Effect of Accelerated Canine Retraction by Vitamin D3 Local Administration on Apical Root Resorption, Alveolar Bone Integrity, and Chair-side Time: A Prospective Clinical Study

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ABSTRACT

Objectives: To evaluate the effect of vitamin D3 local injections on apical root resorption, alveolar bone integrity, and chair-side time following three and six months of canine retraction.

Subjects and Methods: Seventeen adult patients (18-35 years old) of class I and II malocclusions were recruited, who required bilateral maxillary 1st premolars extraction before starting maxillary canines retraction. The experimental side received 25 pg dose of vitamin D3 injected locally into the distal periodontal sulcus of the canine (before force application) every three weeks, while the control side received retraction force only. Periapical radiographic evaluation was conducted after 3 and 6 months of the start of canines’ retraction.

Results: At both time points (3 and 6 months), radiographic findings revealed uniform alveolar bone contour with non-significant differences (p > 0.05) between the experimental and control sides regarding canine root resorption scores. The experimental side exhibited better alveolar bone turnover as indicated by well-defined periodontal ligament widening. However, vitamin D3 injection entailed four minutes extra chair-side time.

Conclusion: Enhancement of canine retraction by local injection of vitamin D3 induced better periodontal response, does not impose detrimental apical root resorption nor adversely affect the alveolar bone integrity, and the procedure does not entail significant extra chair-side time.

KEY WORDS

vitamin D, injection, accelerated orthodontics, root resorption, alveolar bone integrity

INTRODUCTION

Orthodontic treatment (OT) can induce significant impact on the psychological and social well-being of the patients via correcting teeth disorders, function and facial aesthetics1). However, OT is characterized as a lengthy procedure, in addition to other drawbacks such as caries, root resorption, gingival, alveolar bone and periodontal adverse effects2,3). Accordingly, enormous effort has been harnessed to shorten the OT duration using either surgical or non-surgical approaches, with emphasis to reduce the adverse effects, cost and chair-side time4). The surgical approach is known for its invasiveness and, hence, not preferred by most orthodontic patients. On the other hand, most non-surgical methods are premised on the use of biological materials as a locally administered medication, with no or minimal local and/or systemic side effects5).

Although literature is replete with studies investigating the rate of orthodontic tooth movement following local administration of corticosteroids, thyroxine and prostaglandins, most of these studies were conducted on animals6-9). In contrast, trials of using vitamin D to accelerate tooth movement involved both animal and fewer human studies, albeit the effect was merely investigated on short-term basis10-15). These studies reported various rates of accelerated tooth movement post local administration of vitamin D. The first clinical study on humans was conducted in 2011, in which three doses of vitamin D3 were used: 15, 25, and 40 pg/0.2 mL. The local injection of 25 pg/0.2 mL recorded a faster tooth movement (51%) in the experimental side in comparison to the control side than the other tested doses16).

Orthodontic tooth movement using conventional techniques can induce trauma to the teeth and surrounding tissues such as apical root resorption, loss of alveolar bone integrity and damage of the periodontium11-15). In addition, it has been assumed that techniques concerned with accelerating tooth movement can lead to root resorption and periodontal trauma in a higher rate16-20). Although the use of 25 pg/0.2 mL local injection of calcitriol (vitamin D3) was reported successful in accelerating tooth movement17), the results were based on 4 weeks follow-up duration without evaluating the extra chair-side time and the possible damaging effects on the root and alveolar bone. Therefore, the aim of this study was to evaluate the long-term effect of vitamin D3 injection on the apical root resorption and integrity of the alveolar bone at two time points: after 3 and 6 months of the start of canines’ retraction stage. In addition to calculating the average extra chair-side time required to perform the local administration procedure. The null hypothesis stated that acceleration of canine retraction by local injection of vitamin D3 does not exacerbate apical root resorption nor adversely affect the alveolar bone integrity, and the procedure does not entail significant extra chair-side time.
The study involved 30 adult patients (18-35 years old) who sought accelerated orthodontic treatment to be conducted at Baghdad Teaching Hospital (College of Dentistry) and a private clinic in Baghdad, Iraq for the duration from December 2019 to July 2021. However, only 17 patients were managed and followed up according to the study design due to the frequent lock-down periods imposed by the COVID-19 pandemic, which started in Iraq in March 2020.

Based on previous study findings, which involved blood samples collection after vitamin D3 (calcitriol) local injections\(^6\), all patients were informed about the safety and non-significant systemic influence of locally administered calcitriol, and signed consent forms were obtained with an ethical approval (Reference number: 094419) by the College of Dentistry, University of Baghdad. Patients of class I and II malocclusions were recruited, with a treatment plan that requires bilateral maxillary 1st premolars removal followed by maxillary canines retraction to close the extraction space. The selected patients had no history of systemic disease or craniofacial deformities, no previous orthodontic treatment, and no history of chronic use of medications. Panoramic radiographs were taken before treatment to confirm healthy periodontium, alveolar bone and no root resorption.

Pre-adjusted orthodontic brackets (stainless steel MBT 0.022” system, Pinnacle, Ortho Technology, USA) were used for all patients. After leveling and alignment phase, maxillary canine retraction commenced in the second phase using rectangular (0.017 x 0.025”) stainless steel archwire with a distalizing force (applied using transparent elastomeric chain, Ortho Technology, USA) of 200 g measured by a pressure gauge.

Vitamin D3 (1,25-dihydroxyvitamine D3, the active form of vitamin D3 ampules (Calcitriol, Mibe, Germany) were used to prepare a diluted dose (25 pg) for local injections. Dimethylsulfoxide (0.2 ml) (DMSO, Bisolve B.V., Netherlands) was used for dilution and worked as a vehicle\(^8\). The maxillary arch of each patient was divided into experimental (right side) and control (left side). The 25 pg dose of calcitriol was injected locally into the distal periodontal sulcus of the maxillary right canine before retraction force application, while the maxillary left canine received orthodontic retraction force only as a control. The local injections were administered on each orthodontic visit (every three weeks) until extraction space closure (an average duration of six months). A stopwatch was used to calculate the average time required for preparing and injecting the calcitriol on each visit.

**Radiographic Evaluation**

A high quality portable X-ray camera (Remex K100, Korea) was used at (70 kV, 2 mA) to evaluate the long-term effect of calcitriol injection on apical root resorption and integrity of the alveolar bone at two time points: after 3 months of the start of canines' retraction stage and at the end of extraction space closure (an average of six months). Evaluation of apical root resorption was conducted using the scoring system of Levander and Malemgren\(^16\) (figure 1):

0: no root resorption.
1: mild resorption, where the root is of normal length and has an irregular contour.
2: moderate resorption, with small areas of root loss and the apex having almost a straight contour.
3: severe resorption, with a loss of almost one third of the root length.
4: extreme resorption, with a loss of more than one third of the root length.

![Figure 1: Root resorption index for quantitative assessment of root resorption.](image)

**Statistical Analysis**

Data were statistically evaluated using the Statistical Package for Social Sciences (version 27, SPSS Inc., IBM, USA) at a level of significance p < 0.05. Mann Whitney test was applied for testing the difference between the control and experimental sides regarding the radiographic root resorption scores.

**RESULTS**

Radiographs of five patients were selected randomly following three months of canine retraction in order to examine the root and alveolar bone areas for any deleterious effects post frequent local administration of vitamin D3, as shown in figure 2. On the other hand, figure 3 demonstrates the radiographic findings of five patients after six months of canine retraction.

![Figure 2: Radiographic evaluation of root resorption and alveolar bone integrity after 3 months of canine retraction. Top row (A-E) represents the experimental (right) side, while bottom row (F-J) represents the control (contralateral left) side of the same patient.](image)

![Figure 3: Radiographic evaluation of root resorption and alveolar bone integrity after 6 months of canine retraction. Top row (A-E) represents the experimental (right) side, while bottom row (F-J) represents the control (contralateral left) side of the same patient.](image)

At both time points (3 and 6 months), three main scores were encountered (according to the scoring system of root resorption): 0, 1, and 2; with the highest frequency of score 0 indicating absence of root resorption on both control and experimental sides (Table 1).

After 3 months, the experimental (vitamin D injection) side of 6 patients exhibited score 1 (examples are shown in figure 2: A and D), while 7 patients showed score 1 on the control side (as demonstrated in figure 2: G, H, I). All other radiographs depicted score 0 (examples are shown in figure 2: B, C, E, F, J).

Following 6 months, local vitamin D administration into the experimental side of 8 patients resulted in score 1 (examples are shown in figure 3: A, B, C), and 8 patients showed score 1 on the control side (as depicted in figure 3: G and H). Score 2 was recorded by two patients on the experimental side, and by three patients on the control side (an example is shown in figure 3: F). All other radiographs yielded score 0 (examples are shown in figure 3: D, E, I, J). The statistical comparisons (Mann Whitney test) between the experimental and control sides at both time points revealed non-significant differences (p > 0.05) concerning...
the distribution and severity of root resorption scores, i.e. the influence on canine root resorption.

Table 1: Canine root resorption scores after 3 and 6 months of retraction, with inferential statistics between the control and experimental sides.

<table>
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<tr>
<th>Sequence of Patients</th>
<th>Control</th>
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<th>After 6 months</th>
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Regarding the integrity of alveolar bone surrounding the distalized canines, the radiographs showed more well-defined periodontal ligament widening around the canines on the experimental side than the control side at both time points (figures 2 and 3). The alveolar bone contour surrounding the canines exhibited comparable uniformity on the experimental and control sides at both 3 and 6 months follow-up periods. However, the level of alveolar bone height showed radiographic variations between the right and left sides at both time points.

The calculated average time for preparing (including addition of vehicle to the active ingredient) and administering an injection of vitamin D was 4 minutes, representing the time required before placing the power chain elastic for canine retraction; versus zero minute on the control side as power chain placement was carried out immediately without any preceding injection.

**DISCUSSION**

This study aimed at investigating any potential damaging effect of local vitamin D3 local injections used to accelerate orthodontic canine distalization over a relatively long-term follow-up period that covers the average time required for canine movement to close an extraction space. The rationale was premised on the significant role of vitamin D3 in enhancing remodeling of bone, which can be harnessed in orthodontics to accelerate bone resorption and formation, an essential process for the success of orthodontic treatment. In 2011, the first clinical study investigated the role of vitamin D3 in accelerating canine retraction depending on a short-term (one month) follow-up. Although tooth movement was shown to be accelerated, this short period of time is not enough to reveal the detrimental effects on the root and alveolar bone, if any, radiographically. Therefore, longer follow-up durations (3 and 6 months) were sought in the current study as these periods represent the average time required for active orthodontic canine movement, depending on the amount of space to be closed.

This study revealed no significant adverse effects on root resorption of distalized canines following frequent vitamin D local injections, as indicated by the frequency of certain root resorption scores. Non-significant differences were found between the control and experimental sides in terms of the distribution and severity of root resorption scores. Although the root resorption scoring system adopted in this study was composed of 5 categories, only three categories (scores 0 through 2) were recorded by both the control and experimental sides, with a majority of score 0 (no root resorption) and absence of severe root resorption categories (scores 3 and 4). The description of these scores (0, 1, and 2) has been commonly reported in previous studies and described as a normal reversible phenomenon accompanying orthodontic tooth movement. This finding came in agreement with Chiu and colleagues (2016) who studied the effect of vitamin D3 (0.2 mL of 42 pg/mL) on the rate of tooth movement during orthodontic treatment and reported minimal root resorption. However, their study did not include a standardized method for root resorption assessment, and involved a very small sample size (6 patients only). In another study conducted on rats by Seifi et al, they used prostaglandin E2 alone versus a combination of thyroxine and prostaglandin E2 to boost orthodontic tooth movement. They reported acceleration in tooth movement with both formulations; however, prostaglandin E2 alone yielded more destructive effect on the root in comparison with the combination of thyroxine and prostaglandin E2, which showed minimal root resorption. It has been previously reported that thyroxine can induce a protective effect on the root surface. Therefore, tooth movement can be accelerated without deleterious effects on the root, depending on the active ingredient used to enhance the movement.

In comparison with the control side, the radiographs of the current study showed more well-defined periodontal ligament widening around the distalized canines on the experimental side at both 3 and 6 months follow-up periods, with almost identical uniformity of the alveolar bone contour. The level of alveolar bone height showed radiographic variations between the right and left sides at both time points, which reflects the normal individual variation as all the teeth were checked clinically and radiographically (by routine panoramic radiographs) for any alveolar bone destruction and tooth mobility before starting the treatment. These findings can be explained by the significant role of vitamin D3 in the process of bone turnover. It has been reported that vitamin D supports the bone remodeling effect by providing a good balance between the osteoclast and osteoblast activation in the bone remodeling process and alveolar bone. In addition, previous studies showed that intraligamentous and submucosal injections of an active metabolite of vitamin D, caused an increment in the osteoclast number leading to a greater tooth movement during canine retraction with light forces in cats and rats, respectively. On the other hand, it has been found that 1,25-dihydroxyvitamin D3 can enhance orthodontic movement retention by augmenting the osteoblasts role in bone deposition at the tension side; hence, it has a dual effect as it contributes to both bone resorption and deposition.

To study the dual effect of vitamin D3, Kale et al (2004) compared the effect of administering prostaglandin and the active form of vitamin D3 on tooth movement in rats, which was markedly increased in comparison to the controls. However, they found that the effect of vitamin D3 on the differentiation and number of osteoclast on the tension side was minimal. More recently, another study tested the effect of the active form of vitamin D3 on bone remodeling in rats during orthodontic tooth movement, and recorded an increment in the mineral appositional rate on the alveolar bone surface, suggesting that locally administered vitamin D could strengthen and restate the supporting tissue, specifically the alveolar bone. These findings support the outcomes of the current clinical study, which confirmed that the active metabolite of vitamin D3 could boost a healthy tooth movement by balancing the bone resorption and deposition processes during orthodontic treatment. Radiographic evaluation of changes in the alveolar bone has been reported as a reliable method for clinical assessment of bone remodeling around the teeth. Local injections of vitamin D into the periodontal ligament is a simple procedure that does not require special training; however, pain and the need for slow injection of the medicine were reported as the main drawbacks. In addition, the current study estimated the average chair-time for preparing the medication and adding (including addition of vehicle to the active ingredient) and administering an injection of vitamin D, which was around 4 minutes. This extra time is non-significant when considering the benefit of acceleration in tooth movement, reported to be 51% faster canine retraction in the experimental side in contrast to the control side. For proper release and distribution of the active ingredient (1,25-dihydroxyvitamin D3), a vehicle solution (DMSO) was mandatory to be added before injection, a step that necessitated extra time. Therefore, future work to prepare a formulation of a prolonged shelf-life and stability that contains vitamin D3 mixed with the vehicle is recommended to.
reduce the time required for injection preparation.

CONCLUSION

Based on radiographic findings, it was concluded that acceleration of canine retraction by local injection of vitamin D3 enhanced the periodontal ligament response, does not exacerbate apical root resorption nor adversely affect the alveolar bone integrity, and the procedure does not entail significant extra chair-side time.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interests.

REFERENCES