Effect of Timing of Third Molar Extraction on the Rate of Mandibular En Masse Distalization Using Buccal Shelf Implants – A Randomized Controlled Trial

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KEYWORDS

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ABSTRACT

This randomized controlled trial evaluates the impact of the timing of third molar extractions on the rate of mandibular en masse distalization and second molar angulation in orthodontic treatment, using buccal shelf implants in borderline Class III malocclusion patients. Late third molar extractions performed less than two weeks before distalization were compared to early extractions, performed six months prior, to investigate the effect of Regional Acceleratory Phenomenon (RAP) on tooth movement. The study also assessed second molar angulation changes, examining distal tipping differences between groups. Results showed a significantly faster rate of distalization in Group II (late extraction) at 0.637 ± 0.098 mm/month, compared to Group I (early extraction) at 0.422 ± 0.075 mm/month. Additionally, Group I experienced significantly greater second molar distal tipping (9.14°) than Group II (3.47°). These findings suggest that the timing of third molar extractions affects both distalization rates and second molar angulation, with early extraction offering a clinical advantage by leveraging RAP and minimizing undesirable tipping.

1. Introduction

Orthodontic management of borderline Class III malocclusion presents significant challenges, often requiring comprehensive treatment plans to balance the discrepancy between the maxillary and mandibular arches. A frequently employed treatment modality in such cases is mandibular en masse distalization, a technique aimed at moving the entire lower dental arch backward to correct the malocclusion.(1) In these cases, the extraction of third molars is a common procedure to create the necessary space for distalization.(2) However, the timing of third molar extractions remains a subject of clinical debate, as the potential impact of extraction timing on the efficiency and speed of tooth movement has not been extensively studied.

One potential biological mechanism that may influence the rate of tooth movement following extraction is the Regional Acceleratory Phenomenon (RAP), a concept first introduced by Frost in 1983.(3) RAP refers to a localized increase in bone remodelling activity in response to surgical trauma or injury, such as tooth extraction. This phenomenon results in a transient period during which the bone becomes more pliable and responds more readily to mechanical forces, such as those applied during orthodontic treatment.(4) RAP is known to peak within 1–2 weeks after surgical intervention, gradually subsiding over 3–4 months.(5) Given this time frame, performing third molar extractions immediately before initiating distalization could theoretically result in faster and more efficient tooth movement by capitalizing on the peak of RAP.(6)

There is growing interest in whether late premolar extractions, performed within a short period before canine retraction, can enhance the rate of tooth movement compared to early extractions, performed several months prior retraction.(7-9) Extractions performed within a short period before retraction, can enhance the rate of tooth movement compared to early extractions, performed several months prior to treatment.(10,11) Late extraction may trigger the RAP at the optimal time to facilitate tooth movement, while early extraction may result in the effects of RAP having diminished by the time distalization is initiated. Previous studies have suggested that RAP can accelerate tooth movement by enhancing bone remodeling, but direct comparisons of early versus late extractions in the context of mandibular en masse distalization remain sparse.(12)

Starting the process of retraction in an extraction site sooner is thought to lead to faster tooth movement. The presence of only a thin interdental septum separating the thin connective tissue and the tooth helps in rapid movement of the teeth.(13,14) The faster rate of space closure may be due to the less calcified bone around the recent extraction socket when compared to the healed extraction site.(10,15) In addition to influencing the rate of tooth movement, the angulation of the second molars during distalization is another critical factor. Second molar distal tipping is an undesired outcome of en masse distalization, where molar crowns tip backward rather than maintaining a more controlled bodily movement. Excessive tipping can negatively affect occlusion and may complicate the treatment, leading to the need for additional corrective measures. The decreased bone resistance maybe another factor for facilitating bodily tooth movement rather than tipping.(16,17)

This randomized controlled trial aims to compare the rate of mandibular en masse distalization as well as second molar angulation changes between early third molar extractions (performed six months before distalization) and late extractions (performed less than 2 weeks before distalization) using buccal shelf implants. We hypothesize that late extractions will lead to faster and more efficient distalization with decreased distal tipping by exploiting the peak period of RAP and decreased bone resistance. The results of this study could provide valuable insights into the optimal timing of third molar extractions in orthodontic treatments involving en masse distalization.

2. Methodology

Study Setting

This is a single centered randomized controlled trial conducted in Chennai, India between March 2023 to April 2024. The study was conducted on patients who had a borderline Class Ill malocclusion (ANB up to -3 degrees or reverse overjet of 1-3 mm) reporting to the Department of Orthodontics and Dentofacial Orthopaedics, Saveetha Institute of Medical and Technical Sciences, Chennai, India, with their consent. Ethical approval for the study was obtained from the Institutional Scientific Review Board and Institutuional Human Ethical Committee, and all participants were provided with written informed consent prior to enrollment. The trial has been registered with CTRI and the registration number for the same is CTRI/2024/04/065925. This randomized controlled trial was conducted over an average period of 9 ± 2.48 months for the duration of lower en masse distalization to a Class l relationship, and the sample included patients for whom lower thirds molars were extracted and for whom buccal shelf implants were placed for lower molar distalization. The study was designed to assess the effect of third molar extraction timing on the rate of mandibular en masse distalization using buccal shelf implants in patients with borderline Class III malocclusion.

Sample Size

Sample size was calculated based on the statistical evaluation of a previous study Zubair et al. using G-Power software.(11) A total of 12 patients (n = 6/group) were recruited. An additional sample of 2 patients (n = 7/group) was added to compensate for any patients who were lost due to follow-up.

Method of Patient Selection

The screening and selection of the patients was done by a single observer (NS) strictly adhering to the inclusion and exclusion criteria in order to ensure the homogeneity of the study sample.

Inclusion Criteria

1. Patients with permanent dentition and between the age group of 18-25 years.
2. Patients with borderline Class III skeletal and dental malocclusion (ANB between 0 to -3 degrees on lateral cephalograms with negative overjet of 1-3mm) requiring orthodontic camouflage treatment.
3. Patients who required lower third molar extractions as part of their treatment plan.

4. Patients who required mandibular en masse distalization using buccal shelf implants.
5. Good general health, with full complement of non-carious permanent teeth with no contraindications for dental surgery.

Exclusion Criteria

1. Patients with mixed dentition and below 18 years of age for whom adequate bone density would not have been established.
2. Patients with systemic conditions or diseases that could affect bone metabolism or healing, such as osteoporosis, diabetes, or autoimmune disorders.
3. Patients with a history of orthodontic treatment, as previous tooth movement could affect the outcome.
4. Patients with a history of trauma or surgery in the mandibular region within the past year.
5. Patients with Class l and ll skeletal and dental relationships
6. Patients with facial asymmetry or asymmetrical arches
7. Patient with missing teeth or abnormal tooth morphology
8. Patients with functional deviations on occlusion
9. Physically or mentally handicapped patients

Randomization and Group Assignment

The 12 subjects were randomly assigned to one of two groups based on the timing of their third molar extractions. Group I (Early extraction) included patients who underwent third molar extraction six months prior to the start of distalization (n = 7). Group II (Late extraction) included patients who underwent third molar extraction less than two weeks before the start of distalization (n = 7).

Randomization was performed using a hidden opaque envelope filled with computer-generated numbers prior to the start of orthodontic treatment. The patients received comprehensive explanations about the purpose of the study, the treatments given, the follow-up schedule, the advantages, and any possible risks. The patients were made aware that they were free to withdraw themselves from the study without any consequence to the necessary course of the treatment. The "CONSORT" guidelines were followed at every stage of the clinical trial.

Buccal Shelf Implant Placement and Distalization Protocol

Buccal shelf implants were used as anchorage to facilitate mandibular en masse distalization in both groups. The buccal shelf region provides an optimal site for implant placement due to its dense cortical bone and favorable anatomical location for applying distalizing forces. The following steps were followed for all participants:

1. Implant Placement: Two 2x12mm titanium self drilling implants were manually placed bilaterally perpendicular to the buccal shelf area using a minimally invasive surgical technique. Care was taken to ensure proper positioning and angulation of the implants to maximize stability and anchorage during distalization. All implants were placed by the same operator to prevent operator bias.
2. En Masse Distalization: Levelling and aligning was done until 0.019 x 0.025-inch stainless steel wire followed by en masse distalization on the same archwire. Power arms of height 7-8 mm were attached to the archwires distal to the lateral incisors in the lower arch. Power chains were

attached from the buccal shelf implants to the power arms delivering forces up to 450 grams on either side measured using a dontrix gauge.

3. Outcomes Measurement: Patients were reviewed every 45 days to assess the distalization and for engaging new power chains. CBCT (Cone Beam Computed Tomography) were taken prior to start of distalization (T0) and post distalization (T1) for each subject was taken using the Carestream 9600, KODAK CS imaging 8.0.18. The CBCT was standardized with an FOV of 8/5mm, tube current of 4mA, peak voltage of 120 kVp, exposure time of 15 seconds with a radiation dosage of 496 mGy.cm2. Using the canthomeatal orientation line, which was projected by an integrated LED light, all participants were placed in a natural head position with their lips relaxed and their teeth in centric occlusion. Dolphin software was used to conduct the CBCT analysis.

CBCT Measurements

Two standard reference planes were established. The Sella-Nasion (SN) plane was used as the horizontal reference plane. A vertical plane was constructed perpendicular to the SN plane, passing through the posterior nasal spine (PNS).

Midline hard tissue structures that are stable and dependable for precise replication and visibility through all CBCT slices were selected as landmarks for the reference planes. Each landmark used for measurement was precisely marked and identified using the Dolphin Software's 3D Points feature. Every measured parameter and landmark was confirmed in the sagittal, coronal, and axial planes.

The horizontal distance between the mesiobuccal cusp tips of the both right and left mandibular second molars and the constructed vertical plane was measured on the pre- and post-distalization CBCT scans (Figure 1). The rate of distalization was calculated by dividing the total horizontal movement by the number of months of the observation period.

The angles formed by the long axis of the tooth; a line bisecting the pulp chamber of the teeth and the constructed vertical plane were used to measure the axial inclination of the second molars (Figure 1). A mean of both the right and left sides was calculated. The difference in angulation between pre distalization and post distalization values was evaluated for the mandibular second molars and compared between both groups.

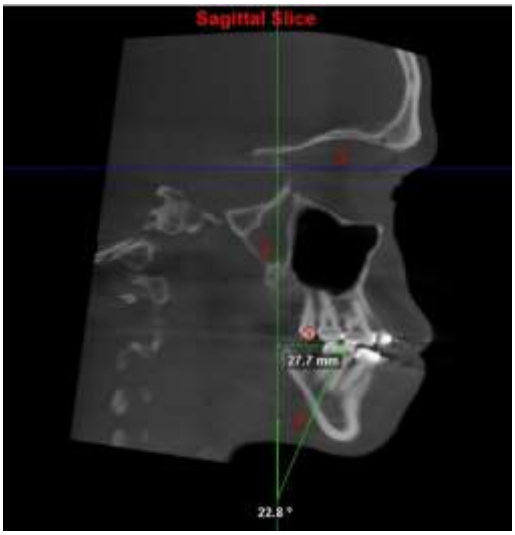

Figure 1: Measurement parameters

1) Horizontal reference plane 2) Vertical reference plane 3) The horizontal distance 4) Angulation

Outcome Measures

The primary outcome measure was the rate of distalization (mm/month) in both groups. The secondary outcome measure was the angulation changes of the second molar axial inclination to differentiate between bodily movement and tipping.

Statistical Analysis

Data were analyzed using SPSS (version 25.0). Descriptive statistics were used to summarize the demographic characteristics of the participants. The data was found to be non-parametrically distributed by the Kolmogorov-Smirnov test results. Consequently, the Mann-Whitney test was employed for intergroup comparison of the second molar angulation and the Wilcoxon signed rank test was used to compare the second molar angulation within each group between the pre- and post-distalization time points. An independent sample t-test was employed to compare the rates of distalization between the two groups. Statistical significance was set at $p < 0.05$. A sample size of 14 participants was deemed adequate to detect significant differences in the rate of distalization between the two groups, with a statistical power of 80%. All the measurements were repeated by the same examiner, and Kappa statistics were done to assess the intra observer error.

3. Result and Discussion

Demographic Characteristics

The demographic characteristics of the participants, including age, gender, and growth pattern, were comparable between the two groups, with no statistically significant differences observed ($p > 0.05$).

Rate of Distalization

The mean rate of distalization in Group I (Early extraction) was 0.422 ± 0.075 mm/month, while the mean rate of distalization in Group II (Late extraction) was significantly higher at 0.637 ± 0.098 mm/month. Statistical analysis using an independent sample t-test revealed a significant difference in the rate of distalization between the two groups ($p = 0.043$). Table 1 presents a summary of the distalization rates for both groups.

Table 1: Rate of distalization of mandibular second molars

Group	N	Mean (mm/month)	Std. Deviation	t	P value
Group I	7	0.422	0.075	-8.245	0.043
Group II	7	0.637	0.098		

The results indicate that late extraction of the third molars, performed less than two weeks before the start of distalization, led to a significantly higher rate of tooth movement compared to early extraction, which was performed six months before distalization.

Change in mandibular second molar angulation

A significant difference is seen in the intragroup comparison of second molar angulation changes between pre and post distalization in both groups ($p < 0.001$, $p < 0.05$). Group l (Early extraction) experienced greater molar distal tipping (9.14 degrees) compared to Group ll (Late extraction) (3.47 degrees). The inter-group comparison shows a statistically significant difference between the two groups ($p = 0.005$), highlighting that late extraction may lead to more pronounced second molar tipping during distalization (Table 2).

Table 2: Change in mandibular second molar angulation

Group	Mean of difference (degrees)	Std. deviation	95% CI lower bound	95% CI upper bound	Intra-group pre-post comparison *p* value	Inter group comparison *p* value

I	9.1400	3.15007	2.4271872	3.8528128	<0.001*	0.005*
II	3.4700	2.16027	4.1310456	6.8089544	<0.05*	

Discussion

The results of this study provide novel evidence supporting the hypothesis that the timing of third molar extraction plays a critical role in determining the rate of mandibular en masse distalization and second molar angulation during distalization. The findings of this randomized controlled trial demonstrate that late extraction of third molars, performed less than two weeks before the initiation of distalization, significantly accelerates tooth movement with reduced second molar distal tipping suggesting better control of tooth movement during distalization.

As hypothesized, the early extraction group (Group II) exhibited a significantly faster rate of distalization compared to the late extraction group (Group I). This is in accordance to several studies comparing canine retraction into healed and recently extracted sockets.(7-11) Excessive distal tipping of the second molars is an undesired effect of en masse distalization and can complicate treatment by altering the occlusal plane and requiring additional correction.(18) In this study, Group I (late extraction) exhibited significantly greater distal tipping of the second molars (9.14°) compared to Group II (early extraction) (3.47°). This difference suggests that late extraction, performed close to the start of distalization, helps bodily movement of the teeth more effectively.

The key mechanism underlying this difference is the RAP, a biological response to surgical trauma that results in increased bone remodeling activity.(5) The RAP is characterized by an initial inflammatory response, followed by enhanced osteoclastic and osteoblastic activity, which leads to temporary bone resorption and formation.(19) During this period, the alveolar bone becomes more malleable and responsive to orthodontic forces, facilitating faster tooth movement.(19,20)

In Group II (late extraction), the third molar extraction was timed to coincide with the peak period of RAP, which occurs within 1-2 weeks after surgery. This allowed the orthodontic forces applied during distalization to take full advantage of the enhanced bone remodeling activity, resulting in a significantly higher rate of distalization. In contrast, in Group I (late extraction), the effects of RAP had diminished by the time distalization began, leading to a slower rate of tooth movement.

These findings are consistent with previous studies that have explored the effects of RAP on orthodontic tooth movement. Several studies have demonstrated that surgical interventions, such as corticotomies or extractions, can accelerate tooth movement by enhancing bone remodeling through the activation of RAP.(20-23) However, this study is one of the first to directly compare the effects of early versus late third molar extractions on the rate of lower en masse distalization using buccal shelf implants.

Typically, the removal of a tooth results in bone resorption, causing a decrease in alveolar bone volume.(24) Atrophy of the alveolar ridge is prone to happen in the healed extraction socket, potentially impeding tooth movement through the defect.(19) Moving teeth into a newly extracted socket is one recommended way to improve the efficiency of space closure.(25)

An examination of how human alveolar socket healing progresses in undisturbed extraction wounds revealed that the extraction site heals quickly. Within 38 days after extraction, approximately two-thirds of the alveolar socket is filled with bony trabeculae, starting from the base.(26) The rapid bone formation peaked around 100 days after extraction, leading to greater radio-opacity on the radiograph. At this stage, the radiodensity of the bone at the extracted socket was identical to the normal bone in neighbouring alveolar processes, making it impossible to distinguish between them.

A different histological examination compared the benefits of moving teeth early after extraction to delaying, finding low bone density and mature lamellar bone at delayed tooth movement sites.(27) In contrast, immature bundle bone is seen in the area around the early tooth movement.(27) As a result, starting orthodontic treatment soon after tooth extraction is recommended based on these histological results.

There exists an anterior and posterior anatomical limit beyond which orthodontic tooth movement cannot be achieved. The posterior limit of the mandible was assumed to be the anterior border of the ramus.(28,29) The anterior border of the ramus serves as the posterior limit for molar crowns. However, the alveolar bone housing consisting of the buccal and lingual cortices of the mandibular body determine the extent of movement of the roots of the posterior teeth.(30) It was observed that the available distance along the AOD showed decreasing trends from hypodivergent to normodivergent to hyperdivergent groups in the Class III patients.(31) The available area at the limit was more in Class ll maxilla than Class lll mandible.(32) These anatomical boundaries can directly affect the feasibility, efficiency, and safety of distalization efforts, particularly in cases where significant movement is required to correct malocclusion. In this context of third molar extractions, the posterior limit becomes particularly relevant because the removal of the third molar creates additional space, allowing for greater movement of the mandibular second molars and the entire posterior dental arch.(33)

The results of this study have important clinical implications for the timing of third molar extractions in orthodontic treatment. Orthodontists should consider performing third molar extractions shortly before initiating distalization to take full advantage of the RAP and achieve faster and more efficient tooth movement. This approach could reduce the overall treatment time for patients undergoing en masse distalization and improve treatment outcomes. The findings of this study suggest that orthodontists can optimize treatment outcomes by timing third molar extractions to coincide with the peak period of RAP, thereby enhancing the efficiency of distalization.

Limitations of this study include small small size, limited focus on bone density and remodelling, exclusion of upper arch movements and lack of evaluation of post treatment stability. The focus was on borderline Class lll maloclussions, which make it difficult to generalize the findings to patients with other malocclusions. Future studies should focus on larger sample sizes and explore different surgical techniques and RAP timing protocols to further refine treatment strategies. Additionally, longer follow-up periods are needed to assess the long-term stability of the treatment outcomes achieved through early third molar extractions.

4. Conclusion and future scope

This randomized controlled trial demonstrates that the timing of third molar extraction significantly impacts both the rate of mandibular en masse distalization and the second molar angulation using buccal shelf implants. Late extractions, performed less than two weeks before distalization, resulted in significantly faster tooth movement compared to early extractions performed six months prior. The enhanced rate of distalization in the late extraction group can be attributed to the activation of the RAP, which facilitates bone remodeling and makes the alveolar bone more responsive to orthodontic forces during its peak phase as well as the decreased bone resistance due to the presence of only a thin interdental septum.

Reference

[1] Biomechanical considerations for total distalization of the mandibular dentition in the treatment of Class III malocclusion. Semin Orthod [Internet]. 2020 Sep 1 [cited 2024 Sep 25];26(3):148–56. Available from: http://dx.doi.org/10.1053/j.sodo.2020.06.012

[2] Hisano M, Chung CRJ, Soma K. Nonsurgical correction of skeletal Class III malocclusion with lateral shift in an adult.

Am J Orthod Dentofacial Orthop [Internet]. 2007 Jun;131(6):797–804. Available from: http://dx.doi.org/10.1016/j.ajodo.2005.06.034

[3] Frost HM. The Regional Acceleratory Phenomenon: A Review. Henry Ford Hosp Med J [Internet]. 1983 [cited 2024 Sep 25];31(1):3–9. Available from: https://scholarlycommons.henryford.com/hfhmedjournal/vol31/iss1/2

[4] Graber LW, Vig KWL, Huang GJ, Fleming P. Orthodontics: Current Principles and Techniques [Internet]. Elsevier; 2022. Available from: https://books.google.com/books/about/Orthodontics.html?hl=&id=2TARzwEACAAJ

[5] Hu Y, Li H. Biological mechanism of surgery-mediated acceleration of orthodontic tooth movement: A narrative review. J Int Med Res [Internet]. 2022 Sep;50(9):3000605221123904. Available from: http://dx.doi.org/10.1177/03000605221123904

[6] Liou EJW, Chen PH, Wang YC, Yu CC, Huang CS, Chen YR. Surgery-first accelerated orthognathic surgery: postoperative rapid orthodontic tooth movement. J Oral Maxillofac Surg [Internet]. 2011 Mar;69(3):781–5. Available from: http://dx.doi.org/10.1016/j.joms.2010.10.035

[7] Daraqel B, Mheissen S, Li J, Khan H, Allan S, Zheng L. The effect of early versus delayed space closure on the rate of orthodontic tooth movement: a systematic review and meta-analysis. Eur J Orthod [Internet]. 2023 Nov 30;45(6):680–9. Available from: http://dx.doi.org/10.1093/ejo/cjad015

[8] Olabintan AA, Otuyemi OD, Kolawole KA. Effects of Recent/Healed Post-Extraction Protocols on Incisor and Canine Alignment During Fixed Orthodontic Appliance Therapy. Turk J Orthod [Internet]. 2022 Jun;35(2):84–93. Available from: http://dx.doi.org/10.5152/TurkJOrthod.2022.21017

[9] Kumar V, Batra P, Sharma K, Raghavan S, Srivastava A. Comparative assessment of the rate of orthodontic tooth movement in adolescent patients undergoing treatment by first bicuspid extraction and en mass retraction, associated with low-frequency mechanical vibrations in passive self-ligating and conventional brackets: A randomized controlled trial. Int Orthod [Internet]. 2020 Dec;18(4):696–705. Available from: http://dx.doi.org/10.1016/j.ortho.2020.08.003

[10] Abu Alhaija ES, Al Shayeb RA, Al-Khateeb S, Daher HO, Daher SO. A comparative assessment of the amount and rate of orthodontic space closure toward a healed vs recent lower premolar extraction site. Angle Orthod [Internet]. 2022 Jul 1;92(4):463–70. Available from: http://dx.doi.org/10.2319/102921-797.1

[11] Zubair NR, Ehsan AA, Sakrani H. Comparison of mean canine retraction between healed and recently extracted site: A single center, randomized control trial. APOS Trends Orthod [Internet]. 2021 Jul 9;11(132):132–9. Available from: https://apospublications.com/comparison-of-mean-canine-retraction-between-healed-and-recently-extracted-site-a-single-center-randomized-control-trial/

[12] Verna C. Regional Acceleratory Phenomenon. Front Oral Biol [Internet]. 2016;18:28–35. Available from: http://dx.doi.org/10.1159/000351897

[13] Ghafari JG, Ammoury MJ. Overcoming compact bone resistance to tooth movement. Am J Orthod Dentofacial Orthop [Internet]. 2020 Sep;158(3):343–8. Available from: http://dx.doi.org/10.1016/j.ajodo.2020.02.006

[14] Jeyashree T, Kumar MPS. Evaluation of difficulty index of impacted mandibular third molar extractions. J Adv Pharm Technol Res [Internet]. 2022 Nov;13(Suppl 1):S98–101. Available from: http://dx.doi.org/10.4103/japtr.japtr_362_22

[15] Murthi M, Dhasarathan P, Rajendran D. Retrospective study of the prevalence of dry socket in patients with mandibular third molar extraction. World J Dent [Internet]. 2020 Dec 14;11(5):425–30. Available from: https://www.wjoud.com/doi/10.5005/jp-journals-10015-1766

[16] Nimeri G, Kau CH, Abou-Kheir NS, Corona R. Acceleration of tooth movement during orthodontic treatment--a frontier in orthodontics. Prog Orthod [Internet]. 2013 Oct 29;14:42. Available from: http://dx.doi.org/10.1186/2196-1042-14-42

[17] Arvind Tr P, Dinesh SS. Can palatal depth influence the buccolingual inclination of molars? A cone beam computed tomography-based retrospective evaluation. J Orthod [Internet]. 2020 Dec;47(4):303–10. Available from: http://dx.doi.org/10.1177/1465312520941523

[18] Fortini A, Lupoli M, Giuntoli F, Franchi L. Dentoskeletal effects induced by rapid molar distalization with the first class appliance. Am J Orthod Dentofacial Orthop [Internet]. 2004 Jun;125(6):697–704; discussion 704–5. Available from: http://dx.doi.org/10.1016/j.ajodo.2003.06.006

[19] Maruyama M, Rhee C, Utsunomiya T, Zhang N, Ueno M, Yao Z, et al. Modulation of the Inflammatory Response and Bone Healing. Front Endocrinol [Internet]. 2020 Jun 11;11:386. Available from: http://dx.doi.org/10.3389/fendo.2020.00386

[20] Keser E, Naini FB. Accelerated orthodontic tooth movement: surgical techniques and the regional acceleratory phenomenon. Maxillofac Plast Reconstr Surg [Internet]. 2022 Jan 5;44(1):1. Available from: http://dx.doi.org/10.1186/s40902-021-00331-5

[21] Meenakshi SS, Malaiappan S. Piezosurgical corticotomy for rapid orthodontic tooth movement - A case series. J Indian Soc Periodontol [Internet]. 2021 Jul 1;25(4):360–4. Available from: http://dx.doi.org/10.4103/jisp.jisp_316_20

[22] Katyal D, George AM, Jain RK, Balasubramaniam A, Srirengalakshmi M, Vaid NR. Platelet-rich derivatives for accelerating the rate of orthodontic tooth movement - a systematic review and meta-analysis. APOS Trends Orthod [Internet]. 2022 Jun 21;12(202):202–13. Available from: https://apospublications.com/platelet-rich-derivatives-for-accelerating-the-rate-of-orthodontic-tooth-movement-a-systematic-review-and-meta-analysis/

[23] Lee W. Corticotomy for orthodontic tooth movement. J Korean Assoc Oral Maxillofac Surg [Internet]. 2018 Dec;44(6):251–8. Available from: http://dx.doi.org/10.5125/jkaoms.2018.44.6.251

[24] Hansson S, Halldin A. Alveolar ridge resorption after tooth extraction: A consequence of a fundamental principle of bone physiology. J Dent Biomech [Internet]. 2012 Aug 16;3:1758736012456543. Available from: http://dx.doi.org/10.1177/1758736012456543

[25] Murphey WH Jr. Oxytetracycline microfluorescent comparison of orthodontic retraction into recent and healed extraction sites. Am J Orthod [Internet]. 1970 Sep;58(3):215–39. Available from: http://dx.doi.org/10.1016/0002-9416(70)90086-2

[26] Amler MH, Johnson PL, Salman I. Histological and histochemical investigation of human alveolar socket healing in undisturbed extraction wounds. J Am Dent Assoc [Internet]. 1960 Jul;61:32–44. Available from: http://dx.doi.org/10.14219/jada.archive.1960.0152

[27] Diedrich P, Wehrbein H. Orthodontic retraction into recent and healed extraction sites. A histologic study. J Orofac Orthop [Internet]. 1997;58(2):90–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/9114558

[28] Sable DL, Woods MG. Growth and treatment changes distal to the mandibular first molar: a lateral cephalometric study. Angle Orthod [Internet]. 2004 Jun;74(3):367–74. Available from: http://dx.doi.org/10.1043/0003-3219(2004)074<0367:GATCDT>2.0.CO;2

[29] Chen LL, Xu TM, Jiang JH, Zhang XZ, Lin JX. Longitudinal changes in mandibular arch posterior space in adolescents with normal occlusion. Am J Orthod Dentofacial Orthop [Internet]. 2010 Feb;137(2):187–93. Available from: http://dx.doi.org/10.1016/j.ajodo.2008.03.021

[30] Nanda R, Uribe FA, Yadav S. Temporary Anchorage Devices in Orthodontics E-Book [Internet]. Elsevier Health Sciences; 2019. 352 p. Available from: https://play.google.com/store/books/details?id=ucy4DwAAQBAJ

[31] Kim SH, Cha KS, Lee JW, Lee SM. Mandibular skeletal posterior anatomic limit for molar distalization in patients with Class III malocclusion with different vertical facial patterns. Korean J Orthod [Internet]. 2021 Jul 25;51(4):250–9. Available from: http://dx.doi.org/10.4041/kjod.2021.51.4.250

[32] Hui VLZ, Xie Y, Zhang K, Chen H, Han W, Tian Y, et al. Anatomical limitations and factors influencing molar distalization. Angle Orthod [Internet]. 2022 May 23;92(5):598–605. Available from: http://dx.doi.org/10.2319/092921-731.1

[33] Iguchi K, Kim YI, Adel M, Nadim M, Hatanaka R, Koizumi S, et al. Association of Mandibular Posterior Anatomic Limit with Skeletal Patterns and Root Morphology Using Three-Dimensional Cone Beam Computed Tomography Comprehensive Analysis. Diagnostics [Internet]. 2022 Dec 2 [cited 2024 Oct 2];12(12):3019. Available from: https://www.mdpi.com/2075-4418/12/12/3019.