

A CLINICAL ASSESSMENT OF MINISCREWS AS ANCHORAGE SOURCES IN TERMS OF STABILITY, RATE OF TOOTH MOVEMENT, AND ANCHORAGE LOSS

Mashhour Mounneh, BSc, BDS, MSc

Department of Developmental Sciences, Beirut Arab University

Fayez Saleh, BDS Honors, MSc, PhD, Dip Med Ed.

Professor of Orthodontics, Chairperson, Department of Developmental Sciences, Beirut Arab University

Nahed Attia, BDS, MSc, PhD

Professor of Periodontology, Chairperson, Department of Oral & Surgical Sciences, Beirut Arab University

Abstract

The purpose of this study was to investigate the stability of temporary anchorage devices, rate of bodily canine retraction and anchorage loss using miniscrews as a skeletal anchorage mean. The sample comprised twelve patients (3 males and 9 females, age range 17-28 years) who were scheduled for extraction of upper premolars. After leveling and alignment, a pilot drill was used and titanium miniscrews 1.2-1.3 mm in diameter and 8 mm length were inserted into the buccal cortical bone between the maxillary second premolars and first molars on both sides. Immediate loading of miniscrews and immediate canine retraction after extraction was performed. The canines were retracted with nitinol springs extending from the canine brackets to the mini-implant. Force magnitude was initially 75 gf and increased to 150 gf after 3 weeks. Patients were seen at 3-week intervals until retraction was considered complete. Stability, gingival index around miniscrews, and patient comfort were rated. Retraction distance evaluated by measuring distance between cusp tip of maxillary canine to buccal cusp tip of maxillary second premolar. Pre and post-retraction panoramic x-rays were taken to categorize type of canine retraction. Pre and post-retraction cephalometric x-rays were superimposed for measuring the amount of anchorage loss. The results revealed a success rate of 87.5% of the miniscrews. 62.5% of miniscrews had healthy gingiva, and 12.5% were acutely inflamed. Bodily retraction of canines occurred only in 61.9% of the cases. Mean anchorage loss was 0.21 mm. The first interval had the lowest mean retraction distance.

The mean rate of retraction was 0.39 mm per week. In conclusion, the TADs are stable absolute anchorage units that can be used for rapid canine retraction. Close relationship exists between implant loss and soft tissue health.

Keywords: Miniscrews, Anchorage, Success rate

Introduction

Foster (1982) considered that anchorage in orthodontics is the most important factor that determines the treatment outcome. Kyung et al. (2003) introduced small titanium miniscrews for orthodontic anchorage with a button-like head and a small hole to accept ligatures and elastomers. The small diameter allows their insertion into many areas of the maxilla and the mandible, even between roots of adjacent teeth.

Few human studies investigated the rate of canine retraction, and only one study reported the rate of canine retraction against a stable anchorage unit (Thiruvengkatachari et al., 2008). The relation of bodily retraction to rate of tooth movement is an important factor to be considered when a study wants to investigate the velocity of canine retraction in order to validate the methodology adopted. It has been reported that micro-implant anchorage system allows the anterior teeth to be retracted effectively without undesirable side-effects such as anchorage loss (Park and Kwon 2004); (Lino et al., 2006); (Choi et al., 2007) and no need to patients' cooperation. However, most have been case reports. There have been only a few studies to date that have statistically investigated the effectiveness of the implant anchorage system (Deguchi et al., 2008); (Park et al., 2008). The aim of this study was to investigate the stability of temporary anchorage devices, rate of bodily canine retraction and anchorage loss using miniscrews as a skeletal anchorage mean.

Materials and methods

An experimental study was conducted where 24 miniscrews were inserted in twelve patients (3 males and 9 females, age range 17-28 years) selected from those admitted to the department of orthodontics in Beirut Arab University and designated as extraction cases to relieve crowding and correct increased overjet. The patients were chosen according to the following criteria: 1-maximum anchorage cases, 2-therapeutic extraction of first premolars were indicated, 3-leveling and alignment phase completed before insertion of miniscrews and initiating retraction of canines. Patients with systemic diseases, bad oral hygiene, or with a D3 or D4 bone quality according to Lekholm and Zarb's, (1985) classification were excluded.

Surgical Phase

With a vertical incision and a pilot drill 0.9 mm diameter and at 300 rpm under profound irrigation, the 24 mini-implants were inserted with maximum 10 N torque. The screws were inserted into the buccal cortical bone between the maxillary second premolars and first molars on both sides under local anesthesia with a manual screwdriver, and considered immobile and stable at the moment of placement (figure 1). After installation, a periapical radiograph was taken to evaluate the position of the mini-screws that were immediately loaded. After the surgical procedure, the patient was informed about oral hygiene instructions.

Orthodontic Phase

Canine retraction was started immediately after extraction. The canines were retracted with nitinol springs extending from the canine brackets to the mini-implant (figure 2). Force magnitude was initially 75 gf and increased to 150 gf after 3 weeks. Force level was measured at each appointment with a digital caliper. Patients were seen at 3-week intervals until retraction was considered complete. A continuous, passively fitted 16-22 stainless steel arch wire was used for canine retraction. The canines were ligated to the arch wire during retraction with elastomeric chain.

Evaluation Phase

A-Stability

Cotton forceps was used bilaterally applying forces (300 g) to implants. A clinical score indicative of clinical survival and treatment objective was used (Justens et al., 2008). Score 1 = perfect result, Score 2 = the implant did not survive until the complete orthodontic treatment was finished, Score 3 = the implant showed an insufficient orthodontic result, and Score 4 = complete failure.

B-Soft tissue health

Gingival index around miniscrews was rated as 0-Normal, 1-Mildly inflamed, 2-Moderately inflamed, or 3-Acutely inflamed (Loe and Sillness 1963).

C-Patient comfort

Determined by asking patient to rate pain associated with the implant site as 1- no discomfort, 2-slight discomfort, 3- discomfort, and 4- pain (Herman et al., 2006).

D-Retraction distance

On the dental casts, distance between cusp tip of maxillary permanent Canine to buccal cusp tip of maxillary second premolar was measured with Digital Caliper.

E-Rate of retraction

The rate of retraction was defined as the distance travelled, divided by the time required to complete space closure. This was recorded in millimeters per interval. An interval was defined as a 3-week period. Canine retraction was considered complete in accordance with treatment plan for that patient.

F-Parallelism

The initial root parallelism of maxillary canine in relation to the permanent lateral incisor or second premolar was compared with root parallelism after retraction using pre and post panoramics. Canine retraction on each side was categorized, according to the grading system of the American board of Orthodontics (2012)¹³, as 1-bodily, 2-slight tipping, or 3-extensive tipping (figure 3).

G-Anchorage loss

Anchorage loss was recorded as the amount of movement in millimeters that occurred in the direction opposite to the direction of the applied resistance. To differentiate between the right and the left molars on the lateral cephalogram, a 0.017 x 0.025-in stainless steel wire was shaped in the form of an “L” and inserted in molar tubes. Molar anchorage loss was determined by superimposing the lateral Cephalometric tracings before and after traction along the palatal plane registered at anterior nasal spine. After superimposition, the horizontal distance from pterygoid vertical to the distal surface of the 1st molar on both sides was calculated to measure anchorage loss (figure 4).

Data

The data analysis was used to examine the data collected and conduct several tests for significance.

Results

A- Stability:

Success rate of miniscrews in the present study was 87.5%. Duration of canine retraction ranged from 12 to 18 weeks. The stability rate of right mini-implants was 83.3%, and that of left mini-implants was 91.7%. The

stability success rate difference between right and left areas was statistically insignificant (P-value = 0.5371).

B- Soft tissue health:

62.5% of our miniscrews had healthy gingiva, 25% were moderately inflamed, and 12.5% were acutely inflamed. The rate of healthy and moderately inflamed gingiva around the right mini-implants was 66.7% and 16.7% respectively. While, rate of healthy and moderately inflamed gingiva around the left mini-implants was 58.3% and 33.3% respectively. The soft tissue health difference between right and left areas was statistically insignificant (P-value= 0.5866). The cross tabulation analysis showed that a relation between soft tissue health and stability existed (P-value = 0.00000614).

C-Patient Comfort:

66.67% of the patients never reported discomfort. Two patients reported discomfort due to head of the implant impinging on surrounding soft tissue. Two patients were in pain on mini-implant site.

D-Root parallelism:

Comparison of the panoramic radiographs before and after retraction showed bodily retraction of canines in 61.9% of the cases, 33.3% slight tipping and 4.8% excessive tipping. Failed implants were excluded since these were removed before completion of retraction. The percentage of bodily tooth movement during retraction on the right and left sides was 80% and 45.5%, respectively. The type of movement difference between left and right cases was statistically insignificant (p-value = 0.9384).

E-Anchorage loss:

The mean anchorage loss of right and left canines was 0.19 mm and 0.24 mm, respectively. Mean anchorage loss of all canines was 0.21 mm, which represented 2.99% of extraction space lost during canine retraction. Anchorage loss difference between right and left areas was insignificant (P-value= 0.5489). The mean percentage of extraction space lost during canine retraction was 2.82% on the right side, 3.14% on the left side, and 2.99% on both sides. The 3 failed mini-implants were excluded since these were removed before completion of retraction. Next, a comparison of the amount of anchorage loss between mini-implant methods with other previous methods was done. The comparison was selected to be with Lotzof et al., (1996) method since it had the smallest mean anchorage loss of 1.71 mm. The mean loss in the present study was significantly less than 1.71 mm (p-value = 0.00E+00).

F-Retraction distance:

Mean distance of retraction of left canines was 6.41 mm, right canines 6.36 mm, and all canines 6.39mm. Retraction distance difference between right and left areas was statistically insignificant (p-value =0.8355).

The first interval had the lowest mean retraction distance and the third had the highest mean retraction distance. The average retraction distance between the two groups: the bodily and tipped retraction cases was statistically the same (p -value=0.7940). The retraction distance for D1 was significantly less than the mean retraction distance for D2 (p -value= 0.0000103).

G-Rate of retraction:

The mean rate of retraction of right canines was $0.40 \text{ mm} \pm 0.07$ per week, left canines $0.38 \text{ mm} \pm 0.04$ per week, and mean rate of all canines $0.39 \text{ mm} \pm 0.06$ per week. Maximum canine rate was 0.54 mm per week and minimum canine rate was 0.31 mm per week.

Discussion

The growing demand for maximum curative effects, in a reasonable time, and because of patient compliance problems, the temporary anchorage device (TAD) was considered an excellent alternative to traditional orthodontic anchorage. The purpose of this study was to investigate the stability of temporary anchorage devices, rate of bodily canine retraction and anchorage loss using miniscrews as a skeletal anchorage mean

A-Stability:

Comparison of success rate between different studies is limited by inconsistent reporting periods and subjective criteria of implant success or survival (Justens and Bruyn, 2008). In the present study, success rate was 87.5% which was similar to the ranges from 83.9 to 91.1 per cent as revealed by (Miyawaki et al. 2003), (Cheng et al. 2004), (Tseng et al. 2006), (Kuroda et al. 2007a), and (Wiechmann et al. 2007). These results were not in agreement with that of Kim and Choi (2001) where failure rate was 30%-40%. This might be attributed to the fact that in the present study, proper selection of miniscrews with a small diameter allowing its insertion between roots of adjacent teeth with acceptable torsional strength to resist fracture (Miyawaki et al., 2003). The proper choice of site of insertion prevented loosening of the mini-implants. This specific site was between second premolar and first molar where more than 1mm cortical bone thickness exists (park 2002) insuring primary stability and 910-940HU bone density at 6mm level apical to alveolar crest (Chun and Lim, 2009) to prevent loosening. The cross tabulation analysis showed a statistical evidence of a relation between soft tissue health and stability. Reasons for this failure might be attributed to the presence of the head of the mini-implant in nonkeratinized tissue. This is in agreement with conclusions by Cheng et al., (2004), Berens et al., (2006), and Wiechmann et al., (2007) who also reported a better prognosis for miniscrews located in the attached gingiva. Keratinized gingiva is thought to reduce the development of hypertrophic tissues and inflammation (Melsen and Verna, 2005), and (Miyawaki et al. 2003).

Similarly, Warrer et al., (1995) claimed that the absence of mucosal keratinization implies a higher susceptibility to destruction of peri-implant tissues induced by plaque. This is in agreement with conclusions by Maino et al. (2005) and Motoyoshi et al., (2007b) who emphasized on proper oral hygiene for mini-implant success. Tests of significance using the p-value showed that success rate of mini-implants was not different whether inserted on right or left areas. Probably, a larger sample size was needed to confirm these results.

B-Anchorage loss:

The findings of the present study showed a mean loss of anchorage 0.21 mm with 2.99% mean loss of extraction space. These results were less than those obtained in previous studies that revealed a range 5%-55% of the extraction space lost (Ziegler and Ingerval 1989), (Aronson et al.1990), (Lotzof et al. 1996), (Geron et al. 2003), and (Shpack et al. 2008). This difference in anchorage loss might be attributed to the fact that in the present study, no reciprocal forces were applied on the molars unlike previous studies mentioned, where all had reciprocal forces acting. Similarly, Yee et al., (2009) concluded that 45% of the total space was lost upon application of a reciprocal heavy force of 300g and 38% lost due to a reciprocal light force of 50g. Furthermore, Hoe et al. (2007) had 2.0 mm loss in patients treated with en-mass retraction and reciprocal forces applied by loop mechanics, and 1.9 mm loss in patients treated with 2-step retraction and reciprocal forces as described by Mclaughlin and Bennet (1989). In a similar manner, Koyama et al. (2011) also concluded that 2.1 mm was lost due the reciprocal vertical component of the elastic force although a headgear was used. In addition, retraction was relatively rapid giving no time to mesial drifting where the mean rate in the present study was 0.39 mm per week. Immediate loading to the miniscrews was applied giving no time to mesial drifting to occur. Tests of significance using the p-value showed that anchorage loss using minimplants was the same whether inserted on right or left areas.

C-Rate of canine retraction:

The findings of the present study revealed a mean rate of 0.39 mm per week. Similarly, Ziegler and Ingerval (1989) showed a rate of 1.41 mm per month with sliding mechanics and 1.71 mm per month with retraction springs, and Sonis et al., (1986) showed 0.99 to 1.51 mm in 3 weeks. The rates of canine retraction were higher than some of the previous studies such as Hixon et al., (1970) who obtained a rate of 0.17 mm per week, Paulsen et al. (1970) and Sleichter et al., (1971) showed a rate of 1 mm per month, Darendeliler et al.(1997) concluded 0.87mm per month with pull coil springs, Dixon et al., (2002) showed in the maxilla 0.81mm per month with titanium coil springs, Herman et al., (2006) reported 1.3 mm per month, Thiruvengkatachari et al.(2008) concluded 0.93mm per month. Possible

explanations for this difference could be due to the light force applied using the NiTi coil spring, so no hyalinized tissue was formed which decreases the rate. Similarly, Gianelly (1969) concluded that forces greater than 3N result in a lag phase caused by necrotic tissue at the periodontal ligament. In the present study, a niticoil spring had been used, which could deliver force duration, magnitude, continuity, and constancy as close as possible to ideal as clinically possible (Miura et al., 1998). On the other hand, in other studies, they used an elastic chain where force deteriorates with time. Retraction was immediately after extraction of the premolars where a high cellular activity existed. This was confirmed by results of Hasler et al. (1997).

In the present study, the first interval had the lowest distance of retraction and thus the lowest rate of canine retraction was during the first 3 weeks. This might be attributed to the fact that in adult patients, which were the case in the present study, initial tooth movement is slower. This was in agreement with Ren et al. (2003) who reported faster mesiodistal initial tooth movement in juvenile rats than in adult rats. Later, Ren et al., (2005) explained this phenomenon histologically by showing that in young rats, the maximum number of osteoclasts at the periodontal ligament compression sites was reached after 2 weeks of treatment; in adult animals this level was reached after 4 weeks. Interestingly, in the following weeks, the number of osteoclasts in the adult group was twice as high as in the young group, but the velocity of tooth movement was the same in both groups. The authors concluded that osteoclasts in young animals are more efficient than those in old animals, and that more osteoclasts are needed to achieve a certain rate of tooth movement in adult rats than in young rats. Furthermore, it was suggested that the initial decrease in orthodontic tooth movement in adults was related to the less responsiveness of the mediator levels in the gingival crevicular fluid in adults (Ren et al., 2002). More recently, it was suggested that the age-related decrease in the initial tooth movement might be related to a decrease in the RANKL/OPG ratio in gingival crevicular fluid (Kawazaki et al., 2006).

D-Root Parallelism during retraction:

In the present study, 61.9% of the Canines were retracted bodily, 33.3% showed slight tipping, and 4.8% showed excessive tipping. Bodily movement of canines occurred in 61.9% since a rectangular stainless steel wire for retraction was used, thus controlling tipping. Hermann et al., (2006) found 14% excessive tipping and 29% slight tipping during retraction of canines using mini-implant anchorage. Similarly, in the present study, tipping occurred probably because the force from the Nitinol coil spring acting on the retracted canines was coronal to the center of resistance of the canine. Another reason for the tipping in our study might be the effect of

tooth movement into a fresh recent extraction site where tipping is more than that into a healed extraction site (Hasler et al. 1997).

Conclusion

TADs are stable absolute anchorage units that can be used for rapid canine retraction. Close relationship exists between implant loss and soft tissue health where mini-implant should be inserted in keratinized tissue. Success rate, anchorage loss, type of canine retraction, and retraction distance of mini-implants were not statistically different whether inserted on right or left areas. Anchorage loss using mini-implants was statistically minimal compared to other methods. Retraction distance was not different whether during tipping movement or bodily movement; however, extra time would be needed to upright canines that were tipped during retraction.

References:

- Aronson SL, Nordenran A, Anneroth G. (1990). Titanium implant anchorage in orthodontic treatment: an experimental investigation in monkeys. *Eur J Orthod*; 12:414-9.
- Berens A, Wiechmann D, Dempf R. (2006). Mini- and Micro-screws for temporary skeletal anchorage in orthodontic therapy. *J Orofacial Orthoped*; 67:450-458.
- Cheng SJ, Tseng IY, Lee JJ, Kok SH. (2004). A prospective study of the risk factors associated with failure of mini-implants used for orthodontic anchorage. *Int J Oral Maxillofac Implants*; 19:100-6.
- Choi NC, Park YC, Lee HA, Lee KJ. (2007). Treatment of class II protrusion with severe crowding use indirect miniscrew anchorage. *Angle Orthod*; 77: 1109-1118.
- Chun YS, Lim WH (2009). Bone density at interradicular sites: implications for orthodontic mini-implant placement. *Orthod Craniofac Res*; 12:25-32.
- Darendeliler MA, Darendeliler H, Uner O. (1997). The drum spring (DS) retractor; a constant and continuous force for canine retraction. *Eur J Orthod*; 19:115-30.
- Deguchi T, Murakami T, Kuroda S, Yabuuchi T, Kamioka H, Takano-Yamamoto T.(2008). Comparison of the intrusion effects on the maxillary incisors between implant anchorage and J-hook headgear. *Am J of Orthod and Dentofacial Orthopedics*; 133: 654-660.
- Dixon V, Read MFJ, O'Brien KD, Worthington HV, Mandall NA. (2002). A randomized clinical trial to compare three methods of orthodontic space closure. *J Orthod*; 29:31-6.
- Foster T.D. (1982). A textbook of orthodontics, Blackwell Scientific Publication; St. Louis: USA, Blackwell Mosby Book Distributers.

- Geron S., Shpack N., Kandos S., Davidovitch M., Verdimon AD. (2003). Anchorage loss – a multifactorial response. *Angle Orthod*; 73:730-737
- Gianelly AA. (1969). Force-induced change in the vascularity of the periodontal ligament. *Am J of Orthod*; 55:5-11.
- Hasler R, Schmid G, Ingervall B, Gehbauer U. (1997). A clinical comparison of the rate of maxillary canine retraction into healed and recent extraction sites – a pilot study. *Eur J Orthod*; 19:711-9.
- Hermann R, Cope J.B. (2005). Miniscrew implants: Intec Mini Ortho Implants. *Semin Orthod*; 11:32-39.
- Hermann RJ, Currier GF, Miyake A. (2006). Mini-implant anchorage for maxillary canine retraction. A pilot study. *Am J Orthod Dentofacial Orthop*; 130:228-235.
- Hixon EH, Aasen TO, Arango J, Clark R, Klosterman R, Miller S, Odom WM. (1970). On force and tooth movement. *Am J Orthod*; 56:476-89.
- Hoe W., Nahm D.G., Beak S.H., (2007). En masse retraction and two-step retraction of maxillary anterior teeth in adult class I women. *Angle Orthod*; 77: No6.
- Justens E, Bruyn H (2008). Clinical outcome of mini-screws used as orthodontic anchorage. *Clin Impl Dent Res.*; 10: n 3.
- Kawazaki K, Takahashi T, Yamagushi M, Kasai K (2006). Effects of aging on RANKL and OPG levels in gingival crevicular fluid during orthodontic tooth movement. *Orthod Craniofac Res*; 9:137-42.
- Kim YJ, Choi JH. (2001). Stability of titanium miniscrew used as intraoral anchorage. *J Korean Assoc*; 39:684-7.
- Koyama I, Iino S, Abe Y, Takano-Yamamoto T and Miyawaki S. (2011). Differences between sliding mechanics with implant anchorage and straight-pull headgear and intermaxillary elastics in adults with bimaxillary protrusion. *Eur J Orthod*; 33:126-131.
- Kuroda S, Sugawara Y, Deguchi T, Kyung HM, Takano-Yamamoto T.(2007a) Clinical use of miniscrew implants as orthodontic anchorage: success rate and postoperative discomfort. *Am J Orthod Dentofacial Orthop*; 131:9-15.
- Kyung HM, Park HS, Bae SM (2003). Development of orthodontic microimplants for intraoral anchorage. *J Clin Orthod*; 37:321 – 8.
- Lekholm U, Zarb GA. (1985). Patient selection and preparation. In: Branemark PI, Zarb GA, Albrektsson T, editors. *Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry*. Chicago: Quintessence. pp. 199-209.
- Iino S, Sakoda S, Miyawaki S. (2006). An adult bimaxillary protrusion treated with corticotomy-facilitated orthodontics and titanium miniplates. *Angle Orthod*; 76: 1074-1082

- Loe H, Sillness J (1963). Periodontal Disease in pregnancy, I. Prevalence and Severity. *Acta Odontol Scand*; 21:533-549.
- Lotzof L, Fine H, Cisneros G. (1996). Canine retraction. A comparison of two preadjusted bracket systems. *Am J Orthod Dentofacial Orthop*; 110:191-196.
- Maino, B., Mura, P. & Gianelly, A. (2002). A retrievable palatal implant for absolute anchorage in orthodontics. *World J Orthod*; 3:125-134
- McLaughlin RP, Bennett JC (1989). The transition from standard edgewise to preadjusted appliance system. *J Clin Orthod*; 23:142-53.
- Melsen B, Verna C (2005). Miniscrew implants: the Aarhus anchorage system. *Semin Orthop*; 11:24-31.
- Miura F, Mogi M, Ohura Y, Karibe M. (1988). The super-elastic Japanese NiTi alloy wire for use in orthodontics. Part 3. Studies on the Japanese NiTi alloy coil springs. *Am J Orthod Dentofacial Orthod*; 94:89-96.
- Miyawaki, S., Koyama, I., Innoue, M., Mishima, K., Sugahara, T. & Takano- Yakamoto, T. (2003) Factors associated with the stability of titanium screws placed in the posterior region anchorage. *American Journal of Orthodontics and Dentofacial Orthopedics*; 24:373-378.
- Motoyoshi M, Yano S, Tsuruoka T, Shimizu N. (2005). Biomechanical effect of abutment on stability of orthodontic mini-implant. *Clin Oral Implants Res*; 16:480-5.
- Park HS, Kwon TG (2004). Sliding mechanics with micro screw implant anchorage. *Angle Orthod*; 74:703-710
- Park HS, Yoon DY, Park CS, Jeong SH (2008). Treatment effects and anchorage potential of sliding mechanics with titanium screws compared with Tweed-Merrifield technique. *Am J Orthod Dentofacial Orthop*; 133:593-600.
- Park HS. (2002). an anatomical study using CT images for the implantation of micro-implants. *Korean J Orthod*; 32:435-441.
- Paulsen R., Speidal T., Isaacson R. (1970). A laminographic study of cuspid retraction versus molar anchorage loss. *Angle Orthod*; 40:110-115.
- Ren Y, Kuijpers-Jagtman AM, Maltha JC (2005). Immunohistochemical evaluation of osteoclast recruitment during experimental tooth movement in young and adult rats. *Arch Oral Biol*; 50:1032-9.
- Ren Y, Maltha JC, Van't Hof MA, Kuijpers-Jagtman AM (2003). Age effect on orthodontic tooth movement in rats. *J Dent Res*; 82:38-42.
- Ren Y, Maltha JC, Van't Hof MA, Von Den Hoff JW, Kuijpers-Jagtman AM, Zhang D (2002). Cytokine levels in crevicular fluid are less responsive to orthodontic force in adults than in juveniles. *J Clin Periodontol*; 29:757-62.

- Shpack N; Davidovitch M; Sarne O; Panayi N; Vardimon A (2008). Duration and anchorage management of canine retraction with bodily versus tipping mechanics. *Angle Orthod*; Vol. 78, No.1, pp.95-100.
- Sleighter CG. (1971). A clinical assessment of light and heavy forces in the closure of extraction spaces. *Angle Orthod*; 41:66-75.
- Sonis AL, Van der Plas E, Gianelly A (1986). A comparison of elastomeric auxiliaries versus elastic thread on premolar extraction site closure: an in vivo study. *Am J Orthod*; 89:73-8.
- The American board of orthodontics. (2012). Grading System for Dental Casts and Panoramic Radiographs.
- Thiruvengkatachari B, Pavithranand A, Rajasijamani K. (2008). Comparison of rate of canine retraction with conventional molar anchorage and titanium implant anchorage. *Am J Orthod Dentofacial Orthop*; 134:305.
- Tseng YC, Hsieh CH, Chen CH, Shen YS, Huang IY, Cheng CM (2006). The application of mini-implants for orthodontic anchorage. *Int J Oral Maxillofacial Surg*; 35:704-707.
- Warrer K, Buser D, Lang NP, Karring T (1995). Plaque-induced peri-implantitis in the presence or absence of keratinized mucosa. *Clin Oral Implants Res*; 6:131-138.
- Wiechmann D, Meyer U, Buechter A (2007). Success rate of mini- and micro-implants used for orthodontic anchorage: a prospective clinical study. *Clin Oral Implants Res*; 18:263-267.
- Yee J, Turk T, Elekdag-Turk S, Cheng L, Darendeliler M.(2009) Rate of tooth movement under heavy and light continuous orthodontic forces. *Am J Orthod Dentofacial Orthop*; 136:150.e1-150.e9.
- Zieglar P., Ingervall P. (1989). A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. *Am J Orthod Dentofacial Orthop*; 95:99.