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# COMPARISON OF UPPER AND LOWER CANINE RETRACTION RATES ASSISTED BY FLAPLESS LASER CORTICOTOMY

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*Canine retraction, CBCT, Corticotomy, Flapless Laser corticotomy.*

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## *ABSTRACT*

**Introduction:** One of the most frequent issues in extraction cases is the prolonged duration of orthodontic therapy and the slow rate of canine retraction. **Aim:** This secondary analysis study aimed to compare the rate of canine retraction in upper and lower canines facilitated with Flapless Laser corticotomy (FLC). **Materials and Methods**: The study included 56 canines from 14 patients (2 males /12 females) with a mean age of (20.4±2.5) years diagnosed with bimaxillary dentoalveolar protrusion and treated with 4 premolars extraction with upper and lower fixed appliances. The intervention was applied in a split-mouth fashion, so before commencing the study, 2 random computer-generated lists with a 1:1 allocation ratio were obtained to detect the side of intervention, these lists were concealed in opaque envelopes until the time of intervention. All participants were allocated into 2 groups, I- (Maxillary canines: which were divided into two subgroups A. Control, B. FLC) and II- (Mandibular canines: which were divided into two subgroups A. Control B. FLC). FLC was applied on the experimental sides before canine retraction by performing 6 holes with 3 mm of depth into the alveolar bone on both mesial and distal sides of all canines, then canines' retraction was performed using closed-coil springs to obtain a force of 150 gm while anchorage was augmented indirectly with TADs. The rate of canine retraction was assessed at T0, T1, T2, and T3 (just before, 1 month, 2 months, and 3 months after retraction), using 3-Dimentional digital casts. Only the statistical analysis expert was blinded. **Results:** The results showed a statistically *non-significant* difference between all groups (upper and lower flapless laser corticotomy and control) in the change in canine retraction distance and monthly rate of Canine retraction. **Conclusion:** There were neither statistically nor clinically significant differences between upper and lower canine retraction rates either by conventional method or assisted by FLC performed in this study.

## INTRODUCTION

One of the most frequent issues in orthodontic therapy, particularly in extraction situations, is the protracted duration of active treatment[(1)]. Premolar extraction situations require time-consuming distal canine migration. Depending on the patient's age and sex, conventional methods result in canine retraction rates of 0.5 to 1 mm every month. Therefore, it may take an average of 5 months for full canine retraction[(2)]. Traditional procedures with fixed appliances could take up to two years to finish [(3)].

The demand for faster orthodontic tooth movement became necessary because practically every orthodontic patient inquired about the potential of shortening the period of treatment. There have been several attempts to speed up tooth movement, including [1] the administration of local and systemic doses of pharmacological and chemical substances such as vitamin D3, corticosteroids, and prostaglandins [4,5]. Physical aids that work in tandem with the orthodontic force to increase its mechanical strength, such as static magnetic fields, localized heating, and electric current [6]. Surgical techniques that use burs, vertical grooves, and/or perforations in the cortical plate to quicken tooth movement (Alveolar corticotomy) [7].

Corticotomy, also known as decortication, is the deliberate removal of the bony cortical surface. This technique has been claimed to considerably shorten treatment time by removing cortical bone resistance to orthodontic tooth movement[7,8,9,10,11]. The provocation of the underlying regional acceleratory phenomenon (RAP) that takes place after a bony surgical insult has been proposed to explain this decreased resistance to tooth movement. RAP is characterized by the recruitment of osteoblasts and osteoclasts to the injury site for wound healing, resulting in transient localized demineralization and remineralization in the dentoalveolar bony housing[12]. Although corticotomy was asserted to be the most efficient method of accelerating tooth movement, it is still regarded as an invasive procedure because the patient must endure flap reflection, bone drilling and cutting with burs, suturing, and these procedures come with risks like contamination, discomfort, and swelling [13,14,15].To avoid these complications, many researchers have attempted to develop other minimally invasive alternative solutions that perform corticotomy without raising the flap (flapless corticotomy), such as corticision[16], piezocision [17], microosteo perforation (MOPs)[18], and Flapless Laser Corticotomy (FLC) [19].

The FLC approach has not been extensively studied to determine its efficacy. The first animal study that performed FLC on rabbits using a high-intensity Erbium, chromium-doped yttrium, scandium, gallium, and garnet (Er-Cr: YSGG) laser revealed that laser-facilitated flapless corticotomy was a useful procedure to shorten the treatment time and avoid the need for more invasive flap surgery[19]. Additional human investigations produced comparable outcomes, albeit with varying degrees of efficacy and without endorsing a uniform strategy for this surgery [20,21,22,23].

Low to moderate evidence was found in a recent systematic review by **Shaadouh et al.** [24] to support the effectiveness of FLC in accelerating orthodontic tooth movement, at least in the first two months, and they also suggested the need for additional properly conducted high-quality RCTs to support these findings. This study aimed to compare the rate of canine retraction in upper and lower canines facilitated with Flapless Laser corticotomy.

## MATERIALS AND METHODS

### Trial Design:

To ensure more reliable results, a split-mouth design with a 1:1 allocation ratio was used in the primary study, which eliminated inter-subject variability and permitted the use of a small sample size for the sample that was set up for each patient to act as his or her control. After the experiment began, the methodology remained unchanged.

### Sample size calculation:

Sample size calculation of the primary study was performed using **G power software***[1], assuming

1. *G power software; Universität Düsseldorf, Germany*

the difference of clinical significance for detecting canine movement velocity was 0.5 mm/month. The software adjusted with an alpha value of 0.05 and a power of 80% using values from a previous study conducted by **Salman and Ali** [20] revealed the mean changes in experimental and control groups were 1.63 mm and 0.82 mm, respectively. These values were inserted into the software with an estimated effect size d of 1 and a standard deviation of 0.5 mm. This revealed the need for 14 subjects per group. A total sample of 14 patients (i.e., a total sample of 56 canines) was included.

**Participants and eligibility criteria:**

The Research Ethics Committee (REC), Faculty of Dentistry, Suez Canal University, Egypt, approved the study methods with the number (46/2017). The participants were chosen from the outpatient clinic of the same faculty's orthodontic department. The sample consisted of 14 patients (2 males/ 12 females) with an average age of (20.4±2.5) years. This group (56 canines: 28 maxillary and 28 mandibular) was further subdivided as follows:

*I-* *Maxillary canines*: (A) Maxillary FLC group: before canine retraction, FLC was randomly assigned to one side of all upper arches (experimental side). (B)Maxillary control group: Canine retraction on the opposite side was performed without FLC.

*II-* *Mandibular canines:* (A) Mandibular FLC group: Before canine retraction, FLC was randomly assigned to one side of all lower arches (experimental side). (B) Mandibular control group: Canine retraction on the opposite side was performed without FLC.

For both male and female subjects, the inclusion criteria were (1) 18 years or older. (2) Class I with bimaxillary protrusion and minimal or no crowding required the extraction of four first premolars and maximum anchorage. (3) No prior orthodontic treatment history. (4) People who are healthy and have no history of craniofacial deformities, chronic systemic illness, or syndromes. (5) Healthy teeth with no evidence of root resorption. (6) Adequate oral hygiene; probing depth values not exceeding 3 mm with adequate attached gingiva thickness (1-2 mm) across the entire dentition. The exclusion criteria were (1) Systemic diseases that may affect bone formation or density, such as osteoporosis, were excluded. (2) Any systemic or local surgical contraindications. (3) Permanent teeth that have been extracted or are missing, except for the third molars. In addition, there is facial asymmetry.

Following recruitment, patients were examined and selected based on inclusion and exclusion criteria, and then the intervention and associated risks were explained. Before enrolling in the study, patients were asked to sign informed consent forms.

**Randomization:**

To choose the side of the experimental intervention randomly, all patients were given numbers, and two equally random computer-generated lists with a 1:1 allocation ratio were then constructed, the first list for the right side and the second for the left side. To prevent selection bias, allocation concealment was accomplished using opaque sealed envelopes up to the day of the intervention. Patients were then asked to identify whether their number was on the right side or left side lists.

**Blinding:**

It was impossible to blind the patients or the operators. An outside statistics specialist conducted an unbiased analysis of the experiment's outcomes (single-blinded).

**Interventions:**

Orthodontic treatment steps: All patients were treated by the same operator with the same fixed upper and lower pre-adjusted orthodontic appliance (TRAX OrthoPro; 121 South Orange Avenue, Orlando, Florida, USA) and slot size (0.022) MBT prescription. Alignment continued until the Niti archwire was 0.019x0.025, at which point the patients were referred to have all first premolars extracted. After 3 months of extraction, the 0.017x0.025" Stainless Steel working archwire was installed, and long crimpable hooks (PARVUSTM; MATT Orthodontics, Ford Ave. Chicago, IL, USA) were installed to the main wire mesial to second premolar brackets. In order to provide the best possible indirect anchorage, self-drilling temporary anchorage devices TADs (MATT Orthodontics, Ford Ave. Chicago, IL, USA; 1.6 8mm) were placed buccally between the first molars and second premolars in the upper and lower arches bilaterally and attached to the crimpable hooks by a 0.010 "stainless steel ligature. The flowable composite was then added to the top of the hook to lessen discomfort. Flapless laser corticotomy technique: The experimental sides were chosen using previously created random lists. The points of laser application were determined using a 0.019x0.025" stainless steel wire guide with markings every 2 mm measured Prior to applying the laser (Figure 1A), the surgical area was cleaned with Betadine solution, and local anesthetic was applied with (ARTINIBSA, Articaine hydrochloride 4% 1:100.000; Inibsa Dental S.L.U Ctra. Lliçà de Vall (Barcelona), Spain). The FLC was performed by a laser specialist using the (WATERLASE iPlus®, Biolase, Inc., USA). Erbium, chromium-doped yttrium, scandium, gallium, and garnet (Er, Cr: YSGG) Laser system, with a wavelength of 2780 nm and sapphire tip MZ8 (800 microns diameter and 6 mm length). With the aid of the specially made guide, a series of circular holes were cut along the planned positions inside the bone. The first hole was made 6 mm above the bracket slot level, and 3 holes distal and 3 holes mesial were created parallel to the long axis of the canine roots of the experimental sides (Figure 1B).

For cutting soft tissue, the laser's parameters were set to an average power of 2.5 W, a pulse repetition rate of 40 Hz, an energy per pulse of 62.5 MJ, a pulse duration of 60 microseconds in H-mode, a peak power of 1041 W, and a 20 air: 40 water concentration (Figure 2A). Reaching the bone required holding the tip in non-contact mode, increasing the average power to 4.5 W at a pulse repetition rate of 40 Hz, increasing the energy per pulse to 112.5 MJ, setting the pulse duration for H-mode (60 microseconds), and increasing the peak power to 1875 W with a 20 air:40 water concentration to enhance laser absorption (Figure 2B).

The depth of laser cutting was measured during surgery using a periodontal probe that was read to reach 3 mm and a few parts of a millimeter deep into the medullary bone to enhance bleeding (Figure 4). Following the intervention, patients were instructed to use acetaminophen 500 mg tablets as needed to manage postoperative pain and chlorhexidine mouthwash 0.2% twice daily for one week to control the infection.

Canine retraction: A closed coil spring, 9mm, from MATT Orthodontics, Ford Ave. Chicago, IL, USA, was attached between the canine bracket hook and the first molar band hook as shown in (Figure 3) after the flapless laser corticotomy procedure. The coil spring was activated to deliver 150 gm of force, which was verified with a force gauge (force gauge; DTC Orthodontics, Hangzhou, China). In order to maintain constant force levels over the course of the trial, the patients were followed up every two weeks.

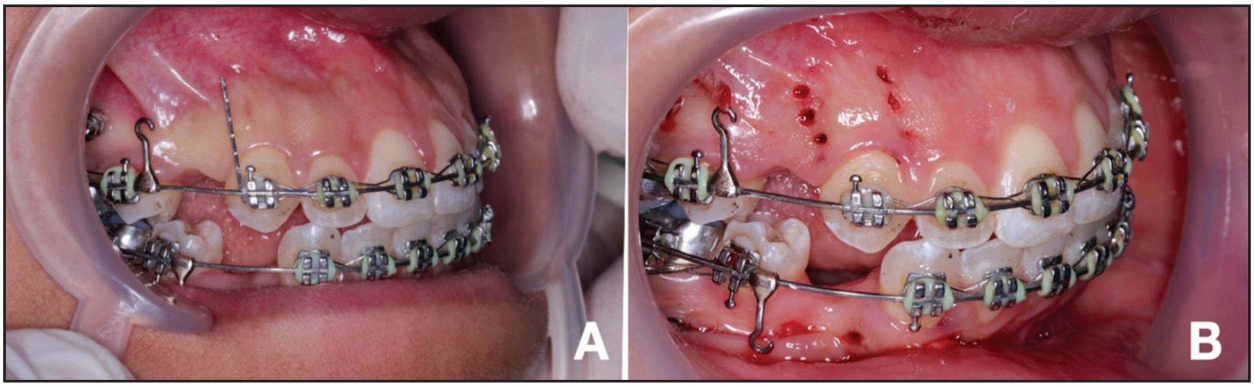


Fig. (1) (A) Custom-made guide. (B) The completed flapless laser corticotomy holes mesial and distal to canines before retraction.


Fig. (2) Laser machine, and laser parameters (A) Soft tissue and (B) Hard tissue parameters.

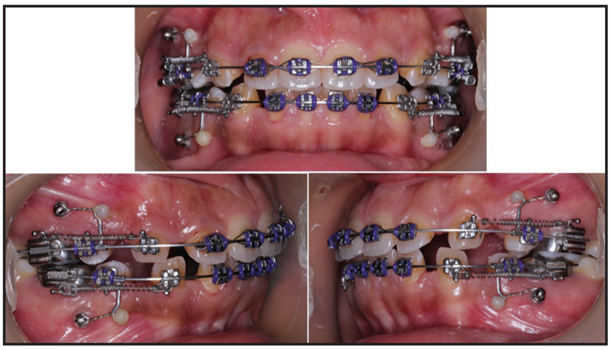

Fig. (3) Orthodontic appliance setup and canine retraction procedure.

**Outcomes assessment**

The rate of canine retraction was measured indirectly using digital models obtained as follows:

At four-time intervals (T0) just before canine retraction, (T1) one month after, (T2) two months after, and (T3) three months after canine retraction, upper and lower alginate impressions and wax bite in centric occlusion were collected. These alginate imprints were immediately used to build study models, and afterward, they were scanned using a desktop scanner (Shining 3D DS-EX; Shinning 3D Dental, César Chavez St. San Francisco, USA) to create the digital models in form of Standard Triangle Language (STL) which was manipulated later using (OrthoAnalyser 2020, 3 Shape, Copenhagen, Denmark) software. A reference plane was required to obtain a standardized measurement method, so the anterior-posterior (AP) plane was chosen for this objective, and it was prepared as follows:

The T0 digital model's upper arch was used to build the occlusal, sagittal, and AP planes.

The AP plane was then repositioned on the model's occlusal view so that it passed through built point that represented the distal end of the incisive papilla and was perpendicular to the sagittal plane. Using the third rugae area, the T0 model was overlaid with the T1, T2, and T3 models (Figure 4A).

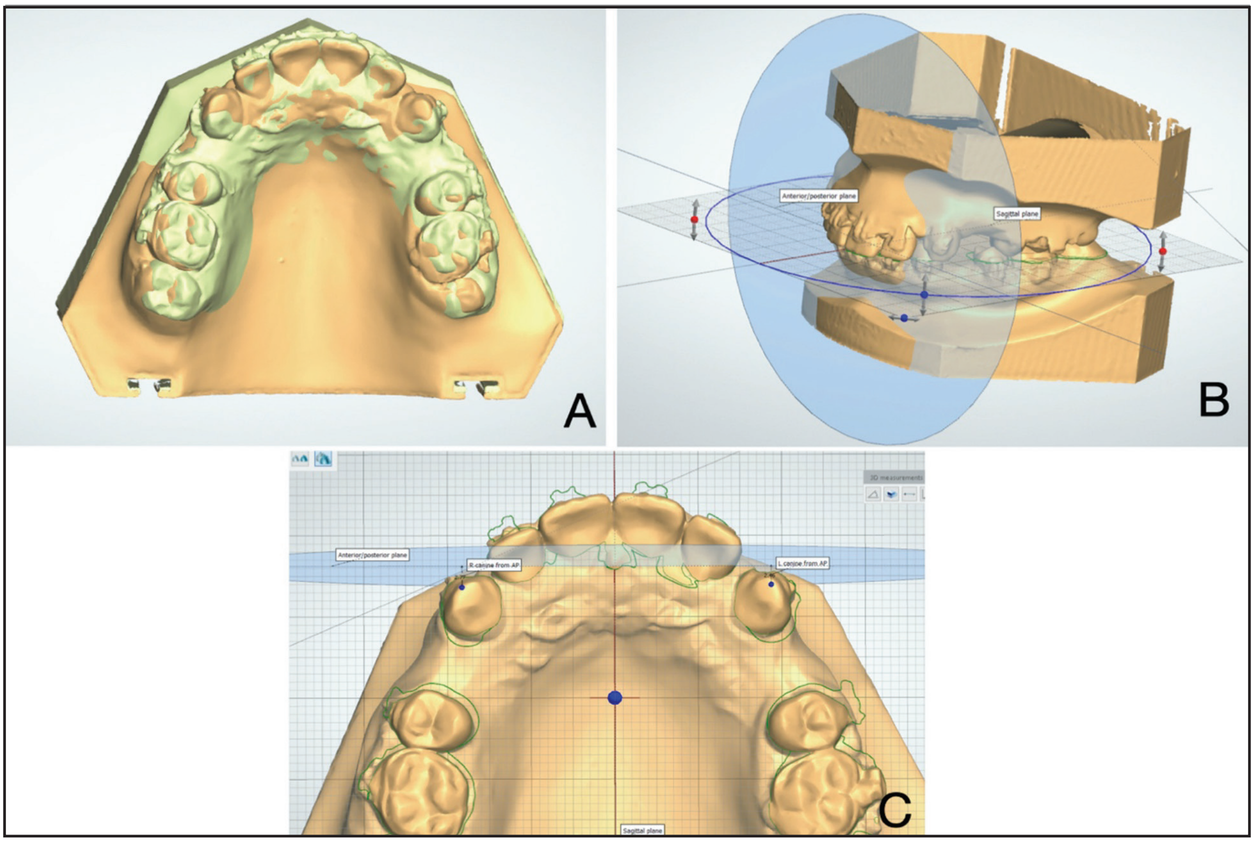


Fig. (4) (A) Different time point 3D digital models and superimposition using third rugae as a stable landmark. (B) Constructed Anterior-posterior plane from a 3D view, which was used as a common reference plane for upper and lower superimposed models. (C) Canine retraction measurement from the cusp tip to the AP plane

The software superimposed the upper and lower casts of all time points on the same landmarks when the option to keep the occlusion chosen was used for superimposition. In addition, the initial AP plane could be applied as a common reference plane for all upper and lower models (Figure 4B).

To determine the monthly rate of canine retraction, the distance between the AP plane and the upper and lower canine tips on the experimental and control sides was measured in T0, T1, T2, and T3 (Figure 4C).

## Statistical analysis

The data was fed into the computer and analyzed with the (IBM SPSS software package version 20.0. IBM Corporation, Armonk, New York). The *Shapiro-Wilk test* was used to ensure that the distribution was normal. Mean, standard deviation, range (minimum and maximum), and median were used to describe quantitative data. The obtained results were deemed significant at the 5% level. *Kruskal Wallis test* for abnormally distributed quantitative variables, to compare between more than two studied groups, and *Post Hoc (Dunn's multiple comparisons test)* for pairwise comparisons were used for comparison between the four studied groups according to change in canine retraction distance from T0 (mm) at T1, T2, and T3. *F-test (ANOVA)* for normally distributed quantitative variables, to compare between more than two groups used for comparison between the four studied groups according to the monthly rate of Canine retraction distance (mm), at 1st month T1 (T0-T1), 2nd month T2 (T1 –T2) and 3rd month T3 (T2-T3).

Measurements of canine retraction were measured again by the same operator one month after the first measurements to perform Intraclass Correlation coefficient to test the intra-examiner reliability. The results showed that there was strong agreement between reading 1 and reading 2 (ICC ranged from 0.985- 0.999).

## RESULTS

The findings indicated that all four groups' canines could be successfully retracted over the follow-up period from T0 to T3; the total retraction of the upper canines was approximately (2.46 ± 0.80 and 2.55±0.79 mm), for the FLC and control groups, respectively. The overall amount of retraction for the lower canines was (2.44 ± 0.96 mm for the FLC group and 2.31± 0.95 mm for the control group, respectively) as shown in Table I, (Figure 5). The results, however, revealed a statistically insignificant difference in the change in canine retraction distance between all groups (upper and lower flapless laser corticotomy and control) (p=0.962). Additionally, there was no statistically significant difference between the groups in the monthly rate of canine retraction distance (mm) (upper and lower flapless laser corticotomy and control) Table II, (Figure 6).

**Table (1)** *Comparison between the four studied groups according to change in canine retraction distance from T0 showing mean, standard deviation (mm), and p-value*

| Change in Canine retraction distance from T0 (mm) | Upper | | Lower | | H | p |
|---|---|---|---|---|---|---|
| | Flapless laser corticotomy mean ± SD | Control mean ± SD | Flapless laser corticotomy mean ± SD | Control mean ± SD | | |
| T1 | 0.62 ± 0.15 | 0.51 ± 0.22 | 0.59 ± 0.27 | 0.54 ± 0.34 | 2.633 | 0.452 |
| T2 | 1.63 ± 0.65 | 1.42 ± 0.43 | 1.47 ± 0.74 | 1.39 ± 0.57 | 1.311 | 0.726 |
| T3 | 2.46 ± 0.80 | 2.55 ± 0.79 | 2.44 ± 0.96 | 2.31 ± 0.95 | 0.290 | 0.962 |

*T1: 1 month after, T2: 2 months after, T3: 3 months after; SD: standard deviation;* **H**: *for* **Kruskal Wallis test;** *p: p value for comparing between the studied groups*

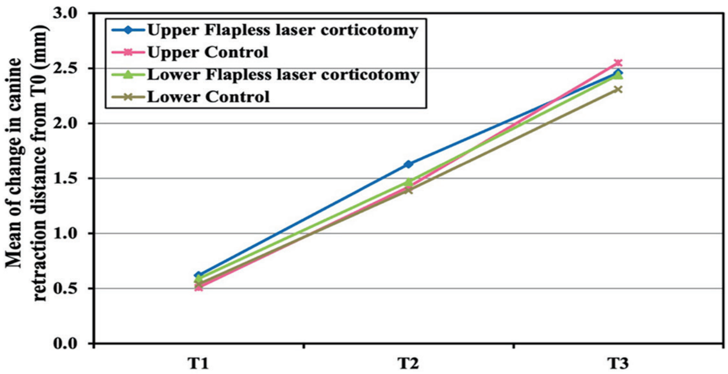


Fig. (5) Line graph showing comparison between the different time periods in each group according to change in canine retraction distance from T0 (mm).

**Table (2)** *Comparison between the four studied groups according to the monthly rate of Canine retraction distance showing mean and standard deviation (mm) ), and p-value*

| Monthly rate of Canine retraction distance (mm) | Upper | | Lower | | F | p |
|---|---|---|---|---|---|---|
| | Flapless laser corticotomy mean ± SD | Control mean ± SD | Flapless laser corticotomy mean ± SD | Control mean ± SD | | |
| 1st month T1 (T0 –T1) | 0.62 ± 0.15 | 0.51 ± 0.22 | 0.59 ± 0.27 | 0.54 ± 0.34 | 0.415 | 0.743 |
| 2nd month T2 (T1 –T2) | 1.01 ± 0.68 | 0.91 ± 0.41 | 0.88 ± 0.65 | 0.85 ± 0.61 | 0.165 | 0.920 |
| 3rd month T3 (T2 – T3) | 0.84 ± 0.36 | 1.13 ± 0.60 | 0.97 ± 0.94 | 0.92 ± 0.77 | 0.374 | 0.772 |

*T1: 1 month after, T2: 2 months after, T3: 3 months after; SD: standard deviation;* **F**: *for* **ANOVA;** *p: p value for comparing between the studied groups*

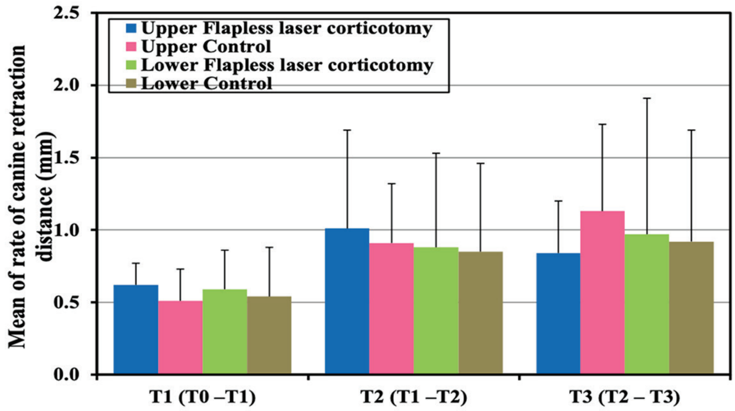


Fig. (6) Histogram showing comparison between groups according to the monthly rate of canine retraction distance (mm).

## DISCUSSION

This study was designed to compare the effects of flapless laser corticotomy on the rate of upper and lower canine retraction The study included 14 patients (2 males and 12 females) with a mean age of (20.4 ±2.5) years. A split-mouth design was chosen to eliminate much of the inter-subject variability. When compared to parallel studies in which patients receive only one intervention, this design helps to increase study power or reduce the number of subjects required [25]. Additionally, our sample was chosen in accordance with inclusion criteria that aimed to obviate the majority of cofounders that might have influenced the outcomes. Patients older than or equivalent to 18 years old were chosen as subjects because corticotomies in teenagers may only occasionally be necessary due to a substantially faster rate of tooth movement. Adults displayed a substantially higher degree of osteoclast activity and cytokine release but had a significantly slower pace of orthodontic tooth movement, according to

**Alikhani et al**. [26]. In order to lessen the resistance of hard tissues and facilitate orthodontic tooth movement, it was evident that elderly patients would benefit from the corticotomy treatment.

This study enrolled individuals who had bimaxillary dentoalveolar protrusion and dental class I that required the extraction of four premolars. This decision was made in accordance with our goal of assessing the canine movement rate in upper and lower canines using FLC. Most studies on canine retraction acceleration focused solely on the upper canines, enrolling patients with class II div 1 malocclusion[20,21,22]. The fact that the maxillary arch is preferred for the study due to the existence of recognizable landmarks on the palate, allowing for more uncomplicated measurement, may be the reason why the majority of research used this arch. In an effort to get around this restriction, we established a common reference plane for the lower and upper models and used the third rugae area as a stable framework for superimposition [27].

The majority of studies that evaluate the canine retraction rate have some characteristics with this methodology. Due to the rigidity of stainless-steel archwire, all cases in this study were treated with fixed upper and lower pre-adjusted edgewise appliances (MBT) with slot sizes of 0.022” and 0.017x0.025”. This aids in preventing the canine’s tipping that occurred during retraction. 0.016x0.022” SS was employed in certain studies[22] to reduce friction and facilitate the canine’s mobility, but at the cost of higher tipping. Some researchers [21, 23] used 0.019 x0.025 “SS archwire, which is, of course, a better option for controlling tipping, but having less play between the bracket and wire leads to higher friction and may slow tooth movement.

To minimize overlapping between the potential acceleration of tooth movement from the FLC and the acceleration after a recent extraction, which happens as a result of elevated cellular activity[28], the extraction was carried out after leveling and alignment and three months before the canine retraction.

Sliding mechanics were chosen in this study for greater control of applied load during the study, as in many other studies with similar interests. The difference, however, could be in the force delivery method. We used a NiTi coil spring adjusted at 150 gm because it was shown in many studies[29,30] to be more effective in space closure; this effectiveness led to the coil spring being the favorite option for force delivery in several studies that investigated the speed of canine retraction[31,1,21,32,22]. Other researchers, however, favored elastic chains for canine retraction [20,23], despite the fact that they may be simpler to use and less expensive, they suffer from rapid force decay and necessitate regular changes to maintain the force levels.

Since mini-screws are thought to be the best approach for anchorage reinforcement in circumstances requiring maximum anchoring, we employed them to strengthen the posterior anchorage. To enable superior sliding mechanics, we used indirect anchorage. The literature on determining the canine retraction acceleration rate has employed both indirect[23,32] and direct[31,33] methods of mini-screw anchorage. Furthermore, **Zhang et al.**[34] demonstrated that indirect mini-screw anchorage allowed for better sliding mechanics than direct anchorage.

We used an (Er-Cr: YSGG) laser device with a wavelength of 2780 nm in this investigation, with average power for bone cutting of 4.5 W at a pulse repetition rate of 40 Hz and energy per pulse of 112.5 MJ. Our parameters differed from those used by **Seifi et al.** **[19]**, who utilized the same laser to deliver energy of 300 MJ at pulse rates of 20 Hz to 8 New Zealand Male rabbits. Furthermore, **Moahmoudzadeh et al**. [22] used the same laser for bone cutting at 3.5 W power and 30 Hz frequency. Other researchers have used various lasers to perform corticotomies. The corticotomy procedure has been carried out by other researchers using various laser types. **Salman et al.** [20] employed Erbium, Yttrium crystal, Aluminum, and Garnet enriched (Er: YAG), but they omitted to disclose their laser settings. The values for hard tissue in another investigation by **Alfawal et al.** [21] were 200 MJ, 12 Hz, and 3 W. **Jaber et al.** [23] also established 200 MJ, 15 Hz as the conditions for hard tissue. With no clear guidelines, it appears that a wide range of values, ranging from 200 mJ to 300 mJ and pulse rates between 12 Hz and 30 Hz, are used.

Regarding surgical technique, we did FLC as a buccal series of six holes, three mesial holes, and three distal holes that were 2-3 mm apart and three millimeters deep in the cancellous bone. Our method was comparable to the method used by **Salman et al.**[20] who made buccal series of four holes that were 1.5 mm in diameter, 3 mm deep, and mesial and distal to the canine. **Moahmoudzadeh et al.**[22] altered this technique by making buccal and vertical cuts parallel to the canine's long axis on the mesial and distal root surfaces, 1 mm below the alveolar crest and extended up to the mucogingival junction, and 2 - 3 mm deep to reach the cancellous bone. **Alfawal et al.** [21] used a different technique, performing 5 buccal perforations 1.5-2 mm apart, 1.3 mm wide, and 3 mm deep between the canine and second premolar. **Jaber et al.** [23] performed 8 buccal perforations in attached mucosa, 4 holes distal and 4 around the canine, a width of 1 mm, and a depth of 3 mm.

The results revealed a statistically *insignificant* difference in the total distance and monthly rate of canine retraction between all groups (FLC and control) at any time point. This suggested that FLC was unable to significantly speed up canine movement. These findings were very similar to those of various split-mouth RCTs, including those by **Aboalnaga et al.**[32], **Alkebsi et al.**[33], **and Mistry et al.**[35]**,** who found no statistically significant differences between their experimental and control groups when they investigated the effects of micro-osteoperforations and low-level laser therapy on canine retraction.

Our findings, however, were in contrast with those of other research that claimed FLC significantly increased the velocity of orthodontic canine movements[20,21,22,23]. The fact that the FLC approach is a very minimally invasive procedure can be used to explain this contradiction with the present results, which demonstrated that FLC could not enhance the rate of tooth movement. According to **Yang et al.**[36], who found that mesial corticotomy cuts in the labial surface had a minor impact on dentoalveolar structures, while distal corticotomy cuts closer to the canine root may be more helpful in corticotomy-facilitated canine retraction. The total number of 6 holes (3 distal / 3 mesial to the canines) performed in the current study may be an insufficient osseous insult and unable to fully trigger the (RAP). **Murphy et al.**[37] demonstrated the significance of the boney insult in stimulating the cellular responses that contribute to tooth movement acceleration, which may explain why the current findings were similar to those of RCTs [32,33], which performed three distal MOPs and discovered that their procedures were insufficient to accelerate the rate of orthodontic canine retraction.

Additionally, the insufficient boney insults also explain the inconsistent outcomes with other studies that used more invasive techniques, such as those performed by **Salman et al.** [20] (eight holes, four mesial and four distal), **Alfawal et al.** [21]**,** (five holes distal), **Moahmoudzadeh et al.** [22]**,** (Distal and mesial vertical Cuts), and **Jaber et al.** [23] (who performed eight holes four distal and four around the canine).

**Salman et al.**[(20)] did not report the exact methods or landmarks used for assessment, **Alfawal et al.** [(21)] used calibrated photos to assess canine retraction distance, and **Jaber et al.** [(23)] used direct intraoral measurements. The differences in assessment methods may have an impact on the results. Furthermore, the lack of data regarding the FLC protocol and laser parameters may influence the result; it has been reported that the protocol affects orthodontic tooth movement acceleration since a small dosage of low-level laser therapy enhances the amount of tooth movement while a higher dosage did result in an inhibitory effect [(38)].

In the current study, the monthly rate of canine retraction assessed with F-test (ANOVA) showed that there was a statistically non-significant difference in the monthly rate of canine retraction distance (mm) between groups (upper and lower flapless laser corticotomy and control). In the flapless laser corticotomy group, the upper canines moved at a rate of 0.62±0.15 mm/month in the first month (T0-T1), and this rate increased to be 1.01 ±0.68mm/month in the second month (T1-T2), then declined to 0.84±0.36 mm /month in the third month (T2-T3). In the control group, the upper canines moved at a rate of 0.51±0.22 mm/month in the first month (T0-T1), and this rate increased to 0.91±0.41 mm/month in the second month (T1-T2), then to be 1.13±0.60 mm /month in the third month (T2-T3). Very similar results were found by **Aboalnaga et al.** [(32)] **and Alkebsi et al.** [(33)], who studied microosteoperforations effect on the rate of canine retraction. They found non-significant differences between their experimental and control groups.

In our study, the experimental lower canines group showed slightly higher but insignificant movements than the control group in the first three months. Experimental canines moved about 0.59±0.27mm at T1, 1.47±0.74 mm at T2, and 2.44±0.96mm at T3, with a monthly rate of 0.59±0.27mm in the first month (T0-T1), 0.88 ±0.65mm in the second month (T1-T2) and 0.97±0.94 mm at the third month (T2-T3). In the control group, canines moved about 0.54±0.34 mm at T1, 1.39 ± 0.57 mm at T2, and 2.31 ± 0.95 mm at T3 with a monthly rate of 0.54±0.34 mm in the first month (T1-T2), 0.85 ± 0.61 at second month and 0.92 ± 0.77 (T2-T3) at the third month. The lower experimental and control groups' difference was 0.05 mm in the first month, 0.03 mm in the second month, and 0.05 mm in the third month. We cannot find enough data dealing with the acceleration rate of lower canine movements. However, our results could be compared to the results found by **Aslan et al.**[(39)] who reported a lower canine retraction rate ranging from 0.88 to 0.93 mm/month and **Monini et al.**[(40)] who found the rate of canine retraction in lower canine was 0.54 mm/month for SLB and 0.60 mm/month for CB.

Regarding the difference between upper and lower canines, our experimental group in the first month upper vs. lower showed 0.62 ± 0.15 mm, 0.59 ± 0.27 mm respectively, and in the control group showed the movement of upper about 0.51 ± 0.22 mm and lower 0.54±0.34 mm. In general, the rate of tooth movement in the upper was slightly higher, but with a statistically non-significant difference. Our results agreed with **Aslan et al.**[(39)] but were contradictory to **Monini et al.**[(41)] who showed a higher maxillary rate of canine retraction.

## Limitations

The limitations of this study were that (1) the majority of the participants in our sample were female, which made it challenging to identify any differences in reactions between males and females that might have existed. 2) Inflammatory markers were not measured at different time points. 3) Finally, digital casts were created by scanning plaster models rather than direct scanning with intraoral scanners.

## CONCLUSIONS

**Within the limitations of this study, the following conclusions could be drawn:**

There were neither statistically nor clinically significant differences between upper and lower canine retraction rates either by conventional method or assisted by FLC performed in this study.

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