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# Effect of Micro-osteoperforations on the Rate of Orthodontic Tooth Movement: A Randomized Controlled Trial

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## ABSTRACT

***Objectives***: To evaluate the efficacy of Micro-osteoperforations(MOPs) on the rate of tooth movement, levels of Pain and Discomfort associated with MOPs as well as differences in anchorage loss between tooth movement with and without MOPs.

***Methods***: Ten patients with Bidentoalveolar Protrusions, who were treated with Extraction of Upper First Premolars; divided into control and experimental groups. MOPs were performed on experimental side and control side did not receive MOPs. Canines on both sides were completely retracted till second premolar contact and time taken was recorded. Pain and discomfort were monitored with a numeric rating as well as visual analog scale. Anchor loss, if any was measured using study models and cephalometric method.

***Results***: Micro-osteoperforations significantly increased the rate of tooth movement by 1.64-fold. The patients did not report to have experienced significant pain or discomfort during or after the procedure. No other complication was reported. And anchorage loss was not encountered.

***Conclusions***: Micro-osteoperforations can be used as an effective, comfortable, and safe procedure to accelerate tooth movement without taxing anchorage and with minimal pain or discomfort. Mops tend to reduce the duration of orthodontic treatment.

***Keywords***: Orthodontic tooth movement, Accelerated orthodontics, Micro-osteoperforations, Canine retraction, Anchorage.

## INTRODUCTION

Altering the biology of tooth movement since the turn of the century, has become an exciting focus of research to pursue treatment proficiency. Patients may elect to forego orthodontic treatment due to the cost and/or duration of treatment, with most cases, traditionally taking 24 to 30 months, or due to the visibility of orthodontic appliances. A multitude of potential benefits of accelerating orthodontic tooth movement has been reported in the literature. [1-6]

It is imperative to understand the biological principles and molecular mechanisms that govern tooth movement, based on which, the existing proposed acceleration techniques can be categorized into two types: a) indirect (acts on cytokines) and b) direct (acts on the target cells). Direct techniques include vibration, laser, and ultrasound and indirect techniques include Micro-osteoperforations(MOPs), Piezocision and Corticotomy etc. The biological mechanism of indirect techniques are based on a physiological healing process known as *Regional Acceleratory Phenomenon(RAP)*.

Many studies have reported that by increasing expressions of inflammatory markers like chemokines and cytokines, tooth movement can be accelerated via prostaglandin E2and RANK/RANKL pathway. [7-9]

Currently, various modalities have been suggested by the literature to accelerate the rate of orthodontic tooth movement. Corticotomy and Low Level Laser Therapy(LLLT) are most commonly used and researched. However, these methods have their own merits and demerits. Corticotomy being an invasive, time consuming and technique sensitive procedure; is difficult to incorporate into routine practice. Lately, *Micro-osteoperforations*(**Alveocentesis™**) have gained momentum and have succeeded in raising inquisitiveness amongst orthodontists to perform studies for research in determining the efficacy of MOPs to accelerate the rate of tooth movement.

Previous animal studies have shown that performing MOPs during orthodontic tooth movement can stimulate the expression of inflammatory markers, leading to increased osteoclastic activity and the rate of tooth movement.[10] Recent human clinical trials have also demonstrated increased level of inflammatory markers like IL-1α in Gingival Crevicular Fluid(GCF), higher number of osteoclasts and bone remodeling activity, accompanied by generalized osteoporosis and increased rate of tooth movement following MOPs.[11 -17]

To investigate whether the rate of tooth movement increases in humans, we designed a clinical trial to study the rate of canine retraction with and without MOPs. In addition, the pain and discomfort experienced by the patients as well as anchorage loss associated with MOPs was measured during the study were evaluated.

## MATERIALS AND METHODS

A Prospective Randomized Clinical Trial (RCT) with Split Mouth Study Design was approved by the Ethical and Research Committee of Dharmsinh Desai University, Nadiad.

**Subjects:** Total pool of samples consisted of 13 subjects.

The **inclusion criteria** for recruitment into the study were:

1) Bidentoalveolar Protrusions which would necessitate Extraction of Upper First Premolars.

2) Presence of Healthy and complete complement of dentition.

3) [i] No radiographic evidence of bone loss.

[ii] No history of/current active periodontal disease.

[iii] No smoking.

[iv]No endodontic lesions.

And the **exclusion Criteria** were:

1) Evidence of unilateral chewing habits.

2) Presence of Parafunctional habits/habitual effects.

3) Any Form of Crossbite and/or occlusal interferences.

These subjects provided 26 maxillary canines (one from each upper quadrant) which were randomly assigned into: Group 1: The Control-side quadrant that received Orthodontic treatment only and Group 2: The Experimental-side quadrant that received Orthodontic treatment and the Micro-osteoperforations(MOPs) both. A Multilayered Lottery Randomization method was employed for random allocation of subjects in both Groups. The randomly assigned partial block split-mouth design was employed to prevent interindividual biologic variation. Prior to the actual procedure of MOPs, the patients were blinded about the experimental and control sides.

***a) Clinical Technique:***

The treatment was initiated by bonding fixed Preadjusted Edgewise 0.022x0.028” MBT Appliance System in both arches. The initial alignment was achieved using 0.014”, 0.018” and 0.017x0.025” NiTi archwires sequentially and then the final working wire placed was: 0.017 X 0.025” stainless steel bended to form a double looped archwire (**Fig. 1**). Maxillary incisors were aligned before retraction of maxillary canine so as to avoid alteration in distance between the maxillary canines and second premolars during the research.

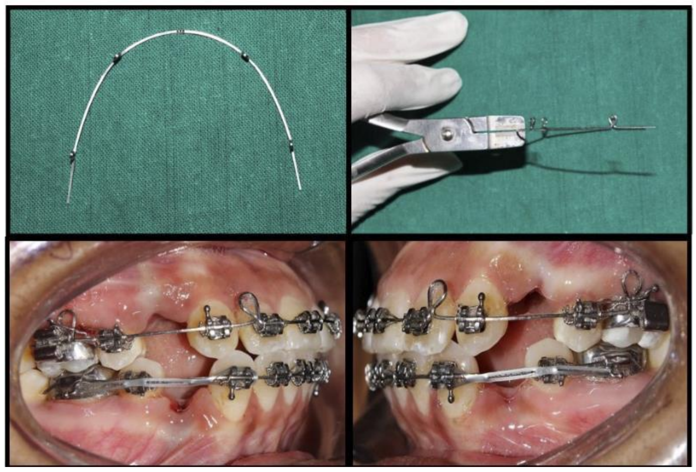


**Figure (1): Design of Double Looped Archwire.**

Individual canine retraction was started with 9 mm NiTi closed-coil spring system. A constant force of 140–160 gm(measured using Dontrix Gauge)was used for canine retraction on both sides. The spring was positioned and stretched from the first molar tube hook to the power arm of the canine bracket and secured with a ligature tie to the bracket. Patients were asked to report immediately if the spring dislodged or broke and was replaced immediately.

Atraumatic extractions of both first premolars on either side were performed; within a week with random allocation and by the same surgeon to eliminate the intra-operator variability one month prior to MOPs. Anchorage reinforcement was done with the help of *Transpalatal arch.*

For the operator to perform *MICRO-OSTEOPERFORATIONS*, a propel device; known as **Excellerator RT™**[(Propel, Milpitas, CA, USA), (**Fig. 2**)] along with ready-to-use sterile closed tips and in-depth limiter at 7mm was procured and used. Micro-osteoperforations were performed on Experimental side on the same day as placement of the Coil Spring.


**Figure (2): Propel Excellerator RT™**

Absolute Surgical Protocols were observed and radiographs were used during each MOP performance. Local topical anesthesia (2% lidocaine with 1:100,000 epinephrine) in gel form was applied to the area of procedure. The gingiva was dried and a probe was used to mark the target region. Three small MOPs, each at apical, middle and cervical thirds; on mesial as well as distal sides of the canine buccally coinciding with the marks were performed keeping Excellerator RT at 90° to the taut tissue, the cutting edge of the tip was slowly engaged while turning the device “clockwise”. Each perforation was 1.5 mm wide and depth of MOP varied according to thickness of alveolar bone and overlying mucosa. Once the desired depth was achieved, the device was rotated “counterclockwise’’ to remove the tip atraumatically (**Fig. 3**). Following the sterilization protocols, MOPS were performed only one-time. Neither any flap was reflected, nor any pain killers/ antibiotic/ other medications were prescribed.

**Figure (3): Micro-osteoperforation Procedure**

Patients were given a pain questionnaire (**Fig. 4**). Patients were instructed to mark their level of pain on a ten (10) cm Numeric Rating Scale (NRS) and Visual Analogue Scale (VAS). They were asked to mark the pain level on the same day (hour 0-on the day of canine retraction), after 24 hours and on the seventh (7th) day.

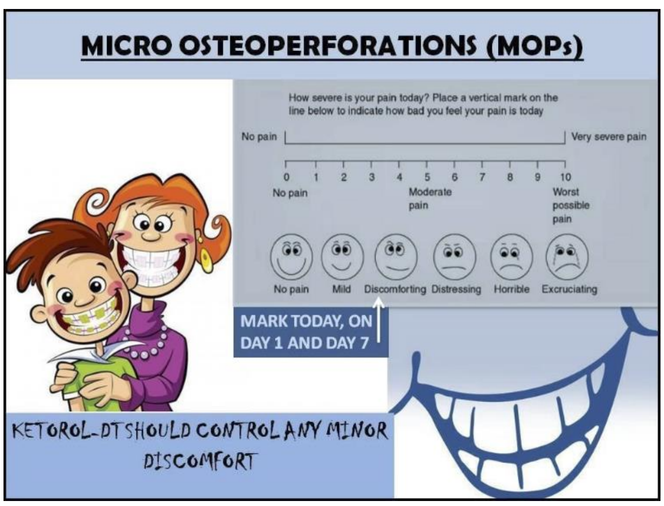



**Figure (4): Pain Questionnaire**

The chewing habit was monitored during the entire course of the study. Three out of thirteen subjects developed unilateral chewing post MOPs procedure and hence were excluded from the sample prior to tabulation and analysis of the data.

Alginate impressions were taken at the beginning of the study, immediately before canine retraction, and after completion of canine retraction. The study-models were labeled and stored. At the completion of the study all the models were retrieved and were blindly examined by Operators not involved in the Study to prevent any bias. The Mesiobuccal cusp tips of First Molar and the Canine cusp tips were the Reference points. The distance between the first molar and the canine was measured on all both pre and post models for each patient with a Digital Caliper ± 0.02 mm. These distances were recorded at T0 (at the start of Canine Retraction), i1, i2, i3… (recorded on intermediate models made at every month) and T1 (on completion of Canine Retraction on the Experimental Side or the Control Side).

Lateral Cephalograms at T0 and T1: All Lateral Cephalometric head films were taken in Natural Head Position (NHP) by a single operator in the Standard International Cephalometric norms with precise procedural STEPS using the Carestream make CS8000C Machine.

***b) Determining Anchorage Loss:***

Anchorage loss measurement techniques, both on models and cephalograms incorporated were not only to demonstrate effect of MOPs on anchorage but more to ascertain and to prove that the distance travelled by canine did not change significantly during the study and that the rate of tooth movement calculated was not affected by the loss of true distance travelled by the canine on the experimental and control side. Anchor loss, if any, was measured and ascertained from Plaster models and Superimposition of Lateral Cephalograms of Pre and Post retraction of canines. An acrylic and wire comprised device as reported in literature to be employed in such situations, [18, 19] ‘DDU Spider’ was designed similarly and configured contraption using Maxillary Third Rugae area documented as the most stable structure (**Fig. 5**). This was constructed on the Pre-canine, Intermediate- and Post-canine retraction time point’s Plaster Models.

**Figure (5): DDU SPIDER**

Each Plaster model was then subjected to the placement of this Device. Variation of the Balls of Ball ended Clasps from the Original point of placement in the pits were quantum of change in the position of Canines (Retraction) and molars (Anchor loss).

If any mesial movement of molars would have been encountered, it would result in change in inclination of the Incisors which was demonstrated by superimposition of Pre- and Post- retraction Lateral cephalogram along the palatal plane registered at anterior nasal spine (ANS). The amount of molar anchorage loss was measured from Pterygoid Vertical (PtV): i.e. the horizontal distance from PtV to the distal surface of the maxillary first molar. [20] (**Fig. 6**)

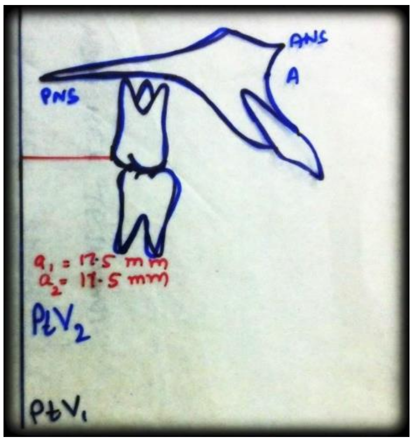
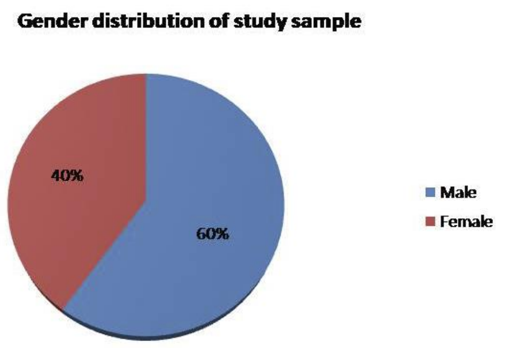



**Figure (6): Superimposition done along the palatal plane registered at anterior nasal spine (ANS) to assess Anchorage Loss. 1) $PtV_1$ and $PtV_2$ for pre (black) - and post (blue) - canine Lat cephalogram respectively and 2) $a_1$ and $a_2$: pre- and post- horizontal distance on Pre- and Post- Lat cephalograms respectively.**

Experimental Group and b) Rate of Distal Movement of Canine in Control and Experimental Group were performed.

## RESULTS

10 maxillary canines in Control Group and 10 in Experimental Group i.e. 50-50% in both groups; 6 males and 4 females, were analyzed. (**Graph 1**)




**Graph 1: Gender distribution of study sample**

Mean age of subjects was **19.80 ± 3.458 years**. (Ranging from 15 years to 27 years). (**Table 1**)

**Mean distance** between the Canine and Second Premolar was **22.36 mm** for Control group at **T0 DC** and a mean of **22.32 mm** in Experimental group at **T0 DE**. This was statistically insignificant ($P$ = 0.939). The mean distal movement of canine at **T1 DC** and **T1 DE** over same period of time was found to be **17.92 mm and 15.01 mm** respectively. These results show a statistically significant difference in mean Distal Movement of the Canine between two groups with ***p* value <0.001**.(**Table 2**).

| TABLE 1: Descriptive Statistics for age of the subjects | | | | |
|---|---|---|---|---|
| | **N** | **Minimum** | **Maximum** | **Mean ± SD** |
| **Age** | 10 | 15 | 27 | 19.8± 3.46 |

## STATISTICAL ANALYSIS

All statistical analyses were performed using STATA/IC 13 (StataCorp). Statistical significance was set at $P$< 0.001 for all tests. Univariate frequency distribution for Sample distribution, Gender distribution and pain perception was performed. Univariate frequency distribution shows summarized grouping of data divided into mutually exclusive classes and the number of occurrences in a class. Descriptive Statistics for Age of the subjects was performed. Independent sample T-tests were calculated to analyze the results of the primary outcome to compare the difference between MOP and control sides. Independent T tests for: a) Mean Distal Movement of Canine Every Month in Control and

*D= distance travelled by canine; distance between canine tip and mesiobuccal cusp tip of first permanent molar; **P<0.001= Statistically Significant.

The **total mean rate** of Distal movement of Canine, which was found to be **4.44 mm (44.4%)** in Control group whereas **7.31mm (73.1%)** in experimental group (**Table 3**).

Both methods of assessing anchor loss, cephalometric as well as study models, demonstrated that there was no anchor loss in form of mesial movement of posterior anchor units and also there was no labial movement of incisors (**Fig.7**). This signifies that the difference between the distances measured at T0 and T1 show a true distance travelled by maxillary canine in this study.

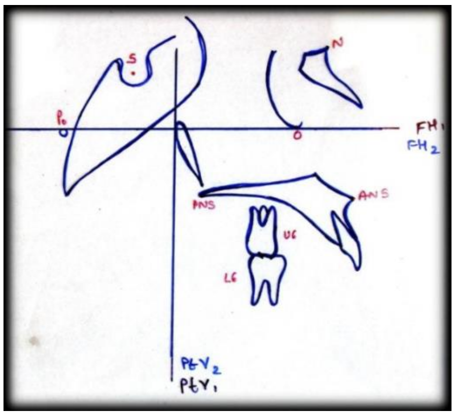



**Figure 7: PRE (black) - and POST (blue) - Canine Retraction traced on Lateral Cephalogram**

The **perception of pain** of the subjects post MOP procedure (stimulus) on **Day 0**, was perceived variably from no pain (20%) to mild (70%) and horrible (10%) at **Visual Analog Scale (VAS)**. On **Day 1**, pain reduced considerably amongst the Group 2 (Experimental) sides. On **Day 7**, **no pain** was perceived by any of the subjects **(100%)** (**Table 4**).

| TABLE 4: Pain Perception of the Subjects on Day 0, 1 and 7 | | | |
|---|---|---|---|
| **PAIN** | **Baseline (DAY 0)** | **DAY 1** | **DAY 7** |
| **HORRIBLE** | 1 (10%) | 0 (0%) | 0 (0%) |
| **MILD** | 7 (70%) | 3 (30%) | 0 (0%) |
| **NO PAIN** | 2 (20%) | 7 (70%) | 10 (100%) |
| **TOTAL** | 10 | 10 | 10 |

## DISCUSSION

Number of adults seeking orthodontic treatment to enhance the social and psychological status of their life is large.[21,22] With the increasing average age of orthodontic patients, there is a concomitant increase in the demand for faster and more efficient orthodontic treatment. In adults compared to children, cell mobilization and conversion of collagen fibers is much slower.[23,24] Factors like active periodontal disease, loss of attached gingiva or alveolar bone do make the orthodontic treatment difficult, different and challenging.[25,26]

Considering the fact that various clinical factors; timing of force application and implant maintenance factors, contribute to the Success or Failure of Skeletal Anchorage Devices(TADs).The failure rate of TADs ranges from 13 to 17%.[27-29] In present study, a novel approach combining the Segmental Mechanics Philosophy with Reinforced Anchorage Methods was employed (i.e. TPA+ Double Looped Archwire) to ensure smooth progression of the treatment, study and also not to compromise the sample size. As presumed there was no mesial movement of the molars or any labial movement of the Incisors.

In both the control and the experimental groups the difference in the average distance between points of application of force on the Canine and the Anchor unit was found to be insignificant, thus it ensured equal stretching of the coil spring, resulting in a constant force on all canines of the both the Groups.

Extractions were performed one month prior to MOPs; that would nullify sole or adjunctive effect of extractions on rate of tooth movement because even if any sort of prolong acceleration effect due to extraction did persist; due to randomization in extractions and in MOPs, it is not possible to prove that acceleration achieved was purely because of prolong RAP effect of extractions as both experimental and control sides would be having same extractions induced cellular biology. Also, Sebaoun JD has documented that postsurgical insult, the catabolic activity of RAP is at peak by 3rd week. By 4th week, increased anabolic modeling of alveolar trabecular bone adjacent to the trauma has been observed. The impact of surgical insult dissipates considerably by postoperative week 7 and stabilizes to a steady state by postoperative week 11.[30]

In present study the **total mean rate** of Distal movement of Canine, which was found to be **4.44 mm (44.4%)** in Control group whereas **7.31mm (73.1%)** in experimental group. The **mean difference** (2.91 mm) between both groups was found to be statistically significant. The results showed a 1.64 fold increase in the rate of tooth movement in the experimental group. Similarly, Mani Alikhani et al. in their study on canine retraction over 28 days, albeit, using mini implants as source of anchorage, observed 2.3 fold increase in the rate of tooth movement in experimental group [11]. The results of our study are also in agreement with study by same Researchers, Mani distalization acceleration using MOP leads to upto 41% faster space closure[15]. Masood Feizbakhsh et al. found that MOPs

TABLE 2: Independent t-Test for Mean Distal Movement of Canine Every Month in Control and Experimental Group

| | Group | N | D* Mean + SD | Std. Error Mean | **p value | 95% Confidence Interval of the Difference | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| T0 (mm) | Control | 10 | 22.36+ 1.15 | 0.364 | 0.939 | -1.048 | 1.128 |
| | Experiment | 10 | 22.32+ 1.16 | 0.368 | | | |
| i1 (mm) | Control | 10 | 21.12+ 1.06 | 0.336 | 0.158 | -0.344 | 1.964 |
| | Experiment | 10 | 20.61+ 1.37 | 0.434 | | | |
| i2 (mm) | Control | 10 | 19.98+ 1.24 | 0.392 | 0.011 | 0.452 | 3.108 |
| | Experiment | 10 | 19.10+1.57 | 0.496 | | | |
| i3 (mm) | Control | 10 | 19.12+ 1.65 | 0.523 | 0.000 | 1.379 | 4.021 |
| | Experiment | 10 | 17.49+ 1.11 | 0.35 | | | |
| i4 (mm) | Control | 10 | 18.66+1.69 | 0.535 | 0.001 | 1.198 | 4.242 |
| | Experiment | 10 | 16.04+ 1.54 | 0.488 | | | |
| T1 (mm) | Control | 10 | 17.92+ 1.76 | 0.557 | 0.001 | 2.808 | 5.592 |

Alikhani et al, which also measured the IL-1 α level in the Gingival Crevicular Fluid(GCF) before and after the MOPs, and found a more than 2 fold increase in rate of tooth movement, along with increased IL1- α activity. [12]

Also in concurrence with our findings, Teixeira et al.[10] who studied efficacy of MOPs on mesialization of molar in rats, reported increased rate of tooth movement in the OFP (force application plus flap plus 3 small perforations of the cortical plate) group. Investigation by Kim SJ et al., demonstrated 2.08-fold increase with LLLT and 2.23-fold increase in the rate of tooth movement with corticision. [31]

Similarly Tracy Cheung et al. evaluated the effectiveness of MI-facilitated MOPs and observed 1.86-fold increase in the rate of tooth movement on MOP side.[13] Chi-Yang Tsai et al. concluded that Corticotomy and MOPs induced faster orthodontic tooth movement for at least 2 weeks in rats.[14] Yamile Zamora Escobar et al. also suggested that canine significantly increased the rate of tooth movement by more than 2-fold.[16] A systemic review suggested increased rate of tooth movement after performing MOP but higher root resorption was observed in at least one study. Therefore, it is recommended to use MOPs after weighing the benefits and disadvantages this intervention can bring for each patient.[32] In contrast with our results Alkebsi et al. and Aboalnaga et al. found in their recent studies Micro-osteoperforations were not able to accelerate the rate of canine retraction; however, it seemed to facilitate root movement.[33,34]

In present study, the subjects on experimental side demonstrated mild pain or discomfort only on the day of MOPs procedure which reduced dramatically on second day and by day seven no pain or discomfort was experienced, thereby depicts that patient comfort and compliance is not affected. Attri et al. investigated the influence of MOPs on rate of orthodontic tooth movement and pain perception and concluded that MOP appears to enhance the rate of tooth movement with no differences in pain perception. [17]

It has been hypothesized that in the conventional mechanics without MOPs, there is no decrease in the bone density around the canine therefore the time needed to distalize canine is more and this in turn results into greater reactionary force on anchor units. [12] MOPs decrease the bone density only in the surrounding area; while the bone density around anchor teeth remains unchanged. The decrease in bone density renders the bone weak and resistance to movement reduces dramatically. Consequently, when conventional mechanics with MOPs is employed, the canines move faster through the bone. Hence the anchorage is not taxed. In our study, both techniques showed no mesial movement of anchor units and no distal tipping of the Upper Incisal Segment. In previous studies; in agreement with our results very mild anchorage loss was reported in both the control and MOP sides.[33] And were similar even with the utilization of absolute anchorage means, was documented formerly by El-Beialy et al.[35]

**TABLE 3: Independent t-Test for rate of distal movement of canine in control and experimental group**

| | Group | N | Mean ± SD | p value | 95% Confidence Interval of the Difference | |
|---|---|---|---|---|---|---|
| **DIFFERENCE** | **Control** | 10 | 4.44± 0.88 | <0.001 | Lower | Upper |
| | **Experiment** | 10 | 7.31± 0.58 | | -5.012 | -3.608 |

This study was performed primarily with intention to study effect of MOPs on Indian population who may have genetically different biological response to Orthodontic force system. Our study found similar increase in rate of tooth movement as in the studies performed on Caucasians and other Non-Indian Populations across the Globe.

We recommend conducting further studies with a larger Sample size, gender predilections, age dependence, racial differences in response, on more multitudes of clinical situations, managed by contemporary biomechanical methods in terms of Force generating systems as well as the biomaterials used.

## CONCLUSION

Within the limitations of this study, the following conclusions could be withdrawn:

In tandem with most recent studies as well as certain classical findings, our study similarly concludes that *Micro-osteoperforations increase the rate of Orthodontic Tooth Movement* ***1.64-fold****, with minimal pain or discomfort and clinically insignificant Anchor loss/minimal taxing on Anchor Units* (**Fig. 8**).

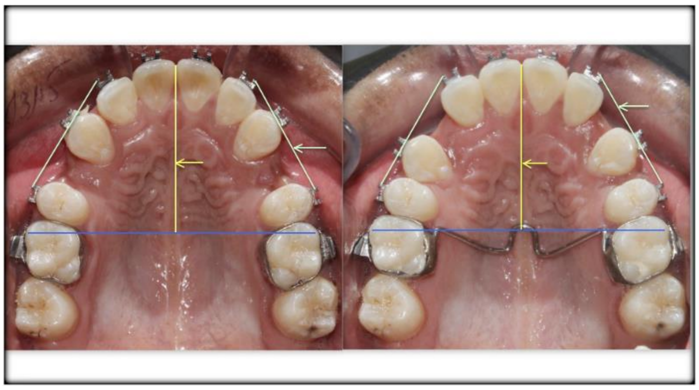


**Figure (8): PRE- and POST- Canine Retraction Upper Occlusal View Vertical distance between contact area of maxillary central incisors and the line joining the mesiobuccal cusp tips of maxillary first molars (pre- & post-canine retraction) Distance between the distal wing of the maxillary lateral incisor bracket and mesial wing of maxillary second premolar bracket on control and experimental sides (pre- & post- canine retraction).**

Therefore, the flapless, minimally invasive MOPs procedure enables orthodontists to provide shorter duration of orthodontic treatment by accelerating the rate of orthodontic tooth movement.

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