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# THE EFFECT OF HYPERBARIC OXYGEN ON TWO DIFFERENT METHODS OF RAPID CANINE DISTRACTION

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## *ABSTRACT:*

***Objectives:*** *To evaluate the possible increase in bone formation using hyberbaric oxygen and to detect the possible root resorption in rapid canine distraction.* ***Methods:*** *Sixteen healthy patients Indicated for orthodontic treatment with extraction of at least the maxillary first premolars were selected. They were divided into two groups; a hyperbaric group (HBO) and a control group (NHBO). Split mouth technique was implemented where one side was randomly selected to encounter periodontal ligament distraction (PDLD) while the other side received dentoalveolar distraction (DAD). The PDLD and DAD surgries were carried out after the extraction of the maxillary first premolars. The distractors were cemented in their places and are left for one week latency period. The HBO group started their hyperbaric oxygen sessions for 20 days; where 90 minutes of complete oxygen inhalation at 2.5 atmosphere absolute (ATA) were received in every section serum bone alkaline phosphatase (B-ALP) samples and standardized periapical Xray were taken from the subjects before the surgery. The distractors were activated. The screw moved 1mm/day. B-ALP samples and periapical X-rays were collected from the subjects when the canines were fully retracted* ***Results:*** *The serum bone alkaline phosphatase of HBO group was significantly elevated. The average degree of tipping in the PDLD side of both*

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*groups was significantly higher than that of the DAD side. The DAD preserves more bodily movement in comparison to PDLD. The hyperbaric oxygen aids of attaining more bodily movement during the distraction of the canines. No root resorption incidence was detected during the short time of distraction.*

***Keywords:*** *Hyperbaric oxygen, Rapid canine distraction, Periodontal ligament distraction, Dentoalveolar distraction, Serum Bone alkaline phosphatase.*

## INTRODUCTION

Distraction osteogenesis (DO), that is bone lengthening following an osteotomy and a latency period, was originally introduced by a Russian orthopaedic surgeon Ilizarov, who also defined the main principles used nowadays in DO. The guidelines include the use of a corticotomy or an osteotomy with maximal preservation of vascularity and osteogenic tissue. Distraction osteogenesis is a process of growing new bone by mechanical stretching of the preexisting bone tissue. The most common technique in distraction osteogenesis is mechanical stretching of the reparative bone tissue by a distraction device through an osteotomy or corticotomy site.[1-4]

In 1998, Liou and Huang presented a method of rapid canine distraction after the extraction of the first premolar through weakening of the interseptal bone distal to the canine causing stretching of the periodontal ligament, where both the upper and lower canines were distracted bodily 6.5 mm into extraction space within three weeks. (Periodontal ligament distraction PDLD).[5-6]

Reha-Kisnici and Haluk-Iseri in their study established a new approach to reduce the overall orthodontic treatment time by means of dentoalveolar distraction osteogenesis. The dentoalveolus itself is designed as a bone transport segment for posterior movement. Vertical osteotomies were performed around the root of the canine teeth, followed by splitting the spongy bone around it resulting in complete canine distraction in one week. (Dentoalveolar distraction)[7] Hyperbaric oxygen

therapy (HBO) is the inhalation of 100% oxygen inside a hyperbaric chamber that is pressurized to greater than 1 atmosphere absolute (ATA; 760 mm Hg). HBO delivers oxygen quickly and systemically in high concentrations to all over the body including the injured areas. The increased pressure changes the normal cellular respiration process and causes oxygen to dissolve in the plasma. HBO is typically administered at 1 to 3 ATA. While the duration of HBO session is typically 90 to 120 minutes, the duration, frequency. and cumulative number of sessions have not been standardized.[8, 9]

Basset and Hermann showed that hypoxia leads to cartilage formation and hyperoxia leads to osseous tissue formation in a culture of multipotent mesenchymal cells.[10] HBO increases dissolved oxygen in the blood and results in a high partial pressure of oxygen ($PaO_2$). An increase of $PaO_2$ affects the oxygen tension in regenerating tissue, which promotes collagen and adenosine-triphosphate (ATP) synthesis, capillary growth, and osteoblastic and osteoclastic activity.[11,12] Oxygen tension has a triggering role in bone remodeling.[13] The increase in oxygen tension causes cellular differentiation to osseous tissue, whereas decreased oxygen tension results in cartilage formation.[14] There is a parallelism between the increase in oxygen tension and increase in osteoblastic and osteoclastic activity. HBO treatment causes a significant increase in bone formation such that lamellar bone develops in the chamber canal.[15] There is also acceleration in bone healing and an increase in the amount of new bone formation with HBO.

## MATERIALS AND METHODS

The study sample consisted of 16 participants.. The selected patients were chosen from both genders (eleven females and five males), according to the following criteria:

1. Age range from 14 to 30 years.
2. All patients required orthodontic treatment which needs the extraction of the upper first premolar on both sides. The canines to be retracted should be in symmetrical positions in every patient.

**Groups:**

The subjects were divided into two groups according to the exposure to hyperbaric oxygen:

1. Hyperbaric Group. (8 subjects).
2. Non Hyperbaric Group "Control Group". (8 subjects).

Each group was subdivided into periodontal ligament distraction (PDLD) subgroup took place on one side and dentoalveolar distraction (DAD) subgroup took place on the other side.

The hyperbaric subjects had the following examinations:

1. E.N.T check: to make sure there are no ear or sinus problems
2. E.C.G and cardiology check.
3. Chest X-ray: to execlude any pulmonary problems.

**Records:**

All the subjects had the following records before the distraction:

1. Panoramic X-ray.
2. Study casts.

All the subjects had the following records before and after the distraction:

1. Periapical X-ray of the maxillary canines.
2. Serum Bone Alkaline Phosphatase level.
3. Lateral cephalometric X-ray.

**The procedures:**

**1. Preparation of the subjects**

Upper and lower impressions were taken for each patient to make the working models. Elastic separators were used before banding the upper first and second molars and the upper canines. The upper second molars

bands and the central incisors bands were ready made bands(*). Custom made bands were made for the upper canines and the upper first molars. Weldable edgewise brackets were welded on the upper canines' bands. The upper first molars bands had a welded tube on its buccal side. The bands were tried in the patients' mouth to check the stability and the contour. A second overall alginate(**) impression was taken and poured into stone(***). After that, the model was referred to the laboratory for fabrication of the distractor.

**2. Fabrication of the distractors**

The same distractor was used for dentoalveolar and periodontal ligament distraction sides.

**The Components of the Distractor used:**

**1. *The Bands***

Two bands were used for each distractor; a canine band and a first molar band. Custom made bands gave more length and contour and were more perfectly adapted than the readymade bands. The bands were perfectly fit to withstand the forces transmitted during distraction. Weldable edgewise brackets were welded on the upper canines' bands. The upper first molars bands had welded tubes on their buccal sides.

**2. *The Screw and the Allen key***

A stainless steel screw of 3 mm width and 35 mm long was used (Fig. 1). The screw length was convenient to cover the distance between the upper canine till the upper first molar. The width of the screw gave enough strength to withstand the forces of distraction. It has an Allen head in order not to injure the tissues and to be calibrated for every turn as the Allen key direction can be calibrated easily. Every full turn of the Allen key is equivalent of 1 mm movement of the canine.

(*) Standard high retention second molar bands, Oromco Corporation, 1717 West Collins. Orange, CA 92867.
(**) Hydrogum® 5, Zhermack CLINICAL, 45021 Badia (Rovigo)- Italy.
(***) Elite® model, Zhermack® CLINICAL, 45021 Badia (Rovigo)- Italy.

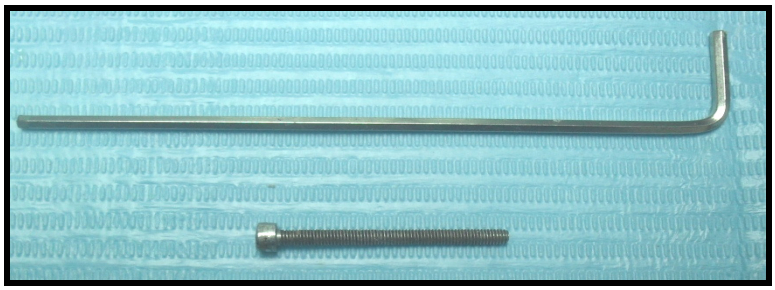

**Figure 1.** The screw and the Allen key.

### 3. *The nuts and the solder bar*

Each screw came with two threaded nuts, with a washer each. The nut which was soldered to the canine band was smoothed in order to allow the sliding motion of the canine. The nut which was soldered to the molar band was threaded. Each nut was hexagonal in shape. A 1.2 mm stainless steel wire was used as the solder bar which connected the bands on the canines and molars to the nuts on the screw. The washers supplied rough surface for the soldering of the nuts to the solder bar. (Fig.2).

**Figure 2.** The hexagonal nut and the washer.

### Preparation of the model for assembling of the distractor:

The first molars and canines bands were seated in its positions on the working model. During the positioning of the screw and the bands we selected appropriate position of the screws away from the ginigiva in order not to harm the tissues during rotation especially the Allen head. So, we made a plaster protective pad "spacer", and we took into

consideration that the smooth nut will be almost touching the head of the Allen screw at the starting position. A uniform tube of wax of about 2mm cross section was placed on the model extending from the gingiva around the upper canine till reaching the upper first molar. Plaster was poured inside the wax tube till it sets, and then the wax was burned out.

**Soldering the nuts to the bands:**

The nuts were soldered to the solder bar. Then the nuts were positioned on the screw in its starting position. The model was tilted so that the side to be soldered was facing upwards. The screw with the two nuts was placed on the model so that the level of the solder bar was 2 mm below the gum margin. The tubes and brackets on the bands act as a balance for the soldering bar to be fixated in its position. Later the bands were soldered to the solder bar. The new appliance was taken to be finished and polished and then carried to the patient's mouth for a try in.

**3. The Surgical Procedure:**

Two different methods of distraction were carried out. Each method had its own type of surgery. On one side of the patient's mouth a PDLD took place and on the other side of the patient's mouth a DAD was performed. The same procedures were performed on all the 16 subjects. Local infiltration anaesthesia(*) was administrated. Extraction of the upper first premolars took place next to that.

**3.I. PDLD Surgical technique:**

Using a surgical bur(**) with a rubber "stopper" which was caliberated according to the length of the extracted premolar, we started cutting on mesial wall of the socket and decorticating the apical bone and the buccal bone in order to perform proper distraction. Carefull cutting was carried out in the endosteum in order not to injure the distal surface of the root of the canine. If the extracted premolar had two roots, the inter radicular bone was removed during the decortication.

(*) Mepicaine-L. Alexandria Co. for Pharmaceuticals. Alexandria, Egypt.

(**) Tung. carbide bur. TK Vrtacek, MEDIN, a.s., Vlachovicka 619, 59231 Nove Mesto na Morave, Czech Republic.

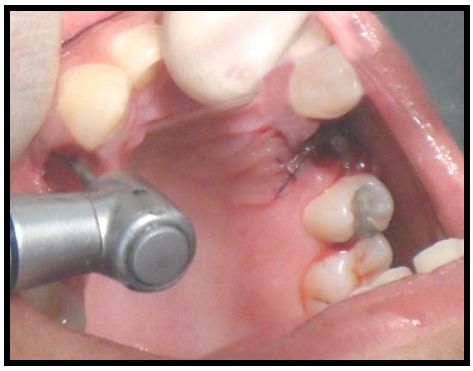

**Figure 3.** The approach on the PDLD side, a surgical bur is used to caliberate estimated length of the Premolar root.

**Figure 4.** The extraction socket where the interseptal bone was undermined and decorticated.

### 3. II. DAD Surgical technique

A flap was raised distal to the upper lateral incisor reaching to the second premolar. Decortications of the bone around the root of the canine mesial side, distal side and apically took place. Suturing and closure of the flap was carried out.

**Figure 5.** Decorticated canine ready for the DAD.

## 4. The cementation of the distracters

### *The Luting cement*

One of the biggest challenges during distraction was to keep the bands in place. Excessive forces during distraction might slip the band from the canine or the molar if it was not securely seated and cemented. Dual cure resin cement gave the best results during distraction. (*) The bands of the distractors were cemented in their positions using dual cure resin cement. Two bands were cemented on the upper right and left second molars too. A 17" x 25" heavy stainless steel rectangular wire (**) connected the upper central incisors and the upper second molars

**Figure 6.** The distractors are cemented inside the patient's mouth

(*) Tgresincem™, Dual Cure Resin Cement. Technical and General ltd, 2 Albion Place, London W60QT.

(**) 0.018x0.025-inch rectangular stainless steel wire. ORTHO TECHNOLOGY Inc. 17401 Commerce Park Blvd. Tampa, Florida 33647.

## 5. Activation of the distracters

After the extraction and the surgical procedure the patients had a latency period of seven days. At Day Eight, distraction in the morning before hyperbaric session for the HBO group was a half mm and then distraction in the evening was another half mm. The distraction took place on the dental chair side. A single complete turn of the screw was equivalent to 1 mm of the screw motion inside the nut. The screw should be turned in clock wise direction in order to transmit the forces that retract the canine distally. The screw was shortened if it touches the buccal mucosa of the cheek. The procedure done in Day eight was repeated every day till the complete retraction of the canine.

## 6. Management of the HBO group

The hyperbaric group had 20 daily sessions starting from the day prior to the extraction. Each session is 90 minutes of complete oxygen inhalation at 2.5 Atmosphere as required by the protocol of treatment by the Naval Hyperbaric Institute.

At day one, HBO group started their hyperbaric oxygen sessions. The first session was an experimental and prophylactic session.

HBO group continue their second hyperbaric session after the surgery. From Day Three to Day Seven HBO group patients continue their HBO sessions and the non HBO patients are completing their latency period. Stitches on the DAD side are removed in both groups

**Figure 7.** The upper left canine after completely distracted through the dentoalveolar distraction method.

**Figure 8.** The distracted upper canines, day 16.

**Figure 9.** The upper left canine after completely distracted.

## 7. Collecting the results and the data

The hyperbaric group and the non hyperbaric group almost shared the same procedure except that the hyperbaric group had twenty daily HBO sessions started one day one prior to the surgery. Serum bone alkaline phosphatase samples are collected and intraoral long cone periapical X-rays are taken using a standardized rim for both canines (Fig. 10). Both X-rays and blood samples are taken at two different points:

($T_0$): before the surgery.

($T_1$): after the canine is fully distracted.

### X-RAYS

#### *Periapical X-rays*

A standardized long cone technique was used to assure the unified results and data collected (Fig. 10). The X-rays were collected at two different timings ($T_0$) and ($T_1$). The Periapical X-rays findings are used to study and compare the following:

1. The tipping of the canines distracted. A heavy wire connecting the second molars to the central teeth was used as a standard plane. The angulation of the central incisors and the upper second molars were checked by panoramic Xray before we made the periapical Xray to make sure there is no change in the plane of the heavy archwire.
2. The amount of root resorption along the path of distraction. The standardized rim long beam periapical Xrays, taken at $T_0$ and $T_1$, were traced and superimposed to see if there were any root resorption during the distraction. All periapical films were digitally scanned and magnified eight-fold to evaluate apical and lateral surface root resorption;[16] evaluations were conducted by three experienced orthodontists.

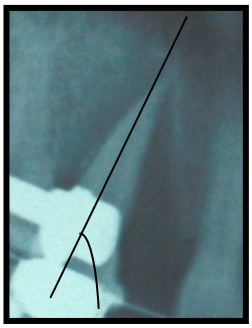

**Figure 10.** Periapical X-ray of a fully distracted canine ($T_2$).

**Blood Samples:**

Blood samples were collected to analyze the serum bone alkaline phosphatase at two intervals ($T_0$) and ($T_1$). The samples were collected and analyzed.

**Statistical analysis of the data[17]**

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0.[18] Quantitative data were described using mean and standard deviation, median, minimum and maximum. The distributions of quantitative variables were tested for normality using Kolmogorov-Smirnov test, Shapiro-Wilk test and D'Agstino test, also Histogram and QQ plot were used for vision test. If it reveals normal data distribution, parametric tests was applied. For normally distributed

data, comparisons between different groups were analyzed using F-test (ANOVA) and Post Hoc test (Scheffe) for pair wise comparisons if the data were abnormally distributed, non-parametric tests were used. For abnormally distributed data, comparisons between two independent populations were done using Mann Whitney test. Significance test results are quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level.

## RESULTS

The following data were collected:

1. Angle of tipping of the retracted canine.
2. Serum bone alkaline phosphatase.
3. Rate and duration of canine movement.
4. Incidence of Root resorption.

### 1. Angle of tipping of the distracted canines

**Table 1.** Comparison within the hyperbaric and non hyperbaric groups according to the degree of tipping.

| | GROUP I HBO | | GROUP II NHBO | | F | P |
|---|---|---|---|---|---|---|
| | PDLD | DAD | PDLD | DAD | | |
| **Angle of Tipping** | | | | | | |
| **Min. – Max** | 0.0 – 13.0 | 0.0 – 15.0 | 7.0 – 22.0 | 2.0 – 26.0 | | |
| **Mean. ± SD.** | 6.63 ± 3.96 | 4.38 ± 4.96 | 13.88 ±5.33 | 8.88 ± 8.18 | 3.896* | 0.019* |
| **Median** | 6.0 | 3.50 | 13.50 | 6.0 | | |
| **$p_1$** | 0.896 | | 0.127 | 0.896 | | |
| **$p_2$** | | | 0.027* | 0.506 | | |
| **$P_3$** | | | | 0.415 | | |

F: F test (ANOVA)

$p_1$: p value for Post Hoc test (Scheffe) for comparing between HBO PDLD and each other group

$p_2$: p value for Post Hoc test (Scheffe) for comparing between HBO DAD and each other group

$p_3$: p value for Post Hoc test (Scheffe) for comparing between NHBO PDLD and NHBO DAD

*: Statistically significant at $p \leq 0.05$

Table 1 can summarize all the results about the degree of tipping in this study. An ANOVA test was found significant in comparing different groups and sides. The DAD side in the HBO group had the least mean degree of tipping 4.38°, followed by PDLD side in the HBO group with average degree of tipping of 6.63°. Then the DAD side of NHBO group had a mean degree of tipping equals to 8.88°. And at last the PDLD side of the NHBO group had the biggest mean degree of tipping of 13.88°. Only the results comparing the NHBO/PDLD subgroup with HBO/DAD subgroup was found statistically significant. Other results comparing within groups were found not significant.

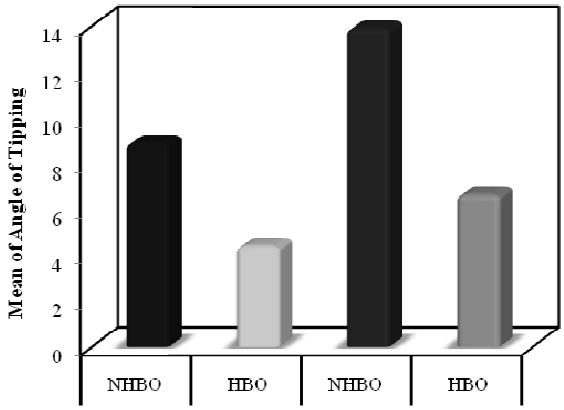


**Figure 11.** 3D bar chart showing comparison within the hyperbaric and non hyperbaric groups between the periodontal ligament and dentoalveolar distraction subgroups according to the mean degree of tipping.

**Table 2.** Comparison between the HBO and NHBO according to difference in degree of tipping.

| | **NHBO (n=16)** | **HBO (n=16)** | **p** |
|---|---|---|---|
| **Degree of tipping** | | | |
| **Min. – Max.** | 2.0 – 26.0 | 0.0 – 15.0 | 0.017* |
| **Mean ± SD.** | 11.13 ± 7.20 | 5.75 ± 4.27 | |
| **Median** | 8.50 | 5.0 | |

p: p value for Mann Whitney test for comparing between the two studied groups

*: Statistically significant at $p \leq 0.05$

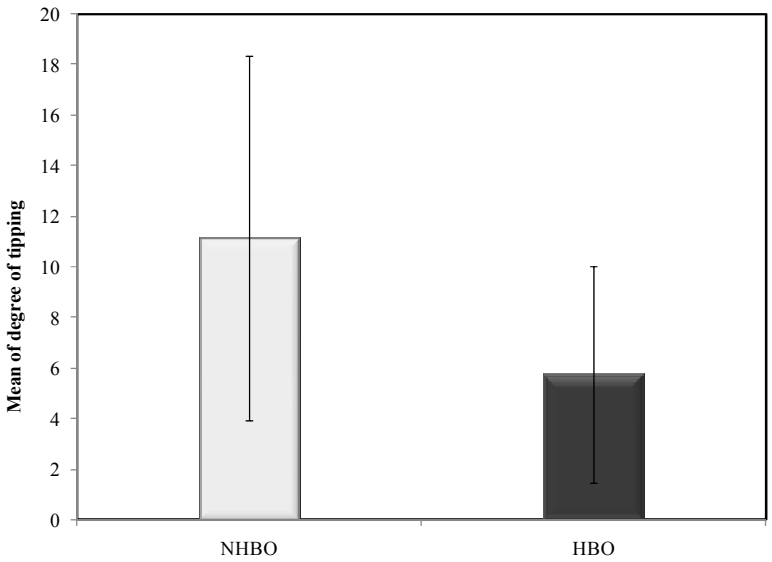


**Figure 12.** Bar chart Comparing between the HBO and NHBO according to difference in degree of tipping

Table 3 illustrated that the average degree of tipping in the HBO group (5.75$^{o}$) was signifcantly less than that in the NHBO group (11.13$^{o}$).

**Table 3:** Comparison between DAD subgroups and PDLD subgroups according to difference in degree of tipping in both groups.

| | **DAD (n=16)** | **PDLD (n=16)** | **P** |
|---|---|---|---|
| **Degree of tipping** | | | |
| **Min. – Max.** | 0.0 – 26.0 | 0.0 – 22.0 | 0.039* |
| **Mean ± SD.** | 6.88 ± 6.75 | 10.0 ± 5.89 | |
| **Median** | 4.50 | 6.43 | |

p: p value for Mann Whitney test for comparing between the DAD and PDLD

*: Statistically significant at $p \leq 0.05$

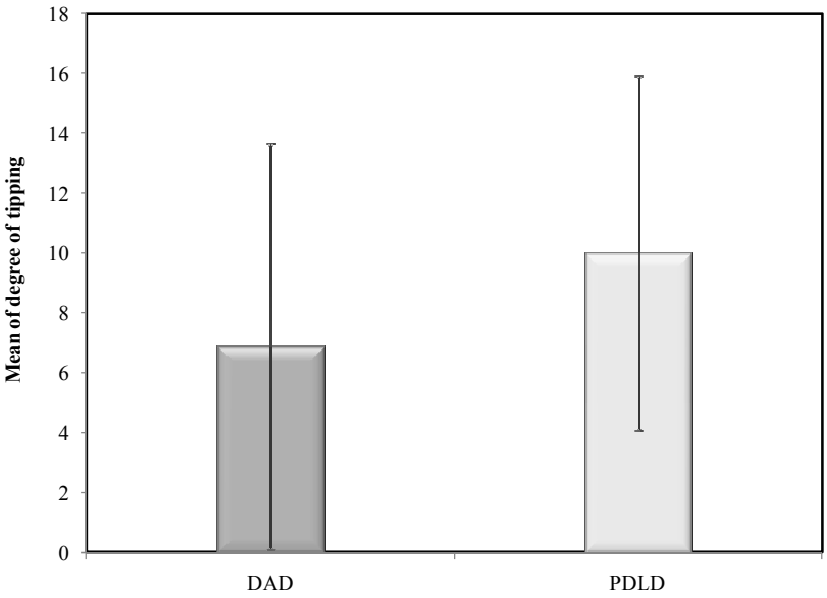


**Figure 13.** Bar chart Comparing between the DAD and PDLD according to degree of tipping.

Table 3 illustrated that the average degree of tipping in the PDLD side of both groups ($10^o$) was significantly higher than that of the DAD side ($6.88^o$). This result is statistically significant according to the Mann Whitney test. This indicates that DAD technique preserves more bodily movement during distraction.

**2. Serum bone alkaline phosphatase**

The mean overall change of serum bone alkaline phosphatase was calculated by dividing its level at $T_1$ by $T_0$ to get the proper ratio. The actual readings of the serum bone alkaline phosphatase were not compared as the initial readings were different from one subject to another.

**Table 4.** Comparison between the studied groups according to increase in serum bone ALP.

| | **HBO Group I (n=8)** | **NHBO Group II (n=8)** | **P** |
|---|---|---|---|
| **Serum ALP** | | | |
| **Min. – Max.** | 0.99 – 2.67 | 0.56 – 1.13 | 0.002* |
| **Mean ± SD.** | 1.43 ± 0.54 | 0.83 ± 0.18 | |
| **Median** | 1.30 | 0.83 | |

p: p value for Mann Whitney test for comparing between the two studied groups

*: Statistically significant at p ≤0.05

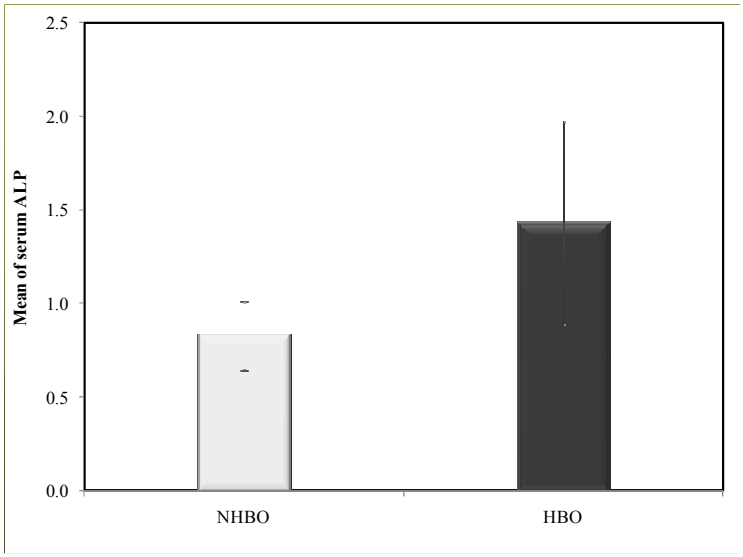


**Figure 14.** Bar chart comparing between the HBO and NHBO groups according to serum bone ALP.

Table 4 and figure 14 illustrated that the average increase in serum bone alkaline phosphatase ratio in HBO group was 1.43, while in the NHBO group the average change of bone serum alkaline phosphatase was 0.83.This result is statistically significant through the Mann Whitney test.

### 3. Rate and duration of canine distraction

The screws moved every day 1 mm / day distally in both of the distracted sides. The distracted canines were fully retracted in its place from 8 to 11 days since the first day of distraction.

**Table 5.** Comparison between the studied groups according to the duration of distraction.

| | **Group I HBO** | | **Group II NHBO** | | **F** | **P** |
|---|---|---|---|---|---|---|
| | PDLD | DAD | PDLD | DAD | | |
| Duration of distraction (days) | | | | | | |
| Min. - Max | 8.0 – 11.0 | 8.0 –11.0 | 8.0 – 11.0 | 8.0 – 11.0 | 1.282 | 0.300 |
| Mean. ± SD. | 9.38 ±1.06 | 9.0 ±1.07 | 9.88 ± 0.99 | 9.88 ±1.13 | | |
| Median | 9.5 | 9.0 | 10.0 | 10.0 | | |

F: F test (ANOVA)

Table 5 illustrated that the DAD side in HBO group had the least average of duration of distraction in days (9 ± 1.07 days). The PDLD side in the HBO group came in second place with average duration of distraction equivalent to (9.38 ± 1.06 days). The two sides of distraction in the NHBO group had the same average of duration of distraction (9.88 days). The average duration of distraction of the 16 retracted canines in the DAD sides was 9.44 days, while it was 9.63 days in the PDLD sides. The average duration of distraction in the HBO group was 9.19 days, while it was 9.88 days in the NHBO group. These results were not significant according to ANOVA test.

### 4. Root resorption

The dentoalveolar and periodontal ligament distraction showed no evidence of root resorption.

## DISCUSSION

The main objective of the current study is to investigate the quantitative and qualitative effect of hyperbaric oxygen on tooth movement. It also aims

at comparing between the dentoalveolar distraction and periodontal ligament distraction. This is the first comparative clinical study to evaluate the effect of hyperbaric oxygen on different distraction osteogenesis methods on human subjects.

Different methods of distraction osteogenesis were tried in the current study; the first method was presented after the extraction of the first premolar through the weakening of the interseptal bone. The described canine tooth retraction technique was achieved through stretching of the periodontal ligament. (Periodontal ligament distraction). The periodontal ligament is a "suture" between alveolar bone and tooth. Although the periodontal ligament surgical technique is very simple, it should be carried out cautiously in order not to injure the distal surface of the canine root. Another technique by Reha-Kisnici and Haluk-Iseri, The DAD technique was found to be a viable innovative method to reduce orthodontic treatment time in extraction cases. Without unfavourable long-term effects on the gingival tissues of the retracted canine teeth, the treatment time could be reduced by 6–9 months.[7] Bone-specific alkaline phosphatase is made in osteoblasts and reflects osteoblast activity during bone formation.[19] So, serum bone alkaline phosphatase (B-ALP) has been considered to be a good marker for bone formation. [20] The average increase of B-ALP was 1.43 times its initial level in hyperbaric group while it was 0.83 in non hyperbaric group. This coincides with what Basset and Hermann stated that hyperoxia leads to osseous tissue formation in a culture of a multipotent mesenchymal cells.[10] Tuncay et al reached the same conclusion and suggested the triggering role of oxygen tension in bone remodelling.[21] Gokce et al concluded that hyperbaric application caused an increase in bone apposition and osteoblastic activity and decrease of osteoclastic activity. They also suggested that the hyperbaric oxygen enhanced the bone formation during experimental tooth movement.[22] This can be explained by HBO increases dissolved oxygen in the blood and results in a high partial pressure of oxygen ($PaO_2$). An increase of $PaO_2$ affects the oxygen tension in regenerating tissue, which promotes collagen and adenosine-triphosphate (ATP) synthesis, capillary growth, and osteoblastic and osteoclastic activity.[11,12] Also, the extremely high dose of oxygen during actual hyperbaric treatment is followed by

a return to the hypoxic state with lactate build-up between treatments. Tissue macrophages migrate to the area and secrete a variety of biochemical messengers, including a chemotactic wound angiogenesis factor, in response to the high lactate levels that exist in the wound space. Therefore, angiogenesis is increased in the hypoxic area (injury area) by HBO. Neovascularization supplies more oxygen to the central area of the wound. This increased oxygen tension promotes osteogenesis, and all of these phenomena accelerate the healing of bone.

The results of the current study showed that the average degree of tipping in the periodontal ligament side of both groups ($10^o$) was higher than that of the dentoalveolar distraction side ($6.88^o$). This result is statistically significant. Also, the average degree of tipping in the hyperbaric group ($5.75^o$) was less than that in the non hyperbaric group ($11.13^o$). This result is statistically significant. Also an ANOVA test was found significant in comparing the different sides of the two groups according to the average degree of tipping. The dentoalveolar side in the hyperbaric group had the least mean degree of tipping $4.38^o$, followed by periodontal ligament side in the hyperbaric group with average degree of tipping of $6.63^o$. Then the dentoalveolar distracted side of non hyperbaric group had a mean degree of tipping equals to $8.88^o$. And at last the periodontal ligament distracted side of the non hyperbaric group had the biggest mean degree of tipping of $13.88^o$.

This can implicate that the least tipping of the retracted canine can be achieved by using the dentoalveolar distraction in association with hyperbaric oxygen, and the highest tipping degree of the retracted canine can be achieved using the periodontal ligament distraction with no use of hyperbaric oxygen. This coincides with further results attained in the current study, although some of them were not statistically significant. The average degree of tipping in dentoalveolar distracted canines in the hyperbaric group was $4.88^o$. The average degree of tipping of the periodontal ligament distracted canines in the hyperbaric group was $6.63^o$ while in the non hyperbaric group was $13.38^o$. This result is statistically significant.

The explanation of the smaller degree of tipping in the hyperbaric group can be attributed to the role of hyperbaric oxygen in enhancing the bone formation during experimental tooth movement.[22] While the smaller degree of tipping in the dentoalveolar side compared to the periodontal ligament side might be attributed to the surgical technique of dentoalveolar distraction does not rely on periodontal stretching, which obviates overloading and stress accumulation in this tissue.[7] The use of the dentoalveolus itself in the dentoalveolar technique might have a role in reducing the degree of tipping allowing the bodily movement of the canine during distracion. Further studies should be made to investigate the role of the hyperbaric oxygen and to compare between the periodontal ligament and dentoalveolar distraction.

In the current study, 32 canines were retracted on fixed daily basis of 1mm/day. This rate describes the amount that the screw moves inside the nut daily but it does not represent the distance moved by the canine daily. The canines were fully retracted in a range of 8- 11 days. The current study results might suggest that the rate of retraction of the canine in the hyperbaric group was higher than that of the non hyperbaric group. Also, it might suggest that the rate of retraction of the canine in the dentoalveolar distraction sides was higher than the periodontal ligament distraction sides. These suggestions were based upon the average duration of distraction of the 16 retracted canines in the dentoalveolar sides was 9.44 days, while it was 9.63 days in the periodontal ligament sides. The average duration of distraction in the hyperbaric group was 9.19 days, while it was 9.88 days in the non hyperbaric group. But these results were not statistically significant. The activation of the distractors were planned to be twice per day in order to reduce the pain accompanied during the procedure. The pain usually started during the manipulation and stopped as the activation ended.

According to the results of the current study, no clue has proved that the hyperbaric oxygen enhances the rate of canine retraction. Liou et al stated that the resorption of the apical and lateral surfaces of the root of canines was minimal in their PDLD method.[23] Kurt G. et al had no evidence of root resorption during their DAD of the canine.[24] Hong et al suggested minimal apical and lateral root resorption following the

distraction.[25] The current study coincides with most of the previous literature that the root resorption was minimal detected during retraction. But it should be noted that all the previous studies were just for short term follow up.

## REFERENCES

1. Ilizarov G, Lediov V, Shitin V. The course of compact bone reparative regeneration in distraction osteosynthesis under different conditions of bone fragment fixation and experimental study [Russian]. Exp Khir Anesteziol 1969; 14: 3-12.
2. Snyder C, Levine G, Swanson H, et al. Mandibular lengthening by gradual distraction: preliminary report. Plast Reconstr Surg 1973; 51: 506-8.
3. McCarthy J, Schreiber J, Karp N, et al. lengthening the human mandible by gradual distraction. Plast Reconstr Surg 1992; 89: 1-10.
4. Polley J, Figueroa A. Management of severe maxillary deficiency in childhood and adolescence through distraction osteogenesis with an external, adjustable, rigid distraction device. J Craniofac Surg 1997; 8: 181-5.
5. Figueroa A, Polley J, Breckler G, Liou E, Cohen M. Orthodontic tooth movement through distracted mandibular bone. American Cleft Palate-Craniofacial Association 54th Annual Meeting, New Orleans, Louisiana, April 7-12, 1997.
6. Liou E, Figueroa A, Polley J. The orthodontic tooth movement into distraction osteogenesis. American Cleft Palate-Craniofacial Association 55th Annual Meeting, Baltimore, Maryland, April 20-25, 1998.
7. Kisnisci R, Iseri H, Tuz H, Altug A. Dentoalveolar distraction osteogenesis for rapid orthodontic canine retraction. J Oral Maxillofac Surg 2002; 60: 389-94.
8. Gottrup F. Oxygen in wound healing and infection. World J Surg 2004; 28: 312–5.
9. Tibbles P, Edelsberg J. Hyperbaric-oxygen therapy. N Engl J Med 1996; 334: 1642–8.

10. Basset A, Hermann I. Influence of oxygen concentration and mechanical factors on differentiation of connective tissue in vivo. Nature 1961; 190: 460.

11. Niinikoski J, Hunt T. Oxygen tensions in healing bone. Surg Gynecol Obstet. 1972; 134: 746–50.

12. Stern B, Glimcher M, Mechanic G, Goldhaber P. Studies of collagen degradation during bone resorption in tissue culture. Proc Soc Exp Biol Med 1965; 119: 577–83.

13. Tuncay OC, Ho D, Barker MK. Oxygen tension regulates osteoblast function. Am J Orthod Dentofacial Orthop 1994; 105: 457–63.

14. Shaw J, Bassett A. The effects of varying oxygen concentrations on osteogenesis and embryonic cartilage in vitro. J Bone Joint Surg Am 1967; 49: 73–80.

15. Nilsson P, Albrektsson T, Granstrom G, Rockert H. The effect of hyperbaric oxygen treatment on bone regeneration: an experimental study using the bone harvest chamber in the rabbit. Int J Oral Maxillofac Implants 1988; 3: 43–8.

16. Sharpe W, Reed B, Subtelny J, Polson A. Orthodontic relapse, apical root resorption, and crestal alveolar bone level. Am J Orthod Dentofacial Orthop 1987; 91: 252-8.

17. Leslie E, Geoffrey J, and James M. Statistical analysis. In: Interpretation and uses of medical statistics (4th ed). Oxford Scientific Publications (pub). 1991, pp: 411-6.

18. Kirkpatrick L, Feeney B. A simple guide to IBM SPSS statistics for version 20.0. Student ed. Belmont, Calif.: Wadsworth, Cengage Learning. 2013. x: 115 p. p.

19. Thomas S. Bone turnover markers. Aust Prescr 2012; 35: 156–8.

20. Tobiume H, Kanzaki S, Hida S, Ono T, Moriwake T, Yamauchi S, et al. Serum bone alkaline phosphatase isoenzyme levels in normal children and children with growth hormone (GH) deficiency: a potential marker for bone formation and response to GH therapy. J Clin Metab 1997; 82: 2056-61.

21. Tuncay O, Ho D, Barker M. Oxygen tension regulates osteoblast function. Am J Orthod Dentofacial Orthop 1994; 105: 457-63.

22. Gokcea S, Bengi O, Akinc E, Karacayd S, Sagdicc D, Kurkcue M, et al. Effects of Hyperbaric Oxygen during Experimental Tooth Movement. Angle Orthodontist 2008; 78: 2.

23. Liou E, Huang C. Rapid canine retraction through distraction of the periodontal ligament. Am J Orthod Dentofacial Orthop 1998; 114: 372-82.

24. Gürgan C, Iseri H, Kisnisci R. Alterations in gingival dimensions following rapid canine retraction using dentoalveolar distraction osteogenesis. Eur J Orthod 2005; 27: 324–32

25. Hong A, Qing-feng X, Hong-fei L, Zhi-hui M, Ai-qun A, Guo-ping L. Rapid tooth movement through distraction osteogenesis of the periodontal ligament in dogs. Chin Med J 2008; 121: 455-62