Comparison of Corticotomy and Micro-osteoperforation during Canine Retraction: A Split-Mouth Design

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Objective: Compare the efficacy of the micro-osteoperforation (MOP) and corticotomy techniques in terms of maxillary canine retraction.

Methods: Thirteen patients (5 females, 8 males; mean age, 18.07 ± 6.74 years) with healthy permanent dentition and requiring the extraction of maxillary first premolars were included in a split-mouth randomized clinical trial. Those subjects with previous orthodontic or endodontic treatment of the canines were excluded. At least 3 months post-extraction, MOPs and corticotomies were performed distal to the canines. Mini-screws with closed-coil springs (150 g) were used for the canine retraction. Dental casts were made at baseline (T0) and 3 months post-intervention (T1). Trained and calibrated examiners measured the distances from the canines to the second premolars on both sides. A signed-rank sum test was used to compare the amount of canine retraction achieved in 3 months (T0–T1) on the 2 sides.

Results: Retraction (mm) at the incisal level was similar in the corticotomy (3.34 ± 1.01) and MOP patients (2.74 ± 1.10) (P = 0.11); furthermore, there were no differences in the degree of medial retraction between the corticotomy (2.56 ± 0.67) and MOP (2.27 ± 0.82) (P = 0.31) procedures. No adverse events were observed.

Conclusion: There were not any clinically or statistically significant differences in retraction between the interventions. At 3 months, a MOP is as effective as a corticotomy in accelerating the rate of tooth movement. [*P R Health Sci J 2023;42(4):311-317*]

Key words: Corticotomy, Micro-osteoperforation, Accelerated tooth movement

When force is applied to a tooth, an inflammatory response that provokes bone remodeling and subsequent tooth movement is produced (1). Upon injury, the rate of bone remodeling is accelerated, increasing the rate of bone turnover, known as the regional acceleratory phenomenon (RAP). The greatest resistance to tooth movement is the cortical wall; breaking this wall will result in reduced treatment time (2–4).

Several modalities have been developed to take advantage of the RAP. Of them, corticotomy and micro-osteoperforation (MOP) present the most promising statistically significant results in terms of accelerating tooth movement (compared to conventional treatments) (5–8).

A corticotomy can be performed with or without an elevated flap (9), with both approaches outperforming conventional treatments: Tooth movement is greater with traditional corticotomies than with conventional strategies (yielding a 28% to 33% reduction in treatment time [7]) and is greater still with flapless corticotomies (9), providing a correspondingly higher degree of tooth movement.

Less invasive than either version of the corticotomy, however, is the MOP, which, in a split-mouth study from Cheung et al., was found to increase tooth movement 1.86-fold over what was accomplished by conventional techniques (6). Another MOP study reported a 2.3-fold increased rate of tooth movement compared to conventional orthodontic treatments (10).

With fewer post-operative side effects, risks, and complications than those techniques that require a flap, MOP is a simple, minimally invasive flapless technique (5,9). Additionally, healing occurs more rapidly with MOP and presents less discomfort to the patient.

Currently, it remains unclear whether MOP is as effective as corticotomy in accelerating tooth movement. Previous studies individually compared corticotomies and MOPs to conventional treatments but not to each other (5–7,10). To our knowledge, this is the first time that a split-mouth study has been used to compare differences in tooth movement between the corticotomy and MOP techniques.

The purpose of this study was to compare the effects of corticotomy and MOP on the amount of tooth movement (in mm) achieved after 3 months of maxillary canine retraction.

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The null hypotheses were that there would be no significant clinical difference between MOP and a corticotomy in terms of the amounts of tooth movement and that no serious adverse events would occur.

Materials and Methods

Trial design

A split-mouth, randomized, controlled clinical trial with a 1:1 allocation was performed at the University of Puerto Rico, School of Dental Medicine (UPR-SDM). The Institutional Review Board (IRB) approved the study protocol (protocol number: B0710118), and the study was registered via the ClinicalTrials.gov Protocol Registration and Results System (protocol ID: UPR MSC IRB B0710118).

Participants

All the patients seeking orthodontic treatment from November 2018 through July 2019 were considered. Subjects from 12 to 45 years old with healthy permanent dentition and requiring the extraction of maxillary first premolars with less than 8 mm of maxillary anterior crowding were included. Subjects with previous orthodontic or endodontic treatment of the canines were excluded. Consent and assent forms were obtained from each participant, following the IRB guidelines of the UPR-SDM. A Consolidated Standards of Reporting Trials (CONSORT) 2010 Flow Diagram shows participant recruitment, eligibility, and assessment during the study (Figure 1).

Interventions

All the MOPs were performed by the same orthodontist at the UPR-SDM graduate orthodontic clinic. In addition, the same surgeon performed all the extractions, corticotomies, and mini-screw placements at the UPR-SDM graduate oral and maxillofacial surgery clinic.

Fixed edgewise appliances (7-7) (Victory Series brackets, 0.022-inch Roth prescription; 3M Unitek, Monrovia, CA) were used. After the bonding was completed, the patients were referred for the extraction of the maxillary first premolars. A 0.017 x 0.025-inch stainless steel (SS) arch was used as the working archwire. A panoramic radiograph was taken before the interventions to evaluate root positions.

The corticotomy and MOP interventions were performed at least 3 months post-extraction to allow leveling, alignment, rotational control, and healing of the extraction site (11). In addition, this time aided in reducing any possible synergistic RAP effect that could have occurred if any of the interventions had been performed immediately following an extraction.

Mini-screws (OrthoAnchor, KLS Martin Group, Jacksonville, FL; cross-drive, drill-free, 1.5 x 8 mm tissue collar) were placed approximately 4 mm above the cement-enamel junction on the attached gingiva between the maxillary second premolar and the first molar, for canine retraction.

Corticotomy intervention

1. A full-thickness labial mucoperiosteal flap was reflected and irrigated with 0.9% normal saline solution.
2. Two vertical corticotomies (1 mesial and 1 distal to the canine) were performed with a 701 surgical bur (Patterson Dental, St. Paul, MN; 1.20 mm diameter). The cortical bone was cut 2 to 3 mm below the alveolar crest towards the apex until the bone marrow was exposed.
3. Cortical–cancellous bone grafts (0.5 cc; PuraGraft, Kingwood, TX) were placed at the corticotomy sites.
4. The flap was repositioned and sutured with a 3-0 chromic gut suture material (Ethicon, Cincinnati, OH).
5. The mini-screws were placed.
6. A nickel–titanium (NiTi) closed-coil spring was placed and secured with a 0.014-inch SS ligature wire at the canine

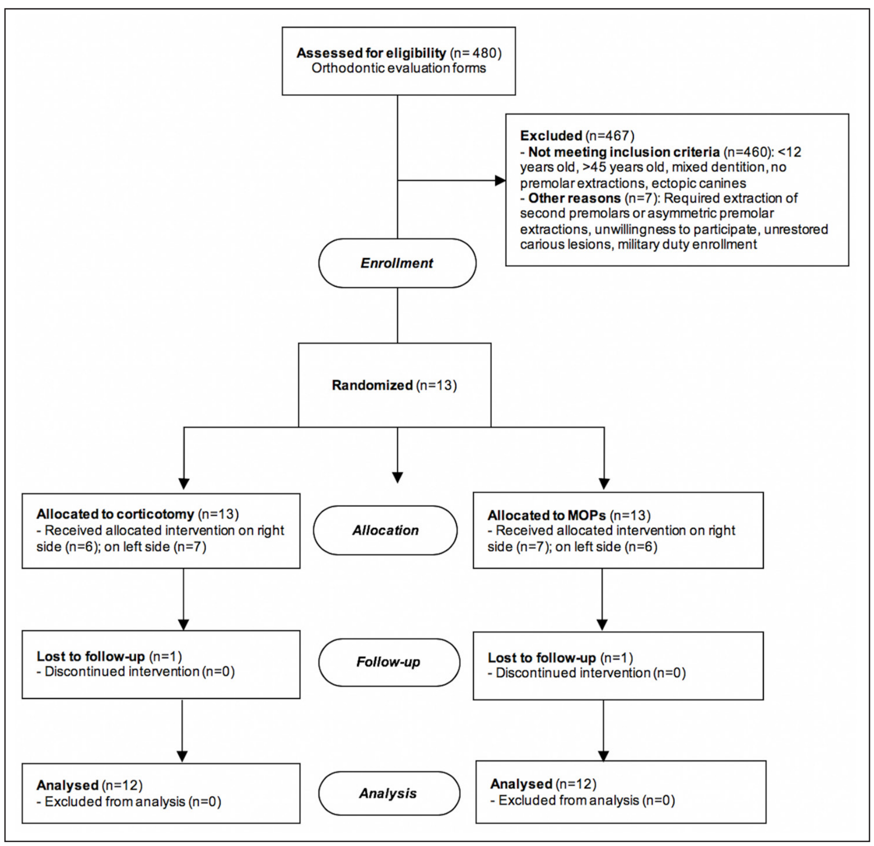

Figure 1. Study Flow Diagram to assess participant eligibility and enrollment.

and mini-screw. A Dontrix gauge (Orthopli Corporation, Philadelphia, PA) was used to measure the force (150 g) (Figure 2).

MOP intervention

1. The MOP interventions were performed with a 1.6 mm diameter SS manual drill tip with an adjustable depth set to 5 mm (Excellerator RT; Propel Orthodontics, Milpitas, CA).
2. Six perforations were made along 2 parallel vertical lines (each line with 3 holes spaced ~2 mm apart) distal to the canine and perpendicular to the buccal cortical bone.
3. The mini-screws were placed.
4. A NiTi closed-coil spring was placed and secured with a 0.014-inch SS ligature wire at the canine and mini-screw. A Dontrix gauge was used to measure the force (150 g) (Figure 3).

Outcomes

The primary outcome of the study was a canine retraction, defined as the amount of tooth movement (in mm) attained by the maxillary canines after retracting them for 3 months. Records taken at T0 (baseline) and T1 (3 months after a given intervention) consisted of dental casts, digital models (TRIOS; 3Shape Manufacturing, Durham, NC), and maxillary occlusal photographs. Using the study models, the total distance moved by a given canine was assessed by comparing the distances at T0 and T1 for each patient. The distance measurements for all the patients were done by 2 examiners and later averaged to reduce measurement variability. The secondary outcome was the occurrence of adverse events.

Standardization and calibration

Two examiners were standardized and calibrated by a reference examiner. The distance was measured from the distal of the canine to the mesial of the second premolar at the incisal, medial, and gingival levels on 10 randomly selected maxillary study models (Figure 4A). For study purposes, the gingival level was not measured since brackets interfered with the precision of the measurement (Figures 4B & C). Each measurement was taken 3 times and averaged per examiner. All the measurements performed by the examiners were repeated within a 2-week interval.

Sample size

The required sample size was calculated using a clinically significant estimate of 2 mm for the difference in tooth movement between the corticotomy and MOP and a 1:1 mean-to-standard deviation ratio. Ten patients were needed to achieve at least an 80% statistical power for a 2-sided paired t-test (level of statistical significance: $P = 0.05$). We assumed a dropout rate of 20% and so included 3 more patients in the sample, resulting in a final sample size of 13 patients.

Randomization and allocation concealment

To eliminate selection bias, the MOP intervention was divided by a simple randomization technique (performed by a computer and resulting in a 1:1 allocation ratio), to be carried out on either the right or left side of the maxillary arch. Then, the corticotomy procedure was automatically assigned to the remaining site. For the study, each patient was randomly assigned an identification number (S1–S13) by picking a sealed envelope; thus, allocation concealment was achieved.

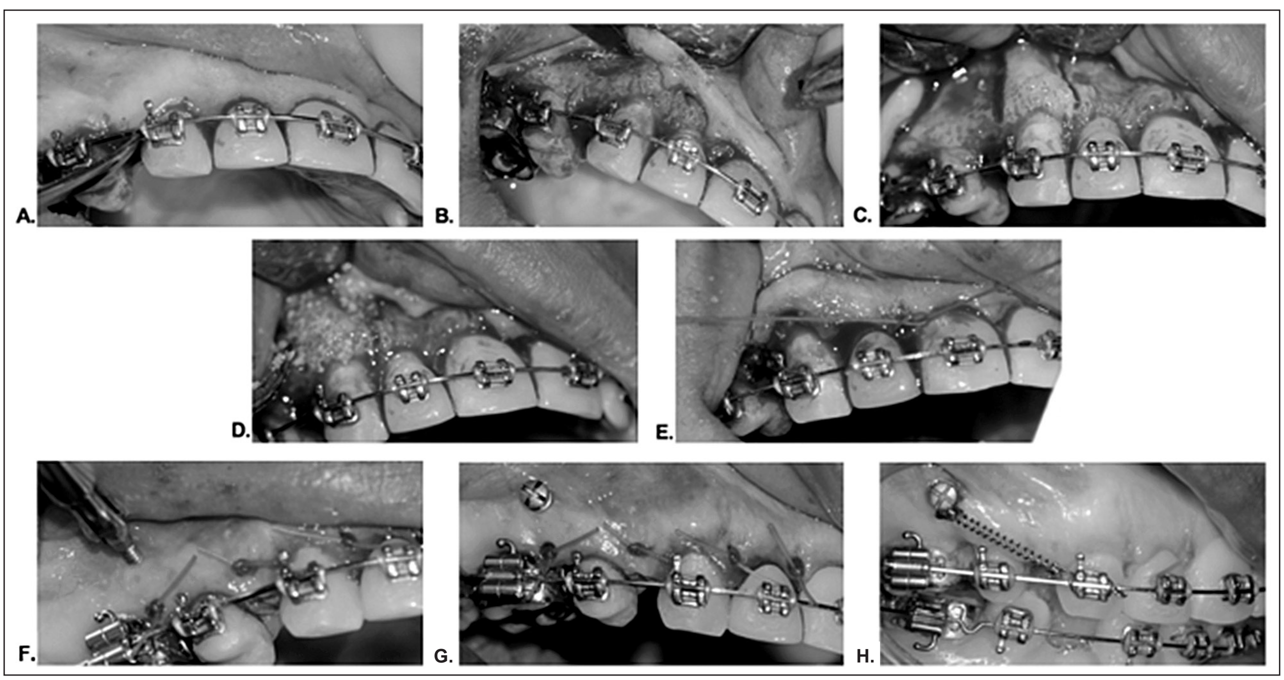

Figure 2. Corticotomy procedure. **A**. Sulcular incisions; **B**. Full-thickness mucoperiosteal flap; **C**. Vertical corticotomies; **D**. Bone graft; **E**. Flap sutured; **F–G**. OrthoAnchor mini-screw placement; **H**. Canine retraction with a NiTi closed-coil spring (150 g).

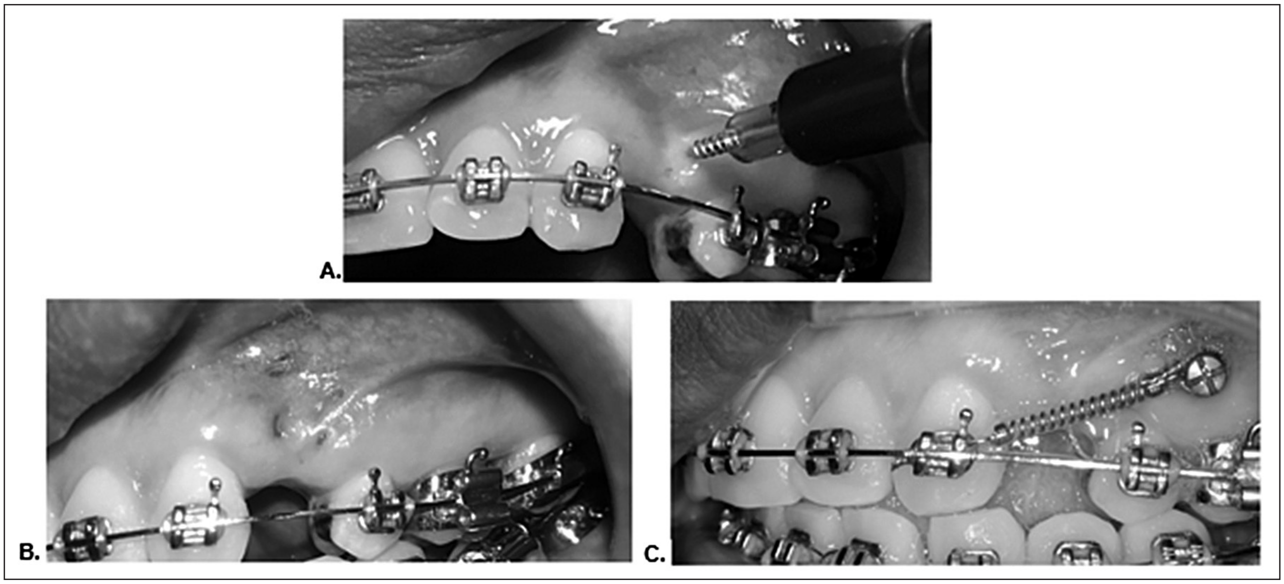

Figure 3. Micro-osteoperforation procedure: **A**. MOP application; **B**. MOP distal to canine; **C**. Canine retraction with a NiTi closed-coil spring (150 g).

Blinding

At the time of each intervention, both the participant and the operator were aware of the treatment due to the nature of the study groups. However, 2 weeks after the interventions, it could not be clinically determined (in each patient) which side of the arch had received the MOP or corticotomy. Therefore, at the time of data collection, the examiners were blinded to the side of the given intervention.

Statistical analysis

Statistical analysis was performed by SAS software (version 9.3; SAS Institute, Cary, NC). The significance level α was set at 0.05. Summary statistics were calculated using means, standard deviations, and medians (interquartile range) for continuous variables and percentages for categorical variables. The Shapiro–Wilk test was used to test for the normality of the distribution of the continuous variables. For the principal analysis, and since the outcomes were not normally distributed, a signed-rank sum test was used to test for paired differences between the corticotomy and MOP sides in the amounts of canine retraction after 3 months (T0–T1). The signed-rank sum test analysis was repeated in patient subgroups defined by sex, malocclusion, and an A point, nasion, and B point (ANB) angle greater than 3.5°.

Results

Participant flow

Patient recruitment commenced in November 2018 and ended in July 2019. The initial sample consisted of 13 patients; however, only 12 patients (median age: 16.5 years; interquartile range, 3 years; range, 12–39) completed the study. One patient missed the appointment for obtaining the T1 records because of government regulations regarding the coronavirus pandemic (quarantine). All the corticotomy and MOP interventions were performed from January 2019 through January 2020. The final data were collected in April 2020.

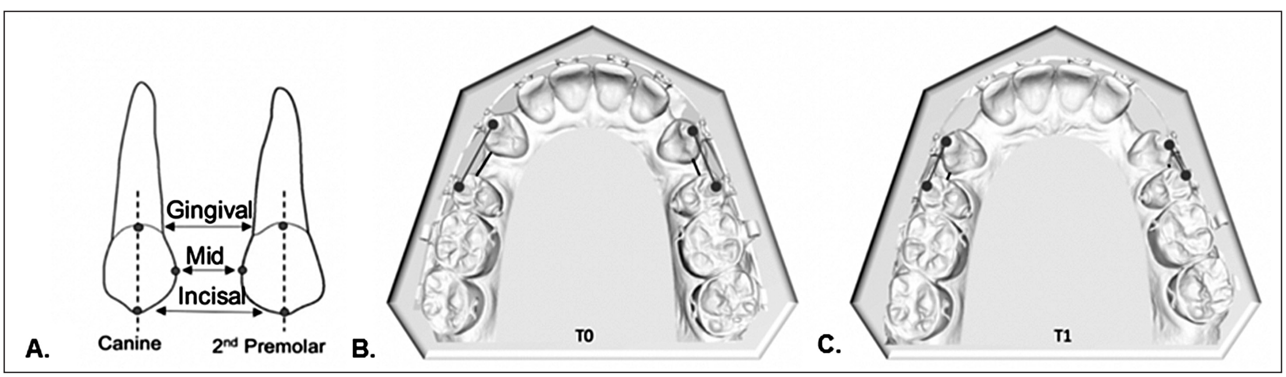

Figure 4. **A**. Reference point measurements (incisal, medial, and gingival) The distance was measured from the distal of the canine to the mesial of the second premolar at the incisal, medial, and gingival levels on 10 randomly chosen maxillary study models; **B** & **C**. Measurement of canine retraction (incisal and medial) at T0 and T1 models, respectively.

Baseline data

The distribution of the baseline characteristics (sex, ethnicity, malocclusion, age, and cephalometric analysis) of the patients are reported in Table 1.

Numbers analyzed

The study models obtained at T0 and T1 were analyzed. None of the mini-screws or brackets failed during the study.

Standardization and calibration exercise

The intra-examiner intraclass correlation coefficient (ICC) ranged from 0.83 to 0.96 for all the examiners. The inter-examiner ICCs were 0.90 and 0.88 for examiner 1 vs. reference (for the incisal and medial levels, respectively), and 0.94 and 0.91 for examiner 2 vs. reference. The average differences between repeated readings were similar for Examiner 1 and Examiner 2.

Study model assessment

At the incisal level, the mean distance moved by the canines on the corticotomy side was 3.34 mm (±1.01 mm); on the MOP side, it was 2.74 mm (±1.10 mm). The difference between the corticotomy and MOP measurements was 0.60 mm (±1.15 mm) (P = 0.11). At the medial level, the mean distance moved by the canines on the corticotomy side was 2.56 mm (±0.67 mm); on the MOP side, it was 2.27 mm (±0.82 mm). The mean difference between the corticotomy and MOP measurements was 0.29 mm (±0.95 mm) (P = 0.31). Therefore, at 3 months, the amounts of canine retraction at the incisal and medial levels were neither clinically nor statistically significant (Table 2).

Subgroup analyses

The responses to the interventions were similar in the subgroups (defined by sex, age, malocclusion, and ANB angle), both at the incisal and medial levels. However, the results were not clinically or statistically significant.

Adverse events

No adverse events were observed during the trial. All the MOP and corticotomy procedures were safely performed without any intra-operative surgical complications.

Discussion

Main findings in the context of the existing evidence

The study aimed to compare the amount of tooth movement caused by a corticotomy and that caused by a MOP after 3 months of maxillary canine retraction. To our knowledge, this is the first study to compare the two interventions; previous studies have compared corticotomies and MOPs only to treatments in which no adjunctive technique to stimulate bone turnover was performed (2,6,7,9,10,12).

This study contended that the mean canine retractions in the corticotomy and MOP sides would be achieved at a similar rate. There were no clinically or statistically significant differences comparing the baseline values or the amounts of canine retraction between the experimental sides. Therefore, the study's null hypothesis is accepted.

Table 1. The distribution of the baseline characteristics (sex, ethnicity, malocclusion, age, and cephalometric analysis) of the patients

	n (%)	Mean ± SD	Norm	Median (IQR)
Sex				
Male	7 (58.33%)			
Female	5 (41.67%)			
Ethnicity				
Hispanic	12 (100%)			
Malocclusion				
Class I	6 (50%)			
Class II Division 1	6 (50%)			
Age (y)		18.25 ± 7.01		16.5 (15; 18)
SNA (º)		83.81 ± 6.93	82 ± 3.5	83.95 (77.7; 87)
SNB (º)		78.33 ± 5.50	80 ± 3.5	78.15 (72.95; 81.95)
ANB (º)		5.41 ± 2.29	2 ± 3.5	5.7 (3.95; 6.95)
Maxillary mandibular plane angle (º)		27.57 ± 6.25	28 ± 5	26.7 (23.7; 31)
Mandibular anterior facial height (mm)		63.63 ± 6.15	65 ± 4.5	63.5 (58.25; 70.4)
Maxillary incisor inclination (º)		111.18 ± 8.57	103.5 ± 5	109.7 (105.2; 116.75)

SNA, Sella-Nasion-A point; SNB, Sella-Nasion-B point; ANB, A point-Nasion-B point; SD, standard deviation; IQR, interquartile range

Table 2. Intervention baseline (T0) and tooth movement (T1) measurements by level and side

	Baseline measurements (mm) by level and intervention side			
	Corticotomy	MOP	Difference	Signed rank-sum test
	Mean ± SD Median (IQR)	Mean ± SD Median (IQR)	Mean ± SD Median (IQR)	*P* value
T0 (incisal level)	14.01 ± 1.64 14.19 (13.93; 15.14)	14.42 ± 1.98 14.28 (13.84; 15.37)	-0.41 ± 2.00 -0.56 (-1.53; 0.99)	.47
T0 (medial level)	5.29 ± 1.70 5.37 (4.28; 6.00)	5.29 ± 1.85 5.29 (4.07; 6.92)	0.00 ± 1.47 -0.08 (-0.72; 1.10)	1.00
T0–T1 (incisal level)	3.34 ± 1.01 3.33 (2.68; 4.17)	2.74 ± 1.10 2.30 (1.99; 3.79)	0.60 ± 1.15 0.42 (-0.34; 1.52)	.11
T0–T1 (medial level)	2.56 ± 0.67 2.54 (1.95; 3.09)	2.27 ± 0.82 2.34 (1.76; 2.89)	0.29 ± 0.95 0.60 (-0.46; 1.09)	.31

T0, baseline measurements; T1, third month measurements; T0–T1, baseline to third month measurements; MOP, micro-osteoperforation; SD, standard deviation; IQR, interquartile range

A greater amount of canine retraction at the incisal level, compared to the medial level, was observed. This may be attributed to crown tipping or the degree of play of a 17x25 SS wire in a 0.022 slot (13). The movement at the medial level was more controlled since it was closer to the center of resistance; therefore, this measure was considered more reliable. Compared to previous studies using maxillary lateral incisors (10), ours used the second premolar as the reference tooth, which offered a more valid measure of canine retraction. Using the second premolar reduced the potential movement that occurs in the laterals during canine retraction.

Subgroup analyses were made for tooth-movement differences at the incisal and medial levels, by sex, age, malocclusion, and ANB. The canine retraction was not clinically or statistically significant at either level. No adverse effects were reported.

The RAP is a window for rapid orthodontic movement; it lasts approximately 3 months and gradually diminishes. To better analyze the RAP effect due to a corticotomy or MOP, a minimum of 3 months between premolar extractions and these interventions was established to allow bone healing around the extraction site (11). As stated by Amler et al., 100 days after a tooth is extracted, the formation of cancellous bone is complete (11). For this reason, the canine was retracted for 3 months to fully evaluate the effect of such interventions. Additionally, it was done this way to avoid round tripping of the canine since some patients could achieve a Class I canine relationship more quickly than others.

According to Alfawal et al.'s systematic review and meta-analysis, there is limited evidence about the effectiveness of minimally invasive surgically accelerated orthodontics (MISAO). Their review indicated that MISAO appeared to help in accelerating canine retraction significantly, at least in the first 2 months, but that further research was needed (14). The results of our study demonstrate the effectiveness of a less-invasive surgical procedure (MOP), enabling treatment to be completed in a shorter period.

The goal of minimally invasive medical procedures is to obtain the same results as those achieved with more invasive procedures and do so with fewer side effects and risks to health and less discomfort (15). Thus, any individual who requires orthodontic treatment will probably benefit from receiving treatment in a shorter time frame. Furthermore, MOP promotes faster healing, eliminates the need for a referral to another specialist, is easier and faster to perform, and is cost-effective (compared to a corticotomy).

Limitations

Studies with increased sample size and an extension of the period of evaluation of the canine retraction could provide significant data. However, it is important to note that the limitation of a 3-month follow-up evaluation in this study was a result of the unforeseen circumstances imposed by the pandemic. The global health crisis posed significant challenges, including restricted access to participants and limitations on clinical visits and data collection. As a result, the follow-up period had to be abbreviated to adhere to safety protocols and ensure the well-being of both patients and researchers.

While the study's limited follow-up time does restrict the depth of information that can be obtained, it remains important to report the available data in the literature. Despite this limitation, the findings of the study still provide valuable insights into the comparison between corticotomy procedures and micro-osteoperforations for canine tooth movement acceleration, and they serve as a starting point for further investigations and discussions. Nevertheless, during the established time frame, one of the patients achieved complete canine retraction.

Conversely, our study has several strengths. The split-mouth design is a vigorous study design that allowed us to control for person-level confounders. "The efficiency of this design is attractive, particularly in orthodontic clinical studies where carry-across, period effects, and dissimilarity between intervention sites does [sic] not pose a problem" (16). The benefit of using a split-mouth randomized controlled trial (RCT) design is that it requires a smaller sample size compared to a parallel-group RCT, because each patient acts as his/her own control, eliminating much of the inter-subject variability. All other factors being equal, parallel RCTs require approximately double the sample size that a split-mouth one does (16).

Additionally, the measurements were done by 2 calibrated examiners who were blinded to the side of the intervention. The intra- and inter-examiner reliability of the measurements was high, contributing to the internal validity of this study. However, measuring the mesial side of the premolar against the mesial of the first molar can be incorporated to rule out possible movement of the premolar into the extraction site.

Future studies with extraction and non-extraction groups of patients and with increased sample sizes are recommended to evaluate the effects of a corticotomy and MOP in both scenarios, ideally utilizing a split-mouth RCT design to eliminate person-level confounding effects and take advantage of statistical efficiency. Moreover, a sample of only adolescents could be analyzed independently from a sample of only adults to avoid age-related discrepancies in space closures.

Conclusions

Our research study demonstrates that the MOP (Micro-osteoperforations) intervention is equally effective as a corticotomy in expediting the rate of tooth movement and both treatment modalities exhibit comparable outcomes in promoting dental alignment. Additionally, it is noteworthy that neither intervention resulted in any serious adverse events, indicating their safety and overall suitability for clinical application.

The findings of this study have significant implications for orthodontic practice, as they provide valuable evidence supporting the adoption of MOP as a viable and safe alternative to corticotomy for accelerating tooth movement. Given the non-invasive nature of the MOP technique and its comparable efficacy, it presents an attractive option for both orthodontists and patients seeking faster treatment progress without compromising on safety.

This research adds to the existing body of knowledge in orthodontics and contributes to the ongoing efforts to improve treatment approaches and patient outcomes. The absence of serious adverse events further supports the favorable risk-benefit profile of both interventions, enhancing the confidence of orthodontic practitioners in employing these techniques to optimize patient care.

Resumen

Objetivo: Comparar la eficacia de las técnicas de micro-osteoperforación (MOP) y corticotomía en la retracción del canino maxilar. Métodos: Trece pacientes (5 mujeres, 8 hombres; edad media, 18.07 ± 6.74 años) con dentición permanente sana que requerían la extracción de los primeros premolares maxilares se incluyeron en un ensayo clínico aleatorizado de boca dividida. Se excluyeron sujetos con tratamiento previo de ortodoncia o endodoncia de caninos. Al menos 3 meses después de la extracción, se realizaron las intervenciones de MOP y corticotomías distales a los caninos. Para la retracción canina se utilizaron minitornillos con resortes cerrados (150 g). Los modelos de estudios dentales se obtuvieron al inicio (T0) y 3 meses después de la intervención (T1). Los examinadores calibrados midieron las distancias desde el canino hasta el segundo premolar maxilar en ambos lados. Se utilizó la prueba de suma de rangos para comparar la retracción canina lograda en 3 meses (T0-T1) en cada lado. Resultados: La retracción (mm) a nivel incisal fue similar entre las intervenciones de corticotomía (3.34±1.01) y MOP (2.74±1.10; P = 0.11); del mismo modo, no hubo diferencias a nivel de retracción medial entre corticotomía (2.56±0.67) y MOP (2.27±0.82; P = 0.31). No se observaron eventos adversos. Conclusión: No hubo diferencias clínicas o estadísticamente significativas en la retracción entre las intervenciones. MOP es tan eficaz como la corticotomía para acelerar la tasa de movimiento de los dientes luego de tres (3) meses.

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