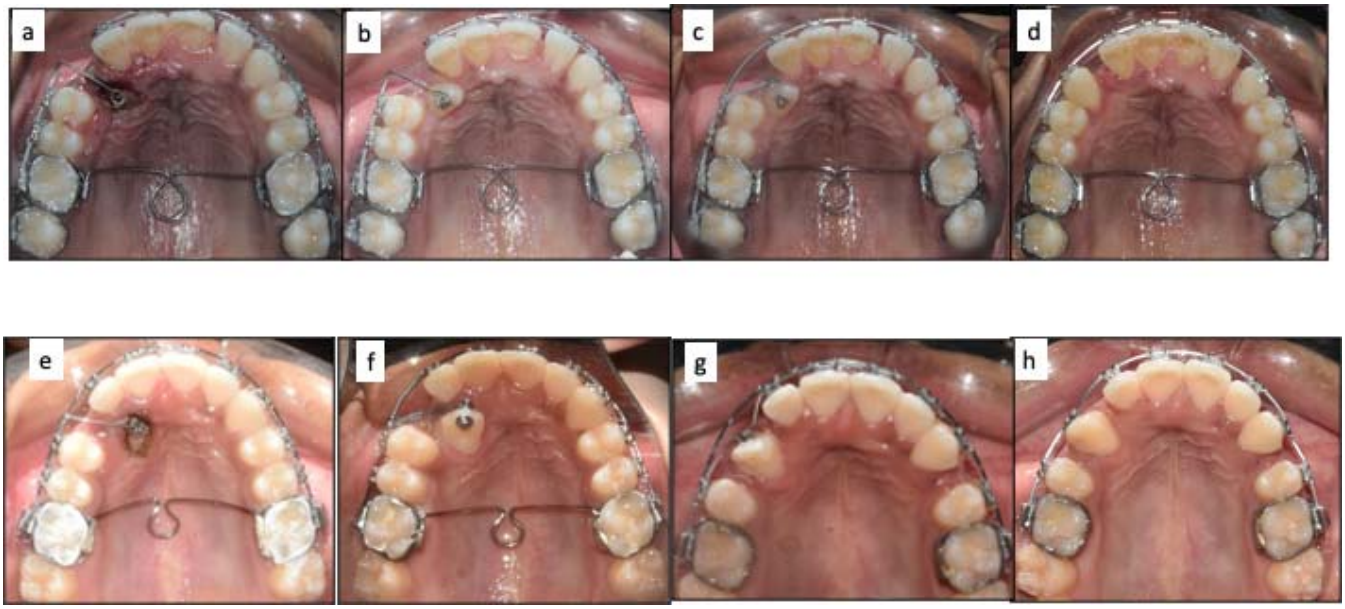
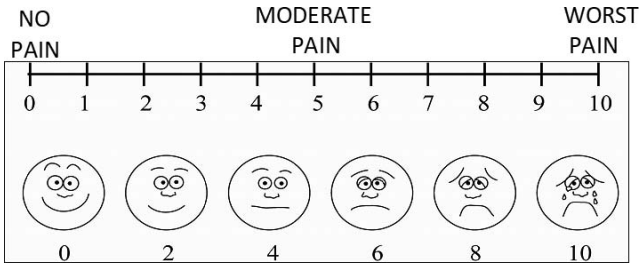


Figure 2. (a) K9 spring ligation; (b) eruption; (c) buccal traction; (d) alignment; (e) Ballista spring ligation; (f) eruption and buccal traction; (g) "piggyback" overlay ligation; (h) alignment.

first permanent molars to provide the anchorage required against forces created by torsion in the spring.

The patients were followed for 12 months and were evaluated for "success or failure," treatment duration, and pain experienced. "Failure" of canine eruption was considered when the impacted canine did not show any sign of eruption in the oral cavity for 9 months of follow-up. Treatment duration was defined as "time-span between orthodontic force application and ligation of the erupted canine into the initial alignment arch-wire."

A 10-point visual analogue scale (VAS) and modified McGill Pain Questionnaire (MMPQ)[18,19] was used to evaluate pain at six observation periods: 1 hour (T1), 24 hours (T2), 48 hours (T3), 1 week (T4), 1 month (T5), and 3 months (T6) after orthodontic force application. All patients were examined every 4 weeks to evaluate eruption of the canine for 12 months of follow-up (Figure 3).



(A)

TYPE	NONE (0)	MILD (1)	MODERATE (2)	SEVERE (3)
THROBING				
SHOOTING				
STABBING				
SHARP				
CRAMPING				
GNAWING				
HOT-BURNING				
ACHING				
HEAVY				
TENDER				
SPLITTING				
TIRING-EXHAUSTING				
SICKENING				
FEARFUL				
PUNISHING-CRUEL				

(B)

Figure 3. (a) VAS; (b) MMPQ questionnaire for Pain Perception.

Randomization

The impacted maxillary canines were allocated to the two groups using block randomization with a block size of six each. Computer software-generated randomization codes were used. Opaque sealed envelopes with sequential numbers were used for allocation concealment. Operator and subject blinding were not possible because of the nature of the intervention. The data were coded and presented to the blinded evaluator for analysis.

Statistical Analysis

Statistical Package for Social Sciences (Windows, version 25.0. Armonk, NY: IBM Corp.) software was used for analyses. Continuous data were presented as

Table 1. Demographic Details of the Sample Based on Gender and Age[a]

	Males	Females	*P* Value	Age (y) (Mean ± SD)	*P* Value
Group 1 (n = 15)	06	09	.719 (NS)	16.8 ± 2.6	.99 (NS)
Group 2 (n = 15)	05	10		17.1 ± 2.4	
Total (n = 30)	11	19		18 ± 4.11	

[a] NS indicates nonsignificant; SD, standard deviation.
* $P \leq .05$ is statistically significant; ** $P \leq .01$ is statistically highly significant; *** $P \leq .001$ is statistically very highly significant.

mean ± SD, and categorical data as frequency (percentage). Shapiro-Wilk / Kolmogorov-Smirnov test was used to assess normal distribution. Chi-square test and Mann-Whitney *U*-test were used to check for differences between the groups. The level of significance was set at $P < .05$.

RESULTS

Table 1 and Figure 4 show the demographic details and CONSORT diagram of the participants included in the trial. The total sample (n = 30) consisted of 19 females and 11 males with a mean age of 16.97 ± 2.47 years. The baseline comparison of age and gender between the groups showed no significant differences. No dropouts were observed from the 30 palatally impacted maxillary canines included in this study. All impacted canines erupted successfully into the oral cavity within 9 months. The average treatment duration for eruption and ligation of the impacted canine into the initial alignment archwire was 304.03 ± 94.08 days. Though the treatment time was shorter for Group 1 (296.13 ± 96.45 days) compared to Group 2 (311.93 ± 94.34 days), the differences between the groups were not statistically significant (Table 2).

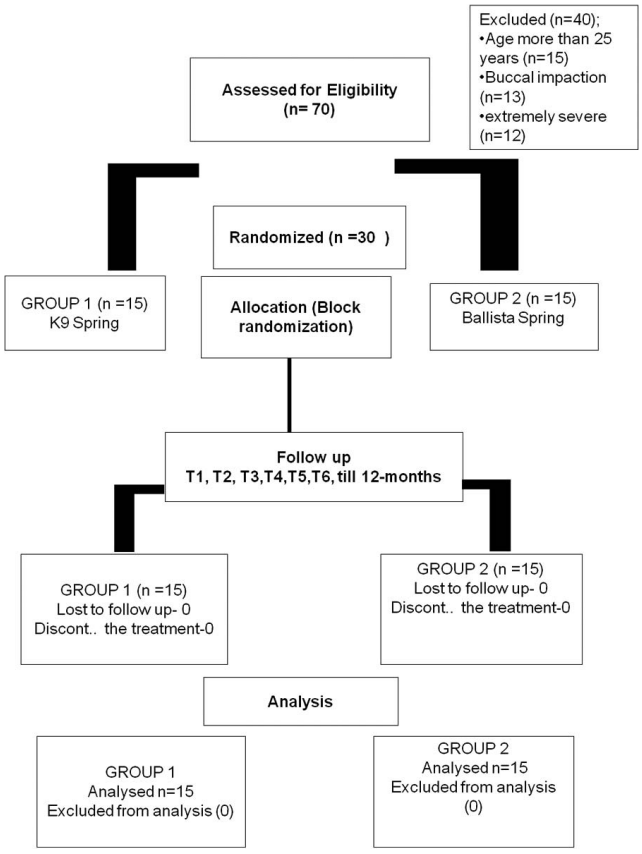


Figure 4. CONSORT diagram.

VAS scores for pain were greater for Group 2 compared to Group 1, and the differences were statistically significant at all time intervals except at T1 (1 hour). No pain was reported by patients at T6 (3 months) (Table 3).

Figure 5 shows the categorical distribution of pain response according to MMPQ as none, mild, moderate, and severe at timepoints T1 to T5. The frequency of none and mild pain was significantly greater at all time intervals and increased from T1 to T5 in both groups. The frequency of responses reported for mild, moderate, and severe categories of pain was significantly greater in Group 2 than Group 1 at T2, T3, T4, and T5. The frequency of pain score 3 in Q 1 and Q 11 was 17.3 and 12%, respectively, in Group 2, compared to 5.3% for both Q1 and Q11 in Group 1 subjects (Figure 6).

Table 4 showed that scores of questions: Q4, Q5, Q10, Q11, Q13, and Q15 in Groups 1 and 2 were not significantly different at any timepoint. The mean differences of scores showed statistically significant differences for questions Q1, Q3, and Q8 at T4 and T5; Q2 and Q9 at T4 and T2, respectively; Q6 at T2, T3; Q7 at T2, T4; Q12 at T1, T2, and T5, and Q14 at T2 and T5.

DISCUSSION

This clinical trial involved palatally impacted canines with similar severity of "moderate" and "difficult" categories according to KPG index[17] scores between 10 and 19. They were exposed surgically using the window technique with cautery in all cases. In a systematic review, Parkin et al. reported no differences in clinical outcome observed using either closed or open technique for exposure of palatally impacted canines.[20] Naoumova et al. showed that the number of appointments and active duration of traction was significantly shorter with an open technique.[21]

Table 2. Comparison of Treatment Duration and Success Rate for Management of Palatally Impacted Maxillary Canine With Two Different Intervention Mechanics[a]

	Group 1 (n = 15)	Group 2 (n = 15)	Total (n = 30)	Group 1 vs Group 2 (*P* Value)
Mean ± SD Treatment Duration (d)	296.13 ± 96.45	311.93 ± 94.34	304.03 ± 94.08	.27 (NS)
Success	15	15	30	1.000 (NS)
Failure	0	0	0	1.000 (NS)

[a] NS indicates nonsignificant; SD, standard deviation.
* $P \leq .05$ is statistically significant; ** $P \leq .01$ is statistically highly significant; *** $P \leq .001$ is statistically very highly significant.

In the present clinical trial, the success rate of orthodontic forced eruption of palatally impacted canines was 100%. No failures were observed because very severe cases with a KPG index score of 20 and above (poor prognosis) were excluded from the study. According to Becker and Chaushu, the success rate of eruption of palatally impacted canines among 19 adults in the age range of 20–47 years was 69.5%, compared to 100% among younger adults (12–16 years), after comprehensive orthodontic treatment.[22] Caminiti et al. also reported a 100% success rate after surgical palatal exposure and bonding traction hook and ligation chain.[23]

Early extraction of the primary canine as an interceptive measure to manage palatal displacement of maxillary canines showed a success rate of 69%, significantly greater than that in untreated controls (39%).[24] However, orthodontic traction is required after surgical exposure when diagnosed later. Several studies[24–27] have shown that interceptive removal of primary canines, headgear therapy, and rapid palatal expansion facilitated the spontaneous eruption of palatally displaced canines in children in the age range of 9-14 years. However, after 14 years of age, no interceptive therapy has been recommended.[24] The average age of the patients included in the present study was 18 years, which was well beyond the age for interceptive therapy. Thus, all canines were exposed surgically, and orthodontic traction was applied.

The average treatment duration for eruption and ligation of the impacted canine into the initial alignment archwire was 304.03 ± 94.08 days, compared to the total treatment duration of 25.8 months for the unilaterally impacted group and 32.3 months for the bilaterally palatally impacted canine group in a study by Stewart et al.[28] The difference may have been because that study assessed the total duration of orthodontic treatment. The treatment time required for the palatally impacted canine to be in the line of the arch was reported in another study to be 17.7 months in the single exposure group and 19.3 months in the bonded attachment group.[29]

A study by Smailiene et al.[30] reported that the mean treatment time required to achieve eruption/extrusion of the impacted canine was 3.05 ± 1.07 months for an open technique and 6.86 ± 4.53 months ($P < .01$) for a closed technique. In the present study, all canines erupted into the oral cavity in less than 3 months before a buccal traction force was applied to align them.

There was a gradual decrease in pain in both groups as the treatment progressed. The frequency of none and mild pain was significantly more prevalent at all timepoints and increased from T1 to T5. The adaptation to pain and discomfort during orthodontic treatment has been reported to occur after 5 to 7 days and was higher with fixed appliances. Thus, patient pain and discomfort, which depends on patient attitude and affects treatment acceptance, tends to decrease with time.[30–33]

The frequency of responses reported for the mild, moderate, and severe categories of pain was found to be greater in Group 2 than Group 1 at the T2, T3, T4, and T5 timepoints. The probable reason may have been the difference in the alloy (TMA vs austenitic SS) used to fabricate the K9 and Ballista springs. The K9 was fabricated from TMA wire, and torque in the rectangular wire provided the necessary eruptive forces. This wire has the properties of delivering continuous and gentle forces, which decreases the requirement for reactivations. Reactivations are generally associated with some pain 4 hours after archwire placement, which will peak at 24 hours and then decline.[28,30]

The MMPQ was used to investigate the type of pain experienced and its severity. The most common type

Table 3. Mean Visual Analogue Score for Pain at Different Timepoints[a]

	(Mean ± SD)		
Time Interval	Group 1 (n = 15)	Group 2 (n = 15)	*P* Value
T1	5.13 ± 2.03	5.93 ± 2.09	.22 (NS)
T2	3.60 ± 1.80	6.13 ± 2.64	.01**
T3	2.33 ± 1.91	4.33 ± 1.98	.007**
T4	1.20 ± 1.61	2.67 ± 1.59	.02*
T5	0.40 ± 1.05	1.87 ± 1.35	.001***
T6	0	0	-

[a] NS indicates nonsignificant; SD, standard deviation.
* $P \leq .05$ is statistically significant; ** $P \leq .01$ is statistically highly significant; *** $P \leq .001$ is statistically very highly significant.

Table 4. Mean Score of Each Question of Modified McGill Pain Questionnaire-Short Form (MMPQ-SF) at Different Timepoints[a]

	T1			T2			T3		
	Group 1 (n = 15) (Mean ± SD)	Group 2 (n = 15) (Mean ± SD)	*P* Value	Group 1 (n = 15) (Mean ± SD)	Group 2 (n = 15) (Mean ± SD)	*P* Value	Group 1 (n = 15) (Mean ± SD)	Group 2 (n = 15) (Mean ± SD)	*P* Value
Q1	1.53 ± 0.74	1.93 ± 1.16	.26	1.20 ± 0.94	1.47 ± 1.24	.58	0.60 ± 0.74	1.13 ± 0.91	.10
Q2	1.13 ± 0.74	0.87 ± 0.99	.21	1.20 ± 0.86	1.07 ± 0.46	.47	0.80 ± 0.77	0.93 ± 0.26	.41
Q3	1.20 ± 0.77	1.13 ± 0.52	.67	1.33 ± 0.82	0.93 ± 0.46	.08	0.73 ± 0.88	0.93 ± 0.46	.31
Q4	0.33 ± 0.72	0.47 ± 0.74	.49	0.47 ± 0.64	0.40 ± 0.51	.88	0.33 ± 0.62	0.40 ± 0.51	.54
Q5	1.20 ± 1.08	0.73 ± 0.70	.24	0.93 ± 0.79	0.53 ± 0.52	.16	0.80 ± 0.68	0.53 ± 0.52	.28
Q6	0.60 ± 0.74	0.53 ± 0.74	.76	0.13 ± 0.35	0.67 ± 0.72	.01**	0.13 ± 0.35	0.67 ± 0.72	.02*
Q7	0.20 ± 0.56	0.53 ± 0.74	.12	0.07 ± 0.26	0.47 ± 0.52	.01**	0.20 ± 0.41	0.47 ± 0.52	.13
Q8	0.20 ± 0.56	0.27 ± 0.46	.44	0.20 ± 0.56	0.27 ± 0.46	.44	0.20 ± 0.56	0.27 ± 0.46	.44
Q9	1.33 ± 0.72	1.07 ± 0.79	.35	0.73 ± 0.70	1.40 ± 0.91	.04*	0.93 ± 0.79	0.80 ± 0.68	.65
Q10	0.20 ± 0.41	0.80 ± 1.01	.10	0.27 ± 0.46	0.67 ± 0.90	.25	0.20 ± 0.41	0.47 ± 0.52	.13
Q11	1.33 ± 0.98	1.33 ± 1.39	.86	1.33 ± 0.90	0.80 ± 1.01	.08	1.00 ± 0.76	0.80 ± 1.01	.25
Q12	1.67 ± 0.82	0.80 ± 0.41	.001***	1.47 ± 0.64	0.80 ± 0.67	.01**	1.07 ± 0.70	0.80 ± 0.68	.29
Q13	1.07 ± 0.88	1.00 ± 0.84	1.00	1.13 ± 0.83	0.67 ± 0.49	.09	0.80 ± 0.77	0.67 ± 0.49	.81
Q14	1.40 ± 1.12	0.67 ± 1.05	.08	1.20 ± 1.01	0.33 ± 0.48	.01**	0.93 ± 1.03	0.33 ± 0.49	.10
Q15	0.47 ± 0.52	0.27 ± 0.70	.11	0.33 ± 0.62	0.13 ± 0.35	.09	0.33 ± 0.62	0.13 ± 0.35	.34
Total	13.87 ± 6.98	12.40 ± 7.89	.44	12.67 ± 6.03	9.93 ± 3.61	.09	9.07 ± 6.93	9.33 ± 3.35	.95

[a] NS indicates nonsignificant; SD, standard deviation.
* $P \leq .05$ is statistically significant; ** $P \leq .01$ is statistically highly significant; *** $P \leq .001$ is statistically very highly significant.

of "severe pain" experienced was "pressure" and "uncomfortable" with 17.3% and 12% reporting, respectively, among group 2 (Ballista spring) (Figure 3), whereas 5.3% of the patients experienced "pressure" and another 5.3% reported being "uncomfortable" in the K9 spring group. The mild to moderate degree of all pain types (Q1 to Q15) were perceived in both intervention groups. Hence, it is inferred that sense of "pressure" and "discomfort" were the most severe types of pain experienced after forced orthodontic

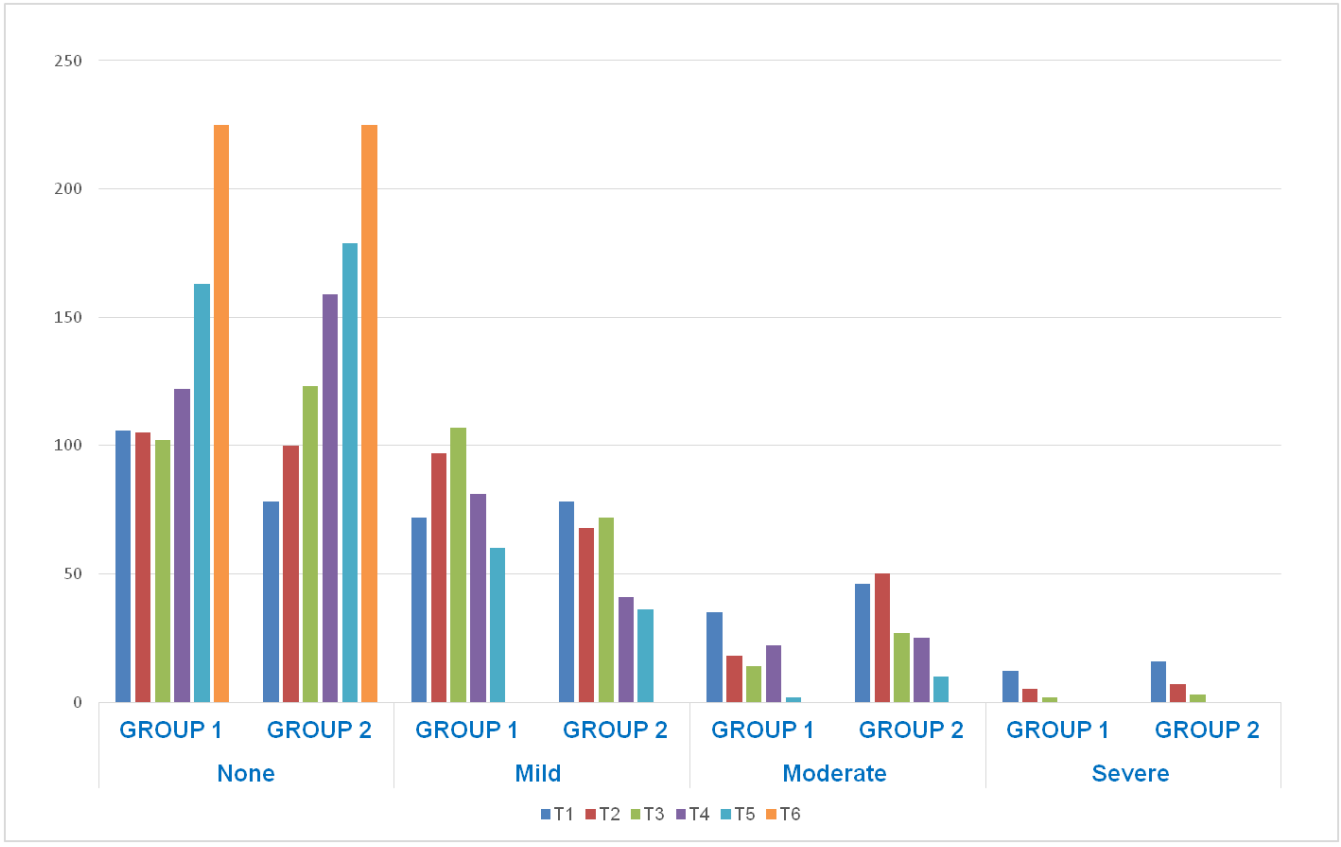


Figure 5. Categorical distribution of Modified McGill Pain Questionnaire-SF in Group 1 and Group 2 at different timepoints.

Table 4. Extended

T4			T5		
Group 1 (n = 15) (Mean ± SD)	Group 2 (n = 15) (Mean ± SD)	*P* Value	Group 1 (n = 15) (Mean ± SD)	Group 2 (n = 15) (Mean ± SD)	*P* Value
0.40 ± 0.51	1.40 ± 0.83	.001***	0.33 ± 0.49	0.80 ± 0.68	.05*
0.20 ± 041	0.60 ± 0.51	.03*	0.13 ± 0.35	0.00 ± 0.00	.15
0.33 ± 0.62	0.80 ± 0.41	.01**	0.13 ± 0.35	0.47 ± 0.52	.05*
0.20 ± 0.41	0.20 ± 0.41	1.00	0.13 ± 0.35	0.13 ± 0.35	1.00
0.60 ± 0.74	0.67 ± 0.72	.77	0.27 ± 0.46	0.27 ± 0.46	1.00
0.27 ± 0.46	0.20 ± 0.41	.67	0.13 ± 0.35	0.13 ± 0.35	1.00
0.07 ± 0.26	0.40 ± 0.51	.03*	0.07 ± 0.26	0.00 ± 0.00	.32
0.07 ± 0.26	0.53 ± 0.74	.03*	0.00 ± 0.00	0.40 ± 0.51	.007**
0.40 ± 0.74	0.80 ± 0.68	.07	0.13 ± 0.35	0.33 ± 0.49	.20
0.20 ± 0.41	0.47 ± 0.52	.13	0.13 ± 0.35	0.13 ± 0.35	1.00
1.13 ± 0.83	0.67 ± 0.72	.12	0.80 ± 0.68	0.60 ± 0.51	.43
0.67 ± 0.90	0.67 ± 0.72	.82	0.33 ± 0.72	0.67 ± 0.49	.04*
0.47 ± 0.83	0.40 ± 0.51	.76	0.40 ± 0.74	0.33 ± 0.49	.89
0.60 ± 0.91	0.20 ± 0.41	.26	0.47 ± 0.74	0.00 ± 0.00	.01**
0.47 ± 0.83	0.27 ± 0.70	.40	0.27 ± 0.70	0.00 ± 0.00	.15
6.07 ± 6.89	8.27 ± 6.15	.17	3.73 ± 5.52	4.27 ± 2.74	.13

traction of maxillary impacted canines with either the K9 or Ballista springs. These findings were also in agreement with the results of the studies of Scheurer et al.[32] and Jones et al.,[34] in which "pressure" and "discomfort" were reported as the most common associated with orthodontic treatment.

Future studies should be aimed to investigate the convenience of fabrication, ligation, and the number of activations for K9 and Ballista springs.

CONCLUSIONS

- Palatally impacted canines categorized as moderate or difficult can be erupted with a high success rate (100% in this study) with the K9 or Ballista spring.
- The average time duration for eruption and buccal traction of the canines until ligation into the initial alignment wire was 304.03 ± 94.08 days.
- The pain scores were found to be greater with the Ballista spring after 24 hours of force application.
- There was a gradual decrease in pain in both groups as the treatment progressed.
- The frequency of none and mild pain was more prevalent at all timepoints and increased from T1 to T5.

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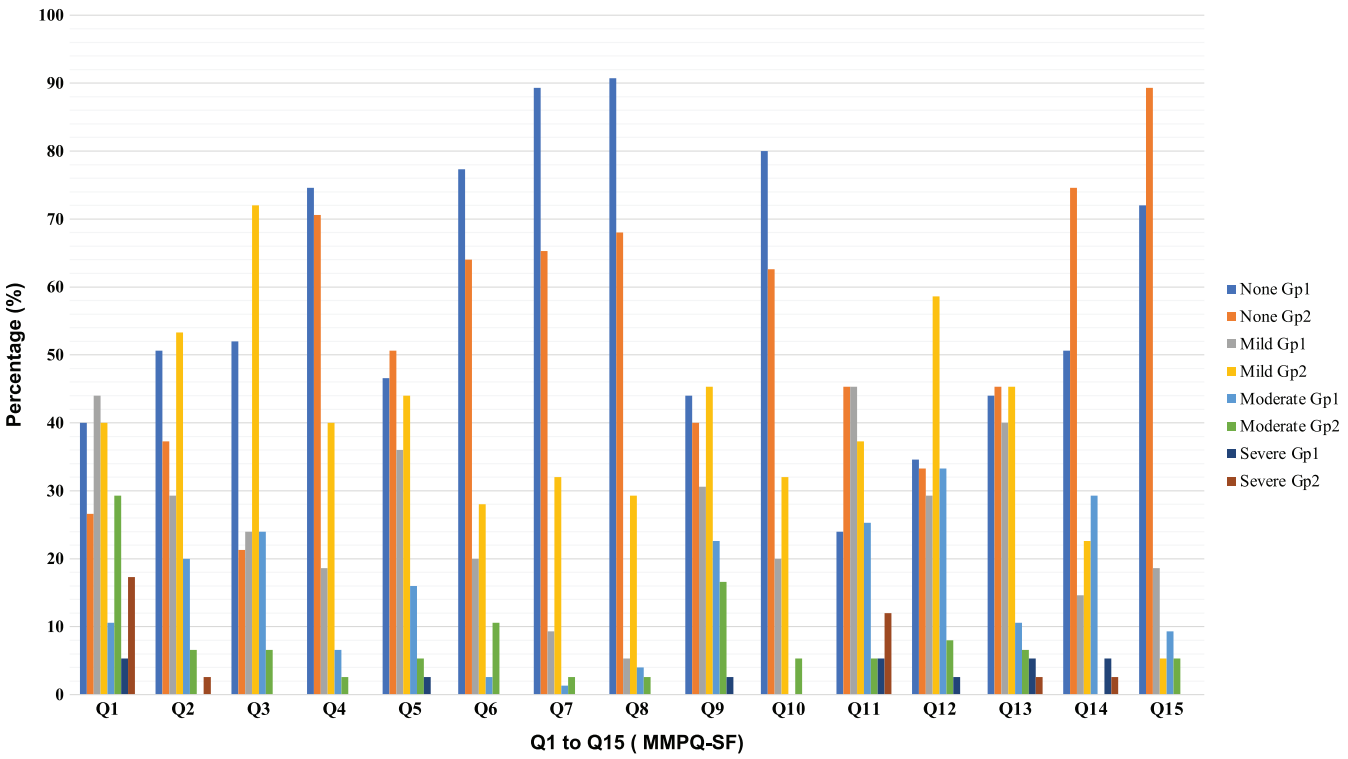

Figure 6. Categorical distribution of pain type and its severity (MMPQ-SF) in Group 1 and Group 2 at different timepoints.

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