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# The Effect of Corticision on the Remodeling Activity and Rate of Tooth Movement in Cats

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*In a search for increased efficiency in the field of orthodontics, selective injury to the cortical plate of the alveolar bone was suggested as a means to modify the balance between bone resorption and apposition, in a process known as corticision. It was the aim of the study to investigate the remodeling activity of the alveolar bone and its effect on the rate of tooth movement in a cat model.*

*This study aims to show that corticision with and without periodic mobilization can significantly increase the speed of orthodontic treatment. This can be a viable option for adult patients who cannot tolerate long treatment duration.*

## **INTRODUCTION**

Over the years, an increasing number of adult patients are seeking orthodontic treatment, with specific objectives and concerns related to facial and dental aesthetics, the type of orthodontic appliance and the duration of treatment. Often times they are discouraged to undergo orthodontic treatment which last for an approximate duration of 24 months. This leads to various investigations to accelerate orthodontic treatment in order to meet the various demands.

Orthodontic tooth movement is a result of biological changes in the periodontal ligament and alveolar bone as a response to mechanically applied stimulus. The amount of tooth movement is determined by the density and turnover rate of the alveolar bone.

Surgical procedures used to facilitate orthodontic treatment were described as early as 1892<sup>1</sup> in the dental literature. Heinrich Köle<sup>2</sup>, in 1959, wrote one of the most important articles when he suggested that the greatest resistance to tooth movement is created by the cortical bone of the alveolus. A technique combining orthodontics with interradiolar corticotomy and supra-apical osteotomy was presented in order to facilitate rapid orthodontic tooth repositioning.

Corticotomy-assisted orthodontic treatment is an established and efficient orthodontic technique that has been studied in a number of publications.<sup>3,4</sup> It has gradually gained popularity as an adjunctive option to orthodontic treatment in adults. It entails selective alveolar decortication in the form of lines and dots performed around the teeth to be moved, thereby removing the

primary resistance to tooth movement exerted by the surrounding cortical bone.<sup>5</sup> This induce a state of increased tissue turnover and transient osteopenia, resulting in a faster rate of orthodontic tooth movement. This make it possible to move teeth by as much as 75 to 80 percent faster in adults.<sup>6</sup> Although considered quite effective, there was little acceptance by the patients due to the aggressive nature of the procedure, and risk of complications associated with intensive corticotomies.<sup>3,7</sup>

An alternative approach that has been recently introduced is the corticision technique.<sup>8</sup> This method involves minimal surgical intervention using surgical blades in order to separate the interproximal cortices transmucosally. This modification provides protection of the alveolar bone, eliminating the risk of crestal bone loss and loss of attached gingiva that is often seen with corticotomy procedures, while accelerating tooth movement. This technique might prove favourable for both the patient and orthodontist by lessening treatment duration and complications involved.

A common feature among these various procedure is that their biological mechanism is based on the regional acceleratory phenomenon (RAP).<sup>8</sup> This is a process by which tissue forms several times faster than the normal regional regeneration process in response to a stimulus, particularly following surgical wounding of the cortical bone.<sup>7,9</sup> This results in bone demineralization observable within the area that affects the rate of tooth movement.<sup>9,10</sup> Therefore, by modifying the balance between resorption and apposition, and by circumventing the waiting time for the alveolar cortex to be resorbed, faster tooth movement can be achieved without causing irreversible damage to the periodontium.<sup>11</sup>

The evidence presented in support of corticision thus far are based on case report studies, which is considered weak evidence to support the purported advantages and mechanism of action. Therefore it is the aim of this study to investigate the effect of corticision on the remodeling activity of alveolar bone and rate of tooth movement in cats, based on the hypothesis that cortical bone incision leads to osteopenia.

## REVIEW OF LITERATURE

### ORTHODONTIC TOOTH MOVEMENT

The purpose of orthodontic treatment is to move teeth as efficiently as possible with minimal adverse effects on the teeth and supporting tissues.<sup>12</sup> Studies have suggested that deformation of the periodontal ligament (PDL) might be the key stimulus for the initiation of orthodontic tooth movement.<sup>13,14</sup>

Most orthodontists became aware of the role of cells in orthodontic tooth movement in the pressure-tension theory.<sup>15</sup> The theory proposes that force-subjected PDL progenitor cells differentiate into compression-associated osteoclasts and tension associated osteoblasts, causing bone resorption and apposition, respectively.<sup>16</sup> Only by this mechanism could tooth movement narrow the PDL on the pressure side and widen it on the tension side, inducing the postulated mechanical alterations in rate of blood flow and fiber tension.<sup>17</sup>

The first histological investigation of orthodontic tooth movement reported bone resorption on the pressure side and bone deposition on the tension side after force application to a tooth,<sup>18</sup> resulting in discussions about ideal magnitude of orthodontic forces. Frontal or direct bone resorption is associated with light force activation, tissue and cell preservation, and vascular patency.<sup>19</sup> This implies that osteoclasts are formed directly along bone surface in the area corresponding to the compressed fibers. For this reaction to occur, the periodontal fibers must be compressed only to a certain extent and must not cause hyalinization (cell free areas).<sup>20</sup>

In addition, undermining resorption was found to be associated with orthodontic forces of large magnitude.<sup>19</sup> The excessive pressure constricts the blood supply to the periodontium causing hyalinization, which hinders tooth movement until they are removed by phagocytosis. At these sites, osteoclastic resorption of the alveolar wall was initiated from the adjacent undamaged areas underneath the lamina dura. This eliminates the hyalinized tissue making orthodontic tooth movement possible.<sup>18</sup> The time taken to remove such tissue by undermining resorption varied from 2 to 4 weeks and occasionally longer depending on the length of the root.<sup>21,22</sup>

Clinically, there are three phases of orthodontic tooth movement that was described.<sup>23</sup> An initial phase, which was characterized by rapid tooth movement that lasted for a few days; a lag phase, during which the tooth showed little or no movement;

and a post-lag phase, when the rate of tooth movement either gradually or suddenly increase as a result of the periodontium and the alveolar bone adapting to the forces placed upon them.<sup>24</sup>

Histologic studies<sup>16,25</sup> suggest that the duration of the lag phase usually lasts 2 to 3 weeks but may take as long as 10 weeks. This is directly related to the patient's age, alveolar bone density, and extent of hyalinization that occur during the initial phase. Another important factor might be that the levels of cytokines and growth factors which are involved in the remodelling process during tooth movement show significant differences between individuals.<sup>26-29</sup>

### Effects of Force Magnitude

In an effort to find the most efficient and effective method of moving teeth through their supporting structures, different types of appliances and tooth movements, as well as varying amount of forces and methods of transmitting them to the teeth was investigated in an attempt to take advantage of the various types of forces described as light, heavy, optimal or differential.<sup>30</sup>

The concept of the optimal force<sup>31</sup> was defined as the "the force leading to a change in tissue pressure that approximated the capillary vessels' blood pressure, thus preventing their occlusion in the compressed periodontal ligament." It was proposed that forces of 15 to 20g./cm.<sup>2</sup> of tooth surface were considered optimum. Forces well below this optimal level will cause no reaction in the periodontal ligament. While forces exceeding the optimal level would lead to areas of tissue necrosis, preventing frontal bone resorption to take place, causing a delay in tooth movement.

From the idea of an optimal force grew the differential force theory.<sup>32</sup> By varying between light and heavy forces, one could get increased movement of the anterior or posterior teeth. Accordingly, as the optimum force for a smaller rooted tooth is exceeded, the rate of movement for that tooth would be greatly reduced or stopped, while an anchor tooth with a larger root surface would continue to move at a near optimum rate, as the optimum rate for the latter would be greater.

However, although the appearance of the necrotic tissue might be related to the force magnitude, this seems to have no significance for the rate of tooth movement. This means that once tooth movement has started, bone remodeling takes place at a certain rate, independent of force magnitude.<sup>33</sup>

### Age-Related Changes During Treatment

The changing demographics of the typical orthodontic practice has been due to our increased understanding with adult orthodontic treatment, increased public awareness of the availability of treatment and advances in diagnostic and orthodontic techniques and materials.<sup>34</sup> There are many reasons why adult orthodontic therapy should be encouraged. This includes the improvement of function, occlusion and of esthetics as well as the psychological outlook. Also, better prognosis will result for prosthetic appliances from having sound, upright teeth for support.<sup>34</sup>

The orthodontic procedures in adults tend to be more complex and time consuming. This longer treatment duration observed might be related to a delay in the initial tissue response.<sup>35,36</sup> As a result of cementum formation, the surface of the cementum and alveolar bone loses its smoothness, assuming a scalloped appearance, and the width of the PDL becomes narrower and more irregular.<sup>37,38</sup> Accordingly, hyalinized tissues are more easily formed.<sup>39</sup>

With advancing age, a decrease in the alveolar bone density<sup>40</sup> and a slower turnover rate of the bone and PDL were also observed.<sup>41</sup> This is in contrast with several studies of bone outside the craniofacial system that reported a gradual decrease in trabecular bone density with increasing age.<sup>42,43</sup> Although the histological response in adults appear to begin more slowly, in the clinical situation, adults and juveniles are equally responsive to mechanical stimuli once tooth movement has started.<sup>35,36</sup>

One paramount difference in adults is the absence of effective growth that normally aids in the correction of a malocclusion.<sup>44</sup> The biological possibilities for tooth movement in adults are decreased to about one-third of those found in children.<sup>45</sup> As a result, tooth movement had to overcompensate. Consequently, the clinician and the patient have to work harder to achieve the desired result, and these efforts go back to the common perception that adults seem to be in treatment longer than teenagers.<sup>44</sup>

### Inflammatory Mediators

Tooth movement through bone depends on local inflammatory reactions of the dentoalveolar tissues. When an orthodontic force is applied to a tooth for a prolonged period of time, mechanical signals cause the sensory afferent nerves to liberate inflammatory peptides around the teeth, initiating an inflammatory response.<sup>46</sup> As a result, bone resorption begins and tooth movement occurs.

A large number of local factors have been identified to be involved in the regulation of bone remodeling during tooth movement. These agents fall into 3 main categories: prostaglandins, pro-inflammatory cytokines and growth factors.

Prostaglandins (PGs) are produced under various physiological and pathophysiological conditions and serve to maintain local homeostasis.<sup>47,48</sup> They are like hormones in that they act as chemical messengers, but do not move to other sites, but work right within the cells where they are synthesized.<sup>49</sup> It was suggested that orthodontic mechanical stress induce synthesis and secretion of PGs by localized cells which stimulates osteoclastic bone resorption.<sup>50</sup> The mechanism of acceleration of the rate of tooth movement in PGE<sub>1</sub> and PGE<sub>2</sub>-treated cases may be related to evidence that local PGs stimulate bone resorption in vivo by increasing osteoclast numbers. It has been demonstrated that repeated mucosal injections of these compounds produced marked changes in alveolar bone morphology, such as extensive loss of bone matrix, fibrous replacement, and increased vascularity.<sup>50,51</sup>

Leukotrienes (LTs)<sup>52</sup> are compounds, closely related to PGs that have also been implicated in the mediation of an inflammatory response. As pro-inflammatory mediators, leukotrienes are strong attractants of polymorphonuclear leukocytes and stimulate cellular responses that are quick in onset but do not last long, such as smooth muscle contraction, phagocyte chemotaxis, and increased vascular permeability. Therefore, inhibition of this compound will result in a weaker bone remodeling.

One of the most important breakthroughs of bone biology has been the identification of the role of cytokines in bone remodeling.<sup>53</sup> Cytokines are local biochemical mediators secreted primarily from leukocytes. They stimulate both humoral and cellular immune responses, as well as the activation of phagocytic cells. They are regulators of host response to infection, immune responses, inflammation, and trauma<sup>54</sup> and have been implicated in the pathology of periodontal diseases, bone destruction, and bone response to orthodontic treatment.

The cytokines important in bone metabolism include the interleukins (IL), tumour necrosis factor (TNF)  $\alpha$  and  $\beta$  and possibly  $\gamma$ -interferon. In addition to having a powerful mitogenic action on osteoblasts, IL-1 is the most potent stimulator of bone resorption known,<sup>55</sup> and is produced not only by activated leukocytes but also by bone and synovial cells. The IL-6 is a pleiotropic cytokine that is commonly produced at local tissue sites and released into circulation during trauma, and acute inflammation.<sup>56,57</sup> It is also involved in other processes such as inhibiting early osteoblast differentiation and enhancing the bone resorbing effects of IL-1 and TNF.<sup>58</sup> The IL-8 is a potent proinflammatory cytokine that has a key role in the recruitment and activation of neutrophils to degranulate during inflammation. It is considered to be important in regulating alveolar bone resorption during tooth movement by acting early in the inflammatory response.<sup>59</sup>

TNF- $\alpha$  is a proinflammatory cytokine produced mainly by activated macrophages or monocytes, neutrophils, endothelial cells, and fibroblasts.<sup>60,61</sup> It has been shown to be an early modulator of bone resorption<sup>62-64</sup> and is detectable in human gingival sulcus.<sup>65</sup> It plays a pivotal part in the assessment of orthodontic tooth movement under pathologic conditions resulting from excessive orthodontic forces.<sup>66,67</sup>

Osteoclasts, which differentiate from hematopoietic stem cells, are required for bone resorption and remodeling. Both receptor activator of nuclear factor kappa B (RANKL) and receptor activator of nuclear factor (RANK) are key proteins regulating osteoclast function.<sup>68-71</sup> RANK is considered as a hematopoietic surface receptor controlling osteoclastogenesis and calcium metabolism, while RANKL may promote osteoresorption by induction of cathepsin K gene expression.<sup>72,73,74</sup> The interaction between RANK on the preosteoclasts and RANKL promotes maturation and fusion of the preosteoclasts into activated osteoclasts.<sup>69,75,76</sup>

## REGIONAL ACCELERATORY PHENOMENON

In 1960, orthopaedist Frost<sup>77</sup> found that surgical wounding of osseous hard tissue results in striking reorganizing activity adjacent to the site of injury. He came to the conclusion that any type of significant injury to a bone usually results in an acceleration of bone turnover that is directly related to degree and proximity of the bone trauma. He termed this cascade of physiologic healing events the regional acceleratory phenomenon (RAP). Since then, this theory has been rigorously studied and proposed as a method of accelerating orthodontic treatment by other researchers.

### Theoretical Aspects of the Regional Acceleratory Phenomenon

The term regional refers to the demineralization of both the cut site and adjacent bone,<sup>9</sup> while acceleratory refers to an exaggerated bone response in cuts that extend to the marrow.<sup>78</sup> In human long bones, RAP begins within a few days following surgery that typically peaks at 1 to 2 months, and may take from 6 to 24 months to completely subside.<sup>79-83</sup> This occurs in more than 97% of bone injuries and is essential for adequate healing.<sup>7</sup> When a RAP fails to develop, infections can progress alarmingly.

A previous study<sup>9</sup> have shown that RAP led to a five-fold increase in new trabecular bone formation that was localized to the area immediately adjacent to the corticotomy cuts without changing the bone volume (BV). The maintenance of BV, despite increased in new bone formation, was due to a local increase in bone remodeling.

In dentistry, RAP can result from local trauma, such as corticotomy, periodontal surgery, orthodontic force, implant,<sup>84-86</sup> and infection and systemic changes in bone due to menopause and parathyroid treatment.<sup>79,80</sup> The RAP that occurs adjacent to the PDL triggered by orthodontic force alone is known as undermining resorption, but the level of expression is only mild to moderate.<sup>78</sup> When orthodontic tooth movement is combined with selective alveolar decortications, this would induce a profound level of RAP activity.<sup>11</sup>

### Structural Features of Bone Repair

The alveolar process forms and supports the sockets of the teeth. It consists of dense outer cortical bone plates with varying amounts of spongy bone between them. Tooth movements in a mesial or distal direction displace the roots through the spongiosa of the alveolar bone.<sup>87</sup>

Bone tissues are formed by differentiation of the osteoprogenitor cells into either mesenchymal osteoblasts, or surface osteoblasts. This osteoblast synthesize and deposit type 1 collagen, the main protein constituent of bone matrix, in only 2 basic conformations: woven bone and lamellar bone.<sup>88</sup> Woven bones are seen in association with initial early repair following fractures and osteotomies. It is a disorganized structure with a high

proportion of osteocytes and exhibits a small quantity of randomly oriented collagen fibers that forms quickly at the site of injury. It is structurally weak and is synthesized primarily to serve as a scaffold upon which the better oriented and mechanically stronger lamellar bone is deposited.<sup>88,89</sup> On the other hand, lamellar bone is less cellular than woven bone. Once sufficient amount of woven bone are available, surface osteoblasts deposit new matrix in a linear or lamellar orientation. This contributes a quality to the bone that is more resistant to torsional and tensional stresses.<sup>88,89</sup>

Bone remodeling is accomplished by the basic multicellular unit (BMU). The BMU comprises a team of osteoclasts in front, a team of osteoblasts in the rear, a central vascular capillary, a nerve supply, and associated connective tissue.<sup>90</sup> Each BMU begins at a particular place and time and advances towards a target. As this advances, osteoclasts leave the resorption site and osteoblasts move in to cover the excavated area and begin the process of new bone formation.<sup>91</sup> However, for bones that are undergoing extensive remodeling, such as during RAP, bone formation cannot keep pace with the large amounts of resorption that are occurring, with the end result being net bone loss. At the end of healing, when the stimulus to RAP resolves, the BMU activation declines to normal, remodeling spaces fill back with new bone, and osteopenia disappears.<sup>92</sup>

### Bone Healing Process

Bone has a remarkable ability to repair itself to full structural and functional effectiveness. Bone repair occurs by different specific mechanisms primarily dependent on the biophysical environment. Although the various types of repair uses differing normal cells and tissues, the eventual bone synthesis is always mediated by the mesenchymal and surface osteoblasts and via the woven and lamellar matrix conformations.<sup>88</sup>

Knowledge of the several mechanisms of bone repair is important for optimal clinical management of operative interventions. The histologic patterns of bone repair are: i) endochondral bone repair (repair by callus formation), mediated by inner periosteal layer and marrow tissues, synthesizing cartilage and then woven and lamellar bone in an environment of interfragmentary space and mobility; ii) primary bone repair (direct contact repair),<sup>93-95</sup> mediated exclusively by intraosseous Haversian system osteoblasts and osteoclasts cutting cone, without a cartilage phase in an environment of no interfragmentary space and rigid stability; iii) direct bone repair (gap repair)<sup>94</sup> mediated also without a cartilage phase by marrow derived vessels and mesenchymal cells in an environment of interfragmentary space greater than 0.1 mm with rigid stability; and iv) distraction osteogenesis mediated by inner layer periosteal and marrow (including endosteal) tissue, synthesizing woven and then lamellar bone in the slowly widening gap in an environment of more or less stability and slow distraction.<sup>88</sup>

An injury of any type initiates a healing process that restores



the tissue to its original physical and mechanical properties influenced by a variety of systemic and local factors. Healing occurs in three distinct but overlapping stages: 1) the early inflammatory stage; 2) the repair stage; and 3) the late remodeling stage.<sup>96,97</sup> Following injury, hematoma develops during the first few hours and days. Local mediator mechanisms (e.g. prostaglandins) begin to produce inflammatory cells and fibroblasts, which secretes cytokines to infiltrate the bone.<sup>88</sup> This results in the formation of a soft granulation tissue in the space created by the fracture, ingrowth of vascular tissue and migration of mesenchymal cells.<sup>98</sup>

During the repair stage, fibroblasts begin to lay down a stroma that helps support the vascular ingrowth. About two weeks after the injury, some osteoclasts usually appear to resorb some of the irregular fracture surfaces. As this progress, a collagen matrix is laid down while osteoid is secreted and consequently mineralized, which leads to the formation of a callus around the repair site. Eventually, the bone remodeling process then replaces the callus with new bone.<sup>92,98</sup> Even though the biomechanical environment for repair leads to different mechanisms of healing, the ideal end result is the same. The healing bone is completely remodelled to a point of no indication as to where the fracture or osteotomy was located.

## SURGICALLY FACILITATED ORTHODONTICS

Surgery as an adjunct to orthodontic therapy can significantly expand the limitations of orthodontics and greatly reduce the treatment duration. Currently, there are two main types of surgically facilitated orthodontic therapy that are popular. Corticotomy is a surgical intervention limited to the cortical portion of the alveolar bone to cause demineralization through the regional acceleratory phenomenon. The second type involves single- or multiple-tooth osteotomies combined with the principles of distraction osteogenesis to rapidly grow hard and soft tissues, thereby enabling changes in the alveolo-skeletal relationships. In the process, both cortical and trabecular bone are removed in significant quantities.<sup>99,100</sup>

Cohn-Stock<sup>101</sup> recognized three basic management alternatives in the correction of malocclusion the strictly orthodontic procedure, the combination of orthodontic and surgical procedure, and the strictly surgical procedure. When purely mechanical orthodontic measures fail, the dentist should use supportive surgical means to achieve successful management, as well as to shorten treatment time.

The primary interest in corticotomy centered on its application for patients older than 16 years in order to accelerate care, extend the envelope of tooth movement and to reduce the possibility of relapse.<sup>102,103</sup> According to previous publications,<sup>104,105</sup> orthodontic management could be reduced by a fourth or a fifth of the usual duration by completing the orthodontic treatment in the first three to four months after corticotomy before fusion of the tooth-borne units occur, without compromising the vascular supply of the pulp nor causing root resorption.<sup>106</sup>

Although corticotomy assisted orthodontic treatment may be considered a less-invasive procedure than osteotomy, there have still been several reports regarding adverse effects to the periodontium following corticotomy, ranging from no problems<sup>6,106,107</sup> to slight interdental bone loss and loss of attached gingiva,<sup>108</sup> to periodontal defects observed in some cases with short interdental distance.<sup>109</sup> In addition, some post-operative swelling and pain is expected for several days.

Over the years, in an effort to eliminate the adverse reactions associated with corticotomy, distraction osteogenesis was presented as another method for accelerating orthodontic tooth movement that initiates the RAP. It is a process of growing bone through a surgical cut<sup>110,111</sup> by stretching the soft tissue callus. In the process, both cortical and trabecular bone are removed in significant quantities.<sup>99,100</sup>

The latest advancement in the distraction armamentarium is the periodontal ligament (PDL) distraction technique.<sup>112</sup> It was shown that the PDL behaves like a craniofacial suture.<sup>113</sup> The process of osteogenesis in the PDL during orthodontic tooth movement is similar to that in the midpalatal suture during rapid palatal expansion. The major difference is the rate of osteogenesis.<sup>112</sup> A case report by Bilodeau<sup>114</sup> showed that the teeth remained vital throughout the treatment. This method is a breakthrough for orthodontic treatment especially in adult patients with critical anchorage requirements.

To achieve rapid orthodontic tooth movement without the downside of an extensive and traumatic surgical approach while maintaining the clinical benefit of a concomitant bone graft, Dibart et al.<sup>115</sup> developed a minimally invasive procedure combining microincisions, minimal piezoelectric osseous cuts to the buccal cortex and bone or soft-tissue grafting concomitant with a tunnel approach. Because of its micrometric and selective cut, the piezoelectric knife is said to lead to safe and precise osteotomies without any osteonecrosis damage.<sup>116</sup> Furthermore, it works only on mineralized tissues, sparing soft tissues and their blood supply.<sup>117</sup> The technique being demonstrated similar clinical outcome when compared with the classic decortication approach but has the added advantages of being quick, minimally invasive, and less traumatic to the patient.

One of the latest techniques involves an incision line through the gums using a scalpel to separate the interproximal cortices transmucosally. Kim et al.<sup>8</sup> termed this as 'Corticision' technique. There was minimal surgical intervention by excluding flap reflection. This eliminates the complications of crestal bone resorption and bone dehiscence after flap surgery.<sup>7</sup> Extensive direct resorption of bundle bone with less hyalinization and more rapid removal of hyalinised tissue were observed in canines with orthodontic movement plus corticision. The accumulated mean apposition area of new bone was observed to be 3.5 fold higher in this group.<sup>8</sup> This supplemental alveolar surgery not only decreased the treatment duration, but also reduced the incidence of root resorption, decalcification and allow better acceptance for adult

patients who can't tolerate a lengthy orthodontic treatment.

To date however, few researchers have conducted experiments to broaden the scope of our knowledge with this new concept. Though corticision is regarded as a convenient procedure for both orthodontist and patient, and has a clinical value for accelerating tooth movement, additional experimental data is needed.

## MATERIALS AND METHODS

A protocol of the proposed study especially those relevant to the animal related procedures, were submitted for review before the Institutional Animal Care and Use Committee of the National Institutes of Health of the University of the Philippines Manila prior to the start of the experiment.

### Experimental Model and Design

Male domestic cats, weighing between 2.8 to 5.0 kg., were used in the study. Accurate determination of the cats' age was impossible as they were not purposely bred for research. Maturation was determined by dental examination and observing the behavioural development to differentiate an adult cat of at least 1 to 6 years of age, which is comparable with late adolescence to adulthood in human beings.<sup>118-120</sup>

Cats with complete sets of maxillary teeth without any sign of tooth mobility were purchased from a local cat supplier providing laboratory animals (e.g., cats) for 30 years in the University of the Philippines Diliman.

Using Russ Lenth's Power and Sample Size Software and data obtained from a previous study with a standard deviation of 0.04 and minimum detectable contrast of 0.1, the sample size was computed to be  $n = 5$  per group with a projected power of 88.06%.

Male domestic cats were housed in a non-collapsible type of cage made of aluminum sheets and with metal mesh for the door (Fig. 2). The size of the cage was 2 x 2 x 2 feet.<sup>121</sup> Each cage housed 1 cat weighing between 2.8 to 5.0 kg. The floor area was covered with newspapers for easy disposal of fecal matters, which were disposed and cleaned every morning for the whole duration of the experiment. The design of the cage did not only provide privacy for the cat, but reduced the stress from confinement.

The cages were housed in the Veterinary Teaching Hospital, located at the University of the Philippines Diliman. A 12:12 hours light-dark regimen was followed in order to imitate the day-night cycle.

Each animal was identified through a letter code attached to their respective cages to indicate their group, that is, GA for Group A, and GB for Group B. A number assigned by the researcher (e.g. GA1, GB1), and designated control or experimental side (e.g. GA1L, GA1R). Each identification code had an accompanying descriptive remark of the fur markings of the cat assigned with that identification code.



**Figure 2.** Experimental subjects housed in a 2 x 2 x 2 feet non-collapsible cages.

Prior to the start of the experiment, cats were quarantined for a minimum period of 3 weeks, during which they were de-wormed using 1% Ivermectin (Ivomec<sup>®</sup>) at 250  $\mu\text{g./kg.}$  body weight and 1% Albendazole (Microzole<sup>®</sup>) at 10 mg./kg. body weight and had undergone anti-rabies shots using Merial-Rabisin<sup>®</sup> at 1 ml. per cat.

Cats were fed twice daily with a common commercially available cat pellets moistened in water, to avoid appliance damage,<sup>30</sup> and drinking water from a plastic receptacle which were replenished daily from a chlorinated main supply to sustain the animals' dietary needs. Weight of the cats and food intakes were monitored during the whole duration of the experiment. In the case of a 10% weight loss, forced feeding was done by softening the food and feeding them through a syringe.

The 10 male domestic cats were randomly divided and assigned into 2 groups, designated as Group A and Group B. A split-mouth design was used with the right segment used as the experimental side and the contralateral side used as the control. Overall, 20 canines were included in the study.

The treatment protocol for the control sides of both Group A and B involved the application of orthodontic forces alone. The experimental sides of Group A consist of orthodontic forces with Corticision, while Group B includes the application of orthodontic forces with Corticision and periodic mobilization of the experimental tooth. Each group was further subdivided into four subgroups depending on the duration of force application: Group 1, 7 days; Group 2, 14 days; Group 3, 21 days; and Group 4, 28 days.

To evaluate the accuracy and precision of appliance design placement and to observe and ensure the distalization of the canines, a cat was installed with the orthodontic appliance for pre-testing. The data gathered from this animal were not included in the results of the study.



### Placement of Orthodontic Appliance

Prior to appliance insertion, Atropine Sulphate (Atrosite) was injected subcutaneously at a dosage of 0.04 mg./kg. General anaesthesia was then induced by the veterinary surgeon at a dosage of 7.5 mg./kg. body weight through an intramuscular administration of Zoletil (a combination of Tiletamine Hypochloride and Zolazepam Hypochloride) into the caudal thigh (semimembranous muscle), halfway between the knee joint and the hip. A maintenance dose of 50% of the total dose was administered as needed. Foods were withheld for 12 hours prior to administration of anaesthesia in order to reduce the risk of vomiting during induction or during the recovery period. Blood tests including Complete Blood Count and Platelet Count were also performed.

Manual oral prophylaxis was done on each subject with the use of a universal scaler. Teeth were brushed using a prophylaxis brush with pumice, attached to a low speed motor followed by water irrigation. Cotton rolls were used to isolate the areas to be bonded.

The fixed orthodontic appliance design for canine retraction was similar in specifications to the appliance used in the study by Kim et al.<sup>8</sup> in 2009. The maxillary second and third premolars on both sides of all animals were etched using 37% phosphoric acid gel for 15 seconds, followed by copious irrigation with water. After drying, the teeth appeared frosty white and a thin uniform coat of primer was applied on each tooth surface to be bonded which was light cured for 20 seconds. The 2 premolars were bonded together using a hybrid flowable composite resin (Hybrisun Flow, Mega Physik) and a packable hybrid composite resin (Premisa,<sup>TM</sup> Kerr) extended to the buccal surface to reinforce anchorage.

The fixed orthodontic appliance consisted of single rectangular slot buccal tubes (American Orthodontics) bonded to the buccal surface of the maxillary third premolars using a packable hybrid composite resin (Premisa,<sup>TM</sup> Kerr), and banded lower incisor edgewise brackets with welded hooks on the distal, cemented to the maxillary canines using a flowable composite resin (Hybrisun Flow, Mega Physik). A 0.016 x 0.016 inch stainless steel sectional wire was inserted passively from the canine brackets to the buccal tubes. Canines were retracted using 0.010 x 0.030 inch Sentalloy closed coil spring exerting a force of 150 gm. upon activation (Fig. 3). The force delivered by the coil spring was checked every week with the use of a tension gauge and reactivated when necessary.

### Alveolar Bone Injury

After local anaesthetic infiltration (1.8 ml Lidocaine HCL with 1:100,000 Epinephrine), cortical incisions were created on the mesiobuccal, distobuccal, and distopalatal aspect of the experimental groups. The mesiopalatal aspect was excluded from the cortical incisions due to the extremely thin palatal bone and the presence of a suture line.<sup>8</sup>

Incisions were performed using reinforced surgical blades (Paragon, No.15T) positioned on the interradicular attached

gingiva at an inclination of 45° to 60° to the long axis of the canines. The blades were gradually inserted into the bone marrow by malleting the blade holder, which gently penetrated through the 1 mm. thick overlying gingiva, cortical bone, and cancellous bone, to an estimated depth of 5 mm. (Fig.4). The surgical incisions were created 2 mm. from the papillary gingiva in order to preserve the alveolar crest, and then were extended 1 mm. beyond the mucogingival junction because of the presence of a narrow attached gingiva in cats. The blades were pulled out using



Figure 3. Canine retraction appliance.

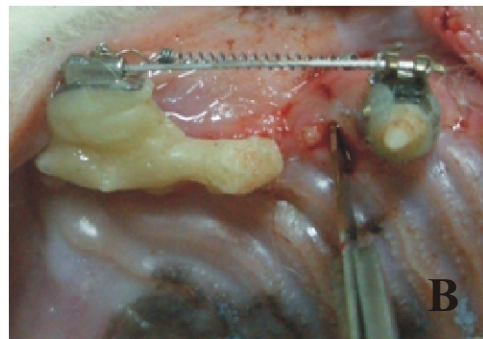


Figure 4. Direction of blade insertion.  
(A) Blade inserted > 45° to the long axis of the canine.  
(B) Distopalatal incision.

a swinging motion. Hemostasis was achieved using cotton rolls and firm pressure.

Cats were kept warm by providing a gentle heat source throughout the duration of the anaesthesia and until the cat has fully recovered. The recovering cat was placed in a warm, quiet room with soft beddings to keep them clean and comfortable, and away from other animals.

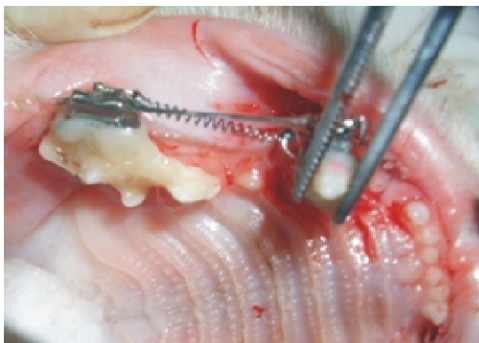
Periodic mobilization was carried out only on the maxillary canines of Group B using a cotton plier in the mesio-distal direction immediately following corticision, and the procedure was repeated every three days throughout the experimental period (Fig. 5). The investigator calibrated the force applied in order to deliver the same amount of force during periodic mobilization.

After completing the experimental procedures, a protective collar was immediately placed around the cat's neck to prevent the animal from scratching, biting and licking its body while the wounds heal, as well as to prevent damage to the orthodontic appliances.

Post-operative care included oral administration of 11 mg./kg. Clindamycin oral suspension (Dalacin C Palmitate, Pfizer) twice daily for 5 days, and 0.1 mg./kg. Meloxicam oral suspension (Petcam, Cipla) for pain, once daily for 5 days. Tooth brushing and daily irrigation with saline water using a syringe for 1 week were done to lessen the probability of infection and delayed wound healing. This was continued once a week thereafter.

### Recording Tooth Movement

The amount of tooth movement was measured using a vernier calliper, accurate to 0.01 mm., prior to the start of canine retraction, and on the 7<sup>th</sup>, 14<sup>th</sup>, 21<sup>st</sup> and 28<sup>th</sup> days thereafter. Each measurement was repeated thrice by the researcher and the mean value was obtained. The distal surface of the buccal tube and the mesial surface of the incisor bracket served as the reference points in obtaining the linear distance of tooth movement.



**Figure 5.** Mobilization of the canine in a mesio-distal direction.

### Animal Euthanasia

Only 4 animals per group were sacrificed during the 4 time intervals to describe the histological effects. A total of 8 cats were sedated using intramuscular injections of Zoletil at a dosage of 5 mg./kg. body weight. Euthanasia through intracardiac injection of 1:1 75% Magnesium Sulfate and Potassium Chloride was performed by the veterinary surgeons.

### Processing of Specimen

Tissue blocks that included the canines, the surrounding paradental tissues, and corticision site were dissected from the maxilla. These tissue blocks were fixed in a 10% neutral buffered formalin, decalcified in 10% Formic Acid Solution, dehydrated in a series of ethyl alcohol concentrations, embedded in paraffin, and longitudinally sectioned in the mesio-distal direction parallel to the direction of orthodontic force application. Three 5  $\mu$ m. sectioned slices were acquired for examination under light microscopy with hematoxylin and eosin stain. Slices were obtained from the buccal, middle and lingual surfaces of the specimens.

The bodies of the 8 sacrificed animals from whom the specimens were collected, were buried in a designated area allotted within the grounds of the Veterinary Teaching Hospital located in the University of the Philippines Diliman, while the remaining 2 cats were kept as household pets.

### Statistical Analysis

A Randomized Complete Block Design analyzed with the two-way Analysis of Variance (ANOVA) was utilized in the study to determine the difference between the rate and distance of tooth movement among the same groups and between the 2 groups with a  $p < 0.05$  level of significance. Post Hoc Test (Tukey's HSD Test) with a  $p < 0.05$  level of significance was employed for additional exploration of the difference among the means to provide specific information on which means are significantly different from each other.

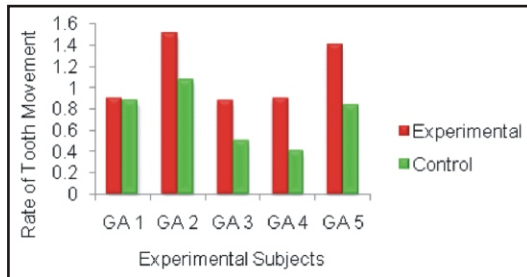
### RESULTS

A split mouth design was used in the study to determine the effect of corticision, with or without periodic mobilization, on the rate of orthodontic tooth movement and alveolar bone remodeling in 10 adult cats. Cuspid retracting appliances delivering the same magnitude of force (150 gm.) were placed on both the right and left sides of the experimental animals. A total of 20 samples were used in the study. The evaluation of tooth movement for these animals was based on a differential comparison of the right and left sides representing the experimental and control groups, respectively, and between the 2 groups.

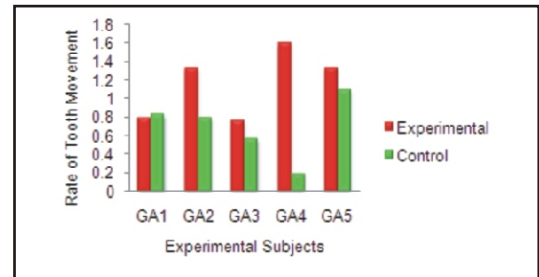
**Rate and Distance of Tooth Movement**

The rate of tooth movement after corticision on the experimental sides of Group A was 34% (mean rate: 0.15920 mm./day; mean distance: 1.11400 mm./week) faster than that of the control sides (mean rate: 0.10480 mm./day.; mean distance: 0.73400 mm./week) (Fig. 6; Tables 1-3; Appendix A). While the

experimental sides of Group B was accelerated by 40% (mean rate: 0.16660 mm./day; mean distance: 1.16600 mm./week) more as compared to the control sides (mean rate: 0.10000 mm./day; mean distance: 0.70000 mm./week) (Fig. 7; Tables 4-6; Appendix B). Both groups shared the greatest distance and most rapid rate of canine retraction ( $p < 0.05$ , Tukey's HSD Test) during the first 7 days of the experimental period.



**Figure 6.** Comparison of the Rate of Tooth Movement after 7 days in Group A.



**Figure 7.** Comparison of the Rate of Tooth Movement after 7 days in Group B.

**Table 1.** Comparison of the Rate and Distance of Canine Movement Between the Control and Experimental Sides of Group A.

Experimental Duration (days)	Mean Rate (mm./day)		Mean Distance (mm./week)	
	Control Side	Experimental Side	Control Side	Experimental Side
7 days	0.10480	0.15920	0.73400	1.11400
14 days	0.04200	0.03900	0.29250	0.27250
21 days	0.05270	0.07700	0.36667	0.54000
28 days	0.04450	0.06400	0.31000	0.45000

**Table 4.** Comparison of the Rate and Distance of Canine Movement Between the Control and Experimental Sides of Group B.

Experimental Duration (days)	Mean Rate (mm./day)		Mean Distance (mm./week)	
	Control Side	Experimental Side	Control Side	Experimental Side
7 days	0.10000	0.16660	0.70000	1.16600
14 days	0.07000	0.05625	0.49000	0.39250
21 days	0.03967	0.03333	0.27667	0.23333
28 days	0.04050	0.02550	0.28500	0.18000

**Table 2.** Two-way ANOVA of the Difference in the Rate of Tooth Movement Between the Control and Experimental Sides of Group A.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.052 <sup>a</sup>	7	0.007	5.961	0.001
Intercept	0.133	1	0.133	105.844	0.000
EXP-CON	0.004	1	0.004	2.823	0.108
WEEKS	0.044	3	0.015	11.597	0.000
EXP-CON*WEEKS	0.004	3	0.001	0.997	0.415
Error	0.025	20	0.001		
Total	0.258	28			
Corrected Total	0.077	27			

a. R Squared = 0.676 (Adjusted R Squared = 0.563)

**Table 5.** Two-way ANOVA of the Difference in the Rate of Tooth Movement Between the Control and Experimental Sides of Group B.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.063 <sup>a</sup>	7	0.009	5.807	0.001
Intercept	0.110	1	0.110	71.632	0.000
EXP-CON	0.000	1	0.000	0.252	0.621
WEEKS	0.051	3	0.017	11.003	0.000
EXP-CON*WEEKS	0.010	3	0.003	2.140	0.127
Error	0.031	20	0.002		
Total	0.264	28			
Corrected Total	0.093	27			

a. R Squared = 0.670 (Adjusted R Squared = 0.555)

**Table 3.** Two-way ANOVA of the Difference in the Distance of Tooth Movement Between the Control and Experimental Sides of Group A.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.565 <sup>b</sup>	7	0.366	5.976	0.001
Intercept	6.485	1	6.485	105.744	0.000
EXP-CON	0.177	1	0.177	2.881	0.105
WEEKS	2.139	3	0.713	11.626	0.000
EXP-CON*WEEKS	0.181	3	0.060	0.986	0.420
Error	1.226	20	0.061		
Total	12.640	28			
Corrected Total	3.792	27			

b. R Squared = 0.677 (Adjusted R Squared = 0.563)

**Table 6.** Two-way ANOVA of the Difference in the Distance of Tooth Movement Between the Control and Experimental Sides of Group B.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.062 <sup>b</sup>	7	0.437	5.812	0.001
Intercept	5.402	1	5.402	71.766	0.000
EXP-CON	0.019	1	0.019	0.251	0.622
WEEKS	2.487	3	0.829	11.012	0.000
EXP-CON*WEEKS	0.484	3	0.161	2.145	0.126
Error	1.505	20	0.075		
Total	12.950	28			
Corrected Total	4.568	27			

b. R Squared = 0.670 (Adjusted R Squared = 0.555)

No statistically significant difference was obtained when comparing the control sides of Group A and B ( $p > 0.05$ , two-way ANOVA). Post Hoc Test revealed a disparity during the third week of tooth movement when comparing the control sides of both groups ( $p < 0.05$ , Tukey's HSD Test) (Tables 7-9).

Comparison between the experimental sides of both groups showed a difference in the rate of tooth movement between the side that received only corticision (mean rate: 0.15920 mm./ day; mean distance: 1.11400 mm./ week) and the side that received corticision with periodic mobilization (mean rate: 0.16660 mm./ day; mean distance: 0.16660 mm./ week) by approximately 4.5% after 7 days (Table 10). However, none of the differences were statistically significant ( $p > 0.05$ , Tukey's HSD Test) (Tables 11 and 12).

Clinically, periodic manipulation of the maxillary canines enhanced the rate and distance of orthodontic tooth movement by the end of the entire experimental period. However, the differences between both experimental groups were unremarkable (Table 12). Statistically, differences observed on the experimental sides were only significant during the first week of tooth movement, but considering that the number of subjects decreased every week, the

sample size can affect the outcome of the results.

As shown in Table 1, a difference of 34% was observed with the experimental sides showing a higher rate and distance of tooth movement within 0 to 7 days.

Statistically, there was no significant difference found when comparing the rate of orthodontic tooth movement between the experimental and control sides of Group A ( $p > 0.05$ ). However, the two-way ANOVA test showed a marked difference during the different experimental periods of tooth movement among the two sides. Further analysis using the Post Hoc Test (Tukey's HSD Test) determined that the difference was observable during the first 7 days of testing ( $p < 0.05$ ).

No statistically significant difference was observed on the amount of tooth movement achieved between the experimental and control sides of group A. However, Post Hoc Test (Tukey's HSD Test) showed that tooth movement was significantly faster during the first experimental week.

An increase in the rate of tooth movement was observed on the experimental sides of Group B which showed a difference of 40% as compared to the control sides during 0 to 7 days.

**Table 7.** Comparison of the Mean Rate and Distance of Canine Movement Between the Control Sides of Group A and Group B.

Experimental Duration (days)	Mean Rate (mm./ day)		Mean Distance (mm./ week)	
	Control Side A	Control Side B	Control Side A	Control Side B
7 days	0.10480	0.10000	0.73400	0.70000
14 days	0.04200	0.07000	0.29250	0.49000
21 days	0.05267	0.03967	0.36667	0.27667
28 days	0.04450	0.04050	0.31000	0.28500

**Table 8.** Two-way ANOVA of the Difference in the Rate of Tooth Movement Between the Control Sides of Group A and B.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.020 <sup>a</sup>	7	0.003	2.194	0.080
Intercept	0.095	1	0.095	71.853	0.000
EXP-CON	1.498	1	1.498	0.011	0.916
WEEKS	0.018	3	0.006	4.642	0.013
EXP-CON*WEEKS	0.002	3	0.001	0.462	0.712
Error	0.026	20	0.001		
Total	0.178	28			
Corrected Total	0.047	27			

b. R Squared = 0.434 (Adjusted R Squared = 0.236)

**Table 9.** Two-way ANOVA of the Difference in the Distance of Tooth Movement Between the Control Sides of Group A and B.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.002 <sup>a</sup>	7	0.143	2.205	0.078
Intercept	4.650	1	4.650	71.633	0.000
EXP-CON	0.001	1	0.001	0.014	0.907
WEEKS	0.908	3	0.303	4.664	0.013
EXP-CON*WEEKS	0.090	3	0.030	0.464	0.710
Error	1.298	20	0.065		
Total	8.732	28			
Corrected Total	2.300	27			

b. R Squared = 0.436 (Adjusted R Squared = 0.238)

**Table 10.** Comparison of the Mean Rate and Distance of Canine Movement Between the Experimental Sides of Group A and Group B.

Experimental Duration (days)	Mean Rate (mm./ day)		Mean Distance (mm./ week)	
	Experimental Side A	Experimental Side B	Experimental Side A	Experimental Side B
7 days	0.15920	0.16660	1.11400	1.16600
14 days	0.03900	0.05625	0.27250	0.39250
21 days	0.07700	0.03333	0.54000	0.23333
28 days	0.06400	0.02550	0.45000	0.18000

**Table 11.** Two-way ANOVA of the Difference in the Rate of Tooth Movement Between the Experimental Sides of Group A and B.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	0.088 <sup>a</sup>	7	0.013	8.578	0.000
Intercept	0.150	1	0.150	102.423	0.000
EXP-CON	0.001	1	0.001	0.879	0.360
WEEKS	0.083	3	0.028	18.862	0.000
EXP-CON*WEEKS	0.005	3	0.002	1.069	0.385
Error	0.029	20	0.001		
Total	0.344	28			
Corrected Total	0.117	27			

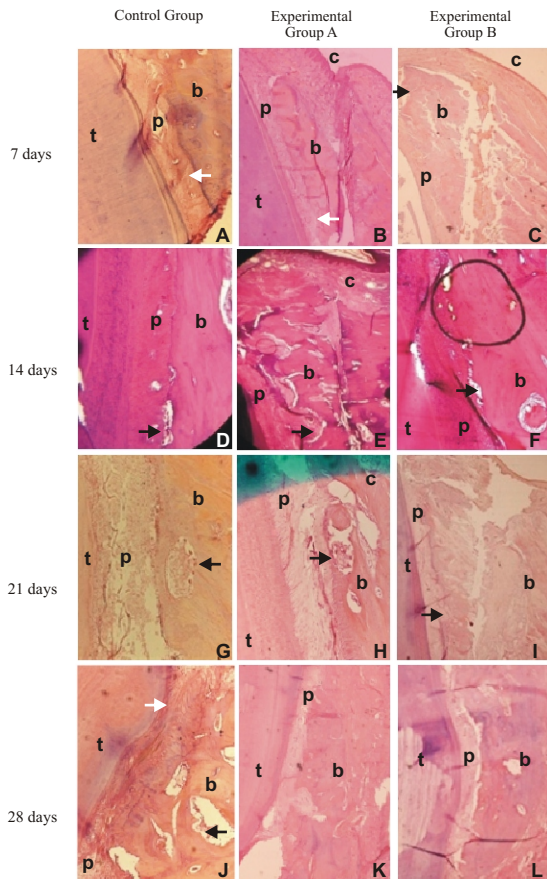
b. R Squared = 0.750 (Adjusted R Squared = 0.663)

**Table 12.** Two-way ANOVA of the Difference in the Distance of Tooth Movement Between the Experimental Sides of Group A and B.

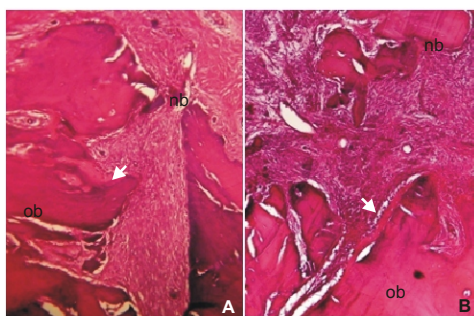
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.311 <sup>a</sup>	7	0.616	8.592	0.000
Intercept	7.367	1	7.367	102.783	0.000
EXP-CON	0.064	1	0.064	0.890	0.357
WEEKS	4.061	3	1.354	18.888	0.000
EXP-CON*WEEKS	0.231	3	0.077	1.074	0.382
Error	1.433	20	0.072		
Total	16.857	28			
Corrected Total	5.744	27			

b. R Squared = 0.750 (Adjusted R Squared = 0.663)

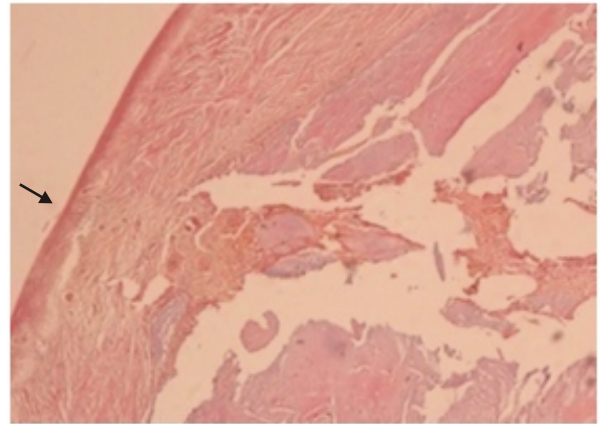




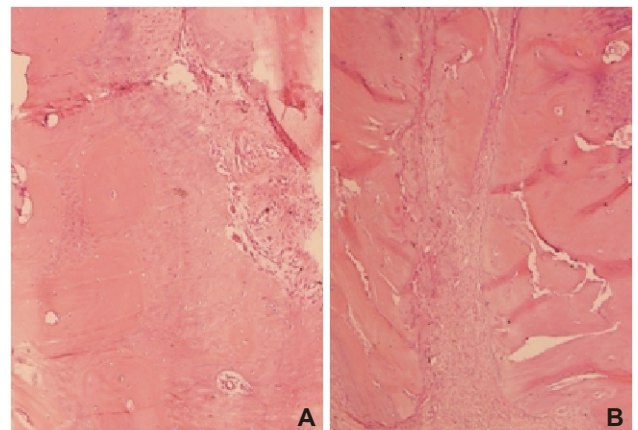
**Figure 8.** Microphotographs of periodontal tissue at pressure sides with hematoxylin and eosin (H & E) stain: (A) Control Group on day 7 (100x), (B) Experimental Group A on day 7 (40x), (C) Experimental Group B on day 7 (40x), (D) Control Group on day 14 (100x), (E) Experimental Group A on day 14 (40x), (F) Experimental Group B on day 14 (100x), (G) Control Group on day 21 (100x), (H) Experimental Group A on day 21 (100x), (I) Experimental Group B on day 21 (40x), (J) Control Group on day 28 (100x), (K) Experimental Group A on day 28 (40x), (L) Experimental Group B on day 14 (40x). The compressed PDL in the control group contained more hyalinized tissue, resulting in undermining resorption. Black arrow means the direction of resorption. White arrow means hyalinized tissue. (t indicates tooth; p, PDL; h, hyalinization; b, alveolar bone; c, corticision).



**Figure 9.** Microphotographs of the corticision site with H & E stain (100x). Experimental Group A on day 14. (A) Mesiobuccal area. (B) Distobuccal area. The surgical gap was filled with fibrous connective tissues and granulation tissues. Numerous plump osteoblasts lined the margin of the newly formed bone. Arrows indicate new bone formation. (ob, old bone; nb, necrotic bone)



**Figure 10.** Microphotographs of the corticision site with H & E stain (40x). Distobuccal area of experimental Group B on day 7. Surgical gap was filled with numerous necrotic bones and inflammatory cells. Arrow indicates the thin epithelium connecting the soft tissue injury.

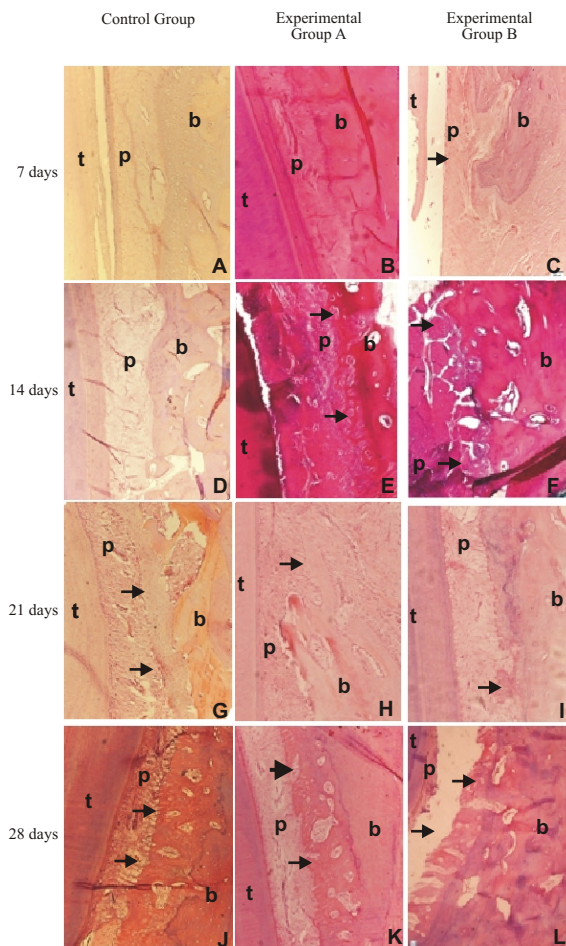


**Figure 11.** Microphotographs of the corticision site with H & E stain. Experimental Group B on day 14. (A) Mesiobuccal area (100x). Bone resorbing cells present on the periphery of the bone defect. (B) Distobuccal area (40x). The surgical gap was filled with fibrous connective tissues and granulation tissues.

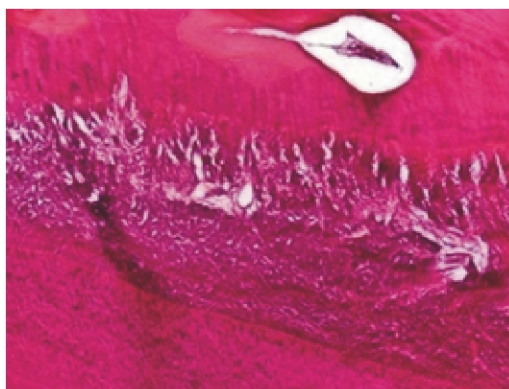
Analysis using the two-way ANOVA shown in Tables 5 and 6 found no significant difference when comparing the rate and distance of tooth movement between the experimental and control sides of Group B ( $p > 0.05$ ). However, a statistically significant difference was found between the four experimental periods. Further analysis using the Post Hoc Test (Tukey's HSD Test) showed that orthodontic tooth movement was able to attain the longest distance during the first week of translation ( $p < 0.05$ ).

The results of the two-way ANOVA test presented in Tables 8 and 9 showed no significant differences in the rate and distance of orthodontic tooth movement between the two control groups

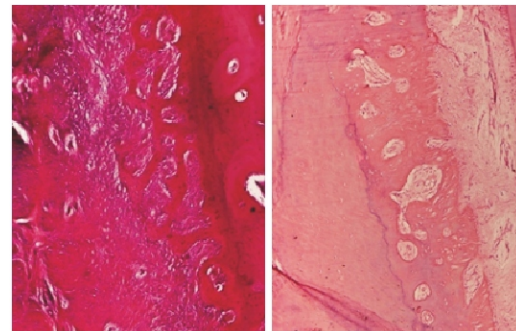




**Figure 12.** Microphotographs of periodontal tissue on tension side with H & E stain: (100x): (A) Control Group on day 7. (B) Experimental Group A on day 7. (C) Experimental Group B on day 7. (D) Control Group on day 14. (E) Experimental Group A on day 14. (F) Experimental Group B on day 14. (G) Control Group on day 21. (H) Experimental Group A on day 21. (I) Experimental Group B on day 21. (J) Control Group on day 28. (K) Experimental Group A on day 28. (L) Experimental Group B on day 28. Arrows indicate areas of bone formation. (t indicates tooth; p, PDL; b, alveolar bone.)



**Figure 13.** Stretched Sharpey's fibers of experimental Group A on day 14 stained with hematoxylin and eosin (H&E) dyes (100x).



**Figure 14.** Spike-like bone formation with multiple newly developed marrow spaces associated with rapid tooth movement (100x). (A) Experimental Group A at 14 days. (B) Experimental Group B at 28 days.

( $p > 0.05$ ). The Post Hoc Test (Tukey's HSD Test) however revealed a difference during the third week of orthodontic tooth movement.

Results of the two-way ANOVA test presented in Tables 11 and 12 was not able to show any significant difference in the rate and distance of tooth movement when the experimental sides of Group A and B were compared. However, further analysis using the Post Hoc Test (Tukey's HSD Test) showed a significant difference in the rate of orthodontic tooth movement during the first experimental week.

### Histological Changes in the Periodontal Ligament Space

#### Pressure Side

Histopathologic evaluation of the slides stained with hematoxylin and eosin demonstrated various morphological changes of the periodontal ligament (PDL) over time. Light microscopic findings of the tissues surrounding the orthodontically moved canines on day 7 showed areas with hyalinization on the compression side, but without signs of resorption (Fig. 8A). On day 14, undermining resorption occurred while frontal resorption was manifested on some areas (Fig. 8D). On day 21, the resorptive activities were widespread with areas of local unresorbed bundle bone (Fig. 8G). On day 28, a small area of hyalinization was detected with numerous spaces within the alveolar bone representing resorption pits (Fig. 8J).

In the corticision group on day 7, the compressed PDL contained less hyalinized tissue compared to the control group. Areas representing resorption pits were evident. The soft tissue injury to the attached gingiva was repaired by stratified squamous epithelium, though the underlying connective tissue stroma was still disorganized with hemorrhage extending along the length of the surgical gap. Necrotic bones were present on the periphery (Fig. 8B). On days 14 to 21, wide areas of bundle bone were resorbed through frontal resorption, however, slight hyalinization still remained (Fig. 8E, 8H). The surgical gap was very fibrotic and filled with granulation tissues (Fig. 9). On day 28, osteoclastic

activity was still dynamic and without any signs of hyalinization. Remodeling of new bone continues to replace the fibrous connective tissue (Fig. 8K).

In the corticision with periodic mobilization group, hyalinized tissues were absent and resorption pits were visible (Fig. 8C). The squamous epithelial attachment was thin and the connective tissue stroma disorganized. The surgical gap was still hemorrhagic and filled with numerous necrotic bone on day 7 (Fig. 10). On day 14, osteoclastic activity was observable together with limited area of hyalinization (Fig. 8F). Bone resorbing cells appeared on the periphery of the bone defect and the gap was filled with granulation and fibrous connective tissues with actively forming bone matrix on some areas (Fig. 11). On day 21, hardly any hyalinized tissues were present and resorption pits were seen adjacent to the compressed PDL (Fig. 8I). Fibrous tissues and newly formed bone continued to fill the gap. On day 28, there was absence of hyalinization and bone resorbing activity (Fig. 8L). Some granulation tissue was still detected within the fibrous connective tissue.

### Tension Side

Light microscopic findings of the control group on day 7 showed areas with stretched collagen fibers and disorganized collagenous tissues in the PDL of the tension side. Band-like osteoid formation associated with slow tooth movement was also evident (Fig. 12A). On days 14 to 28, proliferative PDL cells activity and increase in osteoid formation were observed (Fig. 12D; 12G; 12J).

In both the experimental groups on days 7 to 14, spike-like osteoid formation and stretched Sharpey's fibers associated with rapid tooth movement and increase PDL cell activity can be seen (Figure 12B; 12C; 12E; 12F and 13). On days 21 to 28, multiple marrow space associated with newly formed bone were distinguishable from the old lamellar bone (Fig. 12H; 12I; 12K; 12L and 14).

The histological findings from the study are not absolute due to technical errors during the decalcification process. A highly concentrated decalcifying solution was mistakenly used dispensed by the laboratory technician which damaged significant parts of the third and fourth week specimens. To compensate for the damages, serial sectioning of the samples was employed in order to obtain acceptable sections that could be interpreted by the pathologist.

### Subject's Weights and Behaviour

The experimental subjects displayed different kinds of behaviour. Majority of the subjects remained friendly and docile throughout the experimental period except for a few (2) that became aggressive during manipulation. Aggression came in the form of hissing, biting and scratching, despite conditioning of the animals.

After appliance installation, there was an initial reduction of less than 10% of the experimental subjects' weight for the first 2 weeks, except for 1 (GB2: 10.67%). In order to address the weight loss, forced feeding was done by softening the pellets and feeding the cat through a syringe. This intervention gradually resulted in the stabilization of their weights by the end of 4<sup>th</sup> week (Appendix C).

None of the cats showed any clinical signs of swelling or displayed healing problems after corticision. All the appliances remained intact and in good condition except for those placed on the two subjects during the first day. All four buccal tubes were rebonded the following day and new measurements were obtained.

### DISCUSSION

This study was designed to look particularly at the bone turnover dynamics of the lamina dura and the rate of tooth movement following surgical wounding of the cortical bone. Histological studies of the tissues surrounding the maxillary canines of the cats, displayed features of tissues that had been subjected to orthodontic force, confirming that orthodontic tooth movement had been established.

The data from this study showed large individual differences in the rate of orthodontic tooth movement. Differences were observed within and between the groups, therefore it is safe to assume that in some of the experimental subjects, tooth movement progressed slowly, because the optimum force for that animal was not attained.<sup>122</sup>

In tooth movement, the application of orthodontic force alone is a stimulant sufficient to trigger a mild to moderate regional acceleratory phenomenon<sup>78,85</sup> activity adjacent to the periodontal ligament, which is known as "undermining resorption." However, when tooth movement is combined with alveolar bone surgery, such as corticision, this would induce an intense level of regional acceleratory phenomenon activity by which tissue forms 2 to 10 times faster than the normal regional regeneration process.<sup>11,78</sup>

From the result of the study, orthodontic forces combined with corticision, with or without periodic mobilization, produced substantially greater tooth movement than orthodontic forces alone. Comparison between the experimental and control sides of Group A and B demonstrated statistically significant difference only during the first experimental week. This was confirmed in a study by Iino et al.<sup>123</sup> and Sanjideh et al.<sup>124</sup> who found that the initial acceleratory phase was much greater on the corticotomy side than on the control side, with differences in tooth movement evident during the first 2 weeks.

Researchers<sup>7,10,123,125</sup> have found that the regional acceleratory phenomenon involves a temporary decrease in alveolar bone density, which increases the release of calcium. This in turn triggers rapid bone turnover adjacent to the site of injury, leading to less hyalinization of the periodontal ligament on the alveolar wall. Hence, rapid orthodontic tooth movement was facilitated during

the first week by bypassing the waiting time to eliminate these areas.

In the present study, no significant difference was observed when comparing the rate and distance of tooth movement of Control Group A and B. This finding demonstrates that the main effect of the regional acceleratory phenomenon is limited to the region of the stimulus, which corroborates with the clinical observation of Bogoch et al.<sup>9</sup> Their finding shows that four weeks after performing an incomplete osteotomy of the medial femoral condyle of the rabbits, stimulation of bone formation was not evident in the cancellous bone of the lateral condyle. A similar finding was also demonstrated by Teixeira et al.<sup>126</sup> An increase in the bone remodeling activity and osteoporosity was found in response to bone perforations around a mesially tipped maxillary molar of a rat. This activity was extended to the tissues surrounding the loaded tooth, but was limited enough not to reach the contralateral side.

During the third week of orthodontic tooth movement, a slight disparity was observed on the control side, with Group A slightly higher than Group B. This discrepancy found on the duration of the lag phase may be attributed to individual variations in the density and metabolic activities of the alveolar bone, and the extent of hyalinized (cell-free) areas on the periodontal ligament.<sup>25,127,128</sup> Differences on the level of cytokines and growth factors (e.g., PGE2, IL-1 $\beta$  and TGF- $\beta$ 1) which were involved in the remodeling processes might also potentially affect the rate of tooth movement observed clinically.<sup>26-29</sup>

It was stated by Frost<sup>129</sup> that the intensity and duration of the RAP are proportional to the extent of injury. Clinically, an increase in the rates of tooth movement by approximately 34% and 40%, from Group A and Group B respectively, were noted in the experimental sides during the 7-day experimental period. These were consistent with findings from previous studies that shows a one-third to almost one-half reduction in traditional orthodontic treatment time when utilizing bone surgery in conjunction with orthodontic therapy.<sup>6,130</sup>

A study done by Haij<sup>131</sup> compared the orthodontic treatment duration of nonextraction, extraction and corticotomy facilitated non-extraction therapies in eliminating mandibular anterior dental arch crowding. The result shows that the mean active treatment time for the corticotomy-facilitated group averaged 6.1 months, versus 18.7 months required for non-extraction orthodontics and 26.6 months for extraction therapy. Sanjideh et al.<sup>124</sup> also demonstrated the same relationship indirectly by showing that extractions with corticotomies produce greater tooth movements than extractions alone. These prove that orthodontic treatment time could be reduced with techniques that accelerate space closure.<sup>132</sup>

In the study, the rate and distance of tooth movement on the experimental side of Group B was slightly accelerated in comparison to Group A. This is similar to a previous study<sup>124</sup> that showed only a minor difference in the rate of orthodontic tooth movement following a second corticotomy procedure (2 mm. vs. 2.5 mm.). The difference in the rate of tooth movement might be

brought about by the repeated mobilization of the tooth that was carried out every 3 days in the experimental subjects. These triggers a response at the site of injury, intercepting the lamellation process of woven bone and creating microcracks that tears the cell processes between neighbouring osteocytes.<sup>133,134</sup> Clinically, periodic mobilization should be carried out every 2 weeks<sup>8,103,135,136</sup> to take advantage of the three- to four-month window of opportunity to rapidly move the teeth through the demineralised bone matrix before the bone has sufficiently healed, and tooth movement returns to normal.<sup>11,78</sup>

Although the additional mobilization delays the healing process at the site of injury in comparison to corticision alone, it seems ineffective in prolonging the regional acceleratory phenomenon (RAP).<sup>8</sup> In this study, insignificant difference was observed between the two experimental groups. It seems impractical to warrant further mobilization considering the additional discomfort brought about by frequent orthodontic manipulation, additional expenses, and unnecessary waste of time for both the patient and the dentist.

In both experimental Groups A and B, tooth movement decreases following the initial acceleration, with the rates on the experimental sides approaching those on the control sides at the end of the experimental period. It is reasonable to expect that the rate of tooth movement would slow down as bone density increased, since the anabolic levels of the regional acceleratory phenomenon increases through time. These findings supported those of several authors<sup>123,137,138</sup> who were also not able to identify differences in the rates of tooth movement between the corticotomy and the control sides at the end of their experiments.

Aging results in various changes to the periodontal tissues. The critical adaptive tissue for the expression of tooth movement is the periodontal ligament (PDL). It is a soft connective tissue envelope that separates the tooth from the alveolar bone. It is highly cellular and contains an intricate network of blood vessels and nerve endings. The majority of the PDL cells are fibroblasts, but some of this fibroblast-like cells are actually osteoprogenitor cells.<sup>139</sup> The width of the PDL varies at different parts of the roots,<sup>140</sup> with measurements of the periodontal space in humans revealing an approximate width of 0.25 mm. to 0.5 mm.<sup>19,141</sup>

With increasing age, the periodontal ligament becomes narrower and more irregular due to cementum formation<sup>142</sup> and as the surfaces of the cementum and alveolar bone assumes a rough, scalloped appearance.<sup>37,38,143</sup> This could account for the reason why hyalinized (cell free) tissues are easily formed in adults.

A previous study<sup>19</sup> had shown that during the initial phase of orthodontic tooth movement, a small amount of tooth displacement occurs within the alveolar socket following the application of force. This progressive displacement of the tooth relative to its osseous support stops in about 1 to 3 days, or can be as long as a week, due to the presence of hyalinized tissues.<sup>87</sup> In an attempt to reduce the tissue resistance, corticision was employed in order to control the microenvironment of the alveolar bone. Corticision provides an



instigating stimulus for the catabolic and anabolic remodeling activity of the periodontium.

The total treatment duration of 4 weeks was used in the study in order to observe bone metabolism for a minimum of one remodeling cycle.<sup>25</sup> Microscopic analysis of the decalcified maxillary canine and surrounding tissues of the cats using Haematoxylin and Eosin stains were used in order to distinguish the different biological structures.

Histological findings on the pressure side of experimental Group A showed rapid removal of the hyalinized tissues by direct bone resorption. Bone formation on the tension side was noticeable as early as 1 week and with more apposition areas observed by the end of the fourth week in comparison to the control groups. These findings were consistent with previous reports in which surgical injury to the rat's alveolus induced a three-fold increase in the anabolic and catabolic activity immediately adjacent to the site,<sup>11</sup> and was 3.5 fold higher in the cat's alveolus following corticision.<sup>8</sup>

By contrast, in the control side with orthodontic tooth movement alone, this compression in the limited areas of the periodontal membrane inhibits vascular circulation and cell differentiation, causing vascular and cellular degradation which lasted for several days. Tooth movement slows down, resulting in the clinical manifestation of a delay period, until resorption of the hyalinized tissue and adjacent alveolar bone was achieved by bone marrow osteoclastic precursors recruited to the periphery of the necrotic periodontal ligament.<sup>19,87,144,145</sup> Histological studies suggest that the duration of this lag phase usually lasts two to three weeks but may take as long as ten weeks.<sup>6,25,127</sup>

In the present study, hyalinized tissues were found not only during the phase of arrest but also during the acceleration phase at the 28<sup>th</sup> day in the control sides. Histological findings from a study done by Iino et al.<sup>123</sup> shows that hyalinization was only observable at 1 week on the experimental side in comparison to the sham side, wherein hyalinization can be seen from 1 to 4 weeks after corticotomy, which are consistent with the findings of our study. This suggests that the development and removal of necrotic tissue is a continuous remodeling process during tooth displacement rather than a single event.<sup>146</sup>

Hyalinization is caused by anatomic and mechanical factors and is unavoidable even with light orthodontic forces. However, they appeared earlier and are more extensive if higher forces are applied,<sup>147</sup> though there seems to be no clinical significance for bodily tooth movement as in the present study. This may be explained by the fact that forces are more equally distributed during translation than during tipping, which reduces the risk of hyalinization<sup>23</sup> and encourages direct bone resorption as seen on the control sides at 14 days.

Bone repair occurs by different specific mechanisms primarily dependent on the biophysical environment. In this case, bone repair occurs by primary healing. A different process of direct bone healing called gap healing has been observed in gaps less than 800 um. to 1mm. Here, the fracture site fills directly by

intramembranous bone formation, before undergoing secondary bone reconstruction.<sup>148</sup> Although the various repair processes used different normal cells and tissues, the eventual bone synthesis is always mediated by the surface and mesenchymal osteoblasts and through the woven and lamellar matrix conformations that eventually restores the tissue to its original physical and mechanical properties, influenced by a variety of systemic and local factors.<sup>88</sup>

A week following surgery, the incision gap was hemorrhagic and filled with inflammatory cells that infiltrates the bone. This results in the formation of a soft granulation tissue, ingrowth of vascular tissue and migration of mesenchymal cells into the site of injury.<sup>88,92,98</sup>

During the repair stage two weeks after the injury, some of the necrotic bones were resorbed by osteoclasts, and fibroblasts laid down a connective layer of stroma that helped support the vascular ingrowth. Collagen matrix was laid down as it progressed, while osteoid was secreted and woven bones were produced. This was characterized an irregular trabecular formation that filled in the gaps at the end of four weeks. In the remodeling phase, this process may occur over months to years and consists of restoring the gap to the point of no indication as to where the fracture or injury was located.<sup>88,92,98</sup>

Cats are largely-solitary species and have not developed the complex visual signalling that is typical of species that have had a long evolutionary history of social living. As a result, lacking signals for avoiding conflict such as appeasement, and post-conflict mechanisms such as reconciliation, they do not form distinct dominance hierarchies. Hence, cats were housed individually in order to avoid aggressive encounters with each other.<sup>149</sup>

Adult cats ranging between 1 to 6 years old were chosen for the study. This age is comparable with late adolescence to adulthood in human beings.<sup>118-120</sup> Studies have shown that the biological possibilities for tooth movement is delayed in adult patients due to the decreased proliferative activity in the periodontal ligament and alveolar bone<sup>44,150-152</sup> These contributed to the longer treatment duration caused by a delay in the initial response during orthodontic treatment.<sup>35,36,41</sup> Corticision was thus utilized to facilitate orthodontic tooth movement and to overcome some shortcomings of conventional orthodontic treatment.

As reported by Debbane<sup>153</sup> in 1958, cats are excellent animals for experiments in orthodontic research. The experimental subjects used in the study proved to be quite satisfactory.<sup>8,30,154</sup> The shape and accessibility of the cat's teeth facilitated the placement and manipulation of the canine retracting appliances, as well as minimized the interferences with orthodontic tooth movement that are normally present because occlusion were negligible in cats. This lack of canine interdigitation, and wide spaces mesial and distal to the maxillary canines facilitated bodily movement of these teeth.

A downside in using these experimental subjects for research

purposes is the difficulty in accurately determining the age of the cats. The researcher and the veterinary surgeons have to rely on approximations based on the clinical, dental and behavioural changes observed in the animals. Further difficulty was encountered by the researcher in handling some of the cats, due to their unpredictable response. A wide range of individual responses were being exhibited by the experimental subjects for almost two weeks, following insertion of the orthodontic appliances. Some cats appeared passive, reluctant to move and preferred to sleep. Others, sought after human affection, while a few actually avoided being petted and became aggressive when orthodontic manipulations were carried out. These behavioural changes could be triggered by pain from orthodontic tooth movement or discomfort from having a foreign object inside the oral cavity.

One week after appliance insertion, weight decrease was immediately noticeable. Discomfort from the orthodontic appliances and forces applied to the teeth could be factors contributing to the weight loss. Canker sores located in the mucobuccal fold areas were also evident in almost all subjects. The decline in weights continued until the second week before it gradually improved and stabilized on the fourth week, as the subjects became accustomed to the appliance and food intake resumed back to normal. Weights at the end of the experimental period were almost comparable to their baseline measurements, and were even higher for some. The observed reduction of more than 10% body weight in one of the subject was probably due to individual differences in the level of pain tolerance.

Evaluation of results from human studies had shown that varying degrees of adaptation to pain and discomfort occurred during the first 3 to 7 days after placement of orthodontic appliances and separators.<sup>155-159</sup> There is no doubt that the perception of orthodontic pain is part of an inflammatory reaction causing changes in the blood flow of the periodontal ligament resulting in the release of various chemical mediators (e.g., prostaglandins, cytokines) that elicits a hyperalgaesic response following the application of orthodontic forces.<sup>160</sup> At this time, no objective data exist that describe the severity of postoperative pain following surgical procedures (e.g., corticision, segmental corticotomy and piezocision). On the basis of the few case reports available, patient only described of minor discomfort.<sup>161-164</sup>

All appliances were checked daily, which remained intact and in good condition, until the end of the experiment. The only exception was with the first two subjects, in which four of the buccal tubes were debonded a few hours after the experimental subjects gained consciousness from general anaesthesia. The animals probably felt discomfort from having a foreign object inside the mouth and tried to remove it with their paws. The appliances were reinstalled the following day, new measurements were obtained and protective collars were placed. In order to allow some degree of comfort to the cats, the use of protective collars was not included in the original decision.

The combination of surgical-orthodontic therapy clearly

increases the rate of tooth movement and this can be use as an adjunct during the initial leveling and alignment stage or during space closure following premolar extractions.<sup>165,166</sup> However, a negative aspect of the corticision procedure is the extensive hammering involved in performing the cortical incisions. For some patients, this might appear too aggressive. In addition, benign paroxysmal positional vertigo and dizziness had been reported following the use of hammer and chisel in the maxilla.<sup>167</sup> Nevertheless, orthodontic treatment was accelerated. It is assumed by the researcher that this reduction in the duration of treatment time would increase the acceptability of orthodontic treatment for adult patients who would otherwise decline therapy.

## CONCLUSIONS

Corticision with and without tooth mobilization resulted in a significantly higher rate of canine retraction by approximately 34% and 40% as compared to the control sides on day 7. On the other hand, the corticision with periodic mobilization group resulted in a 4.5% higher rate of tooth movement as compared to corticision alone on day 7, but is not significantly different. The rate observed between the control groups showed no significant difference at all time interval.

For the histologic findings, presence of osteoclastic activity can be seen as early as 7 days on the pressure side of the corticision with tooth mobilization group. Higher osteoblastic activity was detected on the tension side of both Experimental Groups as compared to the Control Groups. Hyalinized tissues were observed from days 7 to 28 in all groups. However, hyalinization was more abundant in the Control Groups. This suggests that the development and removal of necrotic tissue is a continuous remodeling process during tooth displacement rather than a single event.

This study suggests that the Corticision technique, with and without periodic mobilization, in conjunction with traditional orthodontic therapy is a promising procedure for accelerating orthodontic treatment time. Although the sample size used in the study were adequate, results from this study will still need to be ascertained using a larger sample size before definitive conclusions can be made.

At this time, there are no data suggesting that any specific depth and extent of corticision is considered superior in increasing the rate of tooth movement. No data also exist that shows immediate loading following surgical intervention is the best treatment protocol.

Because the Corticision technique is a relatively new clinical procedure, evidence presented in support of this was mostly based on case report studies, which is considered weak evidence to support the purported advantages. A long term controlled clinical and histological studies are still needed to investigate status of the periodontium, pulpal vitality, root resorption and especially post-retention stability after treatment.



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# Re-establishing a Physiologic Vertical Dimension for an Overclosed Patient\*

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Derek Mahony has spoken to thousands of practitioners about the benefits of early interceptive orthodontic treatment. His lectures are based on the positive impact that the combined fixed and functional appliance treatment approach has had on his orthodontic results and the benefits this philosophy provides from a practice management viewpoint.

He has been seeing an average of 250 patients a week for the past decade and has gained a vast amount of experience, which he takes great joy in sharing with his students. His stimulating, step-by-step approach has been featured in keynote presentations at leading Orthodontic meetings, including the International Orthodontic Summit, the International Association of Orthodontics, and the American Association of Orthodontics Sessions.

## Introduction

The term *neuromuscular occlusion* has become associated with certain limited methodologies that are used to obtain a muscle-compatible occlusal relationship. In reality, there are several different approaches that can be used to determine a "neuromuscular" maxillo-mandibular relationship, even with a fully edentulous case. Within each method, however, the common basis for all muscle-oriented approaches involves first determining the resting length of the masticatory muscles.

Historically, opening the bite has been considered hazardous and/or foolhardy by many dentists and with good reason. Arbitrary opening of the bite, especially when accomplished strictly on an articulator, can result in a difficult, uncomfortable and unappreciative patient. Some dentists have recommended against ever opening a bite, perhaps after an especially troublesome experience with a patient.

In spite of the risks, there are some advantages associated with opening an over-closed bite. The identification can be traced back at least 70 years to an ENT physician, Dr. J. B. Costen.<sup>1-3</sup> Dr. Costen discovered, perhaps quite by accident after referring many of his symptomatic, edentulous patients to a local dentist for new dentures, that many returned with their head and ear pain symptoms greatly relieved. His publications were positively received at the time and, in fact, what we refer to today as temporomandibular disorders (TMDs) were originally referred to as "Costen's Syndrome." While we know today that many TMD patients are not over-closed, over-closed patients do often exhibit some of the signs and symptoms commonly associated with TMD. Thus, although over-closure in and of itself is not pathognomonic of TMD, it should be considered as a risk factor.

The use of the patient's own muscles to determine the vertical dimension of occlusion was already being explored in the 1940s by people like orthodontist John R. Thompson.<sup>4</sup> Sears<sup>5</sup> introduced the concept of the "Pivot Appliance" in the 1950s, which was designed to open the bite enough to allow the patient's muscles to reposition

the mandible. Following their lead, others<sup>6-28</sup> have subsequently evolved the current array of neuromuscular registration methods presently in use. At the same time several studies<sup>29-32</sup> have demonstrated that a muscle-determined position, although similar, is not identical to centric relation.

## Common Signs and Symptoms of Over-closure

When asked, over-closed patients often report symptoms such as frequent headaches, dull pain of the elevator muscles and pain or stiffness in their neck muscles. Ear stuffiness, tinnitus and/or vertigo are also commonly reported. A more subtle symptom, less often reported, is frequent gastrointestinal distress in various forms that has no clear, identifiable cause. This may also be accompanied by a report of difficulty in chewing and/or swallowing. An overclosed patient will usually report several, but not all, of the following symptoms.

1. Frequent headaches with no identifiable cause
2. Ear stuffiness with no indication of ear pathology
3. Difficulty in chewing tough foods
4. Difficulty or discomfort in swallowing
5. Frequent gastrointestinal distress
6. Vertigo
7. Tinnitus
8. Persistent dull pain in masticatory elevator muscles
9. Neck pain or stiffness
10. Possible increased wear of incisor teeth

Under examination, a number of signs indicating over-closure may appear. These include; 1) a measured freeway space greater than 3 mm, 2) EMG or visual identification of a tongue-thrust swallow, 3) the appearance of less than fully erupted molars, 4) a deep curve of Spee, 5) one or more posterior edentulous spaces, 6) lingually tipped mandibular molars, 7) EMG identification of elevator muscle hyperactivity at rest of more than 2.0 microvolts

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average (or 2.2 microvolts RMS), 8) worn and shortened teeth (there is no scientific evidence that human teeth "grow out" in response to wear in the way that elephant's teeth do), 9) horizontal skin creasing and saliva weeping at the corners of the mouth, 10) a so-called "Shimbashi" measurement (in centric occlusion) of less than 16 mm from the cemento-enamel junction of the maxillary central incisor to the cemento-enamel junction of its opposing mandibular tooth and 11) long-term chronic internal derangement of the TM Joint(s). However, patients rarely seek dental treatment for any of these objective signs. Instead, they are more likely to seek rehabilitative treatment for headache, jaw-ache, ear-ache, difficulty in chewing/swallowing or for purely esthetic reasons. In other cases they are unaware of their condition, apparently due to their excellent adaptability. In the over-closed patient the "reason" for treatment, either cosmetic or functional, is often dependent more on his/her individual adaptability than on the dental conditions present. While some signs simply indicate the "progress of the destruction" that a pathological maxillo-mandibular relationship fosters, other signs may indicate a successful adaptation.

1. Freeway space > 3 mm [if pain level is low, it is an adaptation, otherwise it is not]
2. Tongue thrust swallow [if full arch tongue thrust, usually a successful compensation]
3. The appearance of less than fully erupted molars [tongue inhibition of natural eruption]
4. A deep curve of Spee [often associated with one or more missing molars or a deep anterior overbite with retroclined upper incisors]
5. One or more posterior edentulous spaces [leads to deep curve of Spee]
6. Lingually tipped posterior teeth [tongue thrust during swallow, restricted maxillary arch]
7. Hyperactivity of elevator muscles at "rest." [an adaptation, successful if no elevator muscle pain]
8. Worn/short teeth, abfractions (ground off) [not a successful adaptation]
9. Skin creasing at corners of mouth [may appear as aesthetic problem only, not an adaptation]
10. Saliva weeping at corners of mouth [an esthetic and functional problem, not an adaptation]
11. CEJ (cemento-enamel junction) to CEJ in C.O. < 16 mm. [less than the normal adaptive range]
12. Internal derangement(s) of the TMJ [if no degeneration, may be a successful adaptation]

### Maxillo-mandibular Bite Relationships

#### Centric Occlusion (CO = habitual)

The maxillo-mandibular position of maximum intercuspatation

is most often the dental treatment position, primarily by default. This is of necessity whenever single tooth preparations or small restorations are involved, since they must fit within the patients existing occlusal scheme. It is only at times of major reconstructive, orthodontic and/or surgical treatments that the option of opening a bite or establishing a new maxillo-mandibular relation may present itself. However, many clinicians still prefer to "play it safe" and retain the existing habitual (CO) maxillo-mandibular relationship, even during major rehabilitative procedures. By definition, the use of centric occlusion as a treatment position excludes re-establishing a proper vertical dimension in an over-closed patient. However, if the patients condition is actively deteriorating this may not be a safe option at all, as the continued physiologic breakdown may lead to failed dentistry and/or a flair up of craniofacial pain.

#### Centric Relation (CR)

The concept of centric relation has a very long history and was originally devised, at least in part, to accommodate the use of articulators during prosthodontic treatment. Although we now know that the jaw doesn't function like a hinge, originally it was convenient to make that assumption when using articulators to make prostheses. Today, one clear difference between centric relation procedures and strictly muscle-oriented methodologies is the priority given by CR methods to evaluating the function of the temporomandibular joints. Typically, centric relation operators give first priority to establishing stable joint function, while muscle-oriented (neuromuscular) approaches tend to focus almost exclusively on muscle comfort.

#### Muscle-related Centric (MC)

In general, muscle-oriented approaches consider joint position and/or stability secondary to muscle function. In the extreme, it is simply assumed that creating "happy muscles" will automatically provide good or at least adequate joint function. In a more practical view, both joint function and muscle function are seriously evaluated and, when indicated, a compromise is sought to provide both joint and muscle compatibility. This represents an approach that bridges the gap between strict CR and rigid MC approaches. Consequently, a variety of methods have evolved to capture and establish a muscle-related centric position, while maintaining favorable joint function.

#### The requirements of proper Neuromuscular Occlusion (NMO)

The first step in all approaches to NMO requires inducing relaxation in the masticatory musculature, however, there is no rational excuse for not evaluating TM joint function prior to beginning the process. This can be accomplished quickly and easily with Joint Vibration Analysis (JVA see figure 1.), or with

more expensive and invasive imaging such as MRI. Muscle relaxation can be aided by Ultra-Low Frequency TENS (ULF-TENS, see Figure 2.), an Aqualizer, soft music or any other technique that reduces the resting hyperactivity of the masticatory muscles. Surface electromyography (see figure 3.) is useful for making a quantitative determination whether relaxation has occurred or whether resting muscle hyperactivity still exists.



**Figure 1.** BioJVA\* testing for normal TM joints



**Figure 2.** BioTENS,\* a ULF TENS unit used for muscle relaxation



**Figure 3.** BioEMG II\* for monitoring rest position and testing muscle function against the new bite

Needles and/or fine wire electrodes not only make relaxation less likely, they record a more localized signal that is less representative of overall muscle activity. However, needle EMG electrodes are required when one is seeking to differentiate a myopathy from a neuropathy. Using the relaxed rest position of the mandible, with respect to the maxilla as a reference, a clinician can select a vertical dimension that allows adequate freeway space, yet avoids overclosing the bite. There are several methods currently used for selecting the treatment vertical. Each has its own rationale and advantages, but all of them benefit from objective diagnostic aids to ensure the best compromise between optimum joint, muscle, and tooth function.

### Several muscle-oriented bite registration techniques

#### The Wax Swallow Bite Registration

A physiologic, muscle-oriented, vertical dimension can be obtained by means of the swallowing reflex technique originally proposed by the late Dr. Willie May. Currently, the *wax swallow bite* technique, developed by James Carlson, is a simple, direct close approximation of a muscle-related bite registration. Small pillars of soft wax are placed on the first molars, then the patient is instructed to swallow several times. Subsequently, fast-curing impression material is injected around the arch to firmly establish

the maxillo-mandibular relationship. Since humans swallow thousands of times per day, it has been proposed that the swallow position should be compatible with the musculature. This technique is recommended only after verification of good TM joint function with Joint Vibration Analysis or MRI.

#### The ULF-TENS Bite Registration

Ultra-low Frequency TENS, originally conceived by Bernard Jankelson, is often used to relax the masticatory muscles. It can also be used to determine a bite registration position, sometimes referred to as myo-centric. After a patient has been "pulsed" for relaxation, usually for about 40 minutes, bite registration material (a quick-cure acrylic) is placed over the mandibular occlusal surfaces and the ULF-TENS is re-applied to "close" the mandible about 1 - 2 mm above the rest position. During this procedure the vertical dimension is usually monitored with a mechanic's inside calipers between marks on the chin and nose. There is a definite "technique sensitivity" to this procedure such that different operators tend to produce slightly to greatly different results. However, once the skill is developed, an operator may produce good consistency. These classic TENS bites ignored the TM joints function in the past, but this should no longer be the case. A final outcome with healthy TMJ's and muscles is our goal today.

#### The Phonetic Bite Registration

As with the previously described muscle-oriented methods, this one begins with muscle relaxation. Then the patient is instructed to speak specific sounds while the anterior teeth are observed by the clinician. Based on the positions assumed by the

teeth with specific phonetics, the clinician recognizes the vertical and antero-posterior requirements and records the position, typically also with impression material. Admittedly, this technique requires subjective clinical judgment and the development of a skill without any objective support.

### The EMG Bite Registration

To enhance the precision with which one can determine the optimum muscle-related position, some practitioners recommend monitoring the activity of the masseter, temporalis and anterior digastric muscles electromyographically. Since the electrical muscle output levels involved are just a few microvolts, this measurement requires a high common mode noise rejection amplifier. After relaxation has been verified electromyographically, the patient is instructed to open very gradually until the digastrics show a slight increase in activity (e.g. 0.5 microvolts average). This establishes the limit to which opening the bite is permissible and is typically used as a position for constructing removable orthodontic appliances. Similar tests are done for closing or repositioning the bite antero-posteriorly while monitoring the elevator muscles. The concept is to find the superior, inferior, anterior and posterior limits of muscle resting. Then the new bite position is selected within these limits. The exact relation chosen may be dependent on many factors, such as clinical



Figure 4. JT-3D\* Jaw Tracker used together with EMG to monitor a bite registration

findings and the clinician's best judgment. With this technique it is also possible to evaluate functional activity of the musculature with the bite registration in place to further evaluate the appropriateness of the new maxillo-mandibular relation.

### The Instrument Monitored Bite Registration

To maximize the precision with which one can determine the bite registration position, clinicians can actively monitor the

position of the mandible using a magnetic jaw tracker while simultaneously recording EMG activity. After the muscles are relaxed, a recording is made of the movement from rest to centric occlusion, light tapping in CO and protrusive guidance. Next, the registration position is selected and targeted on the computer screen. The treatment position chosen can reflect all of the information available regarding the patient's current condition. Finally, the registration material is placed in the mouth and the patient is instructed to close into it while the position of the mandible and the muscle activities are monitored on the computer screen. (Figure 5). This allows the clinician to immediately see the three dimensional relationship between the old centric occlusal position and the new bite position. The saved recording can be recalled later and utilized to evaluate an appliance, provisional restorations or the prosthesis at try-in.

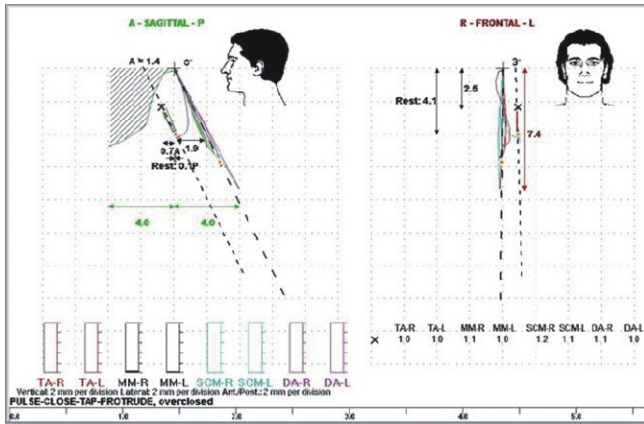
### Predicting a patient's response to correcting overclosure

The question is often asked, "How quickly will a patient adapt to a new bite registration?" Even though the object is to "correct" a mal-relationship of the mandible to the maxilla, the patient's current relationship still has familiarity. The new relationship, no matter how "perfectly" established, will seem strange to the patient at first. There are many factors that influence a patient's adaptation to a new maxillo-mandibular relation. It is possible to estimate a patient's response by considering the following factors:

1. The age of the patient [younger = more adaptive, older = less adaptive]
2. The amount of the change [a big change is more difficult to adapt to than a small change]
3. The duration of the overclosed condition [a long-standing condition will be more difficult to "de-program" than one of short duration]
4. The quality of bilateral TM joint function [good joint function makes adaptation easier]
5. An overclosed bite, due to developmental abnormalities (if caught early) can be corrected easily and with rapid adaptation by the patient [children are much more adaptive]
6. Overclosure resulting from parafunction typically coincides with a strong, healthy musculature. Strong, healthy muscles make adaptation easier, but require a treatment plan to protect the restored occlusion from destructive parafunctional forces.
7. An overclosed bite due to caries, loss of teeth, etc. without evidence of parafunction, typically coincides with a weak musculature, making adaptation difficult. This is very often the case with complete removable prosthetics.

### Summary

Overclosure is a common condition among patients seeking



**Figure 5.** The position of the bite registration and the levels of muscle activity, are simultaneously visible in this combined EMG and jaw tracking recording. The vertical dimension is increased 2.5 millimeters, the freeway space is reduced from 4.1 mm to 1.6 mm.

**BEFORE TREATMENT**



**Figure 6.** Example of a patient with an overclosed vertical dimension, due to previous loss of teeth, that has been successfully treated using Neuromuscular Principles.

restorative and/or orthodontic rehabilitation. By evaluating the patient for common signs and symptoms associated with overclosure, one can determine the need for re-establishing a physiologic vertical dimension. Opening of the bite can be accomplished in a number of ways by following specific guidelines. The use of objective diagnostic aids are extremely helpful by allowing the clinician to optimize TMJ and craniofacial muscle function at the new VDO. The correction of the vertical dimension during a rehabilitative procedure should result in enhanced comfort and improved function in the finished case.

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**AFTER TREATMENT**

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# Lip Position Preference of Filipinos

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*The central feature of the lower third of the face is the lips. Lips are used in speech and during articulation of sounds. Lip position can influence the subjective perception of the face and orthodontic tooth movement can influence lip position. The primary objective of the study was to determine a general preference on lip profile among Filipinos.*

*Sixteen (16) lip profile silhouettes (8 males and 8 females) with Class I angle occlusion, complete set of permanent teeth with no crowding, no history of orthodontic treatment and craniofacial anomalies, were used. A total of 492 respondents (49 Orthodontic students (group 1) and 455 Filipino respondents (group 2) following inclusion and exclusion criteria set in the study were selected and asked to answer the questionnaire.*

*Statistical treatment with the use of regression and ANOVA found that gender, orthodontic students, dental students and patients of orthodontic department did not affect the preference on lip profile. The preference on the lip profile among Filipinos is of 0.5mm difference when compared to American Board of Orthodontics standard E-line.*

*The preferred lip position of the Filipinos is of smaller numerical value compared to the established Standard ABO value. A probable reason for the small difference is that Filipinos generally have shorter nose as compared to Caucasians.*

## INTRODUCTION:

The face is divided into three parts, namely: the upper third of the face, the middle third of the face and the lower third of the face; with the lower one third comprising the lips. Lips are visible parts of the face: soft, movable, and serve as the opening for food intake. Lip position can be influenced by orthodontic tooth movement. It can influence the subjective perception of facial attractiveness. In the last century there have been a gradual increase in lip

prominence among models and currently, lip augmentation procedures have become common in esthetic plastic surgery. Universal standard Cephalometric measurements have been established by the American Board of Orthodontics (ABO) to achieve an ideal facial profile. However, this does not always address the patients' preference for lip position. Preference is highly subjective and this may not always be in accord with the established standard of a facial profile, specifically, the lip position. With the increasing patient participation in treatment plans, it is

important to consider the patient's preference in setting goals. The purpose of this study was to determine the most preferred lip position of Filipinos.

## MATERIAL AND METHODS

The researcher utilized a survey research design as a primary method in evaluating the general lip profile preference among Filipinos in terms of esthetics.

### *The Informed Consent and Interview Questionnaire*

An informed consent was given to each subject. Each of them undergone history taking and thorough clinical examination to exclude any abnormalities or malformations.

Three-page (3) questionnaire with the silhouettes of lip position were used to determine the respondents' preference on the lip position. The first page contain the informed consent which contains the name of the researcher, the title and objective of the study, the signature of the research second page included detailed information regarding the age, gender, and profession of the respondents, the third page the eight male and eight female silhouette lip position. They were asked to choose their preferred lip position among the male and female silhouettes.

### *Selection of the Lip Position Silhouette*

Eighty seven (87) people were given consent and were interviewed. Forty eight (48) participants with less than 75% Filipino race of their grandparents and were not 18 to 30 years old with missing teeth, with history of orthodontic treatment, splint, retainers, expanders, dental prosthesis, orthognathic surgery, plastic surgery, trauma particularly the orofacial region, temporo-mandibular pain and or disease, medical condition that would affect growth of the mandible and maxilla, systemic syndromes and craniofacial anomalies were excluded, leaving Thirty nine (39) participants.

Mouth examinations of the remaining Thirty nine (39) Filipino participants were done at the Post Graduate clinic of University of the East, Manila by the principal investigator. Twenty one (21) Filipino participants with severe crowding, Class II and Class III canine and molar relationship (according to angle classification) unilateral or bilateral with convex or concave profile were excluded, leaving Eighteen (18) Filipino participants.

The remaining Eighteen (18) Filipino participants were evaluated and only sixteen (16) participants (8 males and 8 females) were chosen to have their Cephalometric radiographs taken at Post graduate clinic of University of the East, Manila. The participants were all Filipino of 18 to 30 years old with no less than 75 % Filipino race of their grandparents, with straight profile, class I angle occlusion (both canine and molar bilaterally), with minor or no crowding, all teeth are present except third molars with fully erupted teeth.

### *Cephalometric Analysis and Construction of the Lip Profile Silhouettes*

Cephalometric tracing of the films were performed at the University of the East, Post Graduate clinic, Manila by the principal investigator. Six Cephalometric tracing for each films of the subjects were performed by the principal investigator. The six (6) Cephalometric tracing were measured (upper and lower lip line relative to E-line) and the tracing with the measurement of highest frequency was chosen (one for each Cephalometric film) and were scanned (Canoscan Lide 25, Korea). To determine the error during tracing, retracing and remeasuring of the films were performed in one week interval and were computed using Dahlberg's method.

### *Questionnaire*

Three-page (3) questionnaire with the first page containing the informed consent with the title and objective of the study, the confidentiality of the study, the request for the cooperation of the respondents in completing the form, the name of the researcher, the approval and signature of the respondents. The second page included detailed information regarding the age, gender, citizenship, ethnic background, place of birth and course or profession of the respondents. It also contains the ethnic background and Filipino percentage of the respondent's parents and grandparents. The third page contains an illustration of the lip position photo and silhouette, and an instruction. It contain sixteen (16) lip profile silhouettes (8 males and 8 females) and the respondents were asked to choose one for male and one for female their preferred lip position preferences among the silhouettes. We measure the E-line and were used as a primary reference line to construct the lip profile since it is one of the most commonly used by orthodontists. We placed the silhouettes in a random manner for each gender to allow allowed individuals to make assessments of each silhouette individually.

### *Selection of Sample Respondents*

One thousand (1,000), three-page questionnaires were prepared and distributed. One hundred sixty two (162) questionnaires were not returned. Forty two (42) questionnaires that were returned with missing information were excluded. Three hundred four (304) questionnaires with less than 75% Filipino race of their grandparents and are not 18 to 30 years old were excluded, leaving Four hundred ninety two (492) respondents (49 Group 1 respondents and Group 2 respondents). The Group 2 participants were all Filipino of 18 to 30 years old with no less than 75 % Filipino race of their grandparents.

Three (3) pages questionnaires which contains the informed consent, the aims of the study and sixteen (16) silhouettes of lip position (8 males and 8 females) were given to the participants, who were divided into two groups:

Group 1: Forty nine (49) Orthodontic students (26 males and 23 females) of University of the East, Graduate school, enrolled in the school year 2010 to 2011. The mean age of this group was 29 years old, range 23 to 52 years old.

Group 2: Filipino respondents: Twelve (12) Orthodontic students (5 males and 7 females) of University of the East, Graduate school, enrolled in the school year 2010 to 2011. The mean age of this group was 26 years old, range 23 to 30 years old. And Two hundred seventy three (273) Dental students (101 males and 172 females) of University of the East, College of Dentistry, enrolled in the school year 2010 to 2011. The mean age of this group was 20 years old, range 18 to 29 years old. One hundred seventy (170) Orthodontic patients (46 males and 124 females) of University of the East, Post Graduate clinic, during the second semester of school year 2010 to 2011. The mean age of this group was 21 years old, range 18 to 30 years old.

Four hundred ninety two (492) total sample respondents were gathered. (group 1: Forty nine (49) Orthodontic students of University of the East, Manila, group 2: Four hundred fifty five (455) Filipino Orthodontic students, Dentistry students and Orthodontic patients of University of the East, second semester of school year 2010 to 2011. The mean age of this group was 21 years old, range 18 to 52 years old.

Descriptive statistics (means and standard deviation) were calculated using SPSS program version 16.0. The results were tabulated. The difference between the total Filipino respondents (Group 2: Filipino orthodontic students, dental students and patients of orthodontic patients age 18-30 years old) of University of the East, Manila), gender and the differences between the two groups (Group 1: orthodontic students, Group 2: Filipino orthodontic students, dental students and patients of orthodontic patients age 18-30 years old) of University of the East, Manila were compared using Regression and Analysis of variance (ANOVA).

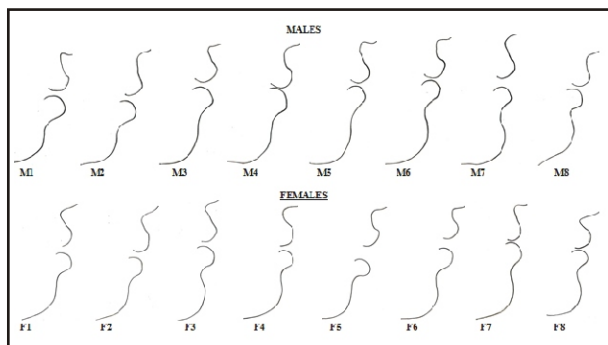


Fig. 1. Lip profile silhouettes of Filipinos used in the study

Table 1. Preferred Lip Profile by 455 Filipino Respondents and 49 Orthodontic Students.

	R value	F value	P value
Group 1	.002	.690	.219
Gender			.587

$P < .05; P < .01; P < .001$

**RESULTS**

The statistical treatment used was regression and ANOVA to determine if gender, orthodontic students, dental students and patients of orthodontic department would affect lip profile preference. The following tables and graphs' show the frequency distribution of the respondents according to their variables:

**General Preference for Lip Profile among Filipinos**

Graph 1 shows Lip Profile F8 (upper lip line measurement of -3.5mm and lower lip line of -1.5mm relative to E-line) is the most preferred with a frequency value of 170; followed by M4 (upper lip line measurement of -1mm and lower lip line of +3mm relative to E-line) with frequency value of 99. The least pleasing lip profile is M1 (upper lip line measurement of +0.5mm and lower lip line of +6mm relative to E-line) with a value of 17.

**Statistical Analysis of the Variables**

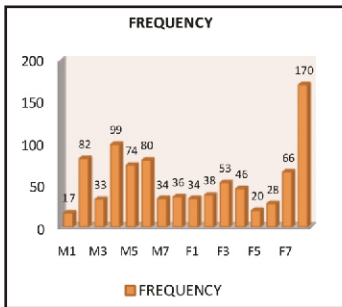
Table 1 shows the following values when comparing variables using Regression and Analysis of variance (ANOVA). There was no significant difference between the genders, and among 455 Filipino respondents namely: orthodontic students, dental students and patients of orthodontic department) when compared to 49 orthodontic students.

**Interpretation:**

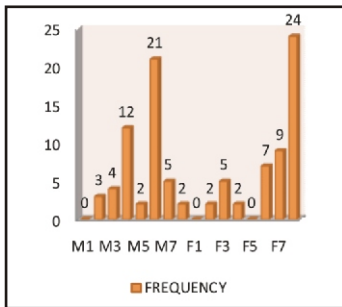
The statistical treatment for the study was done by doing multiple linear regression and analysis of variance (ANOVA) to determine whether gender, 49 orthodontic students (Group 1) and 455 Filipino respondents (Group 2: Filipino orthodontic, dental students and patients of orthodontic department), would affect the preference on lip profile.

The value R-square at 0.002 means the regression equation fits relatively poor in the scatter diagram of the data.

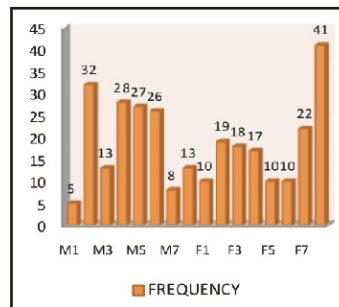
The significance level associated with the computed probabilities of the constant, gender, and group and at 0.000, 0.587 0.219 and 0.832, respectively reveals that none of the independent variables are predictors since their computed probabilities are higher than the critical probability of 0.05 or its complementary confidence level of 95%.



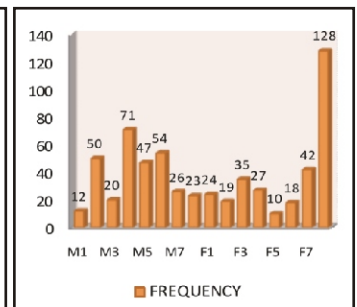
**Graph 1.** Frequency Distribution of 455 Filipino Respondents (Filipino orthodontic and dental students)



**Graph 2.** Frequency Distribution of 49 Orthodontic students



**Graph 3.** Frequency Distribution of 152 Filipino Male Respondents



**Graph 4.** Frequency Distribution of 303 Filipino Female Respondents

The F-value of 0.697 means the mean square of the residuals is relatively lower than the regression factors. Only 0.2% of the observations fall along the regression equation in the norm plot.

When comparing Group 1 from Group 2,  $p=0.219$  meaning that there is no significant difference between the 2 groups in their lip position preference since their P value is higher than 0.05. Orthodontic students perception on the lip position does not differed from the perception of Filipino respondents.

**DISCUSSION**

Lips have played an important role in physical and social status of an individual in different ethnic groups. In certain ethnic groups in Africa and in North America, females stretch their lower lip using wooden or clay plates called “sigaro”. The plate's size symbolizes social maturity and a sign that she has reached child-bearing age, as for them “The bigger the lip, the smoother the dowry negotiations between the two families”. In the ancient history of China at about 5,000 years ago, the beauty of a woman's lips had already been paid special attention. During that time, women believed that by highlighting their lips during religious occasions they would please their Gods. At present, people realized that by highlighting their lips it could lift up one's spirit and sometimes even could reveal one's social status.

In the last century there has been a gradual increase in the lip prominence among models. In the study of Auger and Turley (1999) there appears to be a trend for models to have increasingly fuller lips during the last century among the Caucasians. This study was proven by Sutter and Turley (1998), where they use profile photographs and measured them and concluded that fuller lips was seen in Caucasian models than in their control groups.

However, as a result of the aging process, lips become thinner and less well defined. Currently, several procedures have been established that can provide fuller lips. Orthodontic tooth movement can also affect lip positions as stated by Lu in 2010. According to Riedel in 1950 to properly improve the lip position, a patient with convex profiles is recommended to finish with upright incisors and for patient with straight profiles the incisors may be

allowed greater procumbency. Moseling et al (2004) stated that lip curvature with extraction or with non-extraction was highly variable and highly related to soft tissue morphology. According to the study of Brock et al (2005) they found that there was a greater lip response in white females than black females when they did incisor retraction and they concluded that lower lip response to incisor retraction was more predictable than the upper lip.

Different preference of the lip position among different nationalities was shown by several studies. According to Coleman et al (2007) they found that for extreme retrognathic and prognathic profiles a fuller lip positions were preferred whereas for average profiles a more retrusive lip positions were preferred. Ioi et al (2008) use series of silhouettes with varying lip profiles investigated perceptions of Korean and Japanese and concluded that young Korean and Japanese adults prefer a retruded profile, even though their profiles have historically been characterized by more convex facial features. On the contrary, Nomura et al (2004) took different ethnic groups of judges of European American, Hispanic American, Japanese, and African and asked them to evaluate profile silhouettes. They concluded that African judges preferred more protrusive lips while the other groups of judges preferred lip positions posterior to the E-line, with more retruded lip for males than females.

Studies have been performed on the preferences of lip position among the American, European and other Asian countries but no studies have attempted to compare and quantify the preference of soft-tissue lip position among Filipino respondents and Orthodontic students using lip position profile silhouettes of Filipinos. The objective of the study was to determine the preferred lip position of Filipinos and to compare the preferences among genders and among Filipino orthodontic students, Filipino dental students and Filipino orthodontic patients of University of the East, Manila.

The target population of this study was students and patients of University of the East, Manila. Additional population in the northern and southern parts of the Philippines (Northern part of Luzon, Visayas and Mindanao) may present a better outcome of this study. Unfortunately, due to the financial limitation of the



study, it was not feasible to travel further and recruit more respondents. For future research, ideally more stimulus faces and more respondents should be used, but this will also increase the time and effort to complete any evaluation and may reduce respondent's cooperation.

Filipino samples age 18 to 30 years old (8 males, 8 females) with straight profile, class I angle occlusion, with minor or no crowding, all teeth are present except third molars with fully erupted teeth were the inclusion criteria for the selection of the silhouette lip profile. Filipinos with history of orthodontic treatment, splint, retainers, expanders, dental prosthesis, orthognathic surgery, plastic surgery, trauma particularly the orofacial region, temporo-mandibular pain and or disease, medical condition that would affect growth of the mandible and maxilla, systemic syndromes and craniofacial anomalies, were excluded. These exclusion criteria would prevent any facial irregularities of the subjects in this study.

Sixteen (16) Silhouettes of lip profile (8males and 8 females) were used as a mean of stimulus presentation. According to Wuerpel (1981) the advantage of using silhouettes is it removes many extrinsic (hair, make-up) and intrinsic (complexion of the skin, facial expression) factors that may influence the perception of an individual's concept of beauty. On the other hand, Howells and Shaw (1985) stated that photographs provide valid, reproducible, and visual representation of additional facial component but with the disadvantage of subjective variables such as perception bias. The silhouette lip position profiles were gathered using the criteria mentioned above.

Straightforward method was used to evaluate the preferred lip position among Filipinos. We use two groups of respondents, which are the Group 1: Forty nine (49) Orthodontic students of University of the East, Graduate School, and Group 2: Four hundred fifty five (455) Filipino respondents which include Filipino orthodontic students, Filipino dental students and Filipino orthodontic patients of University of the East, Manila, to determine and compare their preferred lip position. The silhouettes were distributed among the sample respondents by means of questionnaire. The sample respondents of the study were asked to choose their preferred lip profile among the silhouettes. After one (1) to three (3) days the questionnaires were collected. Results were computed using Regression and Analysis of variance (ANOVA) to determine the lip position preference among Filipinos.

In this study when comparing the results between Filipino males and females revealed no significant difference on the lip position preference as observed. As stated in the study of Abu Arqoub and Al-Khateeb (2010) they concluded that gender did not influence attractiveness rankings in the perception of profile attractiveness. De Smit and Dermaut (1984) and Cortez (2011) found that gender has no significance in the choice of an esthetic soft tissue profile. This indicates a similar standard for lip position in terms of esthetics between genders.

When comparing Filipino respondents and Orthodontic students, the study showed no significant difference on the lip position preference among them. In the study of De Smit and Dermaut (1984) and Dongieux (1980) concluded that there was no significant difference in the profile preference between Orthodontists and lay people. Cortez (2011) also found that orthodontic knowledge had no significant effect on esthetic preference. This shows a similar preference on the lip profile between professionals and the general public.

As for the preference in the lip position among Filipinos, it was confirmed that the Filipino subjects preferred a lip position of -3.5mm for the upper lip and -1.5mm for lower lip relative to ABO Standard E-line. Comparing these values to the ABO Standard E-line which is -4mm for upper lip and -2mm for lower lip that was used in this study, a difference of 0.5mm in the measurement was observed. A probable reason for the small difference is that Filipinos generally have shorter nose as compared to Caucasians.

Attractiveness has long been a topic for research. The perception of an attractive face is very subjective and can be influenced by different factors such as age, gender, ethnicity, culture and personality of an individual.

The American Board of Orthodontics has established a universal Cephalometric measurement to achieve an ideal facial profile which includes the lip profile. However, this does not always address the patient's preference for lip position. Preference is highly subjective and this may not be always in accord with the established standard measurement.

## CONCLUSION

In conclusion, we have confirmed that Filipinos prefer a lip position of -3.5mm for the upper lip and lower lip line of -1.5mm relative to E-line. Comparing these values to the ABO Standard E-line (-4mm for upper lip and -2mm for lower lip) that was used in this study, a difference of 0.5mm in the measurement was observed. From this we can conclude that the preferred lip position of the Filipinos is of smaller numerical value compared to the established Standard ABO value. A probable reason for the small difference is that Filipinos generally have shorter nose as compared to Caucasians.

When comparing the results between males and females, we found out that there was no significant difference on the lip position preference. Also no significant difference was observed with the results among the total Filipino respondents (Group 2: Filipino Orthodontic students, Dental student, and Orthodontic patients of university of the East, Manila). Moreover, no significant difference on the lip position preference between the orthodontic students (Group 1) and the Filipino respondents (Group 2).



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# INTRA-ORAL MOLAR DISTALIZATION - REVIEW

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## INTRODUCTION

Recent developments in mechanotherapy & changes in concepts have reduced the need for extraction in several types of discrepancies<sup>(1)</sup>. Management of borderline cases has always surmounted controversies. An estimated 25-30% of all orthodontic patients can be benefited from maxillary expansion, and 95% of class II cases can be improved by molar rotation, distalization & expansion<sup>(2)</sup>. The emergence of various modalities of molar distalization has given new meaning to the non-extraction treatment. These appliances have increased our treatment options and have evolved considerably over the past few years.

With the recent trend towards more non-extraction treatment, several appliances have been advocated to distalize molars in the upper arch. Certain principles, as outlined by Burstone<sup>(3)</sup> must be borne in mind when designing such an appliance<sup>(3)</sup>:

- Magnitude of forces
- Magnitude of moments
- Moment-to-force ratio
- Constancy of forces and moments
- Bracket friction (frictionless appliances are preferable)
- Ease of use
- Cost

The distal movement of the maxillary molars for the correction of a Class II malocclusion without extractions; to establish a class I molar relationship, requires maxillary molar distalization by means of intraoral or extra-oral forces<sup>(4)</sup>. The premolars & canine are then sequentially moved posteriorly to class I positions, & finally the incisors are aligned &/or retracted<sup>(5)</sup>.

An ideal intraoral molar-distalization appliance should meet the following criteria:

- Minimal need for patient compliance
- Acceptable esthetics and comfort
- Minimal loss of anterior anchorage (proclination of the incisors)
- Bodily movement of molars to avoid unstable results
- Minimal chair time for placement and reactivations<sup>(4)</sup>.

Two areas of particular concern are molar tipping and anterior movement of the anchorage teeth. If the first molar is tipped back rather than moved bodily, it will not only pose occlusal problems, but may not provide sufficient anchorage for distalizing the teeth anterior to it<sup>(3)</sup>. Unless a supplemental force system is used to provide a movement that torques the root distally, a significant amount of anchorage may be lost as the molar relapses to an upright position<sup>(6)</sup>.

## INDICATIONS

Controversy reigns supreme over the molar distalization. Careful selection of case is therefore mandatory. It is not that molar distalization is tooth movement of choice in all malocclusions. The extraction of first premolars is much the common most line of orthodontic treatment. However in certain reasonably well defined instances, the distal movement of upper buccal segments is the mechanical treatment of choice. The indications for the distal movement of upper buccal segment are described.

- 1. Long distal bases:** Short dental bases where stacking of unerupted molars in the tuberosity region seen radiographically may be observed as a symptom of crowding.
- 2. Buccal segment relationship:** Ideally for upper molar distalization the buccal segment relationship should be slightly post-normal
- 3. Minimal crowding or Spacing Anteriorly:** Such cases with minimal crowding or spaces anteriorly respond well to distal movement of buccal segments as extractions in the anterior segment may leave residual spacing after treatment.
- 4. Well aligned lower arch:** This is an important prerequisite for distal movement of upper molars; providing other factors are favorable. The distal molar movement in the upper arch will achieve a class I molar relation and the anterior teeth will also be in class I relation.
- 5. Overjet reduction not indicated:** The cases in which prognosis for full overjet reduction is not good; pretreatment naso-labial angle is within normal range 90°-

110°. Therefore extraction of premolars is contraindicated distal movement with or without extraction of upper second molars is the treatment of choice.

- 6. Mesially inclined upper first molars:** For successful distalization of upper buccal segments with removable appliance, upper first permanent molars should be mesially inclined. In such cases distalization is rapid if it coincides with a growth spurt.

#### OTHER CONSIDERATIONS FOR MOLAR DISTALIZATION

- 1. Growth pattern:** Cases showing unfavorable or vertical growth tendency are contraindicated for distal movements of upper buccal segments as it acts as a wedge between maxilla and mandible.
- 2. Degree of Overbite:** Distal movement of upper buccal segments is associated with spontaneous reduction in the overbite. This advantage in deep overbite cases is however a disadvantage in Class III cases and open bite cases.
- 3. Second Molar:** Unerupted second molars rarely create resistance to the distal movement of the maxillary first molars. Indeed even they move distally in response to moving first molar **Poulton (1959)**, **Worms et al. (1973)**<sup>(9)</sup> noted that erupted second molars contact with first molars created a resistance to distal movement. This, in effect altered the position of centre of resistance of the first molar. If the force is applied distally through the centre of resistance of first molar, it should produce translation, but the resistance produce by the erupted second molar crown enforces a rotational moment and the first molar crown tilts distally although the first permanent molars may on occasions be moved distally in the present of an erupted second molar **Armstrong (1971)** suggests that this movement be complete before the eruption of second permanent molar. Alternatively **Graber (1969)**<sup>(10)</sup> suggest second molar extraction to facilitate distalization of the maxillary molars in selected class II division I malocclusion cases.
- 4. Age of the patient:** An important factor, affecting even patients whom the headgear force is of sufficient magnitude and duration, is the dental age of the patient. **Dewel (1967)** and **Hass (1970)** observed faster rate of molar distalization in patients in mixed dentition to those in the adult dentition. This is probably as **Armstrong** observed that the skeletal system of younger patient is apparently more dynamic, possessing a greater capacity to remodel.
- 5. Presence of other force system:** A force system applied for distalization of first molars may be negated or augmented but the presence of other force system like intraoral or elastics, arch wires, etc. For example, presence of a tip back bend in the arch wire mesial to the molar requires a greater compensational distal root rotation force to cause

distalization of first molar by attention be made to antero-posterior, vertical and lateral force vectors being employed.

#### DISADVANTAGES

Molar distalization has its own set of disadvantages. These are associated with the appliance itself, undesirable reciprocal dentoalveolar or skeletal side effects, and patient compliance needs.

Intraorally the appliance may be bulky. It may need good lab support. It requires high level of skill. The appliances may have to be activated frequently, which increases the chair time and the number of patient visits to the clinic.

Most appliances deliver predominantly tipping movement but the true molar distalization aims at a bodily movement. Distalization can cause impaction of third molars. Molar distalization is most appropriate before the eruption of second and third molars.

Molar extrusion may occur, which may increase the Frankfort mandibular plane angle. The appliance shows anchorage loss, which leads to reciprocal anterior segment proclination. Orthodontic implants may be considered to decrease the anchorage loss. Implant placement and removal surgery is then incorporated in the treatment plan. It also increases the treatment cost. Implant failure may also be a complication in some cases.

#### INTRA-ORAL APPLIANCES

##### 1. Pendulum Appliance and its modification

###### Pendulum Appliance<sup>(9)</sup>

The pendulum appliance was first described by **Hilgers** in 1992. This intraoral appliance seems to satisfy most of the requirements of an ideal molar distalization appliance. The appliance derives its name from its broad swinging arc motion, like a pendulum in motion of the force is exerted from the midline of the palate to the upper molars.

###### Fabrication of the appliance:

The appliance can be considered in two parts:

###### i) Active components

This is made by right and left pendulum springs, formed from 0.032 inch TMA wire. The spring extends from as close to the centre of palate as possible to maximize their range of action, to allow easier insertion of springs in to molar palatal sheaths and to reduce force to an acceptable range. These springs should also be placed as close to distal aspects of Nance button as possible to minimize tongue irritation during swallowing.



## ii) The anchor component

It consists of an acrylic Nance button with a retaining wire, soldered to first premolar or first deciduous molar bands. Occlusally bonded rests on the upper second bicuspids or second deciduous molars add even more stability to the Nance button. The acrylic Nance button should be made as large as possible to prevent any tissue impingement. The acrylic should extend to about 5mm away from the teeth to allow adequate hygiene.

In cases requiring simultaneous or otherwise expansion of the upper arch, a mid-palatal jackscrew can be incorporated into the centre of Nance button. This version of the appliance is called as "Pend-X".

### Various modifications of Pendulum appliances

#### A. Fixed Palatal Expander<sup>(10)</sup>

**Snodgrass (1996)** introduced this appliance that incorporates the maxillary expansion, molar rotation & distalization at the same time. This appliance reduces the treatment time.

#### B. M Pendulum<sup>(4)</sup>

Modified Pendulum appliance was introduced by **Scuzzo G et al. (1999)**. The horizontal loops are inverted to allow bodily distalization of molars. The pre-activation given prior to intraoral placement is also 40 to 45 degree rather than 60 degree as in conventional or Hilger's Pendulum appliance.

#### C. Modified Pendulum with removable arms<sup>(11)</sup>

This modification of the appliance given by **Scuzzo G et al. (2000)**, the active arms or springs are made removable. This allows to carry distalization of molars as long as necessary as the arms can be removed and reactivated during treatment without debonding the occlusal rests of Nance button.

#### D. Franzulum Appliance<sup>(12)</sup>

**Buyoff, Darendeliler and stuff (2000)** introduced a pendulum based to appliance, which can distalize *mandibular molars* without the drawbacks of other appliances.

#### E. Bone anchored pendulum appliance<sup>(13)</sup>

**Byloff et al. (2006)** designed the Graz implant-

supported pendulum appliance. The anchorage part of this appliance consisted of a surgical plate fixed with four titanium mini screws to the palatal bone. The acrylic part of the pendulum appliance was fitted to the cylinders, soldered to the center of the surgical plate, on the basis of a telescopic principle. They used this appliance in adult patients.

### Clinical effects of pendulum appliance

The pendulum appliance, a non-compliance intra-arch distal molar movement technique which exhibit excellent patient tolerance and is quite effective and reliable method for distalizing maxillary molars. The data gathered from various studies suggest that using the pendulum appliance, the maxillary first molars move distally at a monthly rate of 1.02 mm ( $\pm 0.68$  mm) using an initial force of 200 to 250 grams in a mean period of 4 months (**Byloff and Darendeliler, 1997**) with a mean anterior movement of incisors of only 0.74 mm. The Pendulum appliance causes insignificant skeletal effects with only significant effect being increase in lower facial height by 2.79 mm (**Ghosh and Nanda, 1996**)<sup>(14,15)</sup>.

The Pendulum appliance for maxillary molar distalization seems to be effective for moderate dental sagittal discrepancy and arch length deficiency. It does not have any corrective skeletal effect and one should never use the Pendulum appliance alone as a tool to treat skeletal Class.

### 2. Three dimensional biometric distalizing arch and three dimensional mandibular lingual arch<sup>(16,17)</sup>

**Wilson (1978)** introduced the concept of modular orthodontics and he method of rapid molar distalization which is one aspect of modular orthodontics. Maxillary molars and buccal segment are distalized with the distalizing arch and 3D mandibular lingual arch and class II elastics.

The Wilson's biometric distalizing arch has a 0.020 anterior section and an 0.045 posterior section that fits into the headgear tube. A 5 mm long, 0.040X 0.010 open coils are compressed by an omega loop. The resulting force moves the maxillary first molars distally. The reciprocal anterior force on the incisors is offset by class II elastic. Distal movement occurs rapidly with this system, which essentially puts the entire mandibular arch which is stationed with a heavy rectangular wire and the six maxillary anterior teeth against the maxillary first molars.

### 3. Lingual Distalizer system<sup>(18)</sup>

A Lingual Distalizer system has been developed by **Carano Aldo, A. Mauro and Siciliani Giuseppe in 1996** to distalize the maxillary ears with minimum drawbacks of other appliance available till then.

The active components of Lingual Distalizer are two bilateral mm tubes connected to a Nance appliance. A bayonet wire is inserted to the lingual sheath of first molar bands. On the tube there is stainless steel coil spring and a clamp.

The clamp can slide towards the molar and can be tightened periodically in order to compress the coil. The force exerted by the spring begins at 150 gms, and increase as space is opened. Consequently, the Lingual Distalizer is activated by sliding the clamp closer to the molar once a month. The rate of movement with the clamp closer to the molar once a month the rate of molar movement with the lingual distalizer were 3-5 mm in 4 months **Carano A et al. (1996)<sup>(18)</sup>** and is equal to magnets or jones jig but neither tipping nor rotation was observed.

### 4. K-loop molar distalizer<sup>(5)</sup>

The appliance based on Burstone's principles was designed by **Dr. Varun Kalra (1995)** to achieve bodily movement or controlled or uncontrolled tipping of molars as required by the case. An efficient, yet simple appliance causes first molar distalization without much loss of anchorage even after the eruption of second molars.

#### Parts of appliance

The appliance consists of an active part the K-Loop provide force and moments and an anchorage unit, a Nance button.

The K-Loop is made of 0.017 X 0.025 inch TMA wire. Each loop of K should be 8 mm long and 1.5 mm wide the legs of K are bent down 20 degrees and inserted in to the molar tube and premolar bracket. Stops are bent in the wire 1 mm distal to distal mark and 1 mm mesial to mesial mark. Each stop should be well defined and about 1.5 mm long.

The legs are bent down to an angulations of about 20 degrees which helps in counteracting the moments created by the force of the appliance, These allows the molars to undergo translatory movement instead of tipping. Root movement continues even after the force has dissipated.

The reactivation is done by opening each loop by 1mm and opening the legs of K loop to restore 20-degree bend.

### 5. C-space regainer<sup>(19)</sup>

To overcome the drawback of incisor flaring caused by equal and opposite to mesial force exerted by various intraoral methods of molar distalization, a removable appliance "c-space regainer" was introduced by **Chung, Park and Ko (2000)** of Korea. Though the newly introduced appliance needs a more comprehensive study before any firm conclusions about treatment effects can be drawn still in appropriately selected cases it appears that C-space regainer is a viable method of molar distalization.

### 6. First Class appliance<sup>(20)</sup>

The appliance was designed by **Fortini A, Lupoli M and Parri M (1999)** of Italy for unilateral or bilateral distalization of maxillary first molars. The First Class appliance requires laboratory construction and has two components involved namely vestibular and palatal components. The vestibular component includes formative screws soldered on the buccal of first molar bands occlusal to 0.022-inch X 0.028-inch single tube. Split rings are welded to second premolar or second deciduous molar bands to control vestibular screws. Stops screws are used to maintain molar position after active treatment.

The appliance so formed has a range of 4 to 8 mm of molar distalization with a time of 28 to 95 days. The appliance design limits tipping on molar during distalization and does not cause anterior anchorage loss or changes in vertical dimensions. The appliance can be left in place as an anchorage unit to maintain the space after distalization.

### 7. Distal Jet Appliance

The Distal Jet is a fixed lingual appliance that can produce lateral or bilateral molar distalization typically in 4 to 9 months out relying on patient compliance. The Distal Jet was introduced by **Aldo A and Testa M (1996)<sup>(21)</sup>** of Italy. The appliance permits ultimate use of full bonded appliances, thus avoiding the need for phases of treatment. The rate of molar movement is comparable to that reported with magnets and the Jones Jig, but is achieved without tipping or rotation. The anterior anchorage units remain stable, while the distalization occurred through bodily translation. The advantage is that it can be converted into a passive Nance appliance, so that the molars can be held in place as the anterior teeth are distalized.

The Distal Jet is relatively easy to insert, is well

tolerated and esthetic, and requires no patient cooperation. It can be used for either unilateral or bilateral Class II correction.

### Modifications of Distal Jet

#### A. Conversion to Nance holding arch<sup>(22)</sup>

Besides the proposed method converting the Distal Jet into a Nance holding arch to prevent further distal movement and relapse of the molar, an alternative method is to wrap an 0.014 inch stainless steel ligature wire around the distal end of double – back wire and tie it around the tube just mesial to the activation collar so that the coil spring is completely compressed and set-screw tightened to prevent mesial movement of the molar.

#### B. Double set screw Distal Jet<sup>(22)</sup>

This modification incorporates use of two sets of screw into the activation collar for a more reliable conversion of Distal Jet to Nance holding arch. Of the two set of screws, the mesial set is used for active distalization and the distal set of screw is used to lock on the bayonet Wire to prevent mesial movement of the molar.

### 8. Fixed Piston Appliance<sup>(6)</sup>

The Fixed Piston Appliance introduced by **Greenfield (1995)** claims to produce bodily distal movement of maxillary first molars without need extra-oral appliance and with no loss of anterior anchorage. The Fixed Piston Appliance consists of bands adapted on maxillary first molars and maxillary first pre-molars such that all the four bands have similar path of insertion, that is to say that buccal and lingual occlusal margins of the bands are all at the same height.

Fixed piston appliance is a non-compliance appliance that produces molar distalization by translation and employs light, continuous force with no loss of anterior anchorage.

### 9. Nickel titanium Double Loop System<sup>(23)</sup>

In an effort to overcome the difficulty in first molar distalization, using nickel titanium wires after complete eruption of permanent second molar, **Giancotti and Cozza in 1998** introduced Double Loop System which utilizes super elastic nickel titanium wire with shape memory for simultaneous distalization of first and

second molars. The system appears useful, when traditional intraoral forces may be ineffective. Use of lighter force minimizes anchorage control, though use of Class II elastics require patient cooperation and up-righting spring may produce an anterior open bite due to intrusive forces exerted by it.

### 10. Molar distalizing bow<sup>(24)</sup>

The Molar Distalizing Bow introduced by **Jecket and Rakosi (1991)** is an intraoral removable appliance that guarantees controlled distal movement of the molars. The appliance is easy to handle which can readily be worn most of the time with the prospect of favorable treatment. Molar Distalizing Bow appears to be a good alternative to conventional headgear means as longer daily wearing is possible due to more acceptances by patients. The appliance does not offer any vertical force and the design offers more static anchorage preventing forward movement of anterior part of the dentition. Various modification of the basic appliance has increased its versatility and promises to be a valuable alternative to conventional molar distalization systems.

### 11. Nance appliance and modifications

Several articles have been published showing modifications of the basic Nance appliance for distalization of molars either unilaterally or bilaterally. In a modification for unilateral molar distalization (**Reiner, 1992**)<sup>(25)</sup>, both sides of appliances were finished with anterior projecting arm like quad-helix, with most anterior terminus soldered to palatal aspect of first bicuspid band on the side of Class II.

Another modification called modified Nance holding arch (**Ghafari Joseph, 1985**)<sup>(26)</sup> provides anchorage for unilateral distalization of molars. A modification capable of producing bilateral molar distalization was proposed by **Pieringer, Droschl and Permann in 1997**<sup>(27)</sup> which involves use of NiTi open coil spring on sectional arch wire to produce distalization force of 100-150 gms. The anchorage component of the appliance consists of two premolar bands connected by a soldered palatal framework and an anterior acrylic shield.

The Nance appliance appears to be an effective method of distalizing maxillary molars but a more comprehensive study is needed to establish a definite correlation between the amount of distalization or duration of treatment with the various modifications proposed.

## 12. Jones Jig/Open Coil Jig/Sectional Jig

One of the most studied fixed intraoral molar distalizing appliance - **Jones Jig** was introduced **Jones and White (1992)**<sup>(28)</sup>. The appliance is capable of producing maxillary molar distalization with second molars erupted or unerupted, in the mixed or permanent dentition, and in growing or non-growing individuals.

The appliance has been widely studied. According to proposes of the appliance, **Jones and White**, it requires 120-180 days for correction of most of the true Class II molar relationships. **Gulati, Kharbanda and Prakash (1998)**<sup>(29)</sup> in their study reported a mean distal movement of 2.78 mm in a treatment period of 12 weeks using 150 gm of force. **Runge, Martin and Bukal (1999)**<sup>(30)</sup> studied the treatment effects of Jones jig assembly and found that besides molar distalization there was significant mesial movement of anchorage unit which is usually desirable in most Class II cases. **Haydar and Uner (2000)**<sup>(31)</sup> compared Jig with extra oral methods of distalization. They reported shorter treatment duration with Jones Jig assembly but more mesial movement and protrusion of the anchorage unit.

Jones Jig assembly therefore seems more appropriate for initialization in those cases in which no orthopedic effect is desired on the maxilla as in skeletal Class I or borderline Class II case with a normal mandibular plane angle.

## 13. Intraoral bodily molar distalizer<sup>(32)</sup>

This intraoral appliance introduced in the year 2000 by **Keles and Sayiusu** to achieve distalization of molars without need of patient cooperation and minimize the treatment period.

The appliance must produce a total of about 230 gms of distalizing force on both sides. The proposes of the appliance claim to establish Class I molar relationship in an average period of 7.5 months with an average molar distalization of 3.37 mm with 8 degree of distal tipping. The intraoral mechanics thus applied to cause bodily molar distalization, did cost some anchorage loss.

## 14. Superelastic NiTi wire (Locasystem)<sup>(33)</sup>

An intraoral method of molar distalization involving the use of Super elastic nickel titanium wire with shape memory. The system was designed by **Locatelli et al. in 1992**. The method produces 1-2 mm of molar distalization if the second molars are unerupted and the appliance is easy to insert even after all the teeth has been bracketed.

## 15. Molar distalization splint<sup>(34)</sup>

This simple to use and fabricate design was introduced by **Ritto A.K. in 1995**. This removable molar distalizer appliance can be used in both maxillary as well as mandibular arch and is much more small, comfortable and esthetic than conventional removable Plates.

## 17. Crozat technique<sup>(35)</sup>

**Dr. George Crozat** was a strong believer in the proper position and function of the tongue, and in good tonus of the lips and muscles of facial expression. The Crozat Appliance was based on the concept that mild stress applied in the desired direction will produce tooth movement without excessive tipping, provided ample time is given to nature to respond. The true George Crozat technique used molar distalization and rotation as the major source of space.

**Wendell H. Taylor (1985)** reviewed the Crozat concept of treatment and presented few cases treated by Crozat Appliance and reported that the type of distal movement of upper molars depended upon the placement of hook for class II elastics. A longer hook reduced the tipping tendency and opening of the bite. Class II hooks should be located as close to occlusal plane as possible to get a more horizontal pull.

## 18. Molar distalizing magnets

Magnets were introduced in dentistry as a source of force a few years before. **Itoh et al. (1991)**<sup>(36)</sup> quoted that used a fractional type of magnetic force, which produces a weak orthodontic force that increases in magnitude as tooth movement occurs. On the other hand, **Itoh et al. (1991) and Gianelly et al. (1988)**<sup>(6)</sup> used a repelling type of magnetic force for distal tooth movement.

**Itoh et al. (1991)** Introduced Molar Distalization System, which employed two repelling magnets for each maxillary quadrant. The system consists of freely moving mesial magnet of each pair mounted on a sectional wire.

A sliding yoke, with legation hook mesial to mesial magnet. The distal end of the system terminates in a three-pronged fork, with the middle prong sized for the insertion into the headgear tube soldered to first molar band. The other tube prongs are ligated there by securing the appliance system to the molar tube. A modified Nance appliance is cemented on first premolars to reinforce anchorage. **Gianelly, Vaitas and Thomas (1989)**<sup>(37)</sup> used a somewhat similar approach of using repelling magnet to move molars distally. In their design



the acrylic palatal coverage of Nance appliance extends anteriorly to the incisor segments by means of a 0.045 inch wire soldered to lingual aspect of first premolar bands. These are bilateral distal extension of a 0.045 inch wire with loops at the ends soldered to buccal aspects of premolar bands. These loops allow placement of ligature wire anteriorly to encircle a tieback hook mesial to the magnets, thereby, when tightened the two magnets of a pair are held in contact. **Bondemark and Kurol (1992)**<sup>(38)</sup> used similar appliance design while using samarium-cobalt-repelling magnets for simultaneous distalization of first and second molars.

### 19. Japanese NiTi Coils<sup>(39)</sup>

**Gianelly, Bednar and Dietz (1991)** successfully presented the use of Japanese NiTi coils developed by Miura *et al.* to move maxillary molars distally. They used 100 gms NiTi open coil springs with 8-10 mm of activation along with fixed appliance. Using such a system can distalize maxillary molars at the rate of 1-1.5mm per month with little or no patient cooperation.

### 20. ACCO Appliance<sup>(40)</sup>

The acrylic cervical occipital appliance is a removable appliance used along with a North West headgear to effect enmass distalization of buccal segments. The appliance originally proposed by **Dr. Hebert Margolis**, can be used on maxillary as well as mandibular buccal segments.

## SUMMARY

Molar distalization procedures have been very useful in non-extraction borderline case management. Over the years the procedures have undergone much refinement to achieve treatment objective more precisely. This has been made possible by a better understanding of bone physiology, tooth movement, biomechanics and newer biomaterials.

This led to the evolution of various intra-oral molar distalization appliances. Refinement in these appliances has concentrated mainly on achieving bodily movement of the molar rather than simple tipping. Moreover the bulk of the appliance has also been of concern to both the operator and the patient.

Implants are being increasingly appreciated and have ushered a new era in orthodontic treatment. Molar distalization is no exception. Further research is necessary before reaching a final stand on the issue.

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