Saudi Dental Journal (2020) 32, 15–20

King Saud University

Saudi Dental Journal

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Micro-osteo perforation effects as an intervention on canine retraction

Ibadullah Kundi [a,*], Mohammad Khursheed Alam [a], Sohrab Shaheed [b]

[a] College of Dentistry, Jouf University, Sakaka, Aljouf, Saudi Arabia
[b] Rehman College of Dentistry Hayatabad, Peshawar Pakistan

Received 10 March 2019; revised 13 May 2019; accepted 20 May 2019
Available online 28 May 2019

KEYWORDS

Flapless cortical perforations;
Canine retraction;
Tooth movement

Abstract *Objective:* To evaluate the rate of canine retraction, mesial movement of molar and pain perception in maxillary first premolar extraction patients with or without flapless cortical perforations (FCPs).

Methods: Thirty adult patients with class II div I malocclusion were randomly allocated with the help of SPSS software to either perforation or conventional group for carrying out this randomized parallel group-controlled trial in 1:1 ratio. Maxillary first premolars were extracted and after canine retraction, distance between the tip of the canine and midpoint of incisal edge and the distance between the cervical midpoints on the height of contour of respective cinguli was measured. Also, mesial movement of molar and pain perception were assessed in both groups. Three bilateral cortical FCP of 1.5 mm diameter were made in the perforation group. Data were analyzed with the help of SPSS software with an intention-to-treat the FCP approach.

Results: Significant canine retraction in patients with FCP (mean retraction of 6.68 ± 0.60 [measured at crown tip level] and 5.97 ± 0.71 mm [measured at mid cervical level]) was revealed, while patients with conventional mechanics had mean retraction of 2.54 ± 0.49 and 2.33 ± 0.46 mm. Mesial movement of molar also showed significant difference (FCP = 0.48 ± 0.11 mm and Conventional = 0.65 ± 0.19 mm). Pain perception in control group was significantly lower in day 1 and 2.

Conclusion: FCPs are an effective method of accelerating the rate of canine retractions by 2–3 fold of tooth movement, however, pain perception was high in day 1 and 2.
© 2019 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Increased duration of treatment is one of the major concerns of patients who need orthodontic treatment (Dibiase et al., 2011; Moresca, 2018; Attri et al., 2018). Infact, a huge number of orthodontic patients do not go ahead with orthodontic treatment due to length treatment time. (Mavreas and Athanasiou, 2008). That is why the concept of accelerated

* Corresponding author at: King Khalid Road, College of Dentistry, Sakaka, Aljouf, Saudi Arabia.
E-mail address: dr.ibadullah.kundi@jodent.org (I. Kundi).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sdentj.2019.05.009
1013-9052 © 2019 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

orthodontic treatment has always fascinated both the orthodontists and the patients.

Orthodontic tooth movement (OTM) is a complex process due to the interplay of multiple biologic and biomechanical factors such as periodontal status, duration and type of force application and regional cellular and molecular activity (Huang et al., 2014). Although careful diagnosis and a well-planned treatment sequence can reduce treatment duration, the biologic activity remains the main limiting factor of the rate of OTM (Mavreas and Athanasiou, 2008).

Many attempts of accelerating the OTM have been made in the past. These include increase in force magnitude and type, regional drug applications, vibratory forces, lasers, and light emitting diode, temporary anchorage devices, inciting regional osteopenia to accelerate the remodelling activity and flapless corticotomy procedure. (Addanki et al., 2017; Chung et al., 2015; Hoffmann et al., 2017; Liou et al., 2011; Kundi, 2018; Abdelhameed and Refai, 2018; Alkebsi et al., 2018; Cassetta et al., 2016; Cassetta et al., 2017).

Regional osteopenia can be induced in the anatomic region of interest in several ways. These can be classified as flap or flapless approaches, corticotomy, medullary osteotomy or both, and cortical incisions with use of burs or piezo instruments (Hoffmann et al., 2017; Liou et al., 2011; Alkebsi et al., 2018; Agrawal et al., 2019). Most of these procedures have produced promising results suggesting increase in rate of OTM from 1.5 to 3 times (Alikhani et al., 2013). However, many of these procedures require additional surgeries, substantial increase in costs and increased morbidity (Sangsuwon et al 2017).

Recently a more conservative approach has been proposed where a standardized needle gun (Propel) is used to induce micro-osteoperforations in the cortical alveolar bone without elevation of periodontal flap. The animal and human studies suggest that this approach may increase the rate of OTM 2–3 fold. It is a procedure based on sound bone biology principles that has been developed to address the growing demand for rapid orthodontic treatment, especially by adult patients. This is a safe, minimally invasive technique that can be used in conjunction with any orthodontic appliances, not only to accelerate tooth movement, but in many other clinical situations, namely to change the type of tooth movement or create differential anchorage (Alikhani et al., 2013; Sangsuwon et al., 2017).

The aim of our study was to evaluate the rate of canine retraction, mesial movement of molar and pain perception in maxillary first premolar extraction patients with or without flapless cortical perforations (FCPs).

2. Materials and methods

2.1. Trial design and any changes after trial commencement

This was a parallel group, randomized controlled trial with a 1:1 allocation ratio. No changes were made after the trial commencement.

2.2. Participants, eligibility criteria and setting (Fig. 1)

This study was carried out at College of Dentistry Jouf University. The duration of study was 16 months. The patients included were 16 females and 14 male patients with the mean age of 27.5 ± 4.4 and 28.4 ± 4.5 years for FCPs and conventional group respectively, Severe Class II div 1 malocclusion, maxillary bilateral premolar extractions indicated, moderate anchorage cases and good oral hygiene. The patients excluded were with high facial divergence (high angle case), previous orthodontic treatment, long-time use of drugs and systemic diseases. Informed consent was taken from the patients included in the study with a thorough explanation of benefits and limitations of the procedures involved.

2.3. Interventions

All patients began the treatment with bonding of upper and lower fixed appliances (0.022 in. slot MBT prescription 3 M Unitek) and banding of 1st molar in both arches and also 2nd molars in maxillary arch for anchorage re-inforcement. The extraction of the first premolars were carried out by a specialist (minimal traumatic extraction) 1 week prior to bonding. Canine retraction was started after 4–6 months of levelling and alignment in both groups by the principal investigator with the help of appropriate sequence of wires. Before starting the retraction of canines, an alginate impression of the dentition was taken for baseline record. For experimental group, local anaesthesia was administered before commencing FCP. Three FCPs were performed in the left and right side distal to the canines by a disposable MOP device (PROPEL Orthodontics, Ossining, NY) of 1.5 mm diameter. The depth of each perforation was 2.5 mm in the buccal cortical bone between canine and premolar. FCPs performed once only. The canine retraction was commenced in both groups with Nickle Titanium coil springs with a long range and low load–deflection rate with an approximate force of 100 g. All patients were recalled after 4 weeks for activation and alginate impression was repeated for data collection after complete canine retraction.

All dental cast were scanned by Cranex (SOREDEX, Tuusula, Finland) to obtain 3D digital model for the ease of precise measurements. All the measurements for 30 patients were performed by two researchers for reliability of the measurements using dedicated software (NewTom 3G: NNT, QR SRL; Scanora 3D: On Demand®, Cypermed Inc., Irvine, CA).

2.4. Rate of canine retraction

To evaluate the effect of FCP on the rate of tooth movement, experimental groups were compared with the control groups for the displacement of canine. Distance between the tip of the canine and midpoint of incisal edge of lateral incisor was denoted tip distance, while the distance between the cervical midpoints on the height of contour of respective cinguli was denoted as cervical distance.

2.5. Mesial movement of the molar

To study the mesial movement of the molar associated with retraction of canines, assessment was made as elaborated by Häsler (Häsler et al., 1997). X and y coordinates were made on 3D images of dental casts. Raphe line was used for y axis of the coordinate system which was made by using distinct points in anterior and posterior median part of the palate whereas x axis was made using mesial end of the most prominent palatal rugae (Fig. 2).

2.6. Pain associated with the movement

To study the pain associated with movement between experimental and control groups, numerical rating scale (NRS) was used (Bertl et al., 2012). An 11 point NRS was used to formulate a questionnaire to record the pain intensity associated with canine retraction, where 0 indicated "no pain" and 10 indicated "an intolerable pain". Questionnaires were given to all the patients to fill out at home and bring back on their next visit. Patients were told to record their pain intensity 4 h after the procedure and then after every 24 h for the next seven days. Reminders to fill the questionnaire were also given to the patients daily by phone calls. Patients were also discouraged to take analgesics, if taken in case of severe pain then they were advised to note it.

2.7. Statistical analyses

SPSS version 22.0 was used to record and analyze the data. To compare the difference in the rate of canine retraction and anchorage loss among experimental and control groups, independent *t* test was used. For the side disparities in the rate of canine retraction and mesial movement of molar were compared by paired *t* test. To compare the level of pain between experimental and control groups, non-parametric Kruskal Wallis test was applied. Inter class correlation (ICC) for 30 patients was performed for intra examiner reliability.

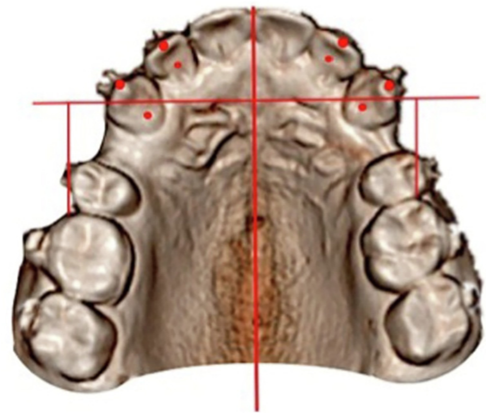

Fig. 2 Measurements of canine retraction and mesial movement of molar.

2.8. Sample size calculation

Sample size was calculated with the help of WHO software for Sample based on the following parameters.

Alpha error: 5%

Power of study: 90%

Minimum difference to detect: The sample was calculated to detect a 50% difference in the rate of canine retraction, which was considered to be clinically meaningful.

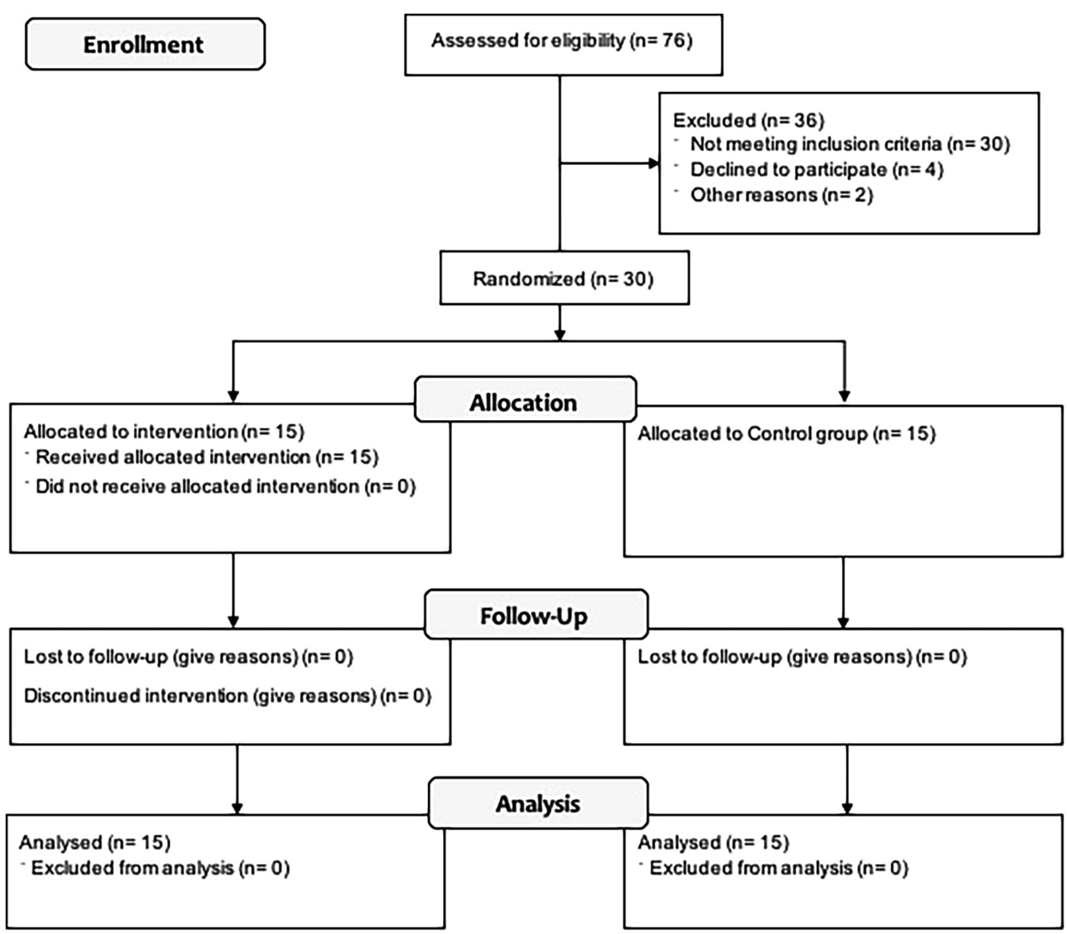

Fig. 1 Consort flow chart.

Population Standard Deviation: 0.3 mm (Alikhani et al., 2013).

2.9. Randomization (random number generation, allocation concealment, implementation)

The patients were randomly allocated by a sequence generated in SPSS with equal number of participants in each group, and the allocation was centrally concealed. Principal investigator assessed the patients for eligibility and discussed the nature of the trial with patients. After obtaining informed consent the patient started with the fixed appliances treatment. The allocation to experimental or control group was carried out when canine retraction was ready to be started.

2.10. Blinding

Blinding was carried out at the analysis stage as patient and operator blinding was not possible due to the nature of the procedure of perforation.

3. Results

60 canines in 30 patients of mean age 27.9 ± 4.5 years (age range 20–36 years) were followed after 4 weeks. There were no losses to follow up.

The ICC reliability coefficient value were ranged from 0.972 to 0.989.

3.1. Canine retraction

The data of all 15 cases for canine retraction are presented in Table 1. The average canine retraction in patients with conventional mechanics was 2.54 ± 0.49 and 2.33 ± 0.46 mm at the canine tip and cervical point respectively. In contrast, canines in patients with osteo-perforation had a mean retraction of 6.68 ± 0.60 mm at the tip and 5.97 ± 0.71 mm at the cervical point showing some degree of tipping (Table 2).

Independent sample *t*-test demonstrated highly significant difference between the two groups ($p < 0.001$). There were no significant differences between right and left sides in both groups.

Canine retraction in experimental group were completed after 4 to 5 months of activation.

3.2. Anchorage loss

The data of all 15 cases for molar movement are presented in Table 1. There was no significant difference in the mesial movement of molars among experimental and control group (Table 2). The mean molar movement on the experimental group was 0.48 (0.11) mm whereas the mean value for molar movement on the control group was 0.66 (0.19) mm.

3.3. Assessment of pain

Maximum pain intensity was reported on first day after the activation of force at the canine retraction stage of treatment (Fig. 3). Experimental group subject reported more pain on first and second day (5 ± 0.87 and 4.16 ± 0.59 respectively), while the intensity reported by control group on first and second day (3.56 ± 0.85 and 3.16 ± 0.46 respectively) were less.

There was significant difference found in the perception of pain among experimental and control group on the first and second day however, the difference was insignificant during rest of the week.

3.4. Harms

No serious harm except pain and minor bleeding in the perforation area. No medications for the pain were necessary.

4. Discussion

Acceleration of orthodontic tooth movement is of interest to clinicians as it has the potential to reduce the orthodontic treatment duration. Although there are several factors which affect this duration, the biologic process of tooth movements is a major factor which has captured attention in the recent past.

Transient localized osteopenia has shown to be effective in increasing the bone turnover which can in turn increase the rate of orthodontic tooth movement. Several methods of inducing such osteopenia have been advocated and range from osteotomies to small flapless alveolar perforations. This indicates the underlying desire to identify ways of reducing trauma to the patient during this procedure. Micro-osteo-perforation (MOP) has the advantage of being minimally invasive, easy to perform and relatively comfortable for the patient. This trial compared the effect of micro-osteo perforations on the rate of the canine movement.

We found significantly higher rate of canine retraction in the perforation group, highlighting the effectiveness of the procedure. This is in agreement with the only available human trial conducted with this technique by Alikhani et al who found 2–3-fold increase in the rate of tooth movement with MOPs in their split mouth design trial (Alikhani et al., 2013). The same group initially experimented this technique in rats and found it effective in enhancing the rate of tooth movement (Teixeira et al., 2010). Recently, Tsai et al also reported increased rate of tooth movement with MOPs in rats (Tsai et al., 2016).

Based on literature search, for the first time, mesial movement of molar in relation to FCPs were investigated in this study. We found significant difference among experimental and control group in relation to the mesial movement of molar. We cannot compare our results with other studies as such measurements yet to be done.

Pain perception caused by MOPs were altered from the control group in day 1 and 2; this indicates that this procedure can have some distress for the patient. These results are different in comparison with Alikhani et al (Alikhani et al., 2013).

The increase in the rate of tooth movement can be explained by the process of regional acceleratory phenomenon (RAP), originally described by Frost (Chackartchi et al., 2017). The osteopenia induced by perforations leads to a zone of increased remodelling activity, which essentially leads to faster tooth movement than normal (Chackartchi et al., 2017; Chan et al., 2018).

Several factors affect the rate of tooth movement (Abdelhameed and Refai, 2018; Elkattan et al., 2019; Patterson et al.,2016:Makrygiannakis et al., 2018; Jiang et al., 2017; Jahanbakhshi et al., 2016). It is reasonable to

Table 1 Canine movement at tip and cervical landmarks and mesial movement of molars for all 15 cases.

Case No	Experimental group						Conventional group					
	Canine retraction				Molar movement		Canine retraction				Molar movement	
	Right		Left		Right	Left	Right		Left		Right	Left
	Tip	Cervical	Tip	Cervical			Tip	Cervical	Tip	Cervical		
1	6.27	6.14	6.71	5.71	0.55	0.38	2.69	2.19	1.79	2.19	0.59	0.67
2	6.27	5.71	6.27	5.71	0.59	0.46	2.00	1.96	2.40	2.44	0.60	0.64
3	6.71	4.83	6.27	5.27	0.51	0.38	2.00	2.44	2.40	2.41	0.48	0.56
4	7.16	6.58	6.27	5.71	0.55	0.29	1.96	2.89	2.45	1.93	0.54	0.49
5	6.71	5.71	6.71	5.27	0.25	0.63	1.96	1.93	2.94	1.93	0.74	0.69
6	6.27	5.71	7.61	5.71	0.51	0.38	2.94	2.41	2.45	1.44	0.05	0.54
7	8.06	5.71	6.00	6.74	0.55	0.35	1.96	1.44	1.91	1.92	0.44	0.69
8	6.40	5.78	5.60	7.22	0.39	0.56	2.39	1.92	2.39	2.39	0.59	0.44
9	6.00	6.74	5.60	6.26	0.35	0.61	2.39	2.54	2.39	1.80	0.83	0.65
10	6.88	7.38	7.31	7.38	0.48	0.44	2.39	2.99	2.99	2.40	0.95	0.83
11	6.71	5.27	7.16	6.58	0.38	0.38	1.79	1.80	2.39	2.99	0.95	0.77
12	6.27	5.71	6.71	6.14	0.59	0.63	2.99	2.99	2.99	2.40	1.00	0.53
13	7.16	4.39	7.61	6.14	0.46	0.59	3.59	2.99	2.99	2.99	0.83	0.77
14	7.61	6.58	7.16	6.14	0.46	0.63	2.99	2.40	2.99	2.99	0.89	0.83
15	6.71	5.71	6.27	5.27	0.59	0.46	3.59	2.40	2.99	2.40	0.65	0.53

All the measurements are in mm (millimetre).

Table 2 Canine movement at tip and cervical landmarks and mesial movement of molar.

Group	Distances (mm)	Mean	S.D.	95% CI		p value
				Lower	Upper	
Perforation	Tip	6.68	0.60	3.85	4.43	> 0.001***
Conventional		2.54	0.49			
Perforation	Cervical	5.97	0. 71	3.33	3.95	> 0.001***
Conventional		2.33	0.46			
Perforation	Mesial movement of Molar	0.48	0.11	−0.26	−0.09	> 0.001***
Conventional		0.66	0.19			

SD: Standard Deviation, CI: Confidence interval. p < 0.001 = ***.

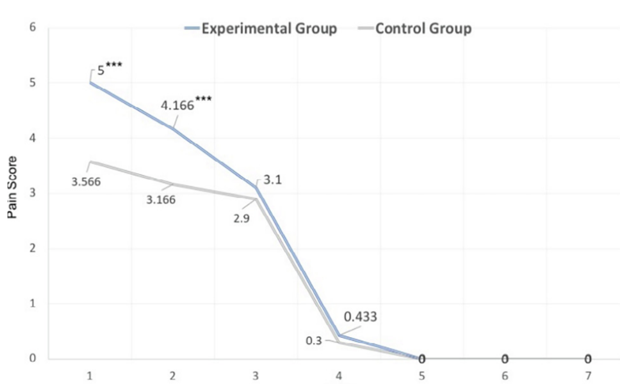

Fig. 3 Pain perception on experimental and control group.

assume that the effect of occlusal interferences was minimal in this study as only class II div I malocclusion cases were included. Similarly, the use of rectangular wires with steel ligatures ensured primarily bodily movement, evident by minimal tipping during the retraction. Age of the patients was well balanced in both groups. Hence age and type to tooth movement are also unlikely to have confounded the results. We found no differences in the rate of retraction on right and left sides, or between males or females. This is also in agreement with previous studies (Patterson et al., 2016).

In comparison to Alikhani et al, there were some notable differences in the study design in our trial. They used miniscrew anchorage for the retraction of canine, while we used compound anchorage, which involved inclusion of second molar in the anchorage segment. However, this is unlikely to be of significance. The perforations were made bilateral, as it was shown by Alikhani et al that the localized regional acceleratory phenomenon (RAP) did not carry across to the contra-lateral side (Alikhani et al., 2013).

The generalizability of these results can be considered good, as all the procedures were performed in a hospital based orthodontic setting and all the patients were adults. Our study evaluated complete canine retraction in experimental group. Blinding of the patient and operator was not feasible and blinding was confined to analysis stage only. Future studies with longer observation time (to compare duration differences between 2 groups), number of perforations and inclusion of variables such as pulp vitality and root resorption are recommended.

5. Conclusion

Flapless Cortical Perforations with orthodontic miniscrew is an easy, safe and effective method of accelerating orthodontic tooth movement by 2–3 times. However, care must be taken to minimize the pain perception.

Conflict of interest

The authors have no conflicts of interest regarding this work.

Ethical statement

There were no ethical issues with the data collection.

References

Abdelhameed, A.N., Refai, W.M.M., 2018. Evaluation of the effect of combined low energy laser application and micro-osteoperforations versus the effect of application of each technique separately on the rate of orthodontic tooth movement. Maced. J. Med. Sci. 6 (11), 2180–2185.

Addanki, P., Gooty, J.R., Palaparthy, R., 2017. Clinical and radiographic comparative evaluation of buccal and palatal corticotomy with buccal corticotomy in periodontally accelerated osteogenic orthodontics with surgical bur. Contemp. Clin. Dent. 8, 321–326.

Agrawal, A.A., Kolte, A.P., Kolte, R.A., Vaswani, V., Shenoy, U., Rathi, P., 2019. Comparative CBCT analysis of the changes in buccal bone morphology after corticotomy and micro-osteoperforations assisted orthodontic treatment – Case series with a split mouth design. Saudi Dent. J. 31 (1), 58–65.

Alikhani, M., Raptis, M., Zoldan, B., 2013. Effect of micro-osteoperforations on the rate of tooth movement. Am. J. Orthod. Dentofacial Orthop. 144 (5), 639–648.

Alkebsi, A1., Al-Maaitah, E., Al-Shorman, H., Abu Alhaija, E., 2018. Three-dimensional assessment of the effect of micro-osteoperforations on the rate of tooth movement during canine retraction in adults with Class II malocclusion: A randomized controlled clinical trial. Am. J. Orthod. Dentofacial Orthop. 153 (6), 771–785.

Attri, S., Mittal, R., Batra, P., Sona, R.S., Sharma, K., Raghavan, S., Rai, K.S., 2018. Comparison of rate of tooth movement and pain perception during accelerated tooth movement associated with conventional fixed appliances with micro-osteoperforations - a randomised controlled trial. J. Orthod. 45 (4), 225–233.

Bertl, M.H., Onodera, K., Celar, A.G., 2012. A prospective randomized split-mouth study on pain experience during chairside archwire manipulation in self-ligating and conventional brackets. Angle Orthod. 83 (2), 292–297.

Cassetta, M., Altieri, F., Pandolfi, S., Giansanti, M., 2017. The combined use of computer guided, minimally invasive, flapless corticotomy and clear aligners as a novel approach to moderate crowding: a case report. Kor. J. Orthod. 47 (2), 130–141.

Cassetta, M., Giansanti, M., Di Mambro, A., Calasso, S., Barbato, E., 2016. Minimally invasive corticotomy in orthodontics using a three-dimensional printed CAD/CAM surgical guide. Int. J. Oral. Maxillofac. Surg. 45 (9), 1059–1064.

Chackartchi, T., Barkana, I., Klinger, A., 2017. Alveolar bone morphology following periodontally accelerated osteogenic orthodontics: a clinical and radiographic analysis. Int. J. Periodontics Restorative Dent. 37, 203–208.

Chan, E., Dalci, O., Petocz, P., Papadopoulou, A.K., Darendeliler, M. A., 2018. Physical properties of root cementum: Part 26. Effects of micro-osteoperforations on orthodontic root resorption: A micro-computed tomography study. Am. J. Orthod. Dentofacial Orthop. 153 (2), 204–213.

Chung, S.E., Tompson, B., Gong, S.G., 2015. The effect of light emitting diode phototherapy on rate of orthodontic tooth movement: a split mouth, controlled clinical trial. J. Orthod. 42 (4), 274–283.

DiBiase, A.T., Nasr, I.H., Scott, P., Cobourne, M.T., 2011. Duration of treatment and occlusal outcome using Damon 3 self-ligated and conventional orthodontic bracket systems in extraction patients: a prospective randomized clinical trial. Am. J. Orthod. Dentofacial Orthop. 139 (2), e111–e116.

Elkattan, A.E., Gheith, M., Fayed, M.S., Yazeed, M.A.E., Farrag, A. H., Khalil, W.K.B., 2019. Effects of different parameters of diode laser on acceleration of orthodontic tooth movement and its effect on relapse: an experimental animal study. Maced. J. Med. Sci. 7 (3), 412–420.

Häsler, R., Schmid, G., Ingervall, B., Gebauer, U., 1997. A clinical comparison of the rate of maxillary canine retraction into healed and recent extraction sites—a pilot study. Eur. J. Orthod. 19 (6), 711–719.

Hoffmann, S., Papadopoulos, N., Visel, D., Visel, T., Jost-Brinkmann, P.G., Präger, T.M., 2017. Influence of piezotomy and osteoperforation of the alveolar process on the rate of orthodontic tooth movement: a systematic review. J. Orofac. Orthop. 78 (4), 301–311.

Huang, H., Williams, R.C., Kyrkanides, S., 2014. Accelerated orthodontic tooth movement: molecular mechanisms. Am. J. Orthod. Dentofacial Orthop. 146 (5), 620–632.

Jahanbakhshi, M.R., Motamedi, A.M., Feizbakhsh, M., Mogharehabed, A., 2016. The effect of buccal corticotomy on accelerating orthodontic tooth movement of maxillary canine. Dent. Res. J.13, 303–308.

Jiang, F., Chen, J., Kula, K., Gu, H., Du, Y., Eckert, G., 2017. Root resorptions associated with canine retraction treatment. Am. J. Orthod. Dentofacial Orthop. 152, 348–354.

Kundi, I., 2018. Flapless retraction of Canine. A randomised controlled trial. Int. Med. J. 25 (2), 16–118.

Liou, E.J., Chen, P.H., Wang, Y.C., et al, 2011. Surgery-first accelerated orthognathic surgery: orthodontic guidelines and setup for model surgery. J. Oral Maxillofac. Surg. 69 (3), 771–780.

Makrygiannakis, M.A., Kaklamanos, E.G., Athanasiou, A.E., 2018. Does common prescription medication affect the rate of orthodontic tooth movement? A systematic review. Eur. J. Orthod. 40 (6), 649–659.

Mavreas, D., Athanasiou, A.E., 2008. Factors affecting the duration of orthodontic treatment: a systematic review. Eur. J. Orthod. 30 (4), 386–395.

Moresca, R., 2018. Orthodontic treatment time: can it be shortened? Dental Press J. Orthod. 23 (6), 90–105.

Patterson, B.M., Dalci, O., Darendeliler, M.A., Papadopoulou, A.K., 2016. Corticotomies and orthodontic tooth movement: a systematic review. J. Oral Maxillofac. Surg. 74 (3), 453–473.

Sangsuwon, C., Alansari, S., Lee, Y.B., Nervina, J., Alikhani, M., 2017. Step-by-Step Guide for Performing Micro-osteoperforations. Springer International Publishing AG, Switzerland, pp. 99–116.

Teixeira, C.C., Khoo, E., Tran, J., et al, 2010. Cytokine expression and accelerated tooth movement. J. Dent. Res. 89 (10), 1135–1141.

Tsai, C.Y., Yang, T.K., Hsieh, H.Y., Yang, L.Y., 2016. Comparison of the effects of micro-osteoperforation and corticision on the rate of orthodontic tooth movement in rats. Angle Orthod. 86 (4), 558–564.