COMPARATIVE EVALUATION OF RATE OF ORTHODONTIC TOOTH MOVEMENT BY VARYING THE TIMING OF THERAPEUTIC EXTRACTIONS IN PATIENTS UNDERGOING FIXED APPLIANCE THERAPY - AN IN VIVO STUDY

A Dissertation submitted

in partial fulfillment of the requirements for the degree of

MASTER OF DENTAL SURGERY

SUBMITTED BY

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CERTIFICATE

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DECLARATION

TITLE OF THE DISSERTATION	**COMPARATIVE EVALUATION OF RATE OF ORTHODONTIC TOOTH MOVEMENT BY VARYING THE TIMING OF THERAPEUTIC EXTRACTIONS IN PATIENTS UNDERGOING FIXED APPLIANCE THERAPY – AN IN VIVO STUDY.**
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I hereby declare that no part of the dissertation will be utilized for gaining financial assistance or any promotion without obtaining prior permission of the Principal, Adhiparasakthi Dental college and Hospital, Melmaruvathur -603319. In addition, I declare that no part of this work will be published either in print or in electronic media without the guides knowledge who have been actively involved in dissertation. The author has the right to reserve for publish work solely with the permission of the principal, Adhiparasakthi Dental college and Hospital, Melmaruvathur-603319.

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Head of Department

Signature of candidate

ABSTRACT

AIM:

This study aims in estimating the rate of tooth movement by mini-implant assisted canine retraction through a simplified Rapid acceleratory phenomenon (RAP) by altering the time of therapeutic extraction.

MATERIALS AND METHOD:

After approval from institutional review board and clearance from ethical committee (IRB/EC Ref No:2017-MDS-BR.V-SUD-12/APDCH) the study was initiated. Out patients who reported to the department of orthodontics, APDCH, after completing their informed consent form, a total of 10 patients having class I malocclusion, bimaxillary protrusion who satisfied the inclusion and exclusion criteria and required therapeutic extraction of both maxillary and mandibular 1^{st} premolars were included in the study.

In total 40 samples were obtained 20 (10 control & 10 experimental) in maxilla and 20 (10 control & 10 experimental) in mandible respectively. Patients were randomly assigned to one of the study groups. Intially the extraction of first premolars in one side of maxilla & mandible performed and taken as control group(Healed extraction site) and the other side extraction performed after compeletion of aligning & levelling stage is taken as experimental group(Recent extraction site). Allocation of control and experimental group is done in randomly unbiased manner.

All the permanent teeth were bonded with 0.022” MBT PRESCRIPTION with auxiliary vertical slot canine brackets. The leveling and alignment was done using the following sequence of 0.016 NiTi, 0.017*0.25 NiTi, 0.019*0.025 NiTi wires and 0.019*0.025 SS arch wire was placed for a period of 4 weeks and then the experimental side extraction was

performed. Then 24 hours after extraction alginate impressions were taken as a record followed by retraction phase. In the which mini-screws were used as the source of anchorage and the individual canine retraction was achieved using 9mm NiTi closed coil spring connected from temporary anchorage device to the customized serpentine hook placed in the vertical slot of canine brackets to deliver a force of 100g to produce bodily tooth movement which was checked periodically using dontrix gauge. Alginate impressions were taken at the beginning of the study, immediately before canine retraction, and at 28^{th}, 56^{th}, 84^{th} day after canine retraction began, to monitor the rate of tooth movement in both arches.

The distance between the canine and lateral incisor was assessed before and after canine retraction at 3 points namely incisal, middle, and cervical third of the crown from palatal aspect on the cast and rechecked to reduce intra and inter examiner error and the results were analyzed statistically.

RESULT:

The results of the study showed that increase in rate of canine retraction of maxilla & mandible by 1-fold in experimental side when compared with control side in 28 days. But, the overall rate of tooth movement in experimental side (Recently extracted site) showed less significant (p-value of 0.012) when compared to control side. Which is almost near to the significant value (p-value $\leq$ 0.005).

CONCLUSION:

Simplified Rapid acceleratory phenomenon (RAP) is an effective, comfortable, non-invasive and safe procedure to accelerate tooth movement and significantly reduce the duration of orthodontic treatment time.

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ABBREVIATIONS

RAP	-	Rapid Acceleratory Phenomenon
TAD	-	Temporary Anchorage Device
MOP	-	Micro Osteo Perforation
PAOO	-	Periodontally Accelerated Osteogenic Orthodontic technique
MBT	-	McLaughlin Bennet Trevisi bracket system
SS	-	Stainless Steel
NiTi	-	Nickel Titanium

INTRODUCTION

Orthodontic treatment is commonly undertaken for the management of malocclusion. The correction of malocclusion involves precise repositioning of the teeth to create a more esthetic and functional dental unit. To achieve it, a profound knowledge of Growth and Development of the face, Tooth movement and a characterization of the form and pattern of Dentofacial complex is required.

In orthodontic tooth movement, space is necessary for rearrangement of teeth. The space for tooth movement is generally gained either by Extracting teeth or Expanding the dental arches. This choice constitutes a major decision and involves a number of considerations including the age and dental pattern of the patient.

The role of extractions in orthodontics has been a controversial subject over a century. **E. H. Angle** believed that all 32 teeth could be accommodated in the jaws, in an ideal occlusion with the first molars in class I occlusion, with the mesiobuccal cusps of upper first molar occluding in the buccal grove of the lower first molar. He believed bone would form around the teeth in their new positions, according to Wolff's law. This was criticized in 1911 by **Calvin S. Case** in an article *"The Question of extraction in orthodontia"* and he believed

extraction were necessary in order to relieve crowding & aid stability of treatment.

Two of Angle's students at around the same time, but in the different countries considered the need for extractions in achieving stable result. **Charles Tweed** became disappointed in the results he achieved and decided to retreat a number of patients who had suffered relapse following orthodontic treatment using extraction of four premolars[27].

In 1940s, a change of philosophy from non-extraction to extraction-based techniques was widely accepted in America. **Raymond Begg**, in Australia, studied Aboriginal skulls and noted a large amount of occlusal and more interproximal wear. He argued that premolar extractions were required to compensate for lack of interproximal wear as seen in Australian dentition due to the lack of coarse diet. Thus, extraction became an important treatment option.

Space closure after extraction gained prime importance and various methods were employed to achieve tight contact between teeth. This procedure of tooth movement is usually done in stage two of orthodontic treatment. This stage of the treatment consumes the majority of the total treatment time.

Most of the patient's primary concern is longer orthodontic treatment duration. So, it became mandatory for all orthodontist to accelerate treatment without compensating the treatment results in patients undergoing fixed appliance therapy. The above scenario forced the orthodontists to speed up the tooth movement by using alternative and adjunctive procedures which led to the introduction of '*Wilckodontics'* by Wilcko-brothers. Wilckodontics involved the surgical intervention, where vertical cuts are given in interradicular area, after raising full thickness mucoperiosteal flap by utilizing the Rapid Acceleratory Phenomenon (RAP) which was initially termed as Periodontally Accelerated Osteogenic Orthodontic (PAOO) technique.

This PAOO technique induced a localized inflammatory response, which encourages local recruitment and stimulation of osteoclasts and increased remodeling.

Even though, periodontally accelerated osteogenic orthodontic (PAOO) technique yielded favorable results, it turned out to be an invasive procedure with disadvantages like damages to the adjacent vital structures, high morbidity, postoperative pain, swelling, avascular necrosis and low patient acceptance.

These shortcomings pressurized the orthodontists to search for minimally invasive technique that would produce same amount of '*Rapid acceleratory phenomenon* (RAP). Later, minimally invasive procedures like corticison, piezocison were introduced, which carried

the risk of injuring the roots, since the incisions were blindly performed. Non-invasive techniques like low-level laser therapy and vibration impulses were also tried with limited success.

Pharmacological agents like vitamin-D, prostaglandin, interleukin, parathyroid hormone, misoprostol. etc. were tried but, undesirable side effects like root resorption, increase in the level of LDH (Lactate dehydrogenase) and CPK (Creatine phosphokinase) enzyme were resulted.

Based on the well-known principle that orthodontic force triggers inflammatory pathways and osteoclast activity. **Alikhani et al**[17] hypothesized that controlled micro-trauma in the form of *Micro – Osteo Perforations* (MOPs) will amplify the expression of inflammatory markers that are normally expressed during orthodontic treatment and this response will accelerate both bone resorption and tooth movement.

The above-mentioned procedures of accelerating the tooth movement had been performed additionally and they are either *invasive* or *minimally-invasive*. In this study, we have analyzed accelerated tooth movement without any other additional surgical procedures, apart from the one that is routinely performed.

Retraction of the maxillary canines after the premolar extractions is a very common orthodontic task. Spontaneous movement of canine into extraction site is the basis of serial extraction (Holtz) and the segmented arch approach for canine retraction has been used since it was pointed out by Burstone and also, various spring have been tried for their suitability and efficiency tested.

Therefore, in this in-vivo clinical trial, we designed to evaluate the increase in the rate of tooth movement by altering the time of therapeutic extraction followed by immediate retraction of the tooth in recently extracted site. This study also aimed to check any possible difference in the rate of tooth movement in between maxilla and mandible.

This current study investigated the difference in rate of Mini-implant assisted individual canine retraction in recently extracted site (experimental side) vs healed extraction site (control side) under extraction of bicuspid was performed at the beginning of fixed orthodontic appliance therapy. This split – mouth randomized trial focused on canine retraction within the maxilla and mandible, carried out at specific time points during 28^{th}, 56^{th}, 84^{th} days of observation.

AIM AND OBJECTIVES

Aim:

This study aims in estimating the rate of tooth movement by mini-implant assisted canine retraction through a simplified Rapid acceleratory phenomenon (RAP) by altering the time of therapeutic extraction.

Objective:

1. To evaluate the changes in the speed of tooth movement in regular interval (28^{th}, 56^{th}, & 84^{th} day) by altering the therapeutic extraction.
2. To evaluate the overall rate of tooth movement between the recently extracted site (experimental side) and healed extraction site (control side).
3. To check any differences in the rate of simplified - RAP assisted tooth movement between maxilla and mandible.

REVIEW OF LITERATURE

Murphey et al 1970[1] histologically evaluate the effect of recent versus healed extraction sites on orthodontic retraction histologically by employing oxytetracycline vital staining. The sample of the study was six female Macaca rhesus monkeys which separated into healed and recent extracted socket group. The healed socket group was extracted mandibular left first molar site and allowed for wound healing 7 weeks. While the recent socket group was immediate mandibular right first molar extraction site. The second premolars on both sides were distalize with three-tooth sectional orthodontic appliances which were placed immediately after recent site extraction. The fluorescent microscopic evaluation showed that in the first and third week, the osteoclastic widening of the periodontal space in area of compression was greater on the healed side. Moreover, the heal side showed an increased amount of new bone and spicule formation on tension area. So, the tooth movement was greater on the healed side. The simultaneous independent activation of both mandibular second premolars showed that no advantage resulted from immediate retraction into site of a recent extraction.

Smith et al 1974[2] detected the bone formation radio graphically on day 7th, and he coordinated with Bodner and Tennebaum who

reported new bone formation in the apical area of the socket on 8th and 7th day post-extraction, respectively.

Houston et al 1983[3] The sources of error in cephalometric measurement and their analyses are discussed in this article and also the importance of distinguishing bias and random errors is emphasized, and methods of control are discussed. Randomization of record measurement is one of the most important methods of avoiding bias, but it is rarely undertaken in cephalometric studies. Random errors are particularly important in the evaluation of individual radiographs, and a measurement that has a high error in relation to its total variability will be of little value in clinical assessment

H. M. Frost et al 1989[4] described about the bone healing process which unites fractures & osteotomies. The process normally precedes in successive stages namely the fracture, granulation, and modelling/remodelling stages. A separate regional acceleratory phenomenon speeds up each of the other stages. They are made by local multicellular mediator mechanisms that contain precursor and supporting cells, capillaries, lymph, and innervation, plus local autocrine and paracrine regulation. Under the influence of local and systemic agents, these mediator mechanisms determine whether new local osteoclasts and osteoblast will appear or not.

Yaffe et al 1994[5] explained about the RAP (regional accelerated phenomenon) in Wister rats and correlated as a reason for healing, increased mobility following periodontal surgery and bone dehiscence.

Rudolf-Hasler et al 1997[6] measured rate of canine retraction into first premolar extraction sites in 22 patients aged 10-27years using Gjessing canine retraction spring. The experiment compared the canine distalization rate between recent extraction premolar and a median time of 86 days after extraction. The study was ended when one of the two canines had been distalized. During the active retraction period, the canine on the recent extraction side was distalized significantly more than on the healed side (median difference 1.14 mm, range -0.22 to 2.84 mm). However, when comparing the median different in total time span after extraction, it was 0.75 mm which didn't significantly different.

Diedrich et al 1997[7] assessed the advantage to begin treatment early or delayed after tooth extraction. The results based on the basis of hard tissue finding, which were density, maturity, osteodynamics and soft-tissue responses at the extraction sites following bilateral extraction of the second incisors in 3 foxhounds. After an 8-week bodily tooth movement period and 2-month retention period, evaluation was undertaken on the basis of clinical, radiologic and histologic criteria. Histological analysis yielded that in delayed group, low bone density with more mature lamellar bone, pronounced horizontal atrophy

of the alveolar process with periosteal bone apposition in the direction of tooth movement, increased tendency toward gingival invagination. Recent extraction group, on the other hands, revealed higher bone density with less bundle bone at the extraction sites, broader alveolar process, and reduce tendency of gingival recession. As results of these finding, the orthodontic retraction into extraction sites were recommended to initiate at an early stage.

Devlin et al 1998[8] examined whether a technique to measure differences in bone mineral density in the maxilla and mandible. And found that the mean bone mineral density for the mandible was twice that of the anterior maxilla

Yuan et al 2003[9] founded that the tooth movement toward recent extraction side moved faster than that on the healed side. The study performed on 36 male Sprague-Dawley rats for maxillary second molars mesialization into maxillary first molar extraction sites. Tooth movement was measured with cephalometric films by Image Analysis Technique before appliance activation and after 1, 3, 4, 7, 10 and 14 days since application activation.

Haluk et al 2005[10] rapid canine retraction and orthodontic treatment with dentoalveolar distraction osteogenesis and arrived with conclusion that dentoalveolar distraction technique is an innovative

method that reduces overall orthodontic treatment time nearly 50% with no unfavourable effects on surrounding structures.

Chung-hochen et al 2006[11] their hypothesis was to study the micro implants of 1.2 mm diameter used in orthodontic anchorage and their success related to length. The aim of this study is to determine the relationship of micro implant length to retention rate. The results obtained was 9 micro implants were removed and the overall success rate was 84.7% exploring the causes for failure the found significant differences between the length and success rate; 6mm was 72.2%and 8mm was 90.2% successful.

Thiruvenkatacheri et al 2008[12] compared the rate of canine retraction with conventional molar anchorage and titanium implant anchorage and proved that canine retraction precedes at a faster rate than titanium micro implants are used for anchorage.

Poggio et al 2008[13] provide an anatomical map to assist the clinician in mini screw placement in a safe location between dental roots. The results were on the buccal side, in the interradicular space between the first molar and second premolar, from five to eight mm from the alveolar crest; in mandible-interradicular space between the first molar and second premolar at 11mm from alveolar crest.

Nirshpack et al 2008[14] they compared tipping mechanics (TM) and bodily movement (BM) with respect to duration, angulation, and anchorage loss during canine retraction. It was concluded that retraction of maxillary canine into the first premolar extraction site using Nickel titanium closed coil springs occurred faster with BM brackets than with TM brackets. They found that greater time was required to fully upright the canine with TM brackets. There was no difference found in the amount of molar anchorage loss between the two groups.

Wilcko et al 2009[15] presented Two case reports to demonstrate a new orthodontic method that offers short treatment times and the ability to simultaneously reshape and increase the buccolingual thickness of the supporting alveolar bone. This new surgery technique included buccal and lingual full-thickness flaps, selective partial decortication of the cortical plates, concomitant bone grafting/augmentation, and primary flap closure. Following the surgery, orthodontic adjustments were made approximately every 2 weeks. From bracketing to de-bracketing, both cases were completed in approximately 6 months and 2 weeks. Post treatment evaluation of both patients revealed good results. At approximately 15 months following surgery in one patient, a full- thickness flap was again reflected. Visual examination revealed good maintenance of the height of the alveolar crest and an increased thickness in the buccal bone. The rapid expansive tooth movements with no significant apical root resorption

may be attributed to the osteoclastic or catabolic phase of the regional acceleratory phenomenon. Instead of bony "block" movement or resorption/apposition, the degree of demineralization/remineralization might be a more accurate explanation of what occurs in the alveolar bone during physiologic tooth movement in these patients.

Theodosia et al 2009[16] evaluated the effect of medication on the rate of orthodontic tooth movement. Medications might have an important influence on the rate of tooth movement, like NSAIDS, ESTROGENS, VITAMIN D3, DIETARY CALCIUM decreased tooth movement, NON-NSAIDS such as paracetamol had no effect. Corticosteroid hormones, parathyroid, thyroxin increases tooth movement.

Alikhani et al 2013[17] Tested the effect of micro osteo perforation on the rate of tooth movement in rats and found it was effective procedure.

AmitKalra et al 2013[18] compared the rate of canine retraction into recent extraction site with or without circumferential supracrestal fiberotomy and measured the rate in 14 patients aged 13 to 22 years. This study was done on 9 maxillary and 5 mandibular arches with preadjusted edgewise (0.022-inch Roth prescription) and retraction performed by frictionless mechanics using Composite T Loop. The distalization of canines was measured at regular intervals (T1, T2, T3

and T4). Recordings of the positions of the canines at the beginning and at different intervals were made from dental casts. They found mean difference between the two sides for the total time span T1-T4, for maxillary arch was 0.36 mm and for mandibular arch was 0.60 mm and concluded as various factors that affect the rate of tooth movement. Factors like bone density, bone metabolism, turnover in the periodontal ligament and amount of force applied may be responsible for the variation. Finally derived that there is no clinically significant increased rate of retraction of cuspids in the recent extraction site with fiberotomy was found in comparison to the retraction in recent extraction site without fiberotomy.

Cohen et al 2014[19] reviewed normal and pathological healing processes that takes place after tooth extraction in orthodontic cases, and their associated complications within the mucosa or alveolar socket, such as gingival clefts or bone defects. The general and local factors that are involved in such deficient healing cases are detailed, in parallel to surgical procedure to enhance ridge preservation or to 'regenerate' tissues. They role out time for healing takes place in three stages, an inflammatory phase (within 5-7 hours), a proliferative phase (10-24 hours) and a maturation phase (48 hour to 3 days). So, this will help us to determine the immediate retraction after therapeutic extraction only performed at the proliferative phase because of a greater number of undifferentiated mesenchymal cells present at that time.

Alikhani et al 2015[20] Their objective was to study the effect of micro-osteo perforations on the rate of tooth movement and the expression of inflammatory markers; and obtained results as effective, comfortable, and safe procedure to accelerate tooth movement and significantly reduced the duration of orthodontic treatment.

SergeDibart et al 2015[21] claimed that the piezocision is an orthodontically guided surgical alternative to conventional corticotomies to a more sophisticated philosophy where the orthodontist is given the tool to control the anchorage value of teeth by selectively altering the bone density surrounding them, using the piezoelectric knife at key time intervals in an effort to successfully solve orthodontic challenges

Donald.J.Ferguson et al 2015[22] gave a guideline for tooth movement limits are meant to help clinicians in treatment planning decisions, especially for 'severe' or 'borderline' adult malocclusions. Periodontally accelerated osteogenic orthodontics (PAOO) is a surgical technique that accelerates tooth movement and expands the scope of conventional orthodontic treatment in adult 2-3fold in most spatial dimensions.

Kulshrestha et al 2015[23] The aim of this systematic review was to examine, in an evidence-based way, which kinds of canine retraction

methods/techniques are most effective and which have the least side effects. The search strategy resulted in 324 articles, of which 22 met the inclusion criteria. All the methods were nearly similar to each other for retraction of canines Most of the techniques lead to anchorage loss in various amounts depending on the methods used. Most of the studies had serious problems with small sample size, confounding factors, lack of method error analysis, and no blinding in measurements.

NohaHusseinAbbas et al 2016[24] The purpose of this study was to evaluate the efficiency of corticotomy-facilitated orthodontics and piezocision in rapid canine retraction. The rates of canine crown tip were greater in the experimental sides than in the control sides in both groups. Corticotomies produced greater rates of canine movement than did piezocision at 4 time points. Canine root resorption was greater in the control sides. The remaining studied variables exhibited no differences between the control and the experimental sides. Conclusions: Corticotomy-facilitated orthodontics and piezocision are efficient treatment modalities for accelerating canine retraction

Chin-yang et al 2016[25] compared the effects of micro-osteo perforation and corticision on the rate of orthodontic tooth movement in rats and found no difference between the two procedures

Carlalberta et al 2016[26] observed under high turnover conditions the accelerated tooth movement happening. The regional

acceleratory phenomenon (RAP) is a tissue reaction to a noxious stimulus that increases the healing capacities of the affected tissues. Orthodontic tooth movement can therefore be seen as a modified skeletal wound healing and adaptation, typified by an increased bone remodelling response in addition to an elevated formation of woven bone. In this perspective, the biological principle of the RAP is exploited in surgically facilitated orthodontics.

AdeebaKhanum et al 2018[27] reviewed and provide a summary of historical background of the controversy, the perspectives of various authors, the reasons for decline in extractions and the present understanding of the debate. Presently, they concluded as the controversy is not afflicted by as much beliefs as it was almost 100 years ago and both treatment options are still open. The option to treat with extraction or non-extraction should be made objectively for each case based on strong evidence with equal attention on the soft tissue paradigm.

Makhlouf et al 2018[28] compared the amount of tooth movement during canine retraction comparing two different retraction mechanics; friction mechanics represented by a NiTi closed coil spring versus frictionless mechanics represented by T - loop, and their effect on root resorption using Cone Beam Computed Tomography (CBCT). The NiTi coil spring side showed more distal movement more than the T-loop

side. Both retraction mechanics with controlled retraction force, do not cause root resorption.

Saritha et al 2019[29] investigated using a split-mouth randomized clinical design, the effect of microosteoperforation (MOP) on mini-implant supported canine retraction using fixed appliances. They chose 30 subjects (seven males and 23 females) with a mean age of 22.2 (3.72) years were randomized into three canine retraction groups: Group 1 (MOP 4-weekly maxilla/8-weekly mandible; n ¼ 10); Group 2 (MOP 8-weekly maxilla/12-weekly mandible; n ¼ 10) and Group 3 (MOP 12-weekly maxilla/4-weekly mandible; n¼10) measured at 4-week intervals over 16 weeks. Subjects also completed pain (5-point Likert scale) and pain impact (Visual Analogue Scale) questionnaires. Overall canine retraction was 4.16 (1.62) mm with MOP and 3.06 (1.64) mm without. They concluded as MOP can increase overall mini-implant supported canine retraction over a 16-week period of observation but this difference is unlikely to be clinically significant.

Kim et al 2019[30] evaluated the amount of tooth movement and histologic changes with different corticotomy designs and micro-osteoperforation in rabbits. Sample consisted of 24 rabbits divided into three experimental groups (triangular corticotomy [TC] and indentation corticotomy [IC] with flap, and flapless micro-osteoperforations [MP]) and a control. A traction force of 100 N was applied by connecting the first premolars to the incisors. The amount of tooth movement was

measured. Kruskal–Wallis test was used to assess differences in tooth movement between the groups. Micro-computed tomography, haematoxylin and eosin staining, and tartrate-resistant acidic phosphatase (TRAP) analysis were performed to assess differences in TRAP-positive osteoclast count between the groups. There were no significant intergroup differences in the number of TRAP positive osteoclasts. They concluded as micro-osteoperforation group showed no significant differences in the amount of tooth movement compared to the corticotomy groups, nor in the TRAP-positive osteoclast count compared to both corticotomy groups and control.

Shahabee et al 2019[31] systematically reviewed to evaluate the effects of micro-osteoperforation on the rate of tooth movement in patients undergoing orthodontic treatment by comprehensive search of MEDLINE, ISI web of science, EMBASE, Scopus, and CENTRAL online databases for studies measuring the effects of micro-osteoperforation on the rate of orthodontic tooth movement from inception to February 2019 was performed. Six randomized clinical trials were finally included in this meta-analysis. The rate of canine retraction per month was significantly higher in the MOP group [mean difference (MD) = 0.45 mm, 95% CI = 0.17–0.74]. These results were similar with regard to different malocclusions, the jaw on which it was performed, and MOP methods. They found the rate of tooth movement was increased after performing MOP but in at least one study higher root resorption was observed. Therefore, the use of MOP can be

recommended after weighing the benefits and disadvantages this intervention can bring for each patient.

Aboalnaga et al 2019[32] investigated the effects of MOPs on the rate of OTM by 18 patients requiring bilateral first premolar extraction and upper canine retraction with maximum anchorage were enrolled in this study. Immediately before canine retraction, three MOPs were randomly allocated to either the right or left sides. MOPs were performed using a mini-screw (1.8mm diameter, 8mm length) distal to the canine. Canine retraction continued for 4 months and data were collected from monthly digital models, in addition to pre- and post-retraction maxillary CBCT images. The mean rate of canine retraction in both sides was 0.99 ± 0.3 mm/month. The total distance moved by the canine cusp tip was greater in the MOP than the control side (mean difference 0.06 ± 0.7 mm), which was statistically insignificant ($P > 0.05$) and they concluded Micro-osteoperforations were not able to accelerate the rate of canine retraction; however, it seemed to facilitate root movement.

Fu-Liu et al 2019[33] systematically reviewed to evaluate the evidence of accelerated tooth movement in minimally invasive surgery and the adverse effects from it. The inclusion criteria was prospective clinical studies of patients treated with a fixed appliance, and the intervention to accelerate orthodontic treatment with minimally invasive surgery. They reviewed 19 articles and 9 studies assess the

rate of upper canine movement to evaluate the en masse retraction time; and 4 studied adverse effects. Results obtained as no accelerated tooth movement was found in the micro-osteoperforation group. After flapless corticotomy procedures, increased tooth movement rates were identified less that than for minimally invasive surgery. Moreover, no significant adverse effect was found and there is not sufficient evidence to support that the single use of micro-osteoperforation could accelerate tooth movement, and there is only low-quality evidence to prove that flapless corticotomy could accelerate tooth movement.

MATERIALS AND METHODS

An in vivo comparative study was presented and approved by the Scientific Review Board and Institutional Ethical Committee of ADHIPARASAKTHI DENTAL COLLEGE AND HOSPITAL, MELMARUVATHUR (IRB/EC Ref No: 2017-MDS-BR.V-SUD-12/APDCH).

The study subjects were selected from the patients who reported as an outpatient in the Department of Orthodontics and Dentofacial Orthopedics, Adhiparasakthi Dental College and Hospital. The patients were explained in detail regarding the study and an audio-visual informed consent was received from them and finally 10 patients who met the following inclusion and exclusion criteria were selected for our study.

Inclusion criteria:

- Patient in permanent dentition between age group of 17 - 23 years both male and female.
- Class 1 bi-maxillary protrusion, fully erupted maxillary canine with closed apex.
- Cases requiring extraction of both maxillary and mandibular first premolars.
- Patients with periodontally sound dentition.

- All second molars were erupted in occlusion.
- Patients with good general health. No previous history of extraction or orthodontic tooth movement.

Exclusion criteria:

- Long-term use of antibiotics, phenytoin, cyclosporine, anti-inflammatory drugs, systemic corticosteroids, and calcium channel blockers.
- Skeletal class II tendency and ANB>2degree
- Skeletal class III tendency and ANB<2degree
- Cases requiring orthognathic surgery
- History of systemic and medical illness
- Contraindication of extraction
- Previous history of orthodontic treatment
- Poor oral hygiene
- Smoking
- Nickel allergy

A total of 10 patients were included in the study, who had fully erupted maxillary canines with class I molar, canine relationship and bi-maxillary protrusion that required the removal of both maxillary and mandibular 1st premolars.

In total, 40 samples were obtained;

20(10 control and 10 experimental) in maxilla and

20 (10 control and 10 experimental) in mandible respectively.

Intially the extraction of first premolars in one side of maxilla & mandible performed and was considered as control side, the other side is taken as experimental side. Allocation of control and experimental group was done randomly in an unbiased manner. Patients were referred for extraction of the maxillary and mandibular 1st premolar by the same surgeon to decrease variability.

Treatment was initiated by bicuspid extraction on control side and fixed appliance was bonded in both arches with MBT 0.022 prescription (DENTAURUM EQUILIBRIUM 2) and with an auxiliary vertical slot canine bracket in the maxillary and mandibular canines (AO, American orthodontics.).

The leveling and aligning was done using the following sequence of 0.016 NiTi, 0.017x0.25 NiTi, 0.019x0.025 NiTi wires and 0.019x0.025 SS arch wire was placed for a period of 4 weeks and then the experimental side extraction was performed. 24 hours after extraction, alginate impressions were taken as a record.

For retraction, a serpentine hook (Fig. 4) was fabricated using 16x16 SS wire and this hook was inserted into vertical slot of canine, so that the applied force was close to the centre of resistance. A temporary anchorage device (1.5mm x 9mm) (S.K. SURGICALS, INDIA) (Fig. 5) was placed between 2nd premolar and first molar on the buccal aspect 6mm from the interdental papilla.

A 9mm NiTi closed coil spring (Fig. 10) was placed between TAD and the serpentine hook. A 100g of force was applied for individual canine retraction and was measured using Dontrix gauge on both experimental and control side. At each visit, the force produced by the coil was checked, and appliances were monitored for any deformation or change in the position because of mastication.

Alginate impressions were taken at the beginning of the study, immediately before canine retraction, and at 28^{th}, 56^{th}, 84^{th} day after canine retraction began, to monitor the rate of tooth movement in both arches. The impressions were poured immediately with orthokal. The casts were labeled with the patient's number, date and stored.

Vertical lines were drawn on the cast over the palatal surface of the canine from middle of the cervical line. The distance between the canine and the lateral incisor was assessed before and after canine retraction at 3 points: incisal, middle, and cervical thirds of the crowns. All the cast measurements were made using an electronic digital caliper with an accuracy of 0.01mm.

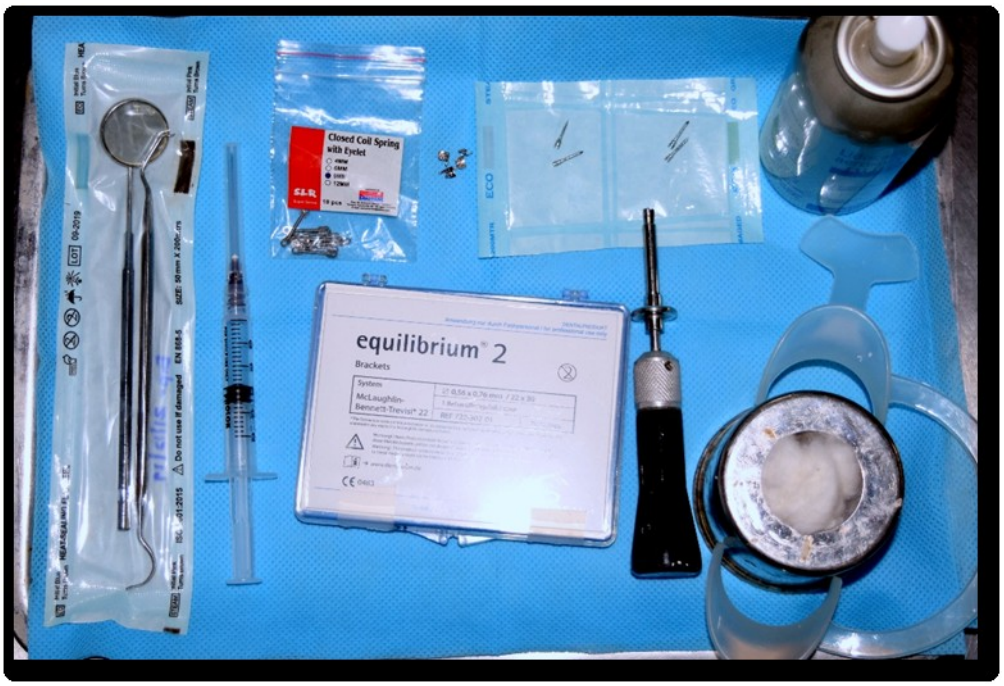
The rate of tooth movement was measured after 4,8,12 weeks (84 days) and was compared with the control and the experimental group of maxilla & mandible. In total, 40 samples were be obtained, 20 (10 -

control and 10 - experimental) in maxilla and 20 (10 - control and 10 - experimental) mandible respectively.

The subjects and the doctor administrating the treatment were aware of the group assignment. To avoid measurement bias, two more investigators took measurements and those investigators performing the measurements and data analysis were blinded from the group assignments

The obtained measurements were tabulated and given for statistical analysis.

Fig 1: Armamentarium



1. Dentaurum bracket kit
2. 2 sets of vertical slot canine brackets
3. LA Bottle
4. Syringe
5. Titanium mini-implants
6. NITI Coil spring
7. Implant driver
8. Cheek retractor
9. Diagnostic instruments

Fig 2: Conventional Canine Bracket

Fig 3: Canine Bracket with Vertical Slot

Conventional Canine Bracket

Canine Bracket with Vertical Slot

Fig 4: Serpentine Hook 16*16 SS

Fig 5: SS Mini Implants 1.5*9mm

Fig 6: Dontrix Guage

Fig 7: Digital Vernier Calliper

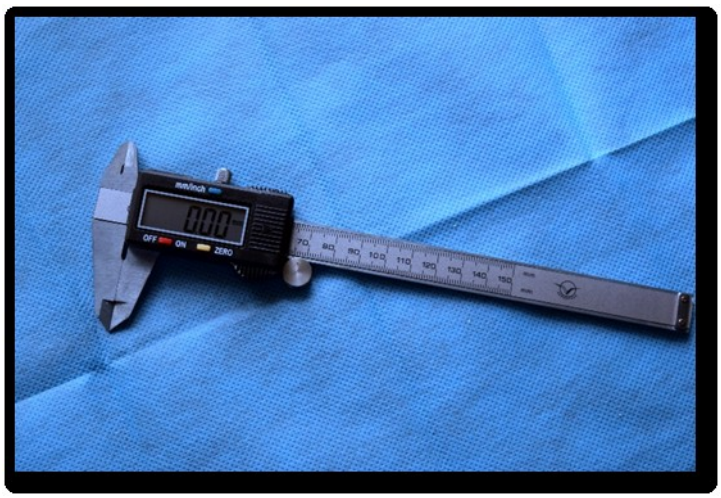
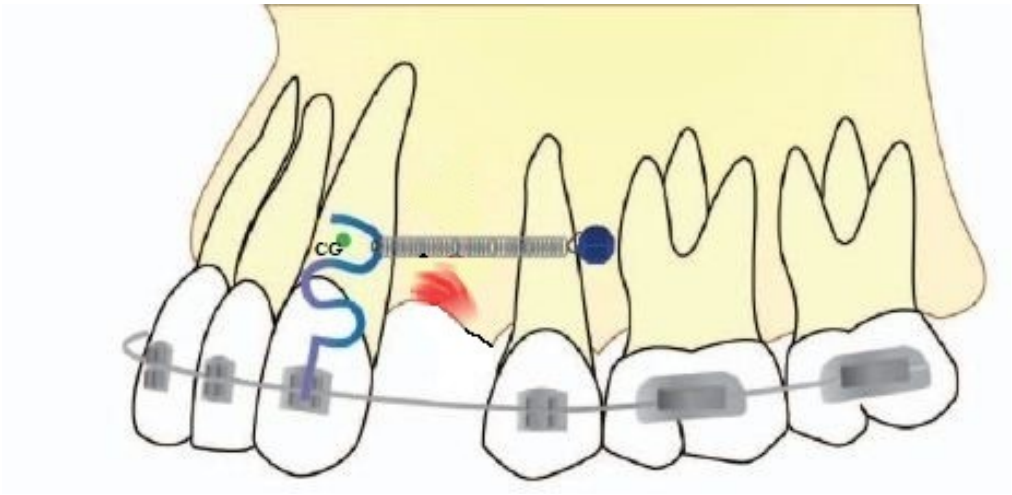


Fig 8: Implant Driver

Fig 9: Implants

Fig 10: Niti closed coil spring

Fig 11: Implant Placement and NiTi Coil Activation performed immediately after therapeutic extraction on experimental side



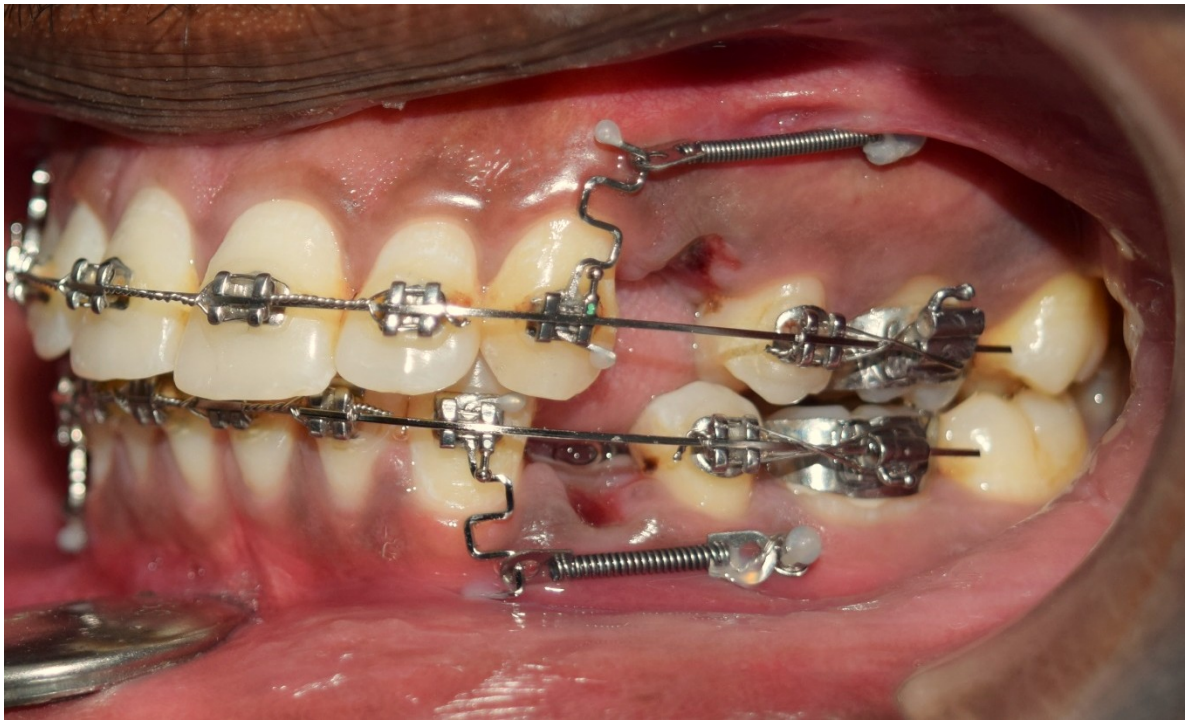


Fig 13: Patients photo: Op. No - 2191239

Intra-Oral Photos

Therapeutic extraction not performed

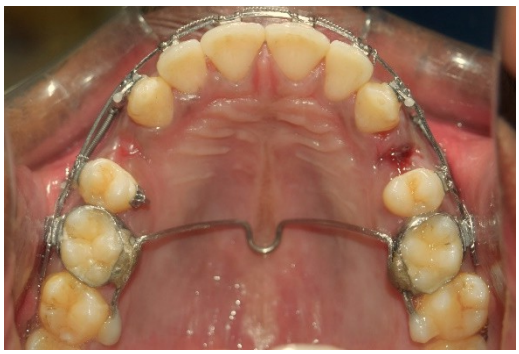
Upper Lower


Therapeutic extraction performed in control side

Upper Lower


Therapeutic extraction performed in the experimental side

Upper Lower



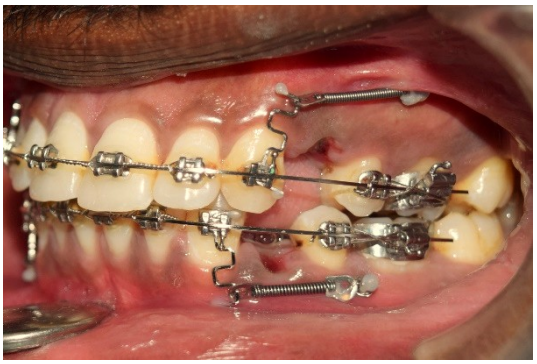

Upper Arch - Control group: Right Experiment group: Left

Lower Arch - Control group: Right Experiment group: Left

Intra-Oral Photos - Day 01

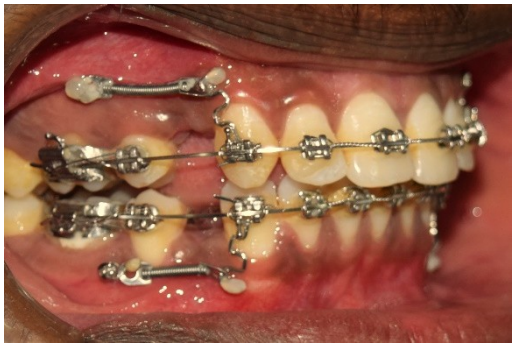
Right

Left



Intra-Oral Photos - Day 28

Right

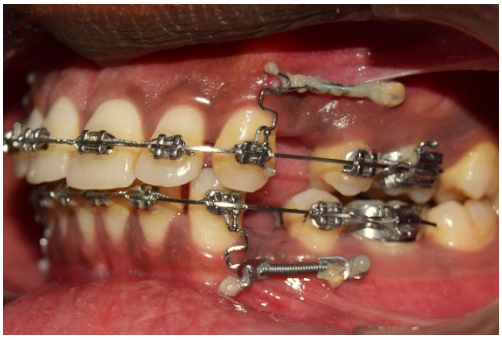


Left

Intra-Oral Photos - Day 56

Right

Left



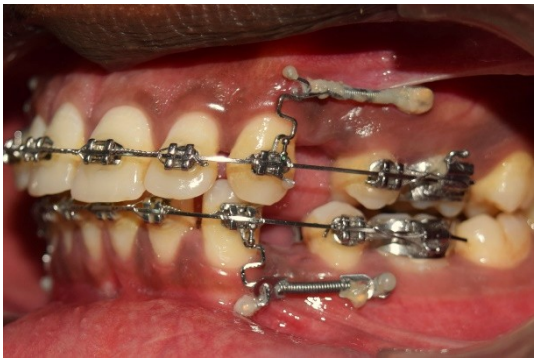
Upper Arch - Control group: Left Experiment group: Right

Lower Arch - Control group: Right Experiment group: Left

Intra-Oral Photos - Day 84

Upper

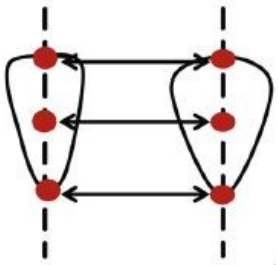
Lower



Upper Arch - Control group: Left Experiment group: Right

Lower Arch - Control group: Right Experiment group: Left

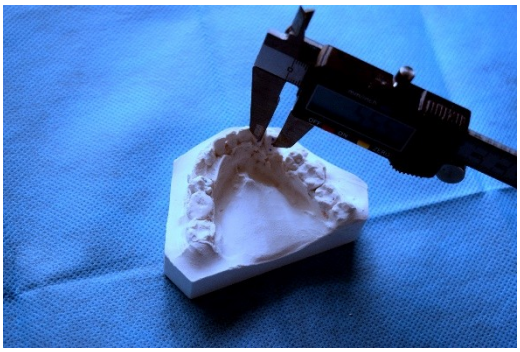
Fig 14: Measurement Method



Measurements noted with Vernier caliper

Upper

Lower



STATISTICAL ANALYSIS:

Data were tabulated in an excel sheet and analyzed using SPSS statistical software (version 22). The data were assessed for normality using Descriptive statistics test which revealed that the data were non-normal in distribution. Hence non-parametric test (Mann Whitney-U-test) was employed to detect the significant difference between experimental side and control side. The same test was employed to detect the significant difference between maxillary and mandibular jaws.

RESULTS

A total of 10 patients were included in the study who had fully erupted maxillary canines with class I molar canine relationship and bi-maxillary protrusion that required the removal of both maxillary and mandibular 1st premolars. In total, 40 samples, the 20 experimental group (recently extracted site) and 20 control group (healed extraction site) were received. Data were tabulated in an excel sheet and analyzed using SPSS statistical software (version 22). The results are as follows:

Table 1: Descriptive statistics.

GROUP ID		TIMELINE	MEAN ± SD
RECENTLY EXTRACTED SITE	Maxilla	28 days	0.8390 ± 0.152
		56 days	0.7230 ± 0.117
		84 days	0.6920 ± 0.075
	Mandible	28 days	0.6250 ± 0.098
		56 days	0.5640 ± 0.093
		84 days	0.5070 ± 0.076
HEALED EXTRACTION SITE	Maxilla	28 days	0.6530 ± 0.163
		56 days	0.6670 ± 0.112
		84 days	0.6670 ± 0.074
	Mandible	28 days	0.4600 ± 0.079
		56 days	0.5350 ± 0.088
		84 days	0.4860 ± 0.079

Table 2: Mann Whitney U test – Inter group comparison of control and experimental side.

TIMELINE	GROUP ID		MEAN RANK	SUM OF RANKS	P-VALUE
28 Days	Maxilla	**Recently extracted site**	12.06	108.50	**0.003***
		Healed extraction site	6.94	62.50	
	Mandible	**Recently extracted site**	13.28	119.50	**0.004***
		Healed extraction site	5.72	51.50	
56 Days	Maxilla	**Recently extracted site**	10.78	97.00	0.309
		Healed extraction site	8.22	74.00	
	Mandible	**Recently extracted site**	10.50	94.50	0.426
		Healed extraction site	8.50	76.50	
84 Days	Maxilla	**Recently extracted site**	10.67	96.00	0.352
		Healed extraction site	8.33	75.00	
	Mandible	**Recently extracted site**	10.44	94.00	0.452
		Healed extraction site	8.56	77.00	

** Mann whitney –u test significance level ≤ 0.005**

Table 3: Mann Whitney U test – Overall comparison of control and experimental groups.

GROUP ID		N	MEAN RANK	SUM OF RANKS	P- VALUE
Maxilla	Recently extracted site	9	36.17	1085.00	**0.012***
	Healed extraction site	9	24.83	745.00	
Mandible	Recently extracted site	9	36.42	1092.50	**0.019***
	Healed extraction site	9	24.58	558.50	

** Mann whitney –u test significance level ≤ 0.005**

Table 4: Friedman test – Intra group comparison between maxilla & mandible at 28, 56 & 84 days in experimental side.

TIMELINE	GROUP ID	MEAN RANK	CHI-SQUARE	P- VALUE
28 DAYS	Maxilla Mandible	2.22 1.00	18.000	0.011*****
56 DAYS	Maxilla Mandible	2.01 1.00	18.000	0.052*
84 DAYS	Maxilla Mandible	2.00 1.00	18.000	0.071*

** Friedman test significance level ≤ 0.005**

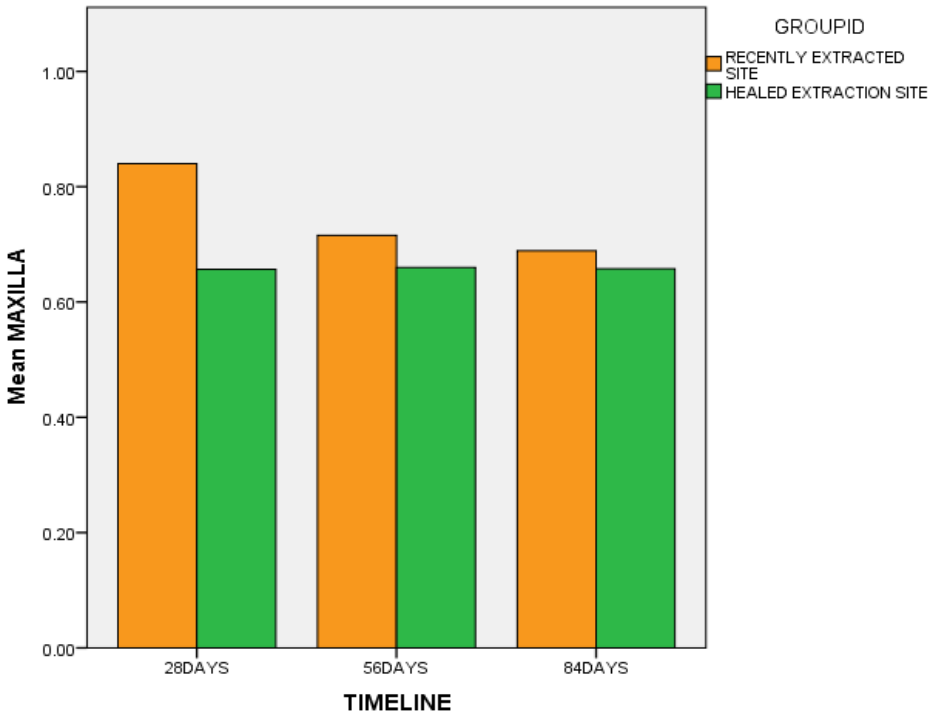
Table 5: Friedman test – Intra group comparison between maxilla & mandible at 28, 56 & 84 days in control side.

TIMELINE	GROUP ID	MEAN RANK	CHI-SQUARE	P- VALUE
28 DAYS	Maxilla Mandible	2.11 1.00	18.000	0.081*
56 DAYS	Maxilla Mandible	2.00 1.00	18.000	0.342*
84 DAYS	Maxilla Mandible	2.00 1.00	18.000	0.321*

** Friedman test significance level ≤ 0.005**

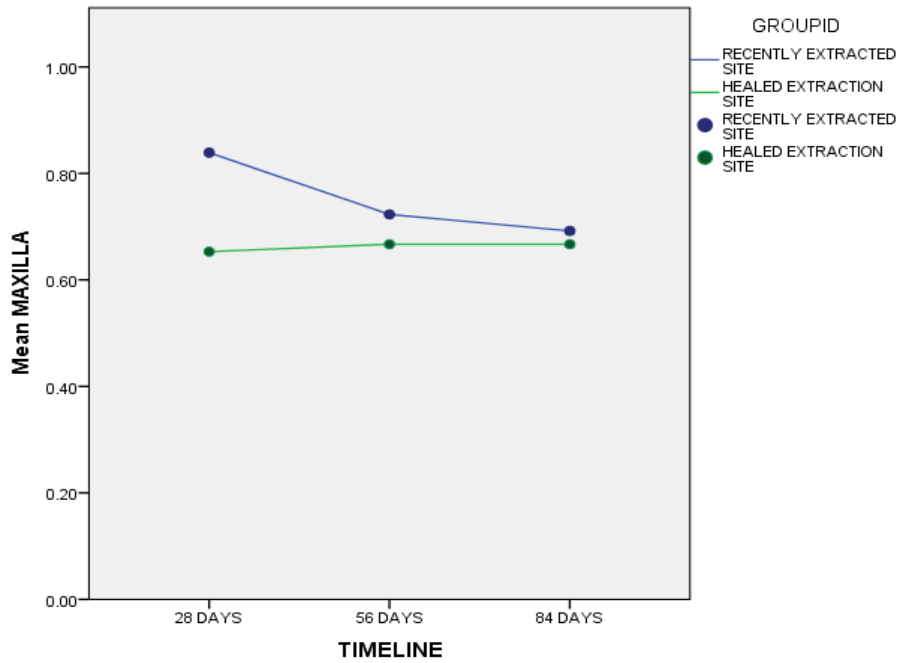
Comparison of experiment side vs control side on 28th, 56th and 84th days in maxillary arch.

Figure: 1



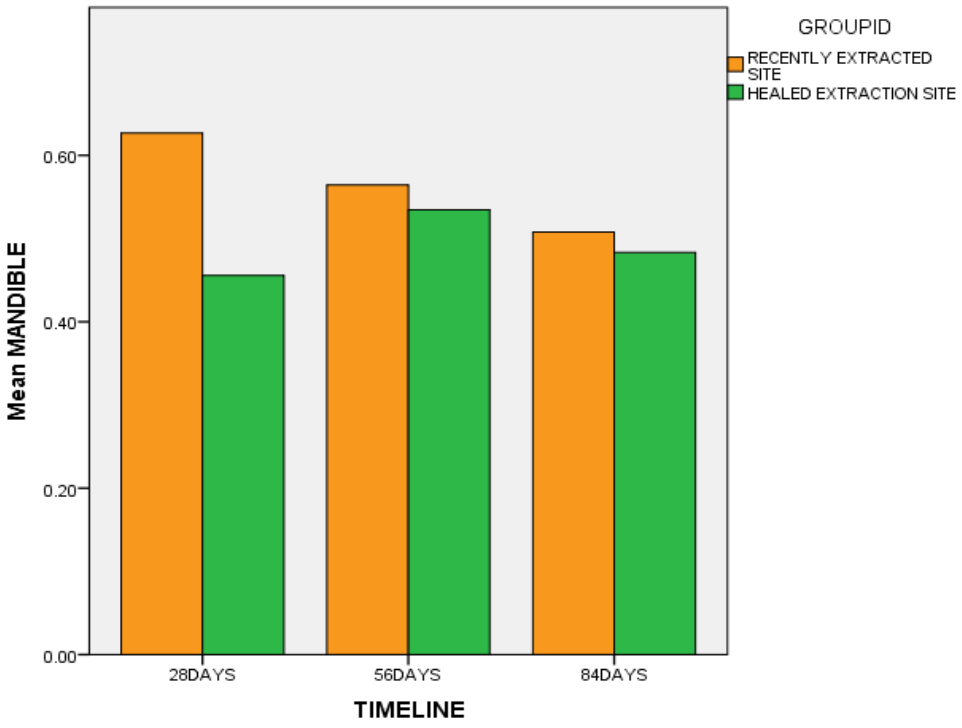
Inter group comparison between experiment side and control side in maxillary arch.

Figure: 2



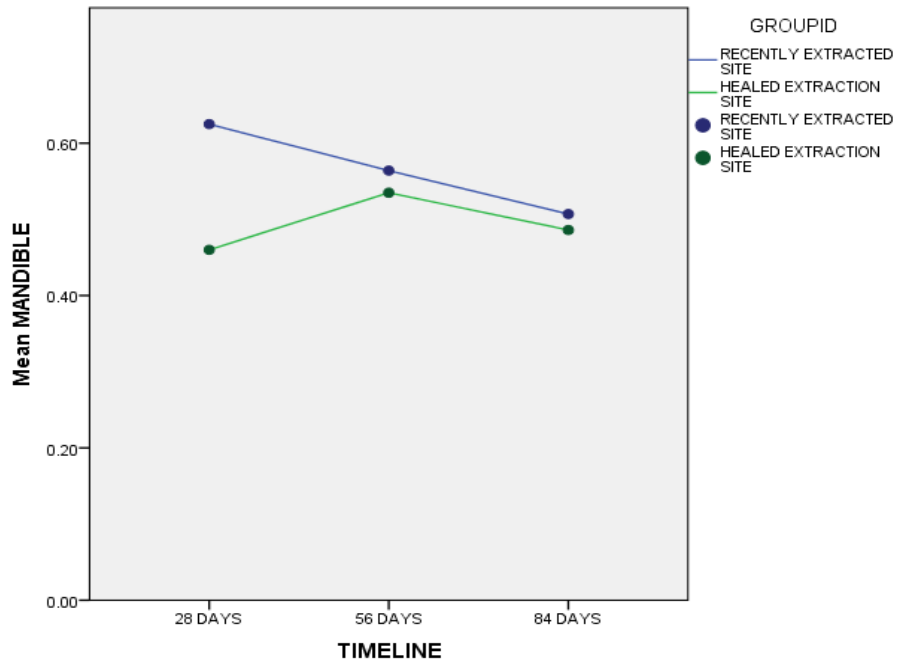
Comparison of experiment side vs control side on 28th, 56th and 84th days in mandibular arch.

Figure: 3



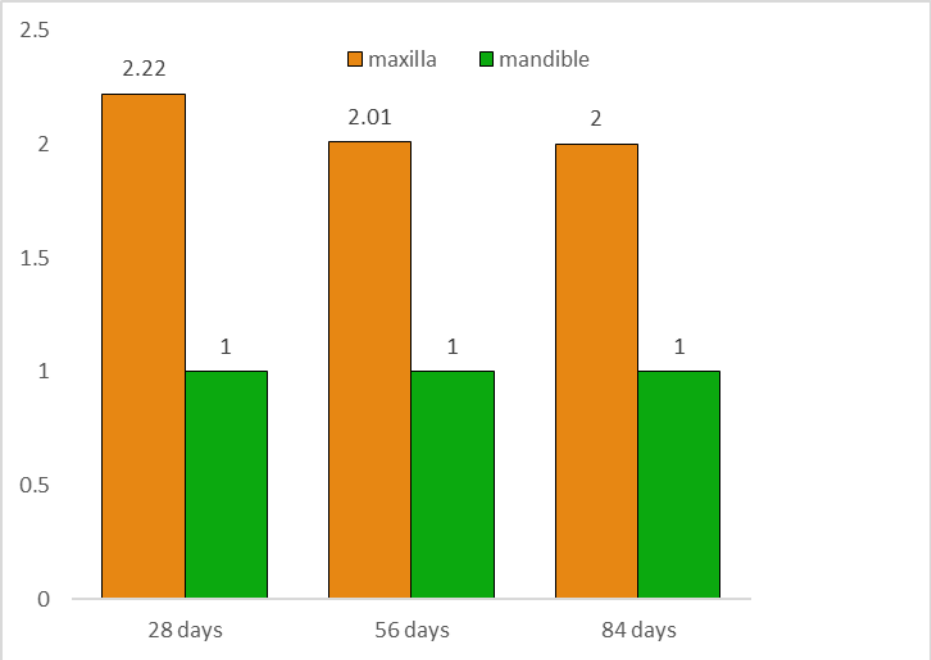
Inter group comparison between experiment side and control side in mandibular arch.

Figure: 4



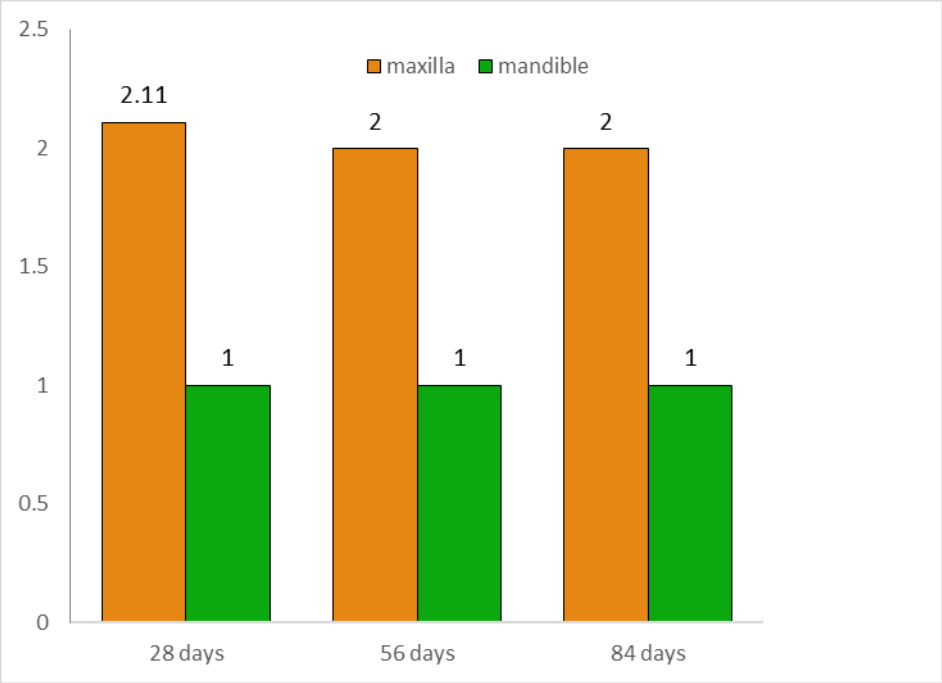
Intra group comparison between maxilla & mandible at 28, 56 & 84 days in experimental side.

Figure: 5



Intra group comparison between maxilla & mandible at 28, 56 & 84 days in control side.

Figure: 6



The amount of canine retraction on both experimental and control side which was calculated from the model on 28^{th}, 56^{th} and 84^{th} day was sent for statistical analyses. The data was assessed using SPSS statistical software (version 22). In order to assess the normality of distribution, descriptive statistics were done (Table 1). The results indicated that the data were non-normal in distribution, therefore Mann Whitney U test was performed (Table 2,3). In this test p value ≤ 0.005 was considered significant.

In our study, the maxillary canine on experimental side (recently extracted site) has moved by 0.83 ± 0.15 mm, 0.72 ± 0.11 mm and 0.69 ± 0.07 mm during 28^{th}, 56^{th} and 84^{th} days respectively, whereas in control side (healed extraction site) the rate of tooth movement was 0.65 ± 0.16 mm, 0.66 ± 0.11 mm, and 0.66 ± 0.07 mm during 28^{th}, 56^{th} and 84^{th} days respectively (Table 1). In which statistically significant was 28 days (p value=0.003) but 56 and 84 days are not statistically significant (p value=0.309 & 0.352) (Table 2).

In mandibular dentition canine on experimental side (recently extracted site) has moved by 0.62 ± 0.09 mm, 0.56 ± 0.09 mm, and 0.50 ± 0.07 mm during 28^{th}, 56^{th} and 84^{th} days respectively, whereas in control side (healed extraction site) the rate of tooth movement was 0.46 ± 0.07 mm, 0.53 ± 0.08 mm, and 0.48 ± 0.07 mm during 28^{th}, 56^{th} and 84^{th} days respectively (Table 1). In which statistically significant

was 28 days (p value=0.004) but 56 and 84 days are not statistically significant (p value=0.426 & 0.452) (Table 2).

Experimental (Recently extracted site) side in the maxillary arch showed one-fold increase in the rate of tooth movement when compared with control side in 28 days. Experimental (Recently extracted site) side in the maxillary arch showed almost same amount of tooth movement when compared with control side in 56 & 84 days.

Experimental (Recently extracted site) side in the mandibular arch showed one-fold increase in the rate of tooth movement when compared with control side in 28 days. Experimental side (Recently extracted site) in the mandibular arch showed almost same amount of tooth movement when compared with control side in 56 & 84 days.

Comparison of maxilla and mandible for rate of tooth movement, shows maxilla faster movement than in the mandible (p-value of 0.001) in experimental side. Whereas in control side it shows statistically less significant (p-value of 0.081).

There was no significant difference in overall rate of tooth movement in between experimental side and control side (p-value of 0.012).

DISCUSSION

In Department of Orthodontics and Dentofacial Orthopaedics, Adhiparasakthi Dental college & Hospital, this study was conducted to Evaluate the rate of Mini Implant assisted individual canine retraction through a simplified *Rapid acceleratory phenomenon* (RAP) without any other additional surgical procedures, apart from the one that is routinely performed by altering the time of therapeutic extraction. The results were compared with the control group in order to estimate the effect of accelerated tooth movement.

After obtaining approval from Scientific Review Board, and Institutional Ethical Committee clearance, 10 patients who satisfied the inclusion and exclusion criteria, were selected for the study after getting their informed consent.

Diedrich et al[7], in his human and animal studies suggested that orthodontic retraction into recent extraction sites will increase the rate of orthodontic tooth movement.

Rudolf Hasler et al[6], compared the canine distalization rate between recent extraction and healed extraction site in a median time of 86 days after extraction. The study was ended when one of the two

canines had been distalized. And he found that, in the activation period, tooth movements were speedier into recent extraction sites

Frost et al[4] found that the Regional acceleratory phenomenon (RAP) is a simplified procedure for accelerating the rate of tooth movement by inducing the temporary physiologic bone healing. In this temporary stage of localized soft and hard-tissue remodelling, the availability of osteoclasts and osteoblasts via local intercellular mediator mechanisms were increased and also pooling of a greater number of undifferentiated mesenchymal progenitor cells into the remodelling tissues. Thereby faster the rate of tooth movement. Based on this concept, we did a simplified RAP phenomenon by altering the time of therapeutic extraction and increasing the availability of undifferentiated mesenchymal progenitor cells.

Diedrich et al[7] in his Histological study, stated that in delayed extraction group, low bone density with more mature lamellar bone, pronounced horizontal atrophy of the alveolar process with periosteal bone apposition in the direction of tooth movement, increased tendency toward gingival invagination, reduced the speed of tooth movement. Whereas in Recent extraction group, higher bone density with less bundle bone at the extraction sites, broader alveolar process, and reduced tendency of gingival recession increased the rate of tooth movement.

A more accelerated tooth movement into recent site than into healed site has been reported by **Hasler et al[6],** but somewhat more with canine tipping in to the extraction site in his study. So, to initiate canine retraction without tipping, in this study we planned bodily retraction of canine. This was achieved by individual canine retraction using calibrated 100g NiTi closed coil spring (9mm) connected from a temporary anchorage device (TAD,1.5mm*9mm) placed between 2nd premolar and 1st molar on the buccal aspect, to a custom-made serpentine hook in the vertical slot of canine brackets. 16x16 **SS** wire was used to fabricate the serpentine hook, with the height of 8mm and the hook was secured in the vertical slot of canine bracket, so that when force was applied by using Nickel Titanium closed coil spring from TAD to the serpentine hook, the site of force application will be closer to the center of resistance of the tooth. Thereby we achieved bodily movement.

In our study Alginate impressions were taken at the beginning of the study, then immediately before canine retraction, and also on 28th, 56th, 84th day after canine retraction. Since the healing takes place in three stages, an inflammatory phase (within 5-7 hours), a proliferative phase (10-24 hours) and a maturation phase (48 hour to 3 days), we have started canine retraction in 24 hours, to make use of proliferative phase of healing, because the greater number of undifferentiated mesenchymal cells were present at that stage as stated by **Cohen et al[19]**.

In order to monitor the rate of tooth movement in both the arches. The distance between the canine and the lateral incisor was assessed before and after canine retraction at 3 points: incisal, middle, and cervical thirds of the crowns. All the cast measurements were made using an electronic digital caliper with an accuracy of 0.01mm.

Both intra-observer and inter-observer errors were evaluated. For the evaluation of the intra-observer error, 10 models were measured twice at least 2 weeks later. For the inter-observer error, a second investigator measured the same set of models twice, and the mean values of the 2 measurements by each investigator were compared. This was done to minimize the errors of measurements as advocated by **Houston et al[3].**

Wilcko et al[15] in his study proved that age can play a significant role in the rate of tooth movement. This effect has been related to bone density or rate of osteoclast recruitment/activation. The variation in the rate of tooth movement due to age was eliminated, by choosing only the adult patients between the age group of 17-23 years and the average age in both the groups were similar in our study.

Poor oral hygiene, periodontal disease, alveolar bone loss, systemic diseases, and consumption of anti-inflammatory medications can affect the rate of tooth movement significantly as shown by

Theodosia et al[16]. To reduce the above variables, monitoring of patients was done to maintain excellent oral hygiene and by applying strict exclusion criteria.

A considerable amount of patient co-operation was necessary; the patients were expected to comply with the instructions regarding strict attention to oral hygiene measures and by proper follow-up visits.

It is well known that in most of the orthodontic extraction patients, anchorage reinforcement is of prime importance from the study done by **Thiruvenkatacheri et al**[12]. Effective and reliable anchorage will dramatically improve the results of the treatment.

In this study, mini- screw implants were used as skeletal anchorage during canine retraction because of their simpler placement technique and the possibility of eliminating the reliance on patient compliance.

Assessment of mini screw mobility after loading was negative during canine retraction except for 4 mini screws which were mobile. One of them became mobile 30 days after loading and the other 3 showed mobility 45 days after loading. These mini screws were immediately repositioned between the maxillary first and second molars, and canine retraction was resumed. The above findings showed

that the success rate of mini screws in this study was approximately 93%, which is in accordance with previous reports by **Chung-hochen et al**[11].

The selected mini screws were 1.5 mm in diameter and 9 mm in length. This was based on the recommendations of **Kuroda et al**[13]. The rationale was to optimize the mechanical retention of the screws and eliminate any risks of root proximity or contact, that might contribute to the failure during treatment.

The placement site of the mini screws was selected in maxilla between the second premolar and first molar buccally and in mandible between the first and second molars, based on the recommendations of **Schnelle et al**[12], who advocated this site as a bone stock for the safe placement of mini screws in the maxillary and mandibular arches respectively.

Placement of the mini screws were performed in the attached gingiva rather than the non- keratinized mucosa because the success rates would be higher, placement and retrieval would be simpler and also the tissue proliferation around the mini screws would be eliminated[11].

The fact that the mini screws were placed in tight soft tissue, where no incisions were required might have contributed to the

relatively high stability of the screws with better patient acceptance to the overall procedure. These findings are in accordance with the report of **Kuroda et al[13]**, who reported that mini screws implanted without flap surgery have higher success rates with less pain and discomfort than those placed with flap surgery.

Nirshpack et al[14] concluded that retraction of maxillary canine into the first premolar extraction site using Nickel Titanium closed coil springs occurred faster. Therefore, Nickel-Titanium closed coil springs (9mm) were used for retraction to permit constant force application.

In this study, root resorption was not investigated because any long-term effect of retraction on root resorption would be difficult to study and many variables can contribute to root resorption. The longer the study, the more difficult it would be to control those variables.

In our study, the maxillary canine on the experimental side had moved by 0.83 ± 0.152 mm during the 28^{th} day was statistically significant (p-value=0.003) when compared to the movement in control side by 0.65 ± 0.16 mm. This shows the rapid tooth movement was happened in 28^{th} day, whereas on the 56^{th} and 84^{th} day the movement was 0.72 ± 0.11 mm and 0.69 ± 0.07 mm respectively in experimental side were not statistically significant (p-value=0.309 & 0.352) when compared to the movement in control side by 0.66 ± 0.11 mm, and 0.66 ± 0.07 mm respectively

In the mandibular dentition, canine on the experimental side had moved by 0.62 ± 0.09 mm during the 28th day was statistically significant (p-value=0.004) when compared to the movement in control side by 0.46 ± 0.07 mm. This shows the rapid tooth movement was happened in 28th day, whereas on the 56th and 84th day the movement was 0.56 ± 0.09 mm, and 0.50 ± 0.07 mm respectively in experimental side were not statistically significant (p-value=0.426 & 0.452) when compared to the movement in control side by 0.53 ± 0.08 mm, and 0.48 ± 0.07 mm respectively.

Our results were in relevance with the histological study conducted by **Diedrich et al[7],** according to which the factors that contribute to increase in rate of tooth movement were higher bone density with less bundle bone, broader alveolar process, and reduced tendency of gingival recession in the recent extraction sites. Based on this study on the 28th day the results were proven statistically significant, whereas on the 56th and 84th day there was no significant change because most of the wound healing occurred within 28 days.

In maxilla the canine moved by the mean value of 0.74 ± 0.13 mm during the 28th, 56th & 84th day respectively and in mandible the canine was moved by the mean value of 0.57 ± 0.09 mm respectively. Although the movement in maxilla was observed faster compared to the mandible, the results were not statistically significant (p – value =

0.011 & 0.081). The rapid tooth movement in maxilla than the mandible was due to the presence of enormous cancellous bone in the maxilla as stated by **Devlin et al**[8].

For a better understanding, an animal study with the histological parameters is needed to assess the rate of tooth movement.

This was the first study to determine the rate of tooth movement in canine retraction by varying the time of therapeutic extraction as a simplified *Rapid Acceleratory Phenomenon (RAP)* in humans. We have shown that this technique was an effective, comfortable, and safe procedure to accelerate the tooth movement significantly.

CONCLUSION

Our study successfully evaluated the rate of tooth movement using simplified *Rapid Acceleratory Phenomenon* for a period of 84 days and the results proved that the rate of tooth movement had increased significantly in 28 days whereas on the 56^{th} & 84^{th} day, the results were not statistically significant.

It was concluded that, although there is an increase in the rate of canine retraction in experimental side for both maxilla & mandible by one-fold at 28 days, the overall rate of tooth movement in experimental side (Recently extracted site) was not very significant when compared to control side.

Conclusively, simplified *Rapid acceleratory phenomenon* could reduce orthodontic treatment time considerably. Therefore, simplified RAP technique (altering the time of therapeutic extraction) can be incorporated into routine orthodontic mechanics, facilitating tooth movement, stimulating bone remodeling in areas of deficient alveolar bone, reducing the stress on anchor units and initial increase in rate of tooth movement at retraction phase.

Hence, simplified RAP phenomenon offers a practical, non-invasive safe procedure without adding any other surgical procedures, apart from the one that is routinely performed. This procedure can be effectively used for increasing the rate of tooth movement, by maximizing the biological response to orthodontic forces.

Further some more in-vivo histological animal studies are required to see the changes in efficiency of simplified RAP phenomenon which occurs during 28^{th}, 56^{th} & 84^{th} days.

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ANNEXURE– 1

Measured mean values in control and Experimental side

S.No	Patient name/OP no	Days	Recently extracted site		Healed extraction site	
			MAXILLA	MANDIBLE	MAXILLA	MANDIBLE
1.	Manikandan 2191239	28	0.66	0.59	048	0.41
		56	0.58	0.51	0.54	0.49
		84	0.62	0.48	0.61	0.46
2.	Clinton 2195025	28	0.82	0.61	0.66	0.46
		56	0.69	0.59	0.61	0.53
		84	0.72	0.51	0.68	0.49
3.	Praveen 2182770	28	0.79	0.51	0.58	0.39
		56	0.61	0.47	0.57	0.47
		84	0.64	0.43	0.61	0.39
4.	Ashwin 2174161	28	0.62	0.46	0.46	0.31
		56	0.57	0.42	0.53	0.38
		84	0.59	0.39	0.57	0.37
5.	Saran 2191954	28	1.02	0.77	0.93	0.56
		56	0.87	0.71	0.83	0.67
		84	0.77	0.63	0.75	0.59
6.	Munniyappan 2086576	28	0.71	0.58	0.47	0.44
		56	0.65	0.52	0.59	0.49
		84	0.61	0.48	0.57	0.45
7.	Sharmila 2185247	28	0.91	0.74	0.70	0.56
		56	0.80	0.68	0.76	0.64
		84	0.69	0.62	0.67	0.60
8.	Senthil 2170465	28	1.09	0.71	0.85	0.53
		56	0.88	0.65	0.81	0.63
		84	0.82	0.56	0.77	0.56
9.	Mukil 2134652	28	0.94	0.67	0.78	0.44
		56	0.79	0.53	0.70	0.51
		84	0.74	0.47	0.69	0.44
10.	Ramanathan 2162770	28	0.83	0.61	0.62	0.50
		56	0.79	0.56	0.73	0.54
		84	0.72	0.50	0.75	0.51

ANNEXURE - 2

Adhiparasakthi Dental College & Hospital
MELMARUVATHUR.
TAMIL NADU-608319
CONTACT NO: 044 – 2752 8082,044 – 27528083 ,
EMAIL: APDCOLLEGE@GMAIL.COM

PATIENT CONSENT FORM

O.P. NO:

I …… , voluntarily consent for the use of mini-implants for the treatment of malocclusion using fixed orthodontics as a part of the ongoing study. The nature and the effect of the procedure have been explained to me……

I also consent to the administration of anesthetics as may be necessary.

I accept all risks involved in these procedures. I have been informed regarding the details and associated complications of the procedures.

I consent to the photographing of the procedure.

I have fully understood the procedure and I consent to such procedure by my own free will.

Date: Patient's signature

ஆராய்ச்சியில் பங்கேற்பதற்கு இணக்கம்

தேதி:

நோயாளியின் பெயர் :

வயது / பாலினம் :

புறநோயாளி எண் :

அறுவை சிகிச்சை மருத்துவ நிபுணரின் பெயர் :

சிகிச்சையின் பெயர் :_____

அளிக்கப்படும் மயக்க மருந்தின் வகை :

எனது தற்போதைய வாய்நலம் குறித்தும், அதற்கு உரிய சிகிச்சை முறைகளையும், மாற்று சிகிச்சை முறைகளையும் மற்றும் சிகிச்சை மேற்கொள்ளாவிடில் ஏற்படும் பின்விளைவுகளையும் பல் மருத்துவர் முழுமையாக என்னிடம் கூறினார். அதற்கான எனது சந்தேகங்களையும் பல் மருத்துவரிடம் கேட்டு தெளிவுபடுத்திகொண்டேன். மேலும் சிகிச்சை முறை, என் சிகிச்சையின் போது தேவைப்படும் மயக்கமருந்துகள் மற்றும் பிறமருந்துகள் செலுத்த சம்மதிக்கின்றேன். நான் மனப்பூர்வமாக எனது சிகிச்சை முறை மற்றும் அதனால் வரும் பின் விளைவுகளையும் ஏற்றுக் கொள்கிறேன் மற்றும் மருத்துவர் கூறும் அறிவுரைகளையும் கடைபிடிப்பேன்.

மேலே சொல்லப்பட்டு இருக்கும் ஆராய்ச்சி ஆய்வில் பங்கேற்பதற்கு மனப்பூர்வமான எனது சம்மதம்.

மேலுள்ள தகவல்கள் உள்ளிட்டு ஆராய்ச்சி ஆய்வானது வாய்வழியாக விளக்கப்பட்டிருக்கிறது மற்றும் பங்கேற்பதற்கு சுயவிருப்பத்தில் இணங்குகிறேன் என்பது இந்த ஆவணத்தில் கையெழுத்திடுவதன் அர்த்தமாகும்.

நோயாளியின் கையொப்பம் அறுவை சிகிச்சை நிபுணரின் கையொப்பம்

ANNEXURE - 3

Om Sakthi

ADHIPARASAKTHI
DENTAL COLLEGE & HOSPITAL
Recognised by Dental Council of India
Affiliated to The Tamilnadu Dr.M.G.R Medical University
A Unit of Adhiparasakthi Charitable, Medical, Educational & Cultural Trust

This Ethical Committee has reviewed the research Protocol submitted by Dr. Kishor Kumar. K.N, Post Graduate Student, Department of Periodontics, under the title "**COMPARATIVE EVALUATION OF RATE OF ORTHODONTIC TOOTH MOVEMENT BY VARYING THE TIMING OF THERAPEUTIC EXTRACTIONS IN PATIENTS UNDERGOING FIXED APPLIANCE THERAPY - AN IN VIVO STUDY**" Ref no.: 2017-MDS-BrV-SUD-12/APDCH under the guidance of *Dr. V. Sudhakar* for consideration of approval to proceed with the study.

This Committee has discussed about the Material being involved with the study, the Qualification of the investigator, the present norms and recommendations from the Clinical Research Scientific body and comes to a conclusion that this Research protocol fulfils the Specific requirements and the Committee authorizes the proposal.

Principal

ANNEXURE - 4

URKUND

Urkund Analysis Result

Analysed Document:	MD final edited.docx (D61639606)
Submitted:	12/23/2019 11:51:00 AM
Submitted By:	kpnkishor@gmail.com
Significance:	12 %

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CERTIFICATE – II

This is to certify that this dissertation work titled ……

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