EVALUATION AND COMPARISON OF MICRO-OSTEOPERFORATIONS AND CORTICOTOMY ON THE RATE OF CANINE RETRACTION AND COMPARATIVE ASSESSMENT OF GINGIVAL ESTHETIC OUTCOME FOR BOTH THE TECHNIQUES

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LIST OF ABBREVIATIONS

SR. NO.	ABBREVIATION	LONG FORM
1.	OTM	Orthodontic tooth movement
2.	RAP	Rapid Acceleratory Phenomenon
3.	MOP's	Micro-Osteoperforations.
4.	PAOO	Periodontally Accelerated Osteogenic Orthodontics.
5.	AOO	Accelerated Osteogenic Orthodontics
6.	CAOT	Corticotomy Assisted Orthodontic Treatment
7.	CAO	Corticotomy Assisted Orthodontics.
8.	PDL	Periodontal Ligament
9.	mm	Millimetre
10.	NSAIDs	Nonsteroidal anti-inflammatory drugs
11.	g	grams
12.	CT	Computed tomography
13.	HR-CT	High-resolution computed tomography
14.	COL-I	Type I collagen
15.	TIMP-1	Tissue inhibitor of metalloproteinase-1
16.	TNF-a	tumor necrosis factor-alpha
17.	OCN	osteocalcin
18.	SAD	Selective Alveolar Decortication.
19.	IL-1β	Interleukin -1 Beta
20.	IL-8	Interleukin- 8
21.	i.e.	That is.
22.	RANKL	Receptor Activator Nuclear Kappa-B Ligand
23.	OPG	Osteoprotegrin.

24.	Ho	Null Hypothesis
25.	Fig	Figure.
26.	K.S	Kolmogorov Smirnov test
27.	ANOVA	Analysis of Variance.
28.	Pg/µl	Picograms/ Microlitre.
29.	MC	Method Corticotomy
30.	%	Percentage
31.	NiTi	Nickel – Titanium
32.	MAPK	Mitogen Activated Protein Kinase
33.	Nm	Nanometres
34.	MW	Megawatt
35.	J/cm2	Joule/square centimetre
36.	LILT	Low-intensity laser therapy
37.	Min	Minutes
38.	PES	Pink Esthetic score
39.	DMP1	Dentin Matrix Acidic Phosphoprotein 1.
40.	SAD	Selective Alveolar Decortication.
41.	Etc	et cetera
42.	N	No of
43.	N	Newton
44.	LLLT	low-level laser therapy
45.	PTH	parathyroid hormone
46.	Fig	Figure
47.	sq.cm	Square centimetre
48.	Hz	Hertz
49.	CI	Central Incisor
50.	DFDB	**Demineralized freeze-dried bone**
51.	OPG	Orthopantomogram

Introduction

In today's aesthetic conscious world an increasing number of adult patients are seeking orthodontic treatment. However, there are several psychological, biological and clinical differences between the orthodontic treatment of adults and adolescents. IN adult patients teeth are confined in non-flexible alveolar bone and so are more prone to periodontal complications. In addition, cell mobilization and conversion of collagen fibers is much slower in adults than in children. Also they have more specific objectives and concerns related to facial and dental aesthetics, the type of orthodontic appliance and the duration of treatment. These considerations make orthodontic treatment of adults different and challenging. [1]

Most patients require extraction of first premolars for orthodontic treatment. The stage of premolar extraction-based orthodontic treatment which can be considered most time-consuming is canine retraction; and usually extends from 6 to 9 months.[2]

Thus, reduction in canine retraction time will help to achieve shorter duration of total orthodontic treatment.

Accelerating the rate of tooth movement is desirable for both; patients as it shortens treatment time and to orthodontists as the treatment duration is linked to an increased risk of gingival inflammation, decalcification, dental caries, and root resorption.[3]

Over the years, many attemps have been made to accelerate OTM which mainly fall into 3 categories. The first is local or systemic administration of drugs such as prostaglandins,interleukins, leukotrienes, cyclic adenosine monophosphate, and vitamin D. They can accelerate periodontal regeneration by inducing or hastening orthodontic inflammation, participating in the formation of osteoclasts from precursor monocytes, or improving capillary permeability. The second category is mechanical or physical stimulation. Direct electrical current, pulsed electromagnetic field, samarium cobalt magnet, and low-energy laser were studied. These 2 methods increase tooth movement speed 0.3 to 1 times according to the literature. However, they are not without problems such as the effects of drugs are not specific, and side effects in the long term are unknown. Physical stimulation also shows unwanted effects.[4]

To overcome these limitations, a third category including surgical interventions like gingival fiberotomy, alveolar surgery, and corticotomy, piezocision and micro osteoperforation.etc have been tried.[4]

Dr. H.M. Frost in (1981) proposed that the mechanism behind acceleration using surgical technique is the induction of rapid orthodontic tooth movement through the involvement of the periodontal ligament. He demonstrated that regional noxious stimuli of sufficient magnitude can result in markedly accelerated re-organizing activity in the osseous and soft tissues and termed this cascade of physiologic healing processes as the Rapid Acceleratory Phenomenon (RAP).[5] He further explained RAP as a temporary stage of remodeling of localized soft and hard-tissue, which resulted in rebuilding of the injured sites to a normal state through recruitment of osteoclasts and osteoblasts via local intercellular mediator mechanisms involving precursors, supporting cells, blood capillaries and lymph.[6]

In the alveolar bone, the RAP occurs typically in the healing process of the alveolar sockets after tooth extraction, in periodontal disease, after surgery and trauma and during orthodontic tooth movement.[7]

The challenge to clinicians is how to take advantage of this bone-remodeling process for the purpose of orthodontic treatment.

In 1959, **Kole** presented a technique that combined orthodontics with ‘‘corticotomy’’ surgery to increase the rate of tooth movement.[1] It is beneficial in overcoming limitations in adult orthodontics with advantages like reduced orthodontic treatment time, earlier treatment of impacted tooth ,reduced anchorage loss and thus inhanced post treatment stability

Wilcko et al used their knowledge of corticotomy and their observations of RAP to develop their patented Periodontally Accelerated Osteogenic Orthodontics (PAOO) technique in 1995. It is a combination of a selective decortications facilitated orthodontic technique and alveolar augmentation.[8] Orthodontic tooth movement was started after healing period of one or two weeks and then followed up using a faster rate of activation at two week intervals.[1]

Corticotomy being effective had disadvantages like chances of damage to adjacent vital structures, post-operative pain and swelling, chances of infection. Also being an invasive procedure had low acceptance by the patient.

As truly quoted "NECESSITY IS THE MOTHER OF INVENTION", various new less invasive techniques have been tried and have shown desirable results in accelerating OTM.

In recent times, a new micro-invasive technique called micro-osteoperforation, was introduced that stimulates cytokine activity .When clinicians create micro-osteoperforations in the alveolar bone, cytokine cascade is activated, resulting in a marked increase in osteoclast activity and bone remodeling.

The first principle in any dental procedure is Primum non nocere" ("First, do no harm") Gingival health post surgeries may be altered and so a gingival index to assess the post operative health of gingiva and periodontium will help the clinician know the consequences of these surgeries used in accelerating tooth movement. In this study PINK Index was used to evaluate and compare the gingival health.[10]

In recent years, many studies have been carried out to evaluate the efficiency of Corticotomy/ PAOO and Micro-osteoperforation, on individual basis, as adjunctive procedures along with fixed orthodontic treatment to accelerate rate of tooth movement. But there have been no comparative studies regarding the effectiveness of the same.

The purpose of this study was to evaluate and compare difference in rate of tooth movement between flapless micro-osteoperforation and corticotomy with flap elevation. The gingival esthetic index was also assessed to compare the effects of flapless verses flap reflection procedures on gingival health.

Aim and Objectives

Aim of the Study

To evaluate and compare the effects of microosteoperforations with corticotomy on the rate of canine retraction and to assess gingival aesthetic index on both sides in patients undergoing orthodontic treatment.

Objectives of the Study

1. To evaluate the effects of microosteoperforations on the rate of tooth movement.
2. To evaluate the effect of corticotomy on rate of tooth movement.
3. To compare the results of both techniques.
4. To evaluate and compare the inclination of canines on both sides in these procedures.
5. To assess and compare gingival aesthetic index and to compare it for both techni

Review of Literature

The review of literature has been divided into following headings:

1. Orthodontic Tooth Movement
2. Accelerated Tooth Movement and “Rap” Phenomenon
3. Corticotomy
4. Other Procedures for Accelerated Orthodontics
5. Microosteoperforations

ORTHODONTIC TOOTH MOVEMENT:

The first investigator who systematically experimented on animals with orthodontic appliances and investigated the results was the **Swede, Carl Sandstedt in 1904**. He reported that on the side of pull, with both weak and strong forces, a deposition of bone takes place on the old alveolar wall. The newly formed bone spicules follow the direction of the strained peridental fibers. On the side of pressure the old alveolar bone is equally resorbed by weak forces. The surface of the tooth itself remains intact. By these fundamental findings Sandstedt justified the pressure theory of Flourens also for the orthodontic movement of teeth.[11]

Martin Schwarz et al (1931)[11]described about tissue changes incidental to orthodontic tooth movement and concluded that t biologically the most favourable treatment is that which works with forces not greater than the pressure in the blood capillaries. This pressure in men as well as in most mammalia is 15 to 20 mm. Hg; it is about 20 to 26 grams for 1 sq.cm. surface.

Storey and Smith et al (1952)[12] reported that applying light forces for tooth movement, demonstrated cell-free compressed areas in the PDL. They studied distal movement of canines in orthodontic patients and suggested that there is an optimum range of pressure (150-200 g) on the tooth-bone interface that produces a maximum rate of tooth movement. Pressure below this range produced no tooth movement. When the force was increased above optimum, the rate of tooth movement was decreased and finally approached zero within a week.

Reitan et al (1960)[13] suggested that tissue reaction is related to a series of factors, that are formation of cell-free areas and reaction of fibrous tissue and both factors may, to a large extent, determine the sequence of events in a tooth movement. Formation of cell-free areas is a characteristic tissue response in a tipping movement. formed primarily in the marginal region of the root. Because of the narrowness of the periodontal membrane, fibrous tissue will soon be compressed, whereby cells gradually disappear in a circumscribed area. In bodily movement the force is distributed over the whole side of the root, there is, in general, fewer tendencies to formation of compressed areas. They concluded that the mechanics involved in a bodily movement tend to favour a direct bone resorption on the pressure side. Following rotation, tension and displacement of supra-alveolar structures may persist even after retention. Early treatment or over rotation may, to a large extent, prevent relapse tendencies.

Becker et al (1962)[14] suggested that metabolically active bone or connective tissue produce electronegative charges that are generally proportional to their activity. Inactive cells and areas are nearly electrically neutral. Although the purpose of this bioelectric potential is unknown, cellular activity can be modified by adding exogenous electric signals.

Timothy Bridges et al (1988)[15] conducted an animal study for comparison of tooth movement cycles and changes in alveolar tissue mineral densities. It was done between young (21 to 28 days old) and adult (90 to 100 days old) rats. An initial 60-g mesial tipping force was applied to the maxillary first molars and tooth movement was estimated by measuring the opening between first and second molars, and tissue mineral density by sample ash weight per cubic centimetre. Tooth movement cycle consists of an early "instantaneous" movement that is a function of the viscoelastic properties of the tissues, a delay period during which little tooth movement occurs due to hyalinization and undermining resorption, and a late period during which bone remodelling and tooth movement occur. Compared with the adult group, the amount of "instantaneous" movement in the young rats was greater, the delay period was shorter, and the rate of late tooth movement was faster. The data indicated that a greater amount and rate of tooth movement occur in younger animals by alterations in all three phases of the tooth movement cycle and that, with the exception of the late movement phase, these differences are reflected by reductions in tissue mineral densities.

Jack J.G.M. Pilon et al (1996)[16] studied the relationship between the magnitude of a constant continuous orthodontic force and rate of bodily tooth movement. They concluded that other factors than magnitudes of force are involved in determining the rate of subsequent tooth movement. Individual differences in bone density, bone metabolism, and turnover in the periodontal ligament may be responsible for the variation

Berti Melson (1999)[17] suggests that when an orthodontic appliance is activated, forces delivered to the tooth are transmitted to all tissues near the area of applied force. These forces bend bone, tooth, and PDL. Bone is more elastic than teeth and bends more readily in response to force application. The active biologic processes that follow bone bending involve accelerated bone turnover and renewal of cellular and inorganic fractions.

Robert A. W. Fuhrmann (2002)[18] conducted a three-Dimensional study to evaluate periodontal remodelling during orthodontic treatment .In 21 adult patients; two or three high-resolution computed tomography (HR-CT) examinations were performed before, during and after orthodontic treatment with fixed appliances. The time between the first, second, and third CT scanning varied according to the individual treatment or retention period from 12 to 36 months. Comparison of the CT examinations permitted three-dimensional evaluation of osteoclastic and osteoblastic periodontal remodelling. The incidence of periodontal lesions, such as bone dehiscence, fenestrations and root resorption were assessed in relation to the initial periodontal situation and the applied orthodontic biomechanics. Anatomic risks were a small alveolar process, thin buccal or lingual bone plates, eccentric positioning of teeth, basally extended maxillary sinus, and progressive alveolar bone loss. Therapeutic risks were uncontrolled sagittal or vertical movements of the incisors and cortical or intermaxillary anchorage preparation. Orthodontically induced bone dehiscences were partly repaired by osteoblastic periodontal remodelling in the retention period.

Thiago P. Garlet et al (2007)[19] conducted a study to assess cytokine expression pattern in compression and tension sides of the periodontal ligament during orthodontic tooth movement in humans. A total of 24 teeth were taken as sample: 14 in the experimental group extracted from patients treatment with rapid maxillary expansion procedure followed by extraction of the first premolars and 10 teeth in control group from whom biopsies of PDL were taken after tooth extractions previously scheduled for orthodontic reasons. The results showed that both sides exhibited significantly higher expression of all targets when compared with controls, except for type I collagen(COL-I) and tissue inhibitor of metalloproteinase-1 (TIMP-1) on the control side. Comparing both sides, the control side exhibited higher expression of tumour necrosis factor-a (TNF-a), receptor activator of nuclear factor-kB ligand (RANKL), and matrix metalloproteinase-1 (MMP-1), whereas the T side presented higher expression of interleukin-10 (IL-10), TIMP-1, COL-I, and osteocalcin (OCN). The expression of transforming growth factor-b (TGF-b) was similar in both C and T sides. They concluded that there is differential expression of pro- and anti-inflammatory cytokines in compressed and stretched PDL during orthodontic tooth movement.

V Krishnan and Davidovitch (2009)[20] suggested that discoveries in mechanobiology have illuminated sequential cellular and molecular events, such as signal generation and transduction, cytoskeletal re-organization, gene expression, differentiation, proliferation, synthesis and secretion of specific products, and apoptosis. Orthodontists work in a unique biological environment, wherein applied forces engender remodelling of both mineralized and non-mineralized paradental tissues, including the associated blood vessels and neural elements. They emphasize the fact that mechanoresponses and inflammation are both essential for achieving tooth movement clinically. If both are working in concert, orthodontists might be able to accelerate or decelerate tooth movement by adding adjuvant methods, whether physical, chemical, or surgical.

ACCELERATED TOOTH MOVEMENT and "RAP" PHENOMENON

Heinrich Kole,(1959)[21] introduced a surgical procedure involving both osteotomy and corticotomy to accelerate orthodontic tooth movement, based on the concept that teeth move faster when the resistance exerted by the surrounding cortical bone is reduced by a surgical procedure. He explained that the corticotomy can be performed for a single tooth or for a group of teeth. The teeth are then moved in a short period and are generally not loosened, as when strong forces are applied to them. The principles of corticotomy being that in order to move a group of teeth, with their alveolar process, by orthodontic means, the cortical layer is osteotomizcd both buccally and lingually in its entire alveolar height. The spongiosa is left intact, serving as a nutritive pedicle to the bone denuded of its mucoperiosteum.

H M Frost (1981)[22] found that the acceleration in orthodontic tooth movement was due to a temporary stage of localized hard-tissue remodelling that resulted in rebuilding of the injured sites to a normal state through recruitment of osteoclasts and osteoblasts via local intercellular mediator mechanisms involving precursor supporting cells, blood capillaries and lymph. This was phenomenon was named the "Regional Acceleratory Phenomenon" (RAP).

Hajji (2001)[23] described Regional Acceleratory Phenomena (RAP) following surgical intervention as resulting in increase in bone turnover and decrease bone density. As such, this concept has potential for accelerating tooth movement and reducing the treatment time frame for both the patient and orthodontist. A study was conducted to investigate the efficacy of a technique combining orthodontic with alveolar corticotomy and grafting as an effective treatment for Class I and II malocclusions in comparison with conventional, non-surgical orthodontic non-extraction and extraction therapies. Orthodontics combined with corticotomy and grafting resulted in increased labial-lingual alveolar width, had cephalometric results similar to non-surgery, non-extraction therapy and was up to four times faster than conventional orthodontic treatment.

Hu Long et al (2013)[24] did a systematic review to evaluate the effectiveness of interventions on accelerating orthodontic tooth movement. Information was collected from databases of PubMed, Embase, Science Citation Index, CENTRAL, and SIGLE from January 1990 to August 2011 for randomized or quasi-randomized controlled trials that assessed the effectiveness of interventions on accelerating orthodontic tooth movement. Five interventions were studied: low-level laser therapy, corticotomy, electrical current, pulsed electromagnetic fields, and dentoalveolar or periodontal distraction and six outcomes were evaluated in these studies being accumulative moved distance or movement rate, time required to move tooth to its destination, anchorage loss, periodontal health, pulp vitality, and root resorption. they concluded that among the five interventions, corticotomy is effective and safe to accelerate orthodontic tooth movement, low-level laser therapy was unable to accelerate orthodontic tooth movement, current evidence does not reveal whether electrical current and pulsed electromagnetic fields are effective in accelerating orthodontic tooth movement, and dentoalveolar or periodontal distraction is promising in accelerating orthodontic tooth movement but lacks convincing evidence.

In this study effects of corticotomy in accelerating tooth movement were evaluated during canine retraction phase of orthodontic treatment.

CORTICOTOMY :

Corticotomy assisted orthodontic treatment is an established and efficient orthodontic technique that has gradually gained popularity as an adjunct treatment option for the orthodontic treatment especially in adults. It involves selective transient osteopenia, which is followed by a faster rate of orthodontic tooth movement.

The application of corticotomy surgery to correct malocclusion was first described in 1892 by **L. C. Bryan**, but it was **Heinrich Köle** in 1959 who reintroduced alveolar corticotomy to resolve malocclusion. He combined interdental alveolar corticotomy surgery with a through-and-through osteotomy apical to the teeth. Corticotomy procedure has several advantages like greater stability of clinical outcomes and less relapse, accelerated treatment, increased alveolar volume and enhanced periodontium by correction of any existing dehiscence and fenestration, rapid recovery of impacted teeth like canines and third molars, correction of unilateral crossbites, etc.[25]

Bichlmayr (1931)[26] described corticotomy for patients older than 16 years, to accelerate tooth movement and reduce relapse for maxillary protrusion. He introduced a surgical technique for rapid correction of severe maxillary protrusion with orthodontic appliances. Wedges of bone were first removed to reduce the volume of bone through which the roots of the maxillary anterior teeth would need to be retracted. This was employed with canine retraction after first bicuspid extraction, by excising the buccal and lingual cortical plates at the extraction site

Duker (1975)[27] investigated the affect of corticotomy on tooth vitality and the marginal periodontium in beagle dogs. They moved an incisor segment 4 mm in 8-20 days. From their results they concluded that preserving the marginal crest bone in relation to interdental cuts was required in corticotomy. Also, the cuts must always be left at least 2 mm short of the alveolar crestal bone level.

Rynearson (1988)[28] made a meaningful contribution to dentoalveolar surgery that many not have appreciated. He tested Kole’s hypothesis that, under orthodontic force, teeth in a corticotomy treated segment move as a tooth- bone unit by utilizing implanted radiopaque pins and bone labelling. He found no evidence of movements of the cortical plates and concluded that the corticotomy procedure, did not elicit any mechanical movement of a tooth borne unit i.e. "bony block" movement, but rather elicited a facilitation of normal physiologic tooth movement metabolism.

Bemard Gantes et al (1990)[29] reported the corticotomy surgical technique used in conjunction with orthodontic therapy and its effect on the periodontal status of the involved teeth. They conducted a study including five adult patientsin the age group of 21 to 32 years. Buccal and lingual vertical incisions extending from the gingival margin towards a level apical to the apices of the teeth was made up distal to the most posterior tooth included in the corticotomy procedure. The vertical incisions were connected by buccal and lingual intracrevicular incisions. A horizontal groove penetrating the cortical bone connected all vertical grooves 2 mm to 3 mm apical to the apices of the teeth. The results showed that treatment time was reduced by approximately 50%.Gingival recession was minimal and the interdental papillae were preserved, insuring a good post-treatment esthetic result. In conclusion the descriptive statistics of these 5 cases indicate that no periodontal adverse effects were clinically noticeable. The increasing number of adults seeking correction of teeth and jaw malpositions may be a group of patients for this procedure.

Suya H (1991)[30] reported corticotomy assisted orthodontic treatment. He reported corticotomy-assisted orthodontic treatment of 395 adult Japanese patients. Suya's technique differed from Kole's with the substitution of a subapical horizontal corticotomy cuts in place of the horizontal osteotomy cut beyond the apices of the teeth (corticotomy: thinning of cortical plate without penetrating medullary bone, osteotomy: complete cut through cortical plate to medullary bone). Fixed orthodontic appliances were used. Some cases were completed in 6 months, other cases were completed in less than 12 months. Suya contrasted his technique with conventional orthodontics in being less painful, producing less root resorption, and exhibiting less relapse. Outstanding results and extreme patient satisfaction with corticotomy procedures were reported. He believed that the tooth movements were made by moving blocks of bone using the crowns of the teeth as handles. Completing tooth movement in 3–4 months were recommended, after which time the edges of the blocks of bone would begin to fuse together.[31]

William M. Wilcko et al (2001) [32] demonstrated 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. They patented and trademarked this technique as Periodontally Accelerated Osteogenic Orthodontics (PAOO).Two case reports one of a 24-year-old man with a Class I severely crowded malocclusion and an overly constricted maxilla with concomitant posterior crossbites and another of a 17-year-old female with a Class I moderately to severely crowded malocclusion requiring shortened orthodontic treatment times were presented by them.

Post treatment evaluation of both patients revealed no probing depths greater than 3 mm, good preservation of the interdental papillae, no loss of tooth vitality, no significant reduction in the radiographic height of the crestal bone, and no radiographic evidence of any significant apical root resorption. No gingival recession was noted in patients. They concluded that with this surgical intervention, an osteoporotic situation that is favourable for rapid orthodontic tooth movement can be induced within the alveolar bone without increasing the risk of apical root resorption. The alveolar bone can be simultaneously augmented and reshaped.

Twaddle et al (2002)[33] conducted a study on Corticotomy-facilitated orthodontics which provides a means for rapidly moving teeth purportedly with little damaging effects to the periodontium and with greatly reduced treatment time. They analyzed the dento-alveolar effects of rapid tooth movement in the anterior mandible of subjects treated orthodontically for moderate to severe crowding following labial-lingual corticotomy. A sample of 10 subjects who underwent orthodontic therapy following labial-lingual corticotomy and an alveolar augmentation procedure was compared to four subjects treated with orthodontics alone without corticotomy. Alveolar sagittal width increased in the area labial to the tooth apex, but the increase did not remain significant. Author concluded that orthodontic therapy facilitated with corticotomy surgery and grafting improved alveolar bony support and resulted in permanent alveolar process width increase.

Wilcko et al (2003)[34] demonstrated a new orthodontic method that provides shortened treatment times and concomitant periodontal alveolar augmentation. They suggested that the rapid orthodontic decrowding and minimal apical root resorption are attributable to increased regional bone turnover (the regional acceleratory phenomenon) and the associated osteopenia (i.e., calcium depletion and diminished bone density) that was precipitated by selective decortication.

T. J. Fischer (2007)[35] conducted a study to evaluate the effectiveness of a new surgical technique in the treatment of palatally impacted canines. Six consecutive patients presenting with bilaterally impacted canines were compared. One canine was surgically exposed using a conventional surgical technique while the contralateral canine was exposed using a corticotomy-assisted technique. This corticotomy-assisted procedure included a series of circular holes made along the bone mesial and distal adjacent to the impacted tooth where possible. These holes were made with a 1½ mm round bur spaced approximately 2 mm apart and extended into the edentulous area into which the tooth was to be moved. Orthodontic traction was applied to both canines in a similar manner utilizing 60 g of force. In all six patients, the treatment time was reduced in the corticotomy-assisted canine impactions. As compared to the non corticotomy canines, the reduction in treatment time ranged from 28% to 33%.They concluded that under the same conditions the corticotomy-assisted approach produced faster tooth movement in all six patients. Additionally, this surgical procedure did not produce any significant difference in the periodontal health of the canine.

K-W Cho et al (2007)[36] conducted an animal study in which the effect of cortical activation on orthodontic tooth movement was investigated clinically and histologically in the surrounding bony tissue. The sample consisted of two beagle dogs. Cortical activation was applied to the buccal and lingual side of the alveolar bone of both jaws on the right side where 12 holes were made on each cortical plate; 4 weeks after the extraction of all the second bicuspids while under deep anaesthesia. All third bicuspids on both jaws were distalised by a 150-g force using NiTi coil spring with/without guiding wire. The tooth movement was measured and the animals were killed after tooth movement. Rapid initial tooth movement was apparent after cortical activation. However, after 6 months of cortical activation, the cell number and cellular activity of the surrounding periodontal tissue were decreased. This experiment showed that rapid initial tooth movement was apparent following the application of orthodontic force after cortical activation but the cellular activity and fibroblast structure were abnormal in the surrounding periodontal tissue.

Shadw Mohammed Badr El-Din Aboul-Ela et al (2011)[37] conducted a comparative study to clinically evaluate miniscrew implant-supported maxillary canine retraction with corticotomy-facilitated orthodontics. 13 adult patients (5 men, 8 women; mean age, 19 years) exhibiting Class II Division 1 malocclusion with increased overjet requiring the therapeutic extraction of the maxillary first premolars, with subsequent retraction of the maxillary canines were taken as samples. Corticotomy-facilitated orthodontics was randomly assigned to 1 side of the maxillary arch at the canine premolar region, and the other side served as the control. By using miniscrews as anchorage, canine retraction was initiated via closed nickel-titanium coil springs applying 150 g of force per side. Over a 4-month follow-up period, rate of tooth movement, molar anchorage loss, plaque index, gingival index, probing depth, attachment loss, and gingival recession were assessed. The showed that the average daily rate of canine retraction was significantly higher on the corticotomy than the control side by 2 times during the first 2 months after the corticotomy surgery. This rate of tooth movement declined to only 1.6 times higher in the third month and 1.06 times higher by the end of the fourth month. No molar anchorage loss occurred during canine retraction on either the operated or the non operated side. There was no statistically significant difference between preoperative and postoperative measurements of plaque index, probing depth, attachment loss, and gingival recession. They concluded that corticotomy facilitated orthodontics can be an effective method for patients who desire shortened orthodontic treatment durations.

Al-Naoum F et al (2014)[38],conducted a split mouth design study to evaluate the efficacy of alveolar corticotomy on orthodontic tooth movement when retracting upper canines compared to the conventional technique; and to evaluate patients' pain and discomfort levels following .The distance between the canine and first molar on each side of the mouth immediately following corticotomy; then at one week, 2 weeks, 4 weeks, 8 weeks and 12 weeks were assessed .Levels of pain and discomfort were evaluated as secondary outcome variables using a questionnaire. The pain encountered during eating was high with 50 and 30% of patients reporting 'severe' pain at one day and three days postoperatively, respectively.

No significant differences could be detected between males and females regarding tooth movement velocity on the experimental side. They concluded that Alveolar corticotomy procedure increased orthodontic tooth movement and was associated with moderate degrees of pain and discomfort. Tooth movement velocities following corticotomies were 2-4 times faster on the experimental side than on the control side particularly during the early stage after corticotomy.

Vijayashri Sakthi et al , (2014)[39] conducted a study to assess the efficiency and treatment outcome of patients treated with corticotomy assisted en-masse orthodontic retraction as compared with the enmass retraction without corticotomy. The study group consisted of 22 patients (male 11, female 11) willing to undergo surgery to reduce the duration of their orthodontic treatment and 18 patients (male 9, female 9) desirous of undergoing conventional orthodontic treatment without surgical intervention constituted the control group. Sulcular incisions from the distal aspect of one canine to the contralateral canine were placed, and full thickness flap was elevated, 3 mm above the apical region of the tooth. 701 fissure bur and number 2 size round bur mounted on a micromotor handpiece under copious irrigation was used for decortications. The graft was placed only in cases with evidence of bone loss (dehiscence and fenestration) on flap elevation with demineralized freeze-dried allograft

Average rate of space closure of 1.8 mm/month in the maxilla and 1.57 mm/month in the mandible was observed in the study group compared to 1.02 mm/month in the maxilla and 0.87 mm/month in the mandible in the control group. The rate of retraction accelerated during the first 2 months of retraction. Molar anchor loss of approximately 0.6 mm occurred in the study group, and 1.8 mm occurred in the control group during the 4 months. They concluded. The rate of retraction with study group was twice as faster when compared to the control group, accelerating during the first 2 months of retraction.

Noha Hussein Abbas et al (2016)[40] conducted a study to evaluate the efficiency of corticotomy-facilitated orthodontics and piezocision in rapid canine retraction. The sample consisted of 20 patients (15-25 years old) with Class II Division 1 malocclusions.. The sample was divided into 2 equal groups. In the first group, 1 side of the maxillary arch was randomly chosen for treatment with corticotomy, and in the second group, piezocision treatment was used. The contralateral sides of both groups served as the controls. Cuts and perforations were performed with a piezotome, and canine retraction was initiated bilaterally in both groups with closed-coil nickel-titanium springs that applied 150 g of force on each side.

The following variables were examined over a 3-month follow-up period: rate of canine crown tip, molar anchorage loss, canine rotation, canine inclination, canine root resorption, plaque index, gingival index, probing depth, attachment level, and gingival recession. The rate of canine crown tip was assessed every 2 weeks after the start of canine retraction at 6 time points. The results showed that 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. They concluded that corticotomy-facilitated orthodontics and piezocision are efficient treatment modalities for accelerating canine retraction.

Ana Paula Lazzari Marques Peron et al (2016)[41] performed a study to compare the histological responses in corticotomy- and corticision-assisted tooth movement. Ninety Wistar rats were divided into three groups: C (control—tooth movement only), CT (tooth movement with corticotomy), and CI (tooth movement with corticision). Surgeries were performed on the vestibular and lingual cortical bone of the maxillary first molar.

Tooth movement was carried out with nickel-titanium closed coil springs having a force of 30 g. The rats were sacrificed at 3, 14, and 28 days. To evaluate the number of osteoclasts and amount of root resorption, a tartrate-resistant acid phosphatase stain was used. Hematoxylin and eosin staining was performed for areas of hyalinization, and the organic bone matrix was stained with picrosirius, the results showed that The CT group showed a greater number of osteoclasts than did the C group on day 3 At the same time point, the CT and CI groups showed a delayed onset of organic bone matrix remodeling and a lower incidence of root resorption than did the C group There were also fewer hyalinization areas in the CI group than in the C group on day 3. They concluded that corticotomy effectively increased bone resorption during the early stages of tooth movement, but this increase was not observed for corticision. The surgical procedures did not accelerate organic bone matrix remodeling. Corticotomies and corticisions decreased the risk of root resorption only during the early stages of movement. Corticision reduced the level of hyalinization, while corticotomy did not.

Deepal Haresh Ajmera et al (2017)[42] conducted a study to evaluate the effect of different corticotomy approaches and modes of loading on the expansion of adult mandibles using biomechanics. Nine finite element models including 2 novel corticotomy designs were simulated. Stress, strain, and displacement of crown, root, and bone were calculated and compared under different corticotomy approaches and loading conditions. The results showed that the biomechanical response seen in the finite element models in terms of displacement on the x-axis was consistent from anterior to posterior teeth with parasymphyseal step corticotomy and tooth-borne force application. In addition, the amount of displacement predicted by parasymphyseal step corticotomy in the tooth-borne mode was greater compared with other models. They concluded that parasymphyseal step corticotomy with tooth-borne force application is a viable treatment option for true bony expansion in an adult mandible.

OTHER PROCEDURES FOR ACCELERATED ORTHODONTICS :

Various other surgical and non surgical methods have been tried to accelerate tooth movement. Surgical methods including alveolar surgery that undermines interseptal bone, corticision , interseptal bone reduction, piezocision work on the principle that when the bone is irritated surgically, an inflammation cascade is initiated which caused increased osteoclastogenesis, thus causing faster tooth movement. Non surgical techniques such as drugs or mechanical or physical stimulation of the periodontal ligament to increase the speed of bone remodelling include vitamin D injection, low-intensity laser therapy, vibration, exogenous electric currents, etc. They have been proven to act by inducing osteoclastogenesis by inducing the RANK/RANKL pathway and induction of signalling molecules such as MAPK (Mitogen Activated Protein Kinase), nitric oxide These modalities have also been shown to reduce relapse, and pain and root resorption caused due to orthodontic forces.[43]

Zeev Davidovitch, **et al (1980)[44]** conducted an experiment to determine the usefulness of exogenous electric currents in accelerating orthodontic tooth movement and to study the effect of electric-orthodontic treatment on periodontal cyclic nucleotides. Maxillary canines were tipped in five cats by 80 g force. Two groups of five cats each were treated by an electric-orthodontic procedure to one maxillary canine for 7 and 14 days, respectively .The results showed that teeth treated by force and electricity moved significantly faster than those treated by force alone. Enhanced bone resorption was observed near the anode (PDL compression site), while bone formation was pronounced near the cathode (PDL tension site). Staining for cyclic nucleotides was increased when electric stimulation was added to the mechanical force. The degree of new bone formation (as judged by the length of the newly formed bony trabeculae in the PDL) at electrically treated tension sites was higher than at the corresponding sites of teeth treated by force alone. They concluded that orthodontic tooth movement may be accelerated by the use of locally applied electric currents, in the range of 10 to 20 microamperes and that piezoelectric currents in mechanically stressed bone were implicated in the activation of bone cell and faster tooth movement.

Delma R. Cruz et al (2004)[45] studied the effects of low-intensity laser therapy on the orthodontic movement velocity of human teeth. Eleven patients were recruited for this split mouth study with one half of the upper arcade was considered control group and received mechanical activation of the canine teeth every 30 days and the opposite half received the same mechanical activation and was also irradiated with a diode laser emitting light at 780 nm, during 10 seconds at 20 mW, 5 J/cm2, on 4 days of each month. The results suggest that LILT significantly accelerates orthodontic movement in humans with a healthy response from periodontal tissues along with being successful in decreasing treatment time.

Aishu Ren et al (2007)[4] conducted a study in beagles to evaluate the effects of alveolar surgery that undermines interseptal bone in orthodontic tooth movement. Ten male beagles, aged 12 to 15 months, were used in which extraction of the mandibular second premolar and alveolar surgery to reduce the osteal resistance on the mesial side of the extraction socket were performed on the experimental side and on the control side, only the second premolar was extracted. The first premolars were distalized against the third premolars with orthodontic nickel-titanium coil springs on the both sides.

The results showed that first premolar on the experimental side moved more rapidly than that on the control side. Active and extensive bone resorption in the compressive area and bone deposition in the tension area were observed on the experimental sides. Tooth movement can be accelerated by undermining the interseptal bone surgically. The movement speed nearly doubled in the experimental side compared with the control side. Active bone deposition in the tension area and bone resorption in the compression area ensured rapid movement. They concluded that clinical application of this method is promising because of its simplicity in comparison with other attempts to shorten treatment times.

Su-Jung Kim et al (2009)[5] investigated the biologic effects of Corticision on alveolar remodeling in orthodontic tooth movement. In the study, 16 cats were divided into 3 groups: group A, only orthodontic force (control); group B, orthodontic force plus Corticision; and group C, orthodontic force plus Corticision and periodic mobilization. Histologic and histomorphometric studies were performed on tissue specimens on days 7, 14, 21, and 28.Extensive direct resorption of bundle bone with less hyalinization and more rapid removal of hyalinized tissue were observed in group B. The accumulated mean apposition area of new bone on day 28 was observed to be 3.5-fold higher in group B than in the control group A. They concluded that Corticision stimulated orthodontic tooth movement in 28 days by accelerating the rate of alveolar bone remodeling. Corticision is an efficient procedure for accelerating orthodontic tooth movement accompanied with alveolar bone remodeling.

Theodosia Bartzela et al(2009)[46] performed a systematic literature review on medication effects on the rate of orthodontic tooth movement using PubMed (1953-Oct 2007), Web of Science, and Biosis, complemented by a hand search. Forty-nine articles were included in the review, but their interpretation was hindered by the variability in experimental design, magnitude of force applied during tooth movement, and medication regimens. Therapeutic administration of eicosanoids resulted in increased tooth movement, whereas their blocking led to a decrease. Non steroidal anti-inflammatory drugs (NSAIDs) decreased tooth movement, but non-NSAID analgesics, such as paracetamol (acetaminophen), had no effect. Corticosteroid hormones, parathyroid hormone, and thyroxin have all been shown to increase tooth movement. Estrogens probably reduce tooth movement, although no direct evidence is available. Vitamin D3 stimulates tooth movement, and dietary calcium seemed to reduce it. Bisphosphonates had a strong inhibitory effect. They concluded that Medications might have an important influence on the rate of tooth movement, and information on their consumption is essential to adequately discuss treatment planning with patient.

M. Alikhani et al (2012)[47] conducted an animal study on 85 adult male sprague-dawley rats with an average weight of 400 g and of120 days of age. Animals were randomly divided into three groups: untreated (control), sham, and experimental. The experimental group received different high-frequency accelerations (vibration) that produced a strain of 4 microstrain on alveolar bone. All stimuli were applied to the occlusal surface of the right first maxillary molar for 5 min/day for 28 days. Devices for mechanical stimulation in the 30-, 60-, 100-, and 200-Hz frequency range and accelerations of 0.3 g and 0.6 g were prepared and calibrated. The study investigated the components of mechanical stimulation that are osteogenic in alveolar bone and safe for application through teeth. The osteogenic effect of vibration in the study exhibited a gradient response, demonstrating an anabolic effect on adjacent alveolar bone that is distant from the point of application. This is clinically significant, because this procedure permits an increase in bone formation in fragile areas with vibration application on teeth away from those areas. The expression of proteins that are responsible for initial crystal formation, such as annexin 5 and biglycan, and crystal growth and organization, such as enamelin and DMP1, significantly increased in response to vibration.

Chidchanok Leethanakul et al (2014)[48] conducted a split-mouth design study to propose and evaluate a novel surgical approach with minimal trauma, termed **interseptal bone reduction**, combined with the use of a conventional orthodontic fixed appliance to accelerate canine retraction. 18 female subjects (mean age, 21.9 years) requiring bilateral upper first premolar extraction and who subsequently canine distalization were selected. The extraction socket on the experimental side was deepened, and interseptal bone distal to the maxillary canine was reduced in thickness using a surgical bur; conventional extraction was performed on the control side. The canines were then distalized using elastomeric chains on both the labial and palatal sides, with a net force of 150 g. The extent of canine movement and rotation was determined from study models, and the angulation was analyzed based on lateral cephalograms. They concluded that interseptal bone reduction combined with the use of a conventional orthodontic appliance with optimum force can effectively accelerate maxillary canine retraction when the bone is sufficiently reduced in both thickness and depth following surgical criteria.

Dubravko Pavlin et al (2015)[49] conducted a double blind, prospective, randomized, controlled trial with the objective to assess the effect to fade fined low-level cyclic loading on the rate of orthodontic tooth movement. 45 orthodontic patients were randomized into two groups, vibration (n = 23) and control (n = 22). Cyclic loading was applied to the vibration group for20min/day using the AcceleDents device, which delivered a force of 0.25 N (25g) at a frequency of 30Hz.The control group was assigned to the same protocol, but the device could not be activated to vibrate. The average monthly rate of maxillary canine retraction into an extraction space was analyzed in all 45 subjects. The mean rate of movement was significantly higher for the AcceleDents group with 1.16mm/month compared to 0.79 mm/month in the control group, with the mean differenceof0.37mm/month. These results showed that low-level cyclic loading of 0.25 N at 30Hz increases the rate of tooth movement when applied as an adjunct to orthodontic treatment.

Kyung-A Kim et al (2015)[50]conducted a study to investigate the effect of low-level laser therapy (LLLT) on the rate of orthodontic tooth movement (OTM) into bone-grafted alveolar defects based on different healing states.. The maxillary second premolars were protracted into the defects for 6 weeks. The defects were irradiated with a diode laser (dose, 4.5 J/cm2) every other day for 2 weeks. The rates of OTM and alveolar bone apposition, and maturational states of the defects were analyzed by histomorphometry, microcomputed tomography, and histology. The results showed that the total amounts of OTM and new bone apposition rates were decreased by LLLT, with increased bone mineral density and trabecular maturation in the defects. Group GL-2 had the slowest movement with root resorption in relation to less woven bone in the hypermatured defect. They concluded that LLLT significantly decreased the rate of OTM into the bone-grafted surgical defects by accelerating defect healing and maturation, particularly when the start of postoperative OTM was delayed.

M R Dinesh et al (2015)[6] described periodontally accelerated osteogenic orthodontics as a technique which combines periodontal therapy with orthodontic therapy, resulting in reduced treatment time. PAOO created greater alveolar volume, which eliminated bony dehiscence and fenestrations under most circumstances. Likewise, this addition of alveolar bone width may be the cause for enhanced long-term orthodontic stability. The recent popularity of PAOO among patients and doctors is due to reported faster tooth movement at 3-4 times greater rate than conventional orthodontics, decreased treatment time and increased range of treatment capabilities.

Sarah Alan sari et al (2015)[51] discussed different approaches to accelerate the rate of tooth. These approaches included local or systemic induction of different chemical factors like the application of parathyroid hormone (PTH), vitamin D3, corticosteroids, thyroxin, and osteocalcin or application of physical(mechanical) stimuli like heat, light, electric currents and laser that can increase the number of osteoclasts independent of orthodontic forces They concluded that in both approaches, there is a general consensus that the rate of tooth movement is controlled by the rate of bone resorption, which in turn is controlled by osteoclast activity. Therefore, to increase the rate of tooth movement, osteoclasts should be the target of treatment.

Donald J. Ferguson et al(2015)[52] have reported various benefits of PAOO therapy. They stated that PAOO therapy increase limits of tooth movement created by augmentation bone grafting, enhanced stability of orthodontic treatment outcomes and facilitates rapid orthodontics. They also elaborated the scope of PAOO for severe malocclusion averaging 6–8 months of active treatment time like extrusion for open bite , intrusion for deep bite, protraction for crowding, expansion for posterior crossbites ,de-crowding in the mandible. They concluded that PAOO treatment expands the scope of conventional orthodontic treatment in the adult 2-fold to 3-fold in most spatial dimensions.

Braydon M. Patterson et al (2017)[53] conducted a study to study was to investigate the effect of piezocision on orthodontically induced inflammatory root resorption. Fourteen patients were included in this split-mouth study; 1 side was assigned to piezocision, and the other side served as the control. Vertical corticotomy cuts of 4 to 5 mm in length were performed on either side of each piezocision premolar, and 150-g buccal tipping forces were applied to the premolars. After 4 weeks, the maxillary first premolars were extracted and scanned with micro-computed tomography. The results showed that there was a significantly greater total amount of root resorption seen on the piezocision sides when compared with the control sides. The piezocision procedure resulted in a 44% average increase in root resorption. In 5 patients, there was noticeable piezocision-related iatrogenic root damage. When that was combined with the orthodontic root resorption found on the piezocision-treated teeth, there was a statistically significant 110% average increase in volumetric root loss when compared with the control side. They concluded that the piezocision procedure that initiates the regional acceleratory phenomenon may increase the iatrogenic root resorption when used in conjunction with orthodontic forces. Piezocision applied close to the roots may cause iatrogenic damage to the neighbouring roots and should be used carefully.

Geokmen Kurt et al (2017)[54] did a study this study to test the null hypothesis that duration of orthodontic treatment can be significantly reduced by accelerating canine retraction using dentoalveolar distraction (DAD). Thirty- six maxillary canines of 19 patients comprised the DAD group, and 28 canines of 14 patients were included in the distalization group (DG). The initial mean ages were 15.8 6 1.96 years for the DAD group and 16.02 6 2.8 years for the DG. A custom-made, rigid, tooth-borne intraoral distraction device was used for the DAD group, and intraoral elastics were applied for canine distalization in the DG. Six skeletal and 11 dental variables were measured for the cephalometric evaluation. The rates of posterior canine movement were 0.67 mm per day after DAD and 0.03 mm per day in the DG. No significant first molar anchorage loss was observed after DAD, although the DG showed some vertical and sagittal first molar movement. They concluded that they failed to reject the null hypothesis. DAD can reduce the duration of orthodontic treatment time by accelerating canine retraction in extraction patients without undesirable side effects.

MICRO-OSTEOPERFORATIONS :

With an increase in age, tissues are less biologically active, and the ability to adapt diminishes. As a result, tooth movement may not only be more uncomfortable for adults but also move at a slower rate

New research has shown that biological principles can be activated to accelerate bone remodelling and therefore tooth movement with minimally invasive procedure. The challenge to clinicians is how to take advantage of this activated bone-remodelling process for the purpose of orthodontic treatment.

A new micro-invasive technique called micro-osteoperforation, is a new perspective to accelerated orthodontics. When clinicians create micro-osteoperforations in the alveolar bone, cytokine cascade is activated, resulting in a marked increase in osteoclast activity and bone remodelling. When an orthodontic force is applied immediately following micro osteoperforation, the teeth will move toward the tension side and pass easily through the remodelled area. There is hardly any discomfort to the patient post-operatively, and there is zero recovery time with no post-operative restrictions. The procedure is indicated for approximately 80% of patients receiving orthodontic treatment and can be used in conjunction with any treatment modality.[9]

Shailesh Shenava et al (2014)[43] did a systematic review to assess the latest methods to accelerate orthodontic tooth movement and concluded that the current methods such as piezocision, micro-osteoperforations, lasers and vibration have reduced or eliminated the invasive nature of previous procedures used to achieve the Regional Acceleratory Phenomenon. Also, they come with additional advantages such as reduced rates of relapse, reduced orthodontic pain and reduced root resorption.

C.C. Teixeira et al (2010)[55] conducted a study on rats to confirm whether stimulating the expression of inflammatory cytokines, through small perforations of cortical bone, increases the rate of bone remodeling and tooth movement. the sample consisted of forty-eight rats that were divided into 4 groups: 50-cN force applied to the maxillary first molar (O), force application plus soft tissue flap (OF), force application plus flap plus 3 small perforations of the cortical plate (OFP), and a control group (C).

Expression of 92 different cytokines/cytokine receptors was studied by RT-PCR, 24 hrs after force application. The expression of 37 cytokines/cytokine receptors increased more than two-fold in the left maxilla of rats in the O, OF, and OFP groups when compared with that in the C group. Quantitative analysis of osteoclasts in the pressure side (mesial) of alveolar bone adjacent to the mesio-palatal root of the maxillary first molar demonstrated a three-fold increase in numbers of osteoclasts. They concluded that the use of flapless minimal cortical perforations as a means of increasing inflammation levels for enhanced tooth movement , enables orthodontists to provide more efficient treatment for their patients.

Mani Alikhani et al (2013)[56] conducted a study to evaluate the effect of micro-osteoperforations on the rate of tooth movement and the expression of inflammatory markers. Twenty adults with Class II Division 1 malocclusion were divided into control and experimental groups. The control group did not receive micro-osteoperforations, and the experimental group received micro-osteoperforations on 1 side of the maxilla. Both maxillary canines were retracted, and movement was measured after 28 days. The activity of inflammatory markers was measured in gingival crevicular fluid using an antibody-based protein assay. Pain and discomfort were monitored with a numeric rating scale. The results showed that micro-osteoperforations significantly increased the rate of tooth movement by 2.3-fold; this was accompanied by a significant increase in the levels of inflammatory markers. Also the patients did not report significant pain or discomfort during or after the procedure, or any other complications. They concluded that micro-osteoperforation significantly increased the expression of cytokines and chemokines known to recruit osteoclast precursors and stimulate osteoclasts differentiation and hence is an effective, comfortable, and safe procedure to accelerate tooth movement and significantly reduce the duration of orthodontic treatment.

Chi-Yang Tsai et al (2016)[57] investigated the effects of flapless micro-osteoperforation and corticision on the rate of orthodontic tooth movement in rats. The study was performed on forty-five 8-week-old male Sprague-Dawley rats divided into the following 3 groups : micro-osteoperforation and orthodontic force (MOP + F), corticision and orthodontic force (C + F), and orthodontic force only (F, control). Flapless surgical interventions were conducted in the MOP + F and C + F groups and the left maxillary first molars were pulled forward with a force of 50 g in all three groups. The total duration of the experiment was 6 weeks. Alveolar bone density and the number of osteoclasts were evaluated using micro-computed tomography and histologic examination, respectively. There was a significant increase in the tooth movement distance in both experimental groups than in the control group. Bone density and bone mineral density decreased in the MOP + F and C + F groups. They concluded that the two minimally invasive flapless surgical interventions increased bone remodeling and osteoclast activity and induced faster orthodontic tooth movement for at least 2 weeks in rats and that that there was no difference between the outcome of flapless micro-osteoperforation and corticision in the rats.

Tracy Cheung,**et al(2016)**[58] performed a study to evaluated the effectiveness of mini-implant–facilitated MOPs in inducing accelerated tooth movement and investigated the potential risks for root resorption. Five MOPs were placed on the left side around the maxillary first molars in 6 rats using an automated mini-implant driver, whereas the right side received no MOPs as the control. Closed-coiled springs were secured from incisors to first molars for orthodontic tooth movement. Tooth movement was measured, and samples underwent radiologic and histologic analyses. They concluded that Mini-implant–facilitated MOPs accelerated tooth movement without increased risk for root resorption and therefore may become a readily available and efficient treatment option to shorten orthodontic treatment time with improved patient acceptance.

Materials and Method

SUBJECT SOURCE:

For this study, a total of 20 patients were selected from the out-patient department of Department of Orthodontics and Dentofacial Orthopedics who had undergone extraction of first premolars for orthodontic treatment.

INCLUSION CRITERIA:

- Subjects in the age group of 18-25 years.
- Full set of teeth including second molar
- No previous history of orthodontic treatment.
- Pre treatment patients indicated for premolar extractions for the correction of malocclusion.
- Patient willing to undergo the procedure with a written consent taken prior to the treatment.

- No systemic disorders.
- No history of use of any anti inflammatory drugs.
- Patients with healthy periodontal conditions

EXCLUSION CRITERIA:

- Patients on anti- inflammatory drugs.
- Patients with habit of smoking.
- Subjects with any severe craniofacial disorder such as cleft palate.
- Asymmetrical extractions

Maxillary arch of patients were divided into two group by a split mouth technique selected randomly into

- Group I –included site where micro osteoperforations were performed under topical local anaesthesia ,after through oral prophylaxis distal to canine before retraction
- Group II –included contralateral site of the patient in which corticotomy procedure was performed under local anaesthesia after proper oral prophylaxis and flap reflection.

DATA COLLECTION:

<u>ARMAMENTARIUM USED FOR CORTICOTOMY PROCEDURE :</u> (Fig:1)

1. 23 gauge, 1 1/2” disposable needle, 5 ml syringe
2. Local Anaesthetic solution (1:200000 adrenaline)
3. BP handle and surgical blade No.15 & No.12.
4. Periosteal elevator

5. No.1 or No.2 round Tungsten Carbide Bur.
6. Micromotor contrangled handpiece - NSKTM
7. Decalcified Freeze Dried Bone Allograft. (Fig2)
8. Suture material (non-resorbable 4-0 silk) (Fig3)

ARMAMENTARIUM USED FOR MICRO OSTEOPERFORATION PROCEDURE : (Fig 4)

1. Local anesthetic spray (1:200000 adrenaline)
2. Periodontal probe
3. Guiding stent made of 0.016 x 0.022 Straight Stainless steel wire (Fig 5)
4. Orthodontic mini implants (Dentos)
5. Implant driver (Dentos)

OTHER MATERIALS USED FOR ORTHODONTIC TREATMENT : (Fig 6)

1. Fixed Orthodontic Appliance: 0.022” Pre-adjusted Edgewise Appliance bracket system
2. 0.010” Stainless Steel Ligature wire
3. Nickel – titanium wire
4. Stainless steel wire – GNH
5. Composite kit – ORTHOFIX
6. Nickel-Titanium closed coil springs (10mm)
7. Dontrix gauge (Fig 8)

8. Alginate Impression material (Marieflex ;SEPTODONT HEALTHCARE) (Fig 10)
9. Dental Plaster {Orthokal (Orthodontic Stone Class III) (Fig 10)

ANALYSIS OF OPG:

1. Pre-retraction (T1) and after 8 weeks observation (T2) OPGs
2. KODAK dental imaging software

All the patients underwent uneventful orthodontic extractions with first premolars followed by orthodontic treatment with following archwire sequence:

Sequence of archwire:

0.014”/0.016” NiTi archwire

- 0.016”/0.018” NiTi archwire

- 0.016” x 0.022” NiTi archwire

- 0.017” x 0.025” NiTi archwire

- 0.017” x 0.025” SS archwire

- 0.019” x 0.025” SS archwire

For both the groups, after aligning upto 0.019” x 0.025” rectangular SS arch wire, photographs, alginate impressions, OPG were recorded and models were constructed.

- These records were collected and saved as **T1** (after completion of leveling and alignment and before starting of retraction).

- Extraction space was measured with the help of a digital vernier caliper to assess the amount of space before start of retraction.
- Space was calculated radiographically with the help of KODAK DIGITAL software.(Fig 7)
- A thorough clinical and radiographic evaluation for the patient was done to evaluate the periodontal status of the patient
- Gingival health was assessed by gingival aesthetic index known as PINK INDEX before performing both surgeries.
- Before opting for the periodontal surgical technique and beginning with the procedures, a complete medical review of the patient was done to rule out any systemic and local factors that may interfere with the surgery.

CORTICOTOMY PROCEDURE:

1. Raising a flap
2. Decortications
3. Particulate grafting
4. Closure of the flap

Corticotomy procedure was performed in the Department of Periodontology after taking a signed consent from the patient.

Site of maxillary arch of the patient on which corticotomy was performed was selected randomly to avoid bias due to uneven occlusal forces because of habitual occlusion predominantly on 1 side.

PROCEDURE FOLLOWED :

- A meticulous phase 1 therapy involving scaling and root planning was done and oral hygiene instructions were given to the patient.
- A full-thickness mucoperiostal flap was reflected beyond the apices of the teeth under local anaesthesia, after an intracrevicular incision that connected the releasing incisions, buccally.
- Special care was taken not to perforate the flaps, and any interdental tissue that remained interproximally.
- Post reflection, the area was thoroughly debrided, and curettage was done to remove any inflamed tissue, if present.
- Using no. 2 round bur in a high-speed hand piece, decortications were made in the alveolar bone.
- Vertical corticotomy cuts stopping just short of the alveolar crest were made between the roots of the teeth. This groove extended from a point 2–3 mm below the crest of the bone to a point 2 mm beyond the apices of the roots. (Fig 12)
- The depth of the decortication cuts barely penetrated into medullary bone and bleeding was promoted .Care was taken not to injure any tooth or encroach on the periodontal ligament
- An allograft was placed, along with antibiotics in areas that have undergone corticotomies. The volume of the graft material used was dictated by the direction and amount of tooth movement, the pre-treatment thickness of the alveolar bone, and the need for labial support by the alveolar bone (Fig 13)

- The graft material used was decalcified freeze-dried bone allograft. A typical volume used was 0.25–0.5 ml of graft material per tooth. The decorticated bone acts to retain the graft material

Wilcko et al.[32] recommended the use of mix of demineralized freeze-dried bone and bovine bone with clindamycin. Care was taken not to place an excessive amount of bone graft, as it might interfere with flap replacement.

- The sutures that approximate the tissues at the midline were placed first to ensure the proper alignment of the papillae. The remaining interproximal sutures were placed next followed by the closure of any vertical incisions. (Fig 14)
- No packing was required. The sutures were left in place for 1 week.

The application of icepacks to the affected areas also was suggested to decrease the severity of any possible postoperative swelling or edema along with chlorhexidine mouthwash and patient was advised to avoid brushing in the surgical area..

MICRO OSTEOPERFORATION PROCEDURE :

- On the third day after corticotomy procedure , micro osteoperforations were performed on the contralateral side .
- Oral prophylaxis was done before starting the surgical procedure .
- To determine exact location of MOPs a stent was prepared in 00.016 x 0.022 S.S wire extending from the molar tube to canine bracket of the side were MOPs were to be performed and a RVG was taken. (Fig 11)

Placement of the stent gave the following advantages:

- To assess the accurate location of implant placement vertically and horizontally
- It served as a guide through which implants could be placed directly into the bone with implant driver
- The implants could be placed directly into the bone with implant driver
- Local anaesthetic spray (1:200000) was used prior to starting MOPs.
- Also a small puncture was made with a probe through the stent at the implant placement site until bone was felt and the depth of soft tissue (gums) was then measured with a periodontal probe.
- Accordingly the length of implant was selected i.e. 6mm,7mm or 8mm long microimplants which created MOP atleast 3-4mm deep and 1.5 mm wide .
- After proper micro implant selection , proper position of stent was assured and the implants were inserted through the stent (Fig 15)
- Inserting all the three impants together assured proper site of implant placement, avoided excessive bleeding in between placements and consumed lesser time. (Fig 16)
- The patient was asked to rinse with chlorhexidine solution and relax for 5min.
- The implants were then carefully removed by turning them in anticlockwise direction followed by stent removal.
- Bleeding spots were seen post implant removal.(Fig 17)
- Bleeding was stopped by applying pressure pack in that area.

- Similar procedure was carried out mesial to the canine between the roots of lateral incisor and canine but the number of MOPs depended on the interdental space available between roots.
- Patient was again asked to rinse with chlorhexidine solution.
- Orthodontic retraction was then started.

ORTHODONTIC TREATMENT PHASE:

- A 0.019 x0.025" stainless steel archwire was used after consolidation of the incisors using 0.010" S.S. ligature.

Anchorage preparation:

- The posterior segments were consolidated bilaterally from second pre-molar to first molar and Nance palatal arch which was cemented at beginning of treatment helped in anchorage conservation.

Distal force component:

- A NiTi closing coil spring was extended bilaterally from the molar hook to the hook of the canine. Distal force of 150 grams was applied by NiTi closing coil spring on each side as measured by Dontrix gauge. (Fig 18)
- The patients were recalled at 15 days intervals for 8 weeks of observation period.
- As the observation period of 8 weeks was completed, alginate impressions, photographs and OPG were recorded and models were made. These records

were labelled as – **T2** (at the end of 8 weeks observation period) and preserved.

- At each appointment, oral hygiene was evaluated and reinforced, and the appliances were assessed for damage. As a quality-control measure, if a bracket, archwire, or coil spring showed any damage, it was corrected or replaced as required.

STUDY MODEL ANALYSIS:

- Alginate impressions were made.(Fig 21)
- T1- Pre-treatment (immediately before surgical procedure) (Fig 19)
- T2- 8 weeks after initiation of retraction (Fig 20)

METHOD OF MEASURING RATE OF TOOTH MOVEMENT:

- Two points were marked on the alveolar ridge distal to canine and mesial to second premolar and distance was measured by Vernier callipers. The difference in measurements between T1-T2 was then calculated to evaluate the rate of tooth movement. Intraobserver error was evaluated by measuring all the models twice. For evaluation of interobserver error, a second investigator measured the same set of models, and the mean values of the 2 measurements were taken.

ANCHORAGE :

- Molar displacement and rotation was also calculated at T1 and T2.

- Linear measurement included the distance from central fossa of 1st molar to center of canine.
- Angular measurements for molar rotation were calculated by measuring angle made by line joining mesio-buccal and disto-lingual cusp of molar and mid palatine raphe.(Fig 22)

OPG ANALYSIS :

- T1- Pre-treatment (immediately before surgical procedure)
- T2- 8 weeks after initiation of retraction
- Two points were marked on the alveolar ridge on the OPG distal to canine and mesial to second premolar and distance was measured by software.
- Magnification error was eliminated by taking central incisor (CI) as reference anatomical landmark and magnification was calculated by the formula :

$$\text{The magnification rate of length} = \frac{\text{The length of CI on digital radiographs}}{\text{The actual length of CI}} \times 100$$

$$\text{The magnification rate of width} = \frac{\text{The width of CI on digital radiographs}}{\text{The actual width of CI}} \times 100$$

Gingival esthetics were assessed on both sides by Pink esthetic index as shown below:

PES			
Parameter	Absent	Incomplete	Complete
(i) Mesial papilla	0	1	2
(ii) Distal papilla	0	1	2
	Major discrepancy	Minor discrepancy	No discrepancy
(iii) Curvature of facial mucosa	0	1	2
(iv)Level of facial mucosa	0	1	2
(v) Root convexity/soft tissue color and texture	0	1	2
Maximum total PES score			10

:

TABLE 1 : Pink esthetic index .

PLATE I

FIGURE 1: ARMAMENTARIUM USED FOR CORTICOTOMY PROCEDURE

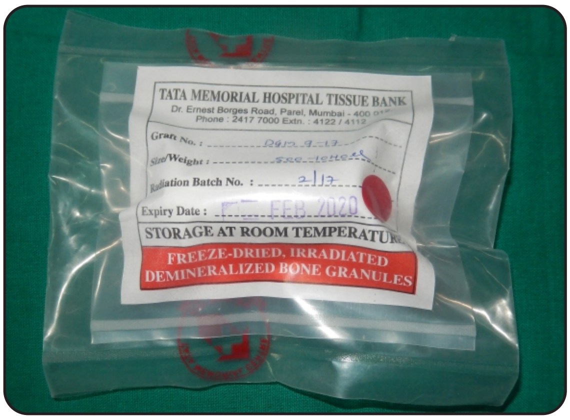


FIGURE 2 : DEMINERALISED FREEZE DRIED BONE GRAFT

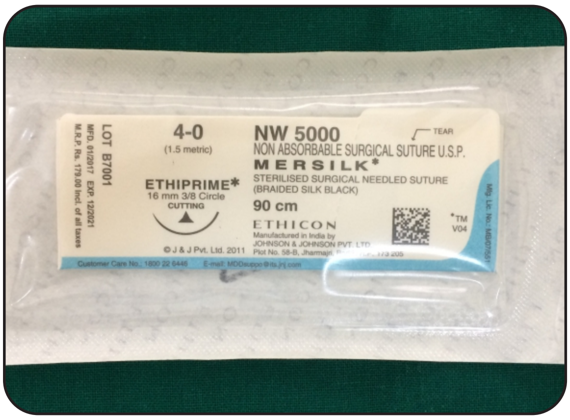


FIGURE 3 : NON ABSORBABLE SURGICAL SUTURE (4-0) MERSILK ,ETHICON

PLATE II

FIGURE 4 : ARMAMENTARIUM USED FOR MICRO-OSTEOPERFORATION PROCEDURE

FIGURE 5 : MODEL WITH STENT

FIGURE 6 : ARMAMENTARIUM USED FOR ORTHODONTIC TREATMENT

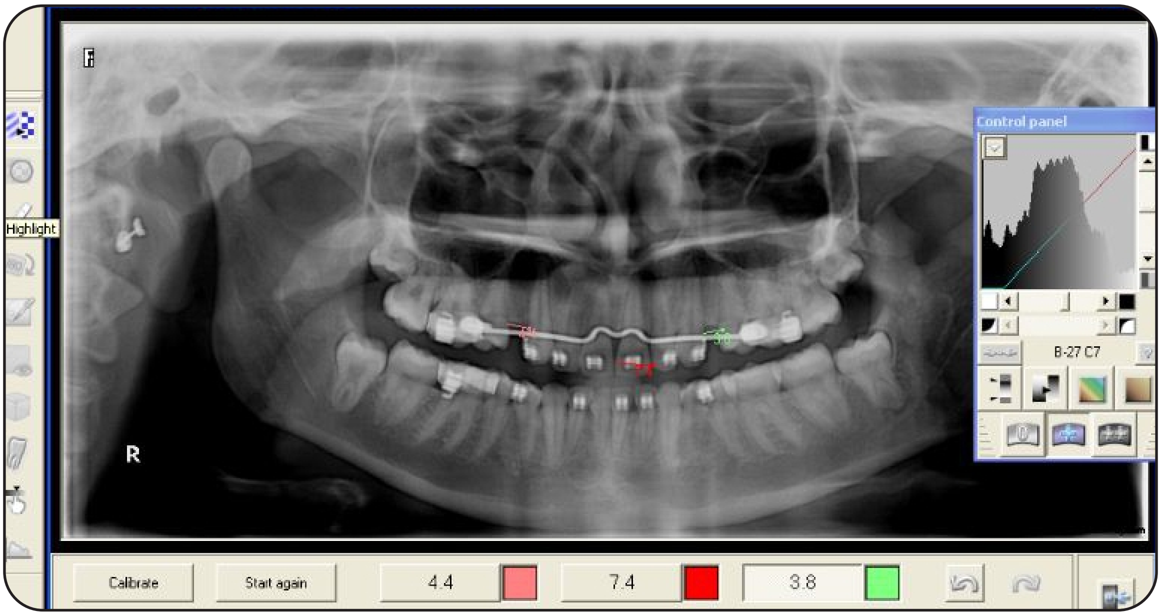


FIGURE 7 : DISTANCE MEASURED ON OPG BY KODAK DIGITAL SOFTWARE

PLATE III

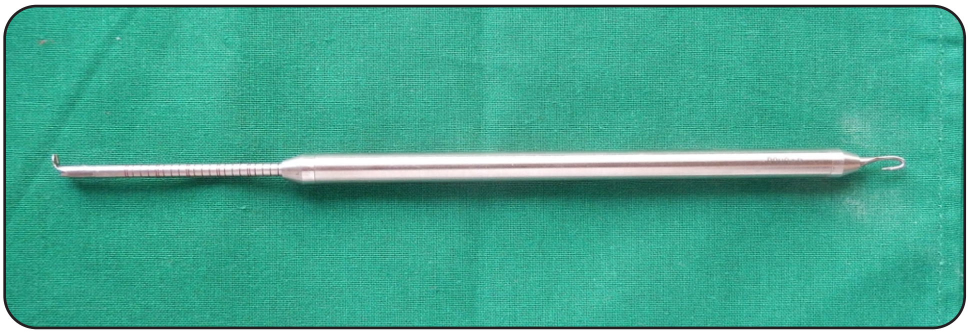


FIGURE 8 : DONTRIX GAUGE

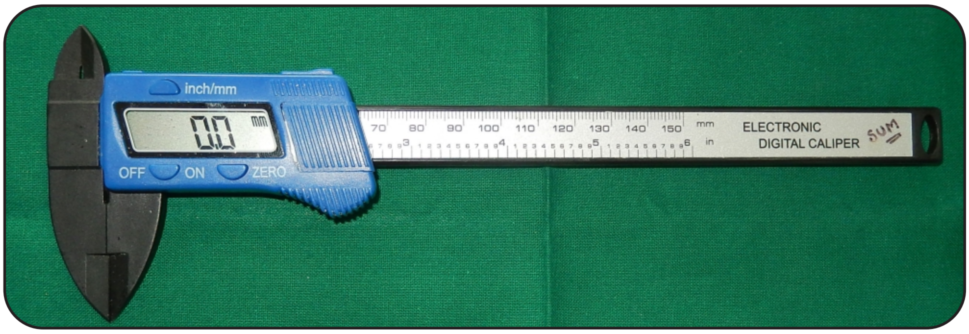


FIGURE 9 : VERNIER CALLIPER

FIGURE 10 : ALGINATE IMPRESSION MATERIAL AND ORTHOKAL

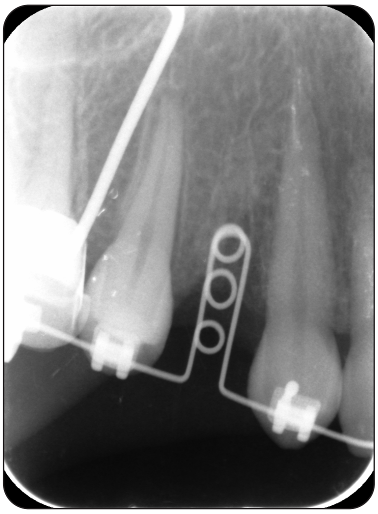


FIGURE 11 : RVG WITH STENT

PLATE IV

FIGURE 12 : VERTICAL CORTICOTOMY CUTS MADE INTERDENTALLY BEYOND APICES

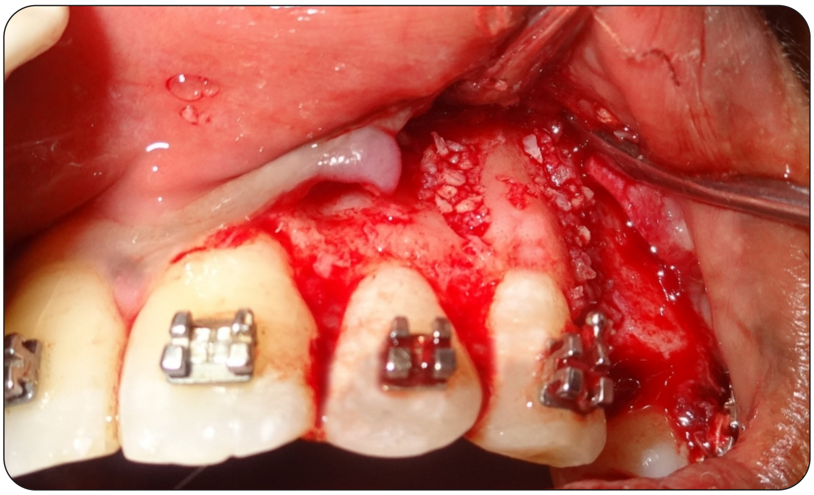


FIGURE 13 : PARTICULATE GRAFTING OF THE DECORTICATED AREAS

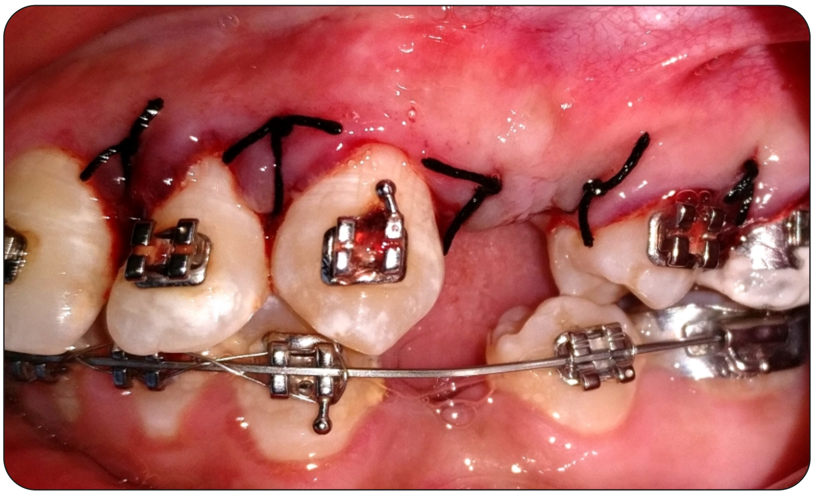


FIGURE 14 : FLAP SUTURED WITH THE PAPILLA USING 4-0 SUTURE MATERIAL

PLATE V

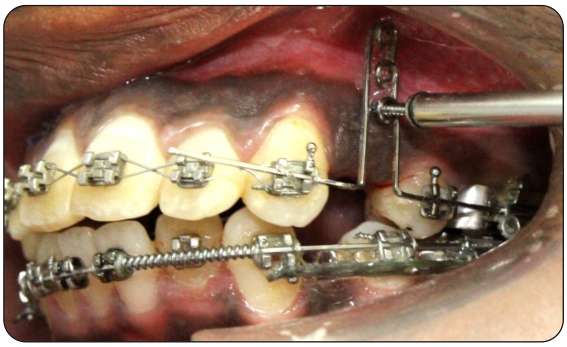


FIGURE 15 :
MICRO-OSTEOPERFORATIONS
MADE INTERDENTALLY DISTAL
TO TOOTH TO BE RETRACTED

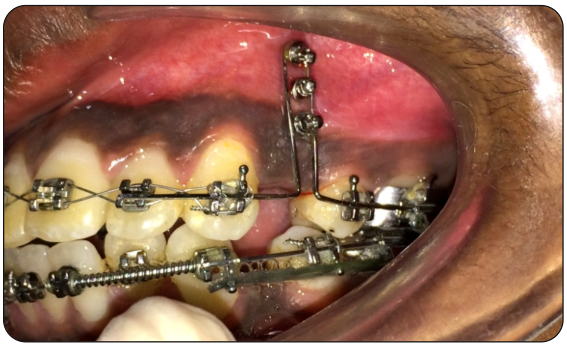


FIGURE 16 :
MICRO-IMPLANTS
PLACED THROUGH THE STENT

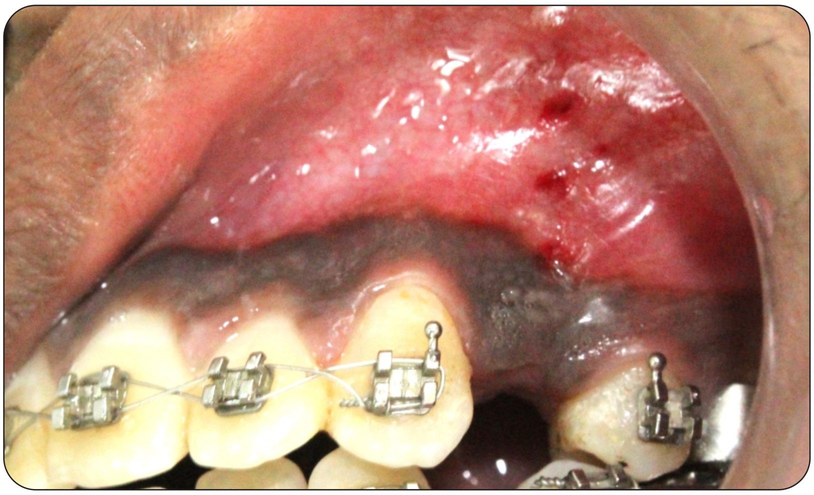


FIGURE 17 : BLEEDING SPOTS POST IMPLANTS REMOVAL

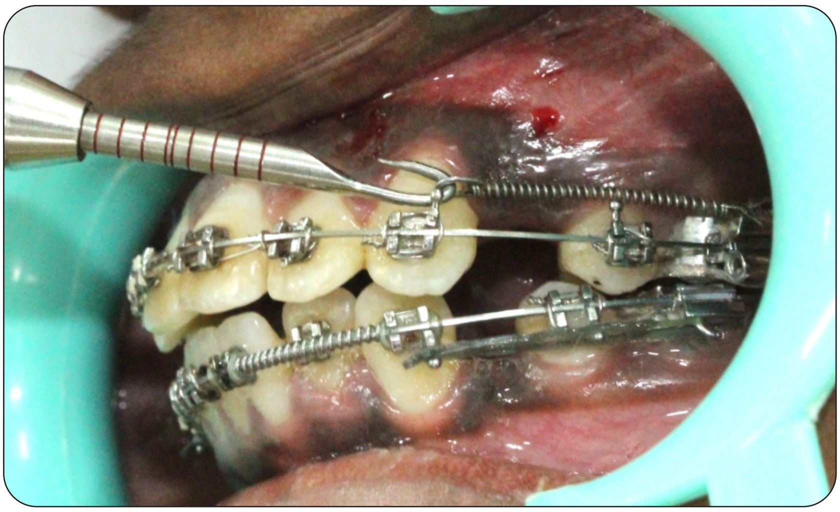


FIGURE 18 : RETRACTION FORCE OF NiTi COIL SPRING
MEASURED BY DONTRIX GAUGE

PLATE VI

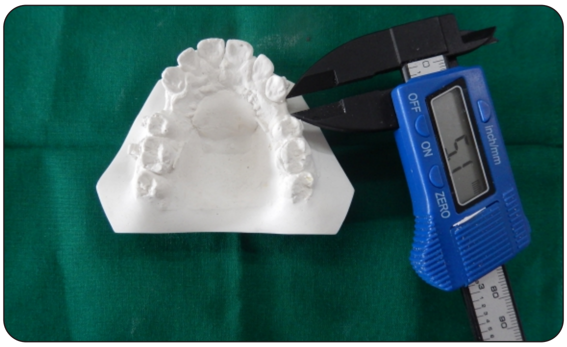


FIGURE 19 : DISTANCE MEASURED ON STUDY MODEL BY VERNIER CALLIPER AT TIME T1

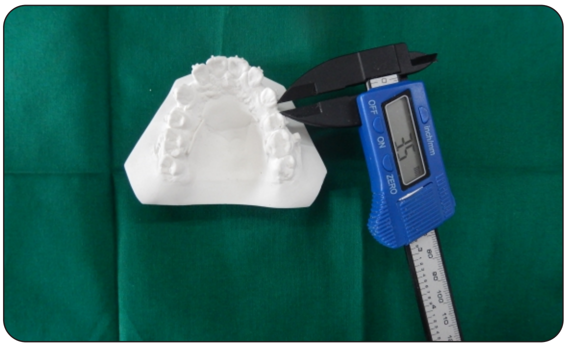


FIGURE 20 : DISTANCE MEASURED ON STUDY MODEL BY VERNIER CALLIPER AT TIME T2

FIGURE 21 : STUDY MODELS AT TIME T1 & T2

FIGURE 22 : MOLAR ANGULATION ASSESSED ON STUDY MODEL

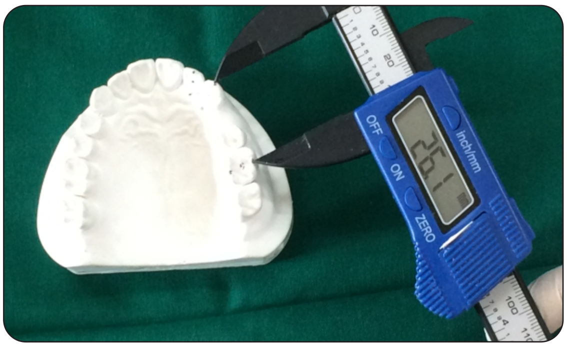


FIGURE 23 : DISTANCE BETWEEN CANINE & MOLAR MEASURED ON STUDY MODEL BY VERNIER CALLIPER

Statistical Analysis

The data on distance measurement in two groups i.e. Corticotomy side and Microosteoperforations were obtained initially from study models and OPG. Summary statistics like mean and standard deviations (SD) were obtained for distance in two groups. The comparison of means was performed using t-test for independent samples from study models and OPG independently. On similar lines, summary statistics for distance were obtained at time T2 and the means were compared using t-test for independent samples. The displacement and the rate of displacement were also summarized and compared using the same test for study models and OPG independently. Pink scores between two groups were expressed in terms of mean, SD and median and compared using .Wilcoxon rank sum test. The change in distance and angle were also compared between two groups from study models using t-test for independent samples. All the analyses were performed using SPSS ver 20.0 (IBM Corp) and statistical significance was tested at 5% level.

Results

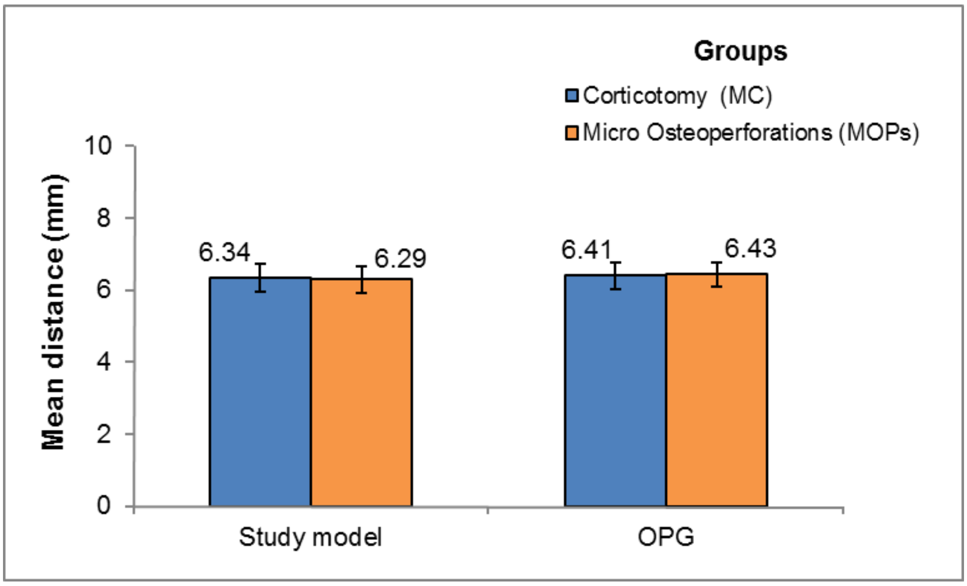
Table 2: Comparison of mean distance in two groups at initial time (T1)

	Group [Mean ± SD]		P-value*
	MC n=20	MOPs n=20	
Study model	6.34 ± 0.90	6.29 ± 0.83	0.8556 (NS)
OPG	6.41 ± 0.82	6.43 ± 0.78	0.9374 (NS)

Calculated using t-test for independent samples, NS: Not Significant, SD: Standard deviation

Table 2 provides the descriptive statistics for distance measured on the study model and OPG in two groups at initial time point T1. The mean distance measured for corticotomy side(MC) was 6.34 ± 0.90 mm using study model and 6.41 ± 0.82 mm using OPG. For Microosteoperforations group(MOPs), the mean distance measured was 6.29 ± 0.83 mm on the study model and 6.43 ± 0.78 mm on the OPG.

The difference in the mean distances between groups was statistically insignificant with p-value of 0.8556, when measured on the study model and p-value of 0.9374 when measured on the OPG; as obtained using t-test for independent samples.



Graph 1: Column chart with error bars showing the mean distance measurement in two groups by study model and OPG at initial time (T1)

Table 3: Descriptive statistics for distance measurement in two groups

	T1		**T2**		**T1-T2**	
	MC	**MOP**	**MC**	**MOP**	**MC**	**MOP**
	n=20	**n=20**	**n=20**	**n=20**	**n=20**	**n=20**
Study model	6.34 ± 0.90	6.29 ± 0.83	3.64 ± 0.81	3.91 ± 0.79	2.70 ± 0.29	2.38 ± 0.26
OPG	6.41 ± 0.82	6.43 ± 0.78	3.59 ± 0.53	3.87 ± 0.83	2.64 ± 0.31	2.41 ± 0.30

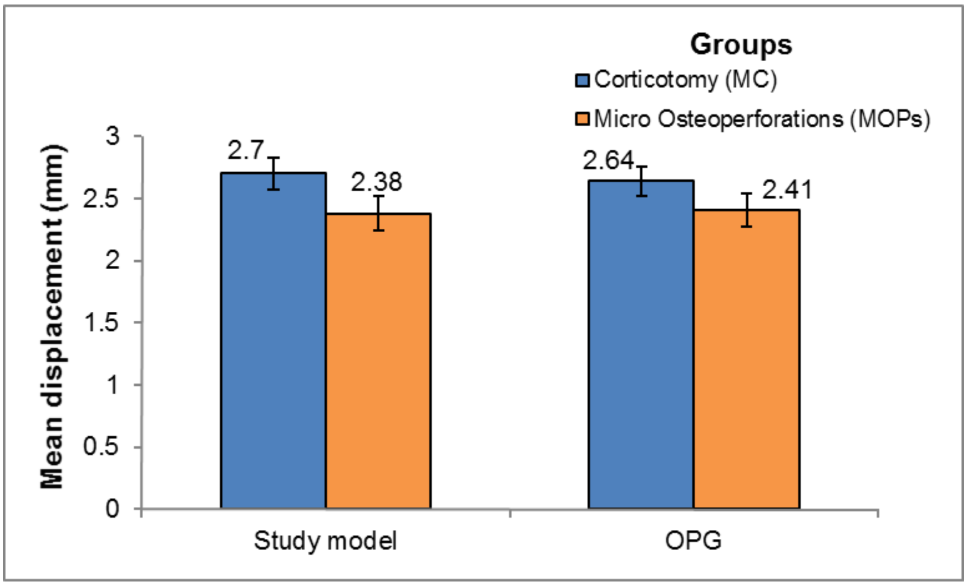
Table 3 provides the descriptive statistics for distance measured on study model and OPG in two groups at time points T1 and T2. Also it shows the displacement of tooth between two time points (T1-T2) in two groups. At T2, the mean distance measured for corticotomy side(MC) was 3.64 ± 0.81 mm on study model and 3.59 ± 0.53 mm on OPG. For Microosteoperforations group (MOPs), the mean distance measured on study model was 3.91 ± 0.79 mm and 3.87 ± 0.83 mm on OPG. The mean displacement of tooth for corticotomy side on study model was 2.70 ± 0.29 mm, while for Microosteoperforations was 2.38 ± 0.26 mm. On OPG, the mean displacement for corticotomy side was 2.64 ± 0.31 mm, while for Microosteoperforations was 2.41 ± 0.30 mm.

Table 4: Comparison of mean displacement of tooth between two groups for study model and OPG

	Groups [Mean ± SD]		P-value*
	MC n=20	MOPs n=20	
Study model	2.70 ± 0.29	2.38 ± 0.26	0.001 (S)
OPG	2.81 ± 0.35	2.41 ± 0.30	0.0004 (S)

Calculated using t-test for independent samples, S: Significant; SD: Standard deviation

Table 4 provides the descriptive statistics for displacement obtained on study model and OPG in two groups. The mean displacement measured for corticotomy side (MC) was 2.70 ± 0.29 mm on study model and 2.81 ± 0.35 mm on OPG. For microosteoperforations group (MOPs), the mean displacement measured was 2.38 ± 0.26 mm on study model and 2.41 ± 0.30 mm on OPG. The mean displacement in corticotomy side(MC) was significantly higher than that of microosteoperforations group(MOPs) when measured on study model as indicated by p-value of 0.001. Further, the difference in means was statistically significant with p-value of 0.0004, when measured using OPG. These were obtained using t-test for independent samples.

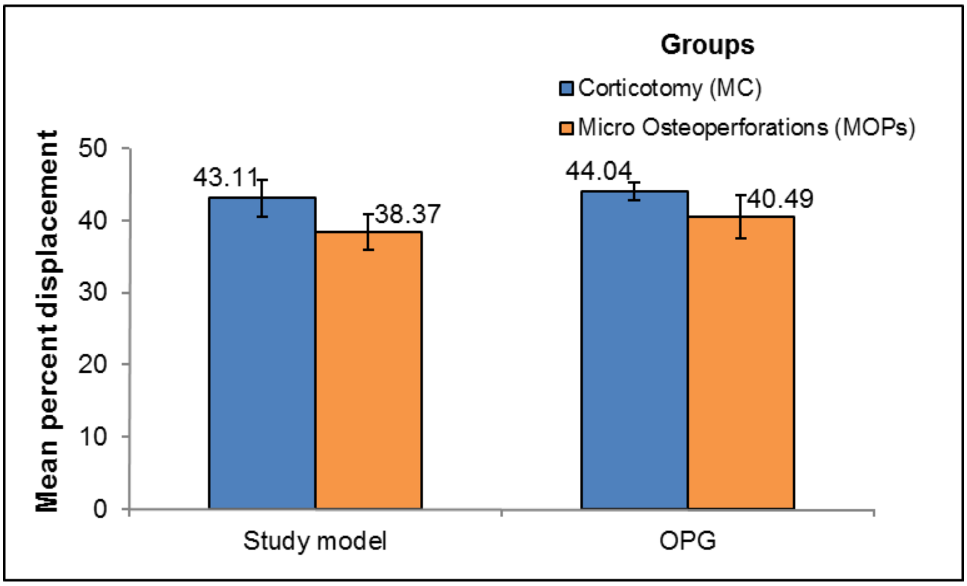


Graph 2: Column chart with error bars showing the mean displacement measured in two groups by study model and OPG.

Table 5: Comparison of mean percent displacement of tooth between two groups for study model and OPG

	Groups [Mean ± SD]		P-value*
	MC n=20	MOPs n=20	
Study model	43.11 ± 5.64	38.37 ± 5.47	0.0103 (S)
OPG	44.04 ± 2.74	40.49 ± 6.76	0.0399 (S)

Table 5 provides the comparison of mean percent displacement of tooth between two groups for study model and OPG. On the study model, the mean percent displacement was 43.11 ± 5.64 for MC group, while for MOPs group, it was 38.27 ± 5.47. The difference in the mean percent displacement was statistically significant as indicated by p-value of 0.0103. On similar lines, on OPG, the mean percent displacement for MC group was 44.04 ± 2.74, while that for MOPs group was 40.49 ± 6.76. This difference was also found statistically significant as revealed by p-value of 0.0399.



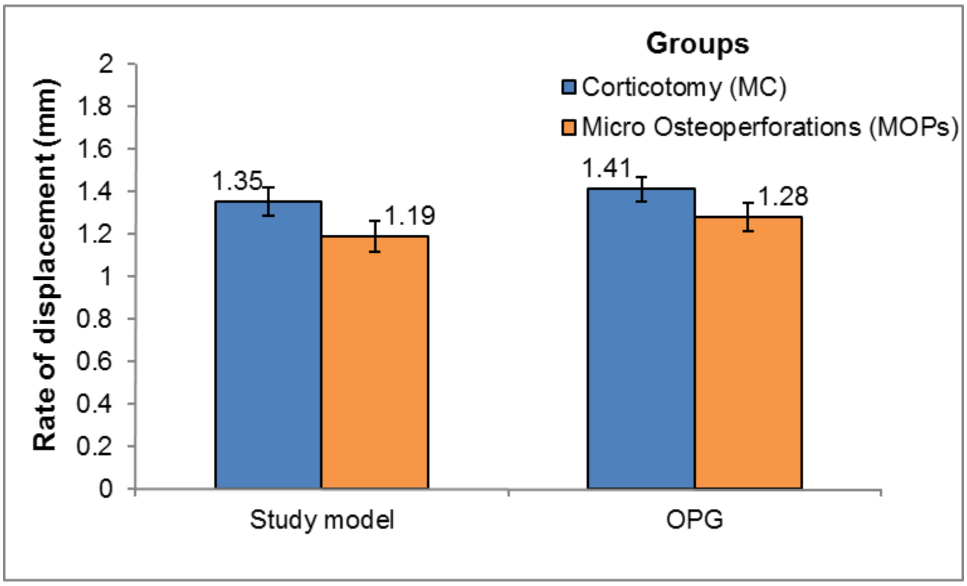
Graph 3: Column chart with error bars showing the mean percent displacement in two groups by study model and OPG.

Table 6: Comparison of rate of displacement of tooth between two groups for study model and OPG

	Groups [Mean ± SD]		P-value*
	MC n=20	MOPs n=20	
Study model	1.35 ± 0.15	1.19 ± 0.13	0.001 (S)
OPG	1.41 ± 0.17	1.28 ± 0.15	0.0014 (S)

*****Calculated using t-test for independent samples, NS: Not Significant, S: Significant; SD: Standard deviation*

Table 6 provides the descriptive statistics for rate of displacement per month as obtained on study model and OPG in two groups. The mean rate of displacement measured for corticotomy side (MC) was 1.35 ± 0.15 mm on study model and 1.41 ± 0.17 mm on OPG. For microosteoperforations (MOPs) group, the mean rate of displacement measured was 1.19 ± 0.13 mm on study model and 1.28 ± 0.15 mm on OPG. The mean rate of displacement in corticotomy side(MC) was significantly higher than that of microosteoperforations group(MOPs) when measured on study model, as indicated by p-value of 0.001. Further, the difference in the means was statistically significant with p-value of 0.0014 when measured on OPG. These were obtained using t-test for independent samples.



Graph 4: Column chart with error bars showing the mean rate of displacement measured in two groups on study model and OPG

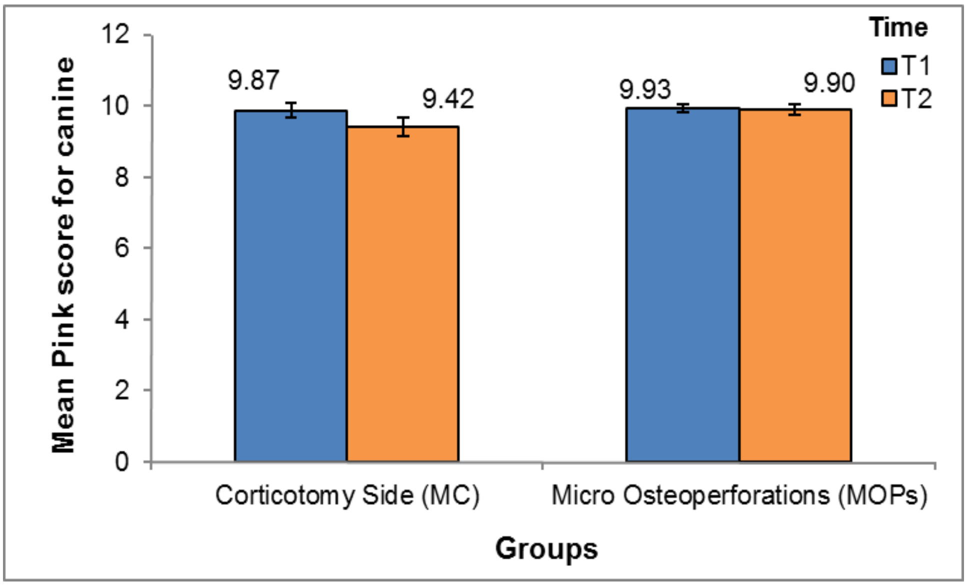
Table 7: Comparison of Pink scores between two groups for canine and lateral incisor

Tooth	Groups	Time		P-value*
		T1	**T2**	
Canine	Corticotomy (MC)	9.87 ± 0.22	9.42 ± 0.57	0.0019 (S)
	Micro Osteoperforations (MOPs)	9.93 ± 0.24	9.90 ± 0.31	0.9999 (NS)
	P-value**	0.5027 (NS)	0.0044 (S)	
Lateral Incisor	Corticotomy (MC)	9.82 ± 0.37	9.35 ± 0.59	0.0021 (S)
	Micro Osteoperforations (MOPs)	9.98 ± 0.11	9.90 ± 0.31	0.3711 (NS)
	P-value**	0.098 (NS)	0.0011 (S)	

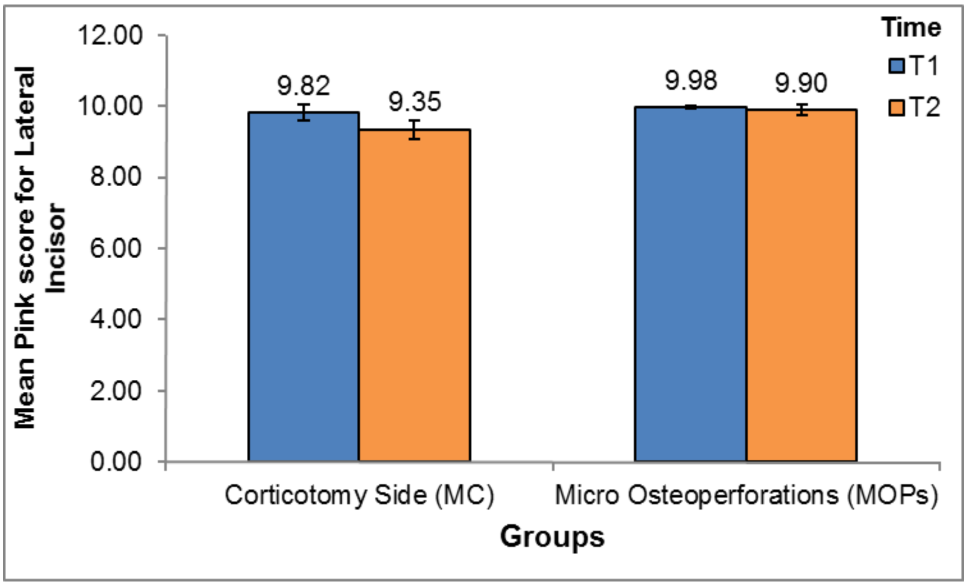
**Calculated using Wilcoxon signed rank test; **Calculated using Wilcoxon rank sum test, S: Significant, NS: Not Significant*

Table 7 provides the descriptive statistics for pink score at different time points in corticotomy (MC) and microosteoperforations (MOPs) group for canine and lateral incisor. In MC group, the difference of pink score, for canine, between two time points was statistically significant with a p-value of 0.0019. However, in MOPs group, the difference was insignificant as indicated by a p-value of 0.9999. The difference between two groups at each time T1 was statistically insignificant for canine as indicated by p-value of 0.5027, while at T2, the difference was significant with p-value of 0.0044.

For lateral incisor, in MC group, the difference of pink score between two time points was significant with a p-value of 0.0021. However, in MOPs group, the difference was insignificant as indicated by a p-value of 0.3711. The difference between two groups at each time T1 was statistically insignificant for lateral incisor as indicated by p-value of 0.098, while at T2, the difference was significant with p-value of 0.0011.



Graph 5: Column chart with error bars showing the mean Pink score in two groups for Canine



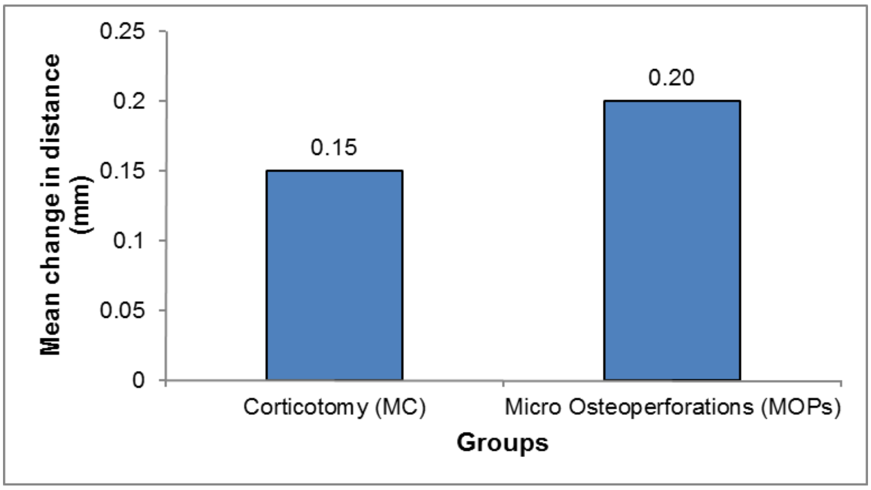
Graph 6: Column chart with error bars showing the mean Pink score in two groups for Lateral Incisor

Table 8: Comparison of change in distance and change in angle of tooth for two groups

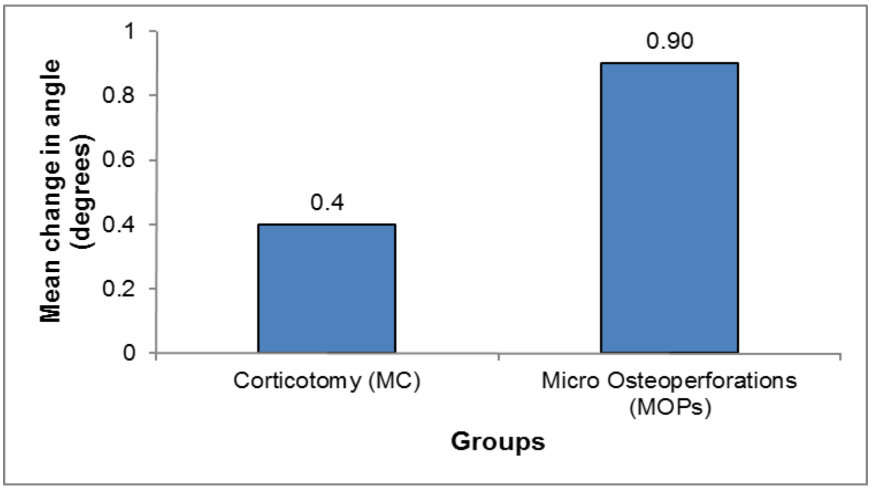
Parameters	**Groups [Mean ± SD]**		**P-value***
	MC n=20	**MOPs n=20**	
Distance (mm)	0.15 ± 0.61	0.20 ± 0.73	0.8158 (NS)
Angle (degrees)	0.40 ± 0.50	0.90 ± 0.85	0.0311 (S)

***Calculated using t-test for independent samples, NS: Not Significant; S: Significant; SD: Standard deviation*

Table 8 gives the comparison of two parameters i.e. change in distance and change in angle between two groups. The mean change in distance for MC group was 0.15 ± 0.61 mm, while that for MOPs was 0.20 ± 0.73 mm. The difference between the two was statistically insignificant with p-value of 0.8158. The mean change in the angle was 0.40 ± 0.5^{o} for MC group, while it was 0.90 ± 0.85^{o} for MOPs group. The difference between the two was statistically significant with p-value of 0.0311.



Graph 7: Column chart showing mean change in distance of 1st molar in two groups



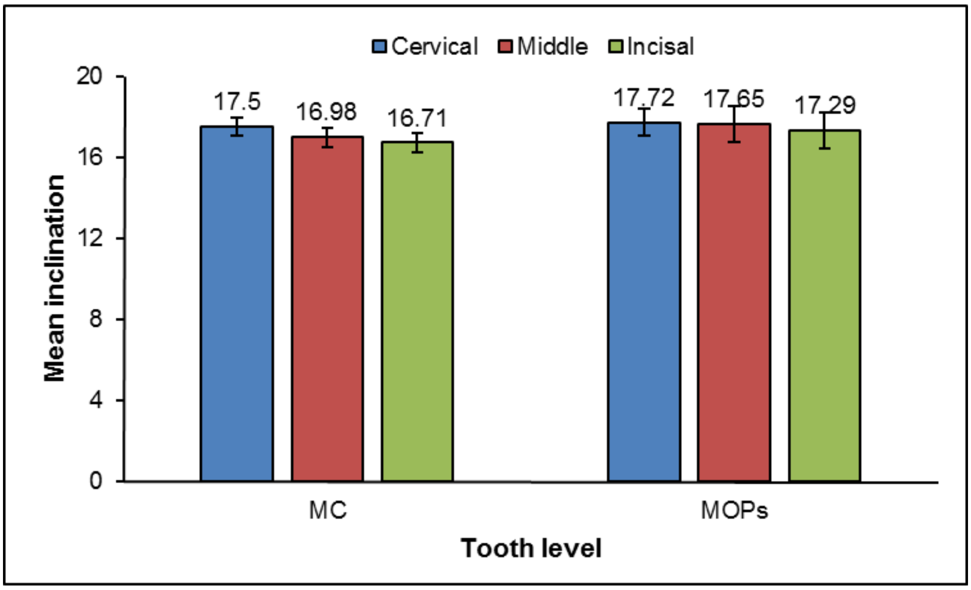
Graph 8 : Column chart showing mean change in angle of 1st molar i two groups

Table 9: Comparison of canine inclination between two groups

Tooth level	Groups [Mean ± SD]	
	MC (n=20)	**MOPs (n=20)**
Cervical	17.50 ± 0.99	17.72 ± 1.44
Middle	16.98 ± 1.08	17.65 ± 1.98
Incisal	16.71 ± 1.07	17.29 ± 1.96
P-value*	0.0604 (NS)	0.728 (NS)

Calculated using one-way ANOVA, NS: Not Significant; SD: Standard deviation

Table 9 provides the comparison of canine inclination in MC and MOPs group independently. In the MC group, mean canine inclination for cervical was 17.50 ± 0.99, for middle was 16.98 ± 1.08 and for incisal edge the inclination was 16.71 ± 1.07. The difference of means in the Corticotomy side for cervical, middle and incisal edge was statistically insignificant as indicated by a p-value of 0.0604. This was obtained using one-way ANOVA. For the MOPs group, mean canine inclination for cervical, middle and incisal edge were 17.72 ± 1.44, 17.65 ± 1.98 and 17.29 ± 1.96 respectively. The difference of means for the group was statistically insignificant with a p-value of 0.728 as obtained using one-way ANOVA.



Graph 9 : Column chart showing mean inclination according to tooth level in two groups

Discussion

The number of patients seeking orthodontic treatment has increased in the past decades esp. the adult age group who often desire that their treatment should be completed in shorter period of time. But in the elderly, the tissue response to orthodontic forces including both cell mobilization and conversion of collagen fibers is much slower than in children and teenagers.[59]

During orthodontic treatment of cases with premolar extraction canine retraction takes 6 to 8 months and thus, conventional treatment with fixed appliances is likely to last 20 to 24 months So, it is a challenge for every orthodontist to reduce the duration of treatment without compromising on the final outcome.[56]

In the past decade many attempts have been made to accelerate tooth movement by various modalities including drug therapy with drugs like misoprostol[60] ,vitamin D[61] prostaglandins[62] etc; mechanical stimulation through high-frequency accelerations (vibration)[47] direct electric current[44], low-intensity laser therapy[45],distraction osteogenesis[54], corticotomies[27,28,29,32] ,interseptal osteotomies[38] ,piezocision[53] ,MOPs[56] etc.

Though many efforts have been made towards accelerated orthodontics; the effective and predictable techniques are through surgical interventions particularly corticotomies which has been researched in detail and has been practiced by many researchers.

Corticotomy is defined as a surgical procedure whereby only the cortical bone is cut, perforated, or mechanically altered.

Kole[21] suggested that bony blocks (bone-teeth unit) were created as a result of the corticotomy, hence causing faster tooth movement. This concept prevailed till 2001, when **Wilcko et al** showed a transient demineralization-remineralisation process taking place after corticotomy[32] combined with graft placement and called it Periodontal Accelerated Osteogenic Orthodontics.

The invasiveness of the procedure, post-operative swelling and pain and some adverse effects to the periodontium. This led to a low patient acceptance rate for corticotomy as an adjunct to decrease in treatment duration.

Harold Frost(1891), observed a direct correlation between degree of injury and intensity of physiological healing response . This phenomenon which he described as the “regional acceleratory phenomenon” (RAP), represents part of the reaction to injury that usually involves an acceleration of normal activities in both hard and soft tissue .[63] Thus by surgically irritating the bone and increasing the recruitment of osteoclast precursor cells through the prostaglandin E2 pathway and the RANK/RANKL pathway; tooth movement can be accelerated[43].

Since it is the injury that causes tooth movement and not the technique used ,various other less invasive treatment modalities like Piezocision[64], Micro-Osteoperforations[56] have been used as alternatives.

According to **J.Nicozisis** (2012) micro-osteoperforations (MOP's) using PropelTM system yields very little discomfort to the patient. There is zero recovery time, and the patients are able to immediately return to their normal daily routine unlike in corticotomy. Additionally, MOP's stimulate the biological cascade in manner similar to corticotomy. It induces RAP which can be re-initiated every 6-8 weeks as the procedure can be carried out in-office.[65]

Chi-Yang Tsai et al, conducted a study to investigate the effects of flapless micro-osteoperforation and corticision on the rate of orthodontic tooth movement in rats and concluded that no obvious differences were observed between flapless micro-osteoperforation and corticision in rats[57]. Although the study compared two surgical procedures but both were flapless techniques.

But no study has been carried out till date to compare the effects of flapless micro osteoperforation technique with corticotomy after flap reflection on canine retraction. Hence this study was conducted to compare the rate of tooth movement, gingival esthetics and pain perception using both the treatment modalities.

Age is an important variable affecting rate of tooth movement and concentration of biomarkers. Many studies have shown that rate of tooth movement decreases with age [15, 66,67] **Bridges et al (1988)** [15] assumed that this was related to the difference in bone density in different age group. It could also be due to the reduced rate of recruitment of osteoclasts or its activation.[66] To avoid influence of these changes on our study result, only adults age 18-45 were included in this study and average age of both the groups was similar .

Another confounding factor could be extractions which could alter the rate of tooth movement by elevating the activity of inflammatory marker and obscure the effect of Corticotomy or MOP's on increasing rate of tooth movement[56] To minimize this possibility, in this study, extraction were done atleast 3-4 months before initiation of retraction for samples of both the groups.

Corticotomy was performed in subjects on site of maxillary quadrant before the commencement of retraction of maxillary canines wherein full-thickness mucoperiosteal flap was reflected under local anaesthesia, after an intracrevicular incision that connected the releasing incisions.

Wilcko et al[32] have recommended placing cuts on both buccal and lingual cortical plate. Some researches like **Germac D et al**[68] had used modified corticotomy technique, where in vertical cuts were placed only on desired labial cortical plate and thin chisel was used for reaching the lingual cortical plate from the labial side.[20] **Aboul-Ela et al**[37] also used corticotomy technique with only labial flap refection but performed cortical perforations without vertical or subapical cuts. The main purpose of adopting this conservative technique was to reduce operative time and postoperative patient discomfort by eliminating exposure of the patient to the risks of an additional palatal surgery.

Similar conservative approach was used in present study also wherein, vertical cuts were performed only on labial cortical plate of site selected mesial and distal to the canine. This helped to reduce post-operative discomfort along with eliminating bias since microoeteoperforations were to be performed only on the labial side in the opposite quadrant; thus equalizing the intensity of injury to the bone.

There is no objective data suggesting specific pattern, depth and extent of alveolar decortication cuts during surgical procedure. In this present study selective alveolar decortication cuts were performed 0.5 mm in depth which is similar to the cuts given by **Hasan A et al.**[40]

Corticotomy cuts were followed by placing DFDB and the flap was carefully repositioned and sutured with non resorbable 4-0 black silk.

Considering MOPs, according to J.Nicozisis 2012 micro-osteoperforations (MOP's) using PropelTM has been shown to have increased tooth movement two fold as compared to traditional orthodontic treatment.[9]

In India where economy leads the treatment; an economic way for carrying out MOPs was required**.** Thus, in this study we compared the proficiency of corticotomy and MOPs on canine retraction but by a novel technique using TADs.

Cheung et al[58] conducted a study to evaluate the effectiveness of mini-implant–facilitated MOPs in inducing accelerated tooth movement They not only evaluated the effectiveness of MOPs in inducing accelerated tooth movement, but also to examine the use of mini-implants as an additional technique for MOP placement.

In this study on the third day of after corticotomy procedure; TADs were used to create MOPs. The biggest challenge was to carry out the procedure with precision to avoid unwanted consequences like root resorption or injury to periodontium . Thus a stent for miniscrew implant placement was made prior to placing the TADs followed by taking an RVG.

The design was similar to the simplified stent used by **Tarulatha Shyagali et al (2012)**[69] for implant placement .Its main advantage was that it can be fabricated at the chair side and does not require an extra appointment for laboratory fabrication.

Noha Hussein Abbas et al(2016)[40] conducted a study to evaluate the efficiency of corticotomy-facilitated orthodontics and piezocision in rapid canine retraction. In their study canine retraction was initiated in both groups with nickel-titanium closed-coil springs that applied 150 g of force. In our split mouth study also we used nickel-titanium closed-coil springs that applied 150 g of force bilaterally.

Various researchers have proposed different time of starting retraction. **Wilcko et al** [32, 34] started retraction two weeks after the surgery. Contrary to this, **Chung et al** [70] and **Sanjideh et al**[71] started retraction immediately after corticotomy. In the present study canine retraction was started on the third day after corticotomy; after microosteoperforations were carried out .

The results obtained in this study can be discussed under the following headings:

1. Evaluation of rate of tooth movement by both techniques
2. Evaluation of gingival esthetics by pink score
3. Evaluation of canine inclination
4. Evaluation of anchorage loss

Evaluation of rate of tooth movement by both techniques:

To mechanically evaluate the rate of tooth movement achieved by Corticotomy and MOP’s, millimetric distance between two points on alveolar ridge distal to canine and mesial to premolar was measured using Vernier callipers at T1- Pre-treatment (immediately before surgical procedure), T2- 8 weeks after initiation of canine retraction. Also, same distance were measured on the OPG by KODAK digital software.

Abbas et al [40] have stated that conventional techniques result in canine retraction rates of 0.5 to 1 mm per month, depending on the patient's age. So it can be estimated that tooth movement achieved in 2 months should be in the range of 1.- 1.6mm

For corticotomy side(MC) the results of mean distance T2-T1 measured was 2.70 ± 0.29 mm using study models and 2.64 ± 0.31 mm using OPG and for microosteoperforations group(MOPs), the mean distance measured was 2.38 ± 0.26 mm using study models and 2.41 ± 0.30 using OPG.

Values for both the surgical procedures, measured on the study models and OPG suggest an increase in the total amount of distance covered by canine compared to conventional OTM. Thus it can be concluded that both the techniques are efficient in accelerating tooth movement. The results for corticotomy are in agreement with those of studies conducted by **Wicko et al[32], Fisher TJ[35], Aboul SM et al[37]** who have also reported PAOO/ Corticotomy assisted orthodontics reduces treatment time.

The results for microosteoperforations are in accordance with studies conducted by **Mani Alikhani et al**[56]**, J.Nicozisis**[9, 65] and **Cheung et al**[58]

To assess whether any difference existed in efficiency of Corticotomy as compared to MOP's to increase the rate of tooth movement the difference (T2-T1) compared for both the groups after a time interval of 8 weeks.

The mean displacement (T2-T1) on corticotomy side was significantly higher than that of microosteoperforations group when measured on study models and OPG.Teeth in MC group had moved 0.32 mm more than that in MP group as measured on study models and 0.23 mm more as compared on OPG .

Chi-Yang Tsai et al[58], conducted a study to investigate the effects of flapless micro-osteoperforation and corticision on the rate of orthodontic tooth movement in rats and concluded that no obvious differences were observed between flapless micro-osteoperforation and corticision in rats. These finding are in contrast to our study where effects of corticotomy were significantly higher that microosteoperforation .

The comparison of mean percent displacement of tooth between two groups for study model and OPG. On the study model, the mean percent displacement was 43.11 ± 5.64 for MC group, while for MOPs group, it was 38.27 ± 5.47. The difference in the mean percent displacement was statistically significant for corticotomy group as indicated by p-value of 0.0103.

This shows that the efficiency of corticotomy to accelerate tooth movement was proven to be significantly higher than that of micro osteoperforation .Because this is a first of its kind study to compare the rate of tooth movement induced by corticotomy and MOP's using TADs and these comparative values could not be confirmed with any previous studies.

2. Evaluation of gingival esthetics by pink score

Several reports have been published regarding the adverse effects to the periodontium after CFO. These reports range from no problems to slight interdental bone loss, decrease of attached gingival, and periodontal defects observed in some cases with short interdental distances.[37]

Fürhauser.R introduced PEI (Pink esthetic index) [72] where seven variables were evaluated: mesial papilla, distal papilla, soft-tissue level, soft-tissue contour, alveolar process deficiency, soft-tissue color and texture. Using a 0-1-2 scoring system, 0 being the lowest, 2 being the highest value, the maximum achievable PES was assessed.

In this study this index was used to assess the effects on gingival contours post corticotomy and MOPs for lateral incisor and canine.

The patients included in this study had healthy gingival which is indicated by p value of 0.5027 showing that T1 for both lateral incisor and canine was insignificant.

When the initial T1 and post surgery score at T2 were compared for both teeth, corticotomy side the results were significant whereas the results were insignificant for MOP side indicating that theses surgeries do have effects on gingival esthetics when flaps are raised.

When the scores were compared for both groups at T2; the mean pink score was 9.42 ± 0.57for corticotomy side and 9.90 ± 0.31 for Microosteoperforations group for the lateral incisor. Similarly for canine T2 score for corticotomy group was 9.35 ± 0.59 and 9.90 ± 0.31 for MOPs group. The T2 scores for both lateral incisor and canine were significant in corticotomy group and non significant in MOPs group justifying the non invasiveness and safety of flapless techniques.

The results infer that corticotomy being an invasive procedure does have some side effects on the peridontium.

3. Evaluation of canine inclination :

Three points on the crown of the canine were used as reference points to evaluate whether the incisal, middle and cervical area of the tooth was equidistant from the respective points on the molar. If not, then that would indicate that the canine has tipped rather than moved bodily.

The difference between measurements at cervical, middle and incisal reference points for both the groups was calculated and a test of variance was performed to evaluate the significance of the differences. In the MC group, mean canine inclination for cervical was 17.50 ± 0.99, for middle was 16.98 ± 1.08 and for incisal edge the inclination was 16.71 ± 1.07. The difference of means on both side for cervical, middle and incisal edge was statistically insignificant as indicated by a p-value of 0.0604. This explains that more of bodily movement was seen .This can be attributed to the fact that these surgical techniques reduce resistance of the alveolar bone on the tooth being retracted..

4. Evaluation of anchorage loss :

It is well known fact that, in most orthodontic extraction patients, anchorage reinforcement is of prime importance. Effective and reliable anchorage will dramatically improve the results of treatment [37]

Lino S et al[74] performed an orthodontic treatment combined with corticotomy and the placement of titanium miniplates in an adult bimaxillary protrusive patient. Non-significant anchorage loss was observed after active treatment combined with corticotomy. Similar results were seen in present study in which the mean change in distance for MC group was 0.15 ± 0.61 mm, while that for MOPs was 0.20 ± 0.73 mm. The difference between the two was statistically insignificant with p-value of 0.8158.

Ibrahim G (2015)[73] evaluated the amount of anchorage loss of the molars during anterior segment retraction combined with alveolar corticotomies in Syrian population. Authors found out that there was 1.5 mm anchorage loss of molars in Class-II malocclusion treated with conventional method after corticotomy. These findings are in contrast to the present study.

The mean change in the angle measured for assessing 1st molar rotation was 0.40 ± 0.5^{o} for MC group, while it was 0.90 ± 0.85^{o} for MOPs group. The difference between the two was statistically significant with p-value of 0.0311. The results indicate that though no anchorage loss is seen but molar rotations do occur and so frequent activation and heavy forces for canine retraction should be avoided.

In this study, second premolar, first molar and second molar were consolidated firmly using stainless steel ligature wires which offered adequate antero-posterior anchorage. The two posterior segments were further connected transversely by Nance palatal arch, which provided anchorage in antero-posterior and the vertical plane.

This study does prove that both the procedures help in retracting teeth in a shorter time, but that is only one measure of the quality of orthodontic treatment. To prove that Corticotomy truly reduces treatment time more than that by MOP's in adult patients, researchers would need to perform randomized controlled trials and randomly allocate subjects with similar malocclusions to either a MOP's or a Corticotomy facilitated treatment group, and then compare the quality of the treatment result.

Although the results obtained in this study proved that corticotomy accelerates tooth movement more that MOPs but we cannot deny the fact that corticotomy has its own consequences on periodontium and may be root resorption but this requires further research. Also corticotomy procedures are more invasive, less patient friendly, more time consuming and also require sutures, which require a second appointment for their removal.

On the contrary MOPs can be performed chair side with less time avoiding needle prick and is thus more patient friendly.

Clinical Significance of the study:

1. To introduce a novel method to create MOPs which is economical, precise and can be performed chair side with regular inventory
2. The study was one of a kind to assess and compare the performance of two designated modalities in increasing the rate of tooth movement in humans.

Limitation

1. The effect of both the procedures on tooth vitality, root resorption, treatment stability and retention could also not be studied as it requires a more long-term study design.

2. Since our sample size was limited and malocclusion not specified, the results might not be the same with a larger sample size, so further investigation is necessary with randomized controlled trials and with similar malocclusions to prove that Corticotomy truly reduces treatment time more than that by MOP's in adult patients.

3. Panoramic or periapical radiographs are not precise for measuring the magnitude of root resorption, density of bone ,etc and thus future studies are necessary with better radiographic aids.

4. The study did not evaluate the differences between male and females and further studies can be done for the same.

Summary and Conclusion

This study was conducted to evaluate and compare the effects of micro osteoperforations with corticotomy on the rate of canine retraction and to assess gingival aesthetic index on both sides in patients undergoing orthodontic treatment .also the effects of both surgeries on canine and molar were evaluated.

It was a split mouth technique and the sample for the study comprised of 20 patients i.e 40 maxillary quadrants divided into 2 groups, micro osteoperforations group and corticotomy group

Pre-Treatment (T1) and Post-observation (T2) orthopantomographs and study models of patients were taken to evaluate the dental changes after 8 weeks in both the groups. Appropriate statistical analyses were performed

Corticotomy in the present study was performed prior to retraction by giving vertical cuts distal and mesial to the tooth to be retracted followed by placing DFDB granules.

Microosteoperforations were performed using a novel economical technique wherein mini-implants were used. To make the procedure precise implants were placed through a stent which was made chairside and proper horizontal and vertical position checked by taking a RVG with the stent placed between canine and premolar. The procedure was carried out by using local anaesthetic spray avoiding needle prick and thus was more patient friendly

Conclusions derived from the study are:

1. Both the groups were efficient in accelerating tooth movement and showed greater tooth movement compared to conventional OTM .
2. The mean percent displacement of tooth between two groups when measured on study model and OPG showed that corticotomy showed significantly more tooth movement compared to Microosteoperforations .
3. The rate of tooth movement was higher in corticotomy group compared to micro osteoperforation group
4. The mean change in distance of 1^{st} molar for both both groups were statistically insignificant concluding that molar did not move bodily i.e. no anchorage loss was seen but the mean change in the angle were significant indicating tha some amount of molar rotations occurred .It can be thus concluded that both surgical interventions reduce bone resistance on the tooth being retracted and thus helped in anchorage pre

5. The results of PINK index indicate that surgical interventions with flap reflection do have effects on periodontal health and aesthetics.
6. The canine inclinations on corticotomy and micro osteoperforation side indicated that bodily canine retraction was seen with

The results of this study, it can be concluded that corticotomy is a more effective method for accelerating the orthodontic treatment than MOP though both techniques showed accelerated tooth movement .But the fact that patient acceptance of treatment with Corticotomy was alarmingly low, owing to the increased pain and discomfort experienced by the patients for a week post-operatively cannot be neglected.

the novel technique of accelerating tooth movement with MOPs using TADs is cost effective, less painful as it avoids needle prick and less time consuming .thus it can be used as a chair side procedure in dental clinics with minimal armamentarium.

But search for lesser invasive procedures, having a similar effect on RAP like Corticotomy, needs to be continued to increase the number of patients in need for orthodontic treatment to adopt new adjunctive procedures and increase patient satisfaction by effectively and efficiently decreasing orthodontic treatment time without compromising on the outcome

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ANNEXURE-I

(Confidential)
<u>Informed Consent Form</u>

Evaluation and comparison of micro-osteoperforations and corticotomy on the rate of canine retraction and comparative assessment of gingival esthetic outcome for both the techniques.

Mr./Master/Mrs./Miss.____
Resident of: ____
___________________________________ ____________________aged _____ years,
Exercising my free will/choice, without any pressure/lure of incentive in any form, hereby give my consent for the project.

I acknowledge the receipt of “patient’s information sheet”, and also that the doctor has informed me about this research project suitably and sufficiently to my satisfaction. I agree to take part in this project willing and agree to undergo the following surgeries mentioned to me .I permit to publishing the results of my participation in this study. I shall not be given any reimbursement or compensation. I hereby record my consent for participation in the said questionnaire.

_______________	______________________	___________	___________
Patient’s name	Signature/thumbprint	Date	Time
______________________	__________	___________	________
Principal Investigator	Signature	Date	Time

ANNEXURE – II

MASTER CHART

MEAN VALUES OF DISTANCE BETWEEN CANINE AND 2^{ND} PREMOLAR

T1= PRE-RETRACTION

T2= 8 WEEKS POST INITIATION OF RETRACTION

MC = CORTICOTOMY GROUP

MOP = MICRO-OSTEOPERFORATION GROUP

CAST = MEASUREMENTS MADE ON STUDY MODELS

OPG = MEASUREMENTS MADE ON ORTHOPANTOMOGRAM

MEAN DISTANCE BETWEEN CANINE AND 2ND PREMOLAR ON CAST & OPG AT TIME T1 & T2 FOR CORTICOTOMY AND MICRO OESTEOPERFORATIONS SITES

UNIT OF MEASUREMENT = MILLIMETERS

Group A CORTICOTOMY SIDE					Group B - MICRO OESTEOPERFORATIONS			
	CAST		OPG		CAST		OPG	
Sr. no	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**
1	7.0mm	4mm	7.2mm	4.2mm	6.8mm	4.5mm	7mm	4.4mm
2	6.2mm	3.6mm	6mm	3.4mm	6mm	3.8mm	6mm	3.4mm
3	7.6mm	4.8mm	7.4mm	5mm	7mm	4.6mm	7.4mm	5.2mm
4	4.8mm	2.4mm	5mm	2.6mm	5mm	2.8mm	5mm	2.5mm
5	7mm	4mm	7.2mm	4.3mm	7mm	4.5mm	7mm	4mm
6	6mm	3.2mm	6.5mm	3.5mm	6mm	3.6mm	6.5mm	4mm
7	7mm	4mm	6.8mm	4mm	7mm	4.3mm	7mm	4.8mm
8	6.5mm	3.8mm	6.5mm	4mm	6.5mm	4mm	6.5mm	3.7mm
9	6.5mm	3.5mm	6.5mm	3.8mm	6.3mm	3.8mm	6.5mm	4.2mm
10	4.5mm	2.2mm	4.5mm	2.4mm	4.5mm	2.5mm	4.5mm	2.3mm
11	5mm	2.5mm	5.5mm	3mm	5mm	2.6mm	5.5mm	3mm
12	6.5mm	3.8mm	6.5mm	3.5mm	6.5mm	4.1mm	6.7mm	4mm
13	7.5mm	5mm	7.6mm	5mm	7.4mm	5.3mm	7.3mm	5.2mm
14	6.4mm	3.4mm	7mm	3.8mm	6.5mm	3.8mm	7mm	3.8mm
15	5mm	2.6mm	5.5mm	3mm	5mm	2.8mm	5.4mm	2.5mm
16	7.3mm	5.0mm	7mm	4.6mm	7.2mm	5.1mm	7mm	4.8mm
17	6.5mm	3.2mm	7mm	4.4mm	6.5mm	3.4mm	6.8mm	4mm
18	7mm	4.2mm	6.5mm	3.5mm	7mm	4.4mm	6.8mm	4mm
19	6.4mm	4mm	6mm	3.4mm	6.5mm	4.4mm	6.5mm	3.9mm
20	6mm	3.6mm	6mm	4mm	6mm	3.8mm	6.2mm	3.6mm

PINK SCORE

LATERAL INCISOR					CANINE			
	CORTICOTOMY		MOPs		CORTICOTOMY		MOPs	
Sr. no	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**
1	9	9	10	10	9.5	9	10	10
2	10	10	10	10	10	10	10	10
3	10	9	10	10	10	9	10	10
4	10	10	10	10	10	10	10	10
5	9	9	10	10	9.5	9	10	10
6	9.5	9	10	10	9.5	9	10	10
7	10	9	10	10	10	9	10	10
8	8.5	8	10	10	8.5	8	10	10
9	10	10	10	10	10	10	10	10
10	9	9	10	10	9	9	10	10
11	10	10	10	10	10	10	10	10
12	9	9	10	10	9	9	10	10
13	9	9	10	10	9.5	9	10	10
14	9.5	9	10	10	9.5	9	10	10
15	10	10	10	10	10	10	10	10
16	10	10	10	9	10	10	9	9
17	10	10	10	10	10	10	10	10
18	9.5	9	9.5	9	9.5	9	9.5	9
19	10	10	10	10	10	10	10	10
20	10	9	10	10	10	9	10	10

MEAN VALUES OF DISTANCE BETWEEN CANINE AND 1ST MOLAR

UNIT OF MEASUREMENT : MILLIMETRES (MM)

SR.NO	(MC)		MOPS	
	T1	**T2**	**T1**	**T2**
1	29	29	29.5	29
2	28	30	27.5	30
3	30	30	29	29
4	26	26	26	26
5	28	27	28	27
6	31	30.5	30	29
7	27.5	27	27	26.5
8	28.5	28	28	27.5
9	30	30	30	30
10	29	29	29	29
11	28.5	28	28	28
12	27	27	27	27
13	28	28	28	28
14	27	27	28	27.5
15	28	27.5	27	26.5
16	30	29	30	29
17	29	29	29	28.5
18	28	28	28	27.5
19	28.5	28	28	28
20	26	26	26	26

MOLAR ROTATION				
SR NO	**CORTICOTOMY(MC)**		**MICRO OSTEOPERFORATION (MOPs)**	
	T1	**T2**	**T1**	**T2**
1	52	51	52	50
2	54	54	54	53
3	52	52	52	52
4	56	56	56	55
5	60	60	60	59
6	57	57	57	56
7	56	56	56	55
8	53	52	53	51
9	55	53	54	52
10	52	52	52	51
11	58	57	57	57
12	57	55	56	55
13	55	54	55	54
14	56	55	56	54
15	55	55	55	55
16	58	58	57	57
17	57	57	57	57
18	56	55	56	56
19	57	56	57	56
20	55	55	55	55

MEASUREMENTS OF DISTANCE AT INCISAL, MIDDLE AND CERVICAL REFERENCE POINTS ON CANINE AND 1ST MOLAR AT T2

	CORTICOTOMY(MC)			MICRO OSTEOPERFORATION (MOPs)		
SR. NO	CERVICAL	MIDDLE	INCISAL	CERVICAL	MIDDLE	INCISAL
1	18.1	17.6	17	19	17.5	16.5
2	20.1	19.7	19.5	20.6	21.5	21.5
3	19.1	18.72	18.46	19.7	19.5	19.5
4	18.12	17.86	17.1	18.87	21	21
5	17.11	16.89	16.5	18	20.5	19.5
6	17.2	17.67	17.02	17.96	20	19
7	16.49	16	15.76	17.1	17	17
8	17.4	16.93	16.5	18	16.5	16.5
9	17.6	17.02	16.88	18.2	17	17
10	17.66	17.26	16.74	18.3	18	17.5
11	18.1	17.5	17.2	18.8	18.4	18
12	17.62	16.1	15.79	18.4	17.9	17.41
13	17.78	17.16	16.76	18.54	18.01	17.49
14	16.7	15.9	15.6	16.1	15.45	15.11
15	16.26	15.66	15.31	15.66	15.12	14.99
16	17.91	17.36	17	17.1	16.8	16.5
17	17.66	16.93	16.45	16.87	16.44	16
18	16.38	15.76	15.18	16	15.79	15.38
19	16.79	16.2	15.46	16.2	15.83	15.46
20	15.87	15.32	15	15	14.82	14.55