ejpmr, 2020,7(1), 457-463

SJIF Impact Factor 6.222

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Review Article

ISSN 2394-3211

EJPMR

EXTERNAL APICAL ROOT RESORPTION IN ORTHODONTIC PATIENTS: AN OVERVIEW

Dr. Tulika Tripathi*, Dr. Pavan Kumar Shukla, Dr. Shilpa Kalra

India.

***Corresponding Author: Dr. Tulika Tripathi**

India.

Article Received on 20/11/2019 **Article Revised on 11/12/2019** **Article Accepted on 31/12/2019**

ABSTRACT

External apical root resorption (EARR) is an inevitable complication of fixed orthodontic treatment. EARR is multifactorial, influenced by a combination of environmental and host factors. Orthodontist should know the risk factors of EARR and do everything to reduce this. This review describes the literature regarding the association between orthodontic treatment and EARR.

KEYWORDS: external apical root resorption, root resorption, orthodontics.

INTRODUCTION

External apical root resorption (EARR) is an inevitable complication of fixed orthodontic treatment that may lead to permanent loss of tooth structure from root apex.[1]

The prevalence of radiographically discernible EARR associated with orthodontic treatment affects about a third of patients with moderate degree (>3 mm) of root resorption, while severe root resorption >5 mm may occur in 2–5% of cases. However 7 to 13% of individuals who did not have orthodontic treatment also showed root resorption.[1]

EARR associated with orthodontic treatment occurs mainly in the apical third of root.[2] Two viable explanations for the increased incidence of resorption lacuna in the apical third are:[2]

1. The fulcrum is occlusal to the apical half of the root and the differences in the direction of the periodontal fibers could result in increased possibility of trauma in the apical and middle thirds of the root.
2. Cellular cementum is found in apical area of root has more supporting vasculature, which makes it more liable to trauma and cell injury reactions. While the middle and cervical thirds are covered with acellular cementum.

The degree of root resorption is assessed as grade 0, no evidence for resorption, grade 1, Irregular root contour, grade 2, Apical root resorption less than 2 mm, grade 3, Apical root resoption > 2mm and < 1/3 of original root length, and grade 4, root resorption exceeding 1/3 of original root length.[3]

Risk factors that can initiate and induce root resorption during orthodontic treatment are manifold and have been tabulated in the chart. These factors can be distributed to patient related, orthodontic treatment related or both patient and treatment factors.[1] (fig: 1)

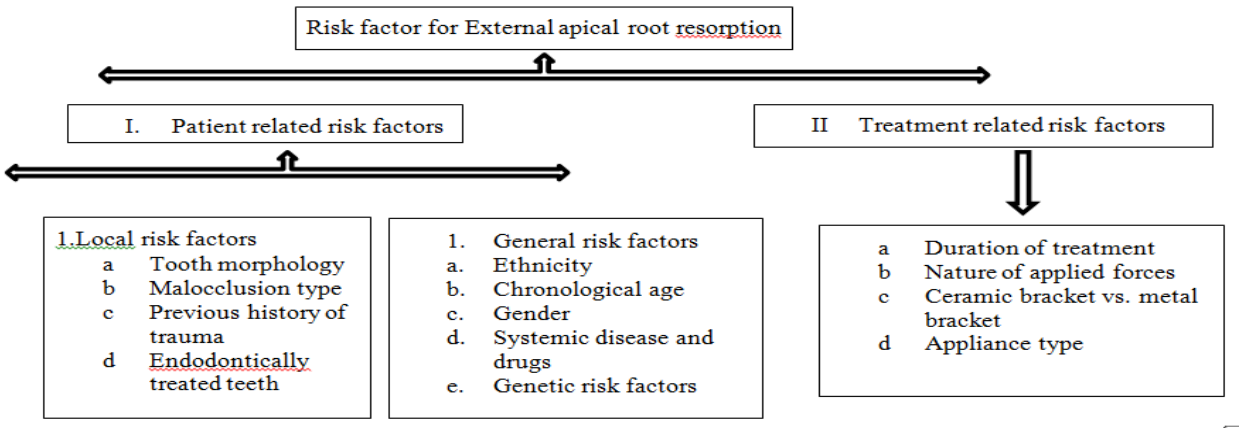

Fig 1: Various risk factors for EARR.

I PATIENT RELATED RISK FACTOR

1. Local Risk Factors

a Tooth Morphology

Teeth with short apices, pipette-shaped roots, bent roots, dilacerated roots and slender roots all have been associated with increased levels of root resorption.

Oyama et al[4] and Picanco et al[5] reported that roots with a short apex enhanced root resorption. This finding is related to the alteration of the crown-root ratio. A decrease in the ratio of the root to the crown is thought to enhance loading on the root, resulting in significant stress.

Levander and Malmgren[6] reported in his radiographic studies, that blunt roots showed more root resorption than normal roots. However, this is contradicted by the findings of Sameshima and Sinclair[7] and FEM study of Oyama et al[4] who found that teeth with blunted roots had the least resorption.

In bent root apex, stress was concentrated at the mesial and distal surface of the root apex during intrusive force application, and at the labial and lingual surface of the root apex when lingual force was applied. The results concerning stress distribution on the bent root shape are in agreement with the findings of Levander and Malmgren[6], and Oyama et al[4] who reported that a bent shape induced root resorption.

In pipette shaped root, regardless of the direction of force application, stress was concentrated at the neck of the root apex. Oyama et al[4], Sameshima and Sinclair[7], described, in their radiographic studies, that teeth with a pipette-shaped root apex enhanced root resorption.

Oyama et al[4] explained the increased levels of root resorption, in short, bent and pipette shaped roots in a FEM study which demonstrated greater loading of forces in the root apices of these teeth compared with normal teeth.

Teeth with increased root lengths have also been implicated as being at risk of increased root resorption. This is due to the requirement for the use of larger forces to move the teeth and the larger displacement of the root apices during tipping and torquing.

Kook et al[8] reported that teeth with a deviated root shape, i.e. peg-shaped or short roots, do not always suffer from root resorption. This is thought to be related to risk factors other than mechanical factors.

Why anomalous roots are resorbed more easily is unknown, but the forces during orthodontic tooth movement are often concentrated at the apex of the tooth. The apical cellular cement is less mineralized, hence more fragile and exposed to damage. During orthodontic force, an overloading of this fragile apex can lead to necrosis of the PDL, and EARR.[9] Sameshima and Sinclair[7] pointed out that the deviant process that caused the abnormal root shape may also play a contribution to these roots being easier resorbed. X-rays should be taken at an earlier point in treatment when the risk of EARR is judged to be increased. They also recommend an x-ray control after active treatment of six months, when total treatment time exceeds this limit. Hollender et al[10] proposed periodic radiography every three months during active treatment. This opinion has been shared by many orthodontists, although the recommended interval varies between three months up to a year.[1]

Partially formed roots appear to develop normally during orthodontic treatment and it has been suggested that teeth with open apices may be more resistant to apical root resorption.[11]

b. Maloccusion Type

Based on the type of malocclusion many studies show that there is no relationship between root resorption and type of malocclusion.[8, 12] However many studies state that a relationship between malocclusion and root resorption exists but these are found mainly in cross sectional data. The significance of the result of these studies shows that the root resorption may be more related to other factors rather than malocclusion itself for example, the distance tooth are moved as in retraction of upper incisors in a class 2 division 1 or direction of tooth movement as in torquing and intrusive movements rather than malocclusion itself or duration of correction of severe malocclusion may take longer to correct and hence, different malocclusions may be associated with EARR because of longer exposure of the teeth to the resorptive process. Harris et al[13] demonstrated that patients with a greater ANB had more root resorption, which supports the theory of a greater distance of dental movement to correct a given malocclusion, rather than being related to the malocclusion directly. Kaley[14] found that class III patients with roots touching the cortical plates had more resorption, as would be expected, and that surgical procedures may change blood supply in some patients and has been proposed as contributory factor to resorption. In contrast Vonderahe[15] assessed root resorption relative to class of malocclusion in 57 individuals and failed to find any association. A study by Xu and Baumrind[16] of 58 individuals had root resorption of incisors measured from periapical films and amount of incisor retraction measured on lateral cephalograms. They found that only a very small contribution to root resorption was from the distance of tooth movement.

c. Previous History Of Trauma

Tooth with the history of trauma before orthodontic treatment shows more apical resorption and possibility of tooth to be non-vital is high.[17] The possibility of loss of vitality is more in tooth with obliterated canal. Tooth with vital pulp or unobliterated pulp after trauma responds similar to normal vital tooth. However, still the

conclusive remark could not be made on the prognosis of orthodontic tooth movement in traumatized tooth due to lack of randomized controlled clinical trial.
Traumatized teeth with signs of root resorption prior to orthodontic treatment may be more prone to root resorption during treatment.[18]

Endodontically Treated Teeth
Study conducted by Spurrier SW et al[19] confirmed that endodontic treatment is a preventive factor for apical root resorption. Remington et al.[20] speculated that an increased density of dentin in endodontially treated teeth provides resistence to resorption. However Esteves et al[21] Llamas-Carreras et al[22] found no signicant differences were observed between vital and non-vital contralateral teeth.

2. GENERAL RISK FACTORS

a. Ethinicity

Study of Sameshima and Sinclair[7] shows that White and Hispanic patient population are susceptible to resorptive process to a greater extent than the Asian population. The authors however, studied that 5 out of 6 orthodontic practices had a dominant attending racial group in which biased outcomes may have been involved, particularly when clinician or treatment factors of practice contributed to root resorption.

No significant difference between groups were present in one practice with more even spread of 3 racial groups.

An inherited polymorphism seems likely related to root resorption carried in certain ethnic lines but underlined mechanisms remain unclear if ethnic etiology does exist.

b. Gender

Previous studies have shown that a significant difference between gender in EARR, and female were found to be more susceptible.[4, 5] Brezniak and Wasserstein[23] reviewed 13 article out of which five reported no associations between gender and apical resorption, seven reported more resorption in females than in male subjects, and only one reported more resorption in male subjects.

Dougherty conferred that the difference in root resorption in male and female is due to root in male is chronologically less mature than the female and hence the male roots are less susceptible to the traumatic effect of orthodontic stress.[24] A hormonal etiology then could exist or a sex linked gene may predispose female to the process.

Authors such as Pereira et al[25] have suggested male subjects are more susceptible for root resorption than female subjects. However, on average, female values were only 3% below male values. However, found more idiopathic root resorption in untreated females. However, others have found no correlation between EARR and gender.

c. Chronological Age

The influence of age as a factor contributing to EARR, has for a long time caused some degree of disagreement among researchers. In orthodontic patients of more advanced age, larger hyalinised areas, longer duration of hyalinization period and reduced capacity of tissue repair are factors that are thought to increase the risk of EARR.[22,26] Another influencing factor is the protective mechanisms of precementum and predentine located on the apices of young individuals.[27] Predentine is not calcified and is therefore not attacked by resorbing cells.[28] Most studies on EARR concentrate on the maxillary incisors, and many of the articles published in recent years found no association between age and the amount of EARR in these teeth claimed that age may not be a significant factor in the contribution of EARR.[22] Sameshima and Sinclair[7], in their study also found no such link.

In most of the articles there was a positive correlation between age and EARR. Although some of the authors concluded that age is not a significant factor in the occurrence of EARR, this seems to be dependent on which teeth were being evaluated, the inclusion/exclusion criteria in the different surveys and not least, at what number the level of significance was being set. A young individual with incomplete root formation has several biological advantages in respect of developing EARR during orthodontic treatment or not.[26] Therefore it is advised to start orthodontic treatment in young age to reduce chances of EARR.

Reduced vascularity, plasticity and width of the periodontal ligament, increased density and reduced vascularity of bone and an increase in the width of cementum are associated with increasing age. Reitan[26] suggested that these changes are responsible for the increased incidence of root resorption seen in adults.

d. Systemic Diseases And Drugs

Engstrom demonstrated root resorption in animals deprived of dietary calcium and vitamin D. However, Linge and Linge[27] and Goldie and King[28] suggested that nutritional imbalance is not a major factor in root resorption during orthodontic treatment.

Altered endocrine conditions such as hyperparathyroidism Paget's disease, hypophosphataemia, hypothyroidism, hypopituitarism and hyperpituitarism are associated with altered resistance to root resorption. This can be explained by the control of the metabolism of mineralised tissues by the endocrine hormones 1,25- Dihydroxycholecalciferol, parathyroid hormone and calcitonin.[24,29]

Liu et al[30] found that local bisphosphonate (clodronate) inhibited root resorption incident to tooth movement and suggested it to be a useful therapeutic adjunct in orthodontic treatment. Igarashi et al[31] evaluated topical administration of residronate on root resorption and

found that it did not appear to inhibit the repair process of root resorption.

In a recent study Verna et al[32] investigated the effect of acute and chronic corticosteroid treatment on orthodontically induced root resorption and found more root resorption in acute group. When compared to chronic group and suggested that it may be due to lack of balance between blastic and clastic activities during intial phase of drug administration.

e. Genetic risk factor

Harris et al[13] found a hereditary component to external apical root resorption following a study amongst siblings which suggests that genetic factors play a role in EARR. Al Qawasmi et al[33] identified a key role of the IL-1β gene polymorphism for a genetic influence in EARR in orthodontically treated individuals. They showed a 5.6 fold risk of external apical root resorption of greater than 2mm in polymorphisms which were homozygous for the IL-1β allele 1. This polymormphism accounted for approximately 15% of variation in EARR of upper centrals. Harris et al[13] and Hartsfiled et al[34] deduced that since half of the variation in EARR was influenced by genetic factors, and the variation at IL-1β accounts for only 15 per cent of phenotypic variation, there must be other genes that influenced EARR.

Genetic factors like P2RX7, IL 1, IL 1RN IL-6, RANK, OPG have been identified in the recent research that influence the occurrence of EARR during orthodontic treatment.[35,36]

II. TREATMENT RELATED RISK FACTORS

a Nature Of Applied Force And Type Of Tooth Movement

Debate exists as to whether more root resorption is associated with continuous or intermittent forces. Many believe that discontinuous forces produce less root resorption because the pause in tooth movement allows the resorbed cementum to heal.[37]

Topkara et al[38] examined 22 human teeth. The patients were exposed to a continuous tipping force of 100g on one side and an intermittent force applied through elastics for 12 hours per day on the other side, over a period of 9 weeks. Their results showed that the intermittent forces resulted in less root resorption. The accuracy of these results is questionable because the intermittent forces were subject to patient compliance.

Contrary to these reports Owman Moll et al[38] found no difference in the amount or severity of root resorption between forces applied continuously or intermittently after application of a buccally directed force of 50g to human premolars.

Four split mouth studies from the same research group by Chan & Darendilier[39] compared fixed orthodontic light (25g) continuous force with fixed orthodontic heavy (225 g) continuous force in patients needing premolar extractions to relieve crowding or overjet. It was observed that heavy continous force produce significantly more root resorption than light forces. Barbagallo et al[40] also found that heavy force produced significantly more root resorption (9 times) than light force.

Harris et al[13] produced intrusive forces & results showed that volume of root resorption craters after intrusion was directly proportional to the magnitude of the intrusive force.

Intrusive vs extrusive forces: Han et al[41] found that root resorption from extrusive force was not significantly high. However intrusive forces significantly increase the percentage of resorbed root area. Intrusion has been consistently implicated as the most likely type of tooth movement to cause root resorption. Stress distribution associated with tipping movements is more likely to cause root resorption than the stress distribution associated with bodily movement.

b. Type Of Treatment (Extraction Vs. Nonextraction)

Most studies agree that patients who have extractions during orthodontic treatment have greater chances of severe resorption than those treated without extractions[38] One possible explanation for this could be the increased movement and retraction of the apex to close extraction spaces.

All treatment plans involving extractions were not found to be associated with an increase in the severity of maxillary incisor root resorption. An explanation for this is that the movement of maxillary incisors is not excessive if teeth have been extracted for severe crowding unlike in cases where maxillary incisors are moved large amounts to facilitate the correction of overjet.

c. Appliance Type

The dramatic difference in incidence of EARR has been noted between Begg and edgewise appliances by previous studies. A study conducted by Mc Nub et al[43] have shown incidence of EARR 2.30 times higher in Begg than edgewise technique. Indeed the incidence increased in extractions cases where Beggs technique shown 3.72 times more resorbtion. Opposite of the above Beck and Harris[44] found no difference in amount of EARR between Begg and tweed technique.

Clifford[45] found that increasing the depth of the reverse curve of spee in a rectangular stainless steel archwire increased the stress patterns observed around the incisor and molar roots.

There is no statically significant difference noted between fully programmed edgewise appliance and a partly programmed edgewise appliance with respect to amount and prevalence of EARR.[46]

While comparing EARR proceeding from removable and fixed appliance, it was evidenced that EARR more often occurred in fixed appliance technique.[47] IlanaBrin et al[48] observed an increase in EARR, this becomes apparent more specifically in children treated with fixed appliance only than children treated with 2-phase orthodontic treatment (functional removable appliance and later fixed appliance) in class II malocclusion.

While assessing the influence of metal and ceramic brackets on root resorption, it was observed that root resorption occur more often in patients treated with aesthetic brackets. This is because treatment with aesthetic brackets lasts longer.[44]

d. Treatment Duration

According to Killiany DM[1] resorption increased as a function of treatment time suggested relation between the duration of treatment and the degree of resorption.

Sameshima and Sinclair[7] looked at a sample of 868 patients collected from 6 different specialist practitioners and found longer treatment times to be significantly associated with increased root resorption for maxillary central incisors.

However, Vonderahe[49] concluded that the treatment time did not influence the amount of resorption.

CONCLUSION

EARR is a multifactorial complication of orthodontic treatment. Strategies to minimize external root resorption should include identification of systemic and local risk factors at the stage of treatment planning, reduction of treatment duration, use of light intermittent forces, and biannual radiographic monitoring in order to detect any possible root resorption at the earliest stage. As some degree of apical external root resorption is a frequent and unavoidable complication of orthodontic treatment, during treatment planning, the patient or parent should be warned of this risk.

REFERENCES

1. Killiany DM. Root resorption caused by orthodontic treatment: review of literature from 1998 to 2001 for evidence. Progress in Orthodontics., 2002 Jan; 3(1): 2-5.
2. Sasaki T, Takahashi N, Watanabe C, Suzuki H, T S. Cytodifferentiation of odontoclasts in physiologic root resorption of human deciduous teeth. In: Davidovitch Z, editor. Biological mechanics of tooth eruption and root resorption; 1988; P. 321-8.
3. Levander E, Malmgren O. Evaluation of the risk of root resorption during orthodontic treatment: a study of upper incisors. The European Journal of Orthodontics, 1988 Feb 1; 10(1): 30-8.
4. Oyama K, Motoyoshi M, Hirabayashi M, Hosoi K, Shimizu N. Effects of root morphology on stress distribution at the root apex. Eur J Orthod, 2007; 29: 113.
5. Picanco GV, de Freitas KM, Cancado RH, Valarelli FP, Picanco PR, Feijao CP. Predisposing factors to severe external root resorption associated to orthodontic treatment. Dental Press J Orthod, 2013; 18: 110–20.
6. Levander E, Malmgren O, Eliasson S. Evaluation of root resorption in relation to two orthodontic treatment regimes. A clinical experimental study. Eur J Orthod, 1994; 16: 223–228.
7. Sameshima GT, Sinclair PM. Predicting and preventing root resorption: Part I. Diagnostic factors. Am J Orthod & Dentofacial Orthop, 2001; 119: 505-510.
8. Kook YA, Park S, Sameshima GT. Peg-shaped and small lateral incisors not at higher risk for root resorption. American journal of orthodontics and dentofacial orthopedics, 2003 Mar 1; 123(3): 253-8.
9. Preoteasa CT, Ionescu E, Preoteasa E, Comes CA, Buzea M-C, Grămescu A. Orthodontically induced root resorption correlated with morphological characteristics. Romanian J Morphology and Embryology, 2009; 50: 257.
10. Hollender L, Rönnerman A, Thilander B. Root resorption, marginal bone support and clinical crown length in orthodontically treated patients. Eur J Orthod, 1980; 2: 197-205.
11. Topkara A, Karaman AI, Kau CH. Apical root resorption caused by orthodontic forces: A brief review and a long-term observation. Eur J Dent., 2012 Oct; 6(4): 445-53.
12. Dindaroğlu F, Doğan S. Root Resorption in Orthodontics. Turk J Orthod. 2016 Dec; 29(4): 103-108. doi: 10.5152/TurkJOrthod.2016.16021. Epub 2016 Dec 1. Review.
13. Harris EF, Kineret SE, Tolley EA. A heritable component for external apical root resorption in patients treated orthodontically. Am J Orthod Dentofacial orthop, 1997 Mar 1; 111(3): 301-9.
14. Kaley J, Phillips C. Factors related to root resorption in edgewise practice. Angle Orthod, 1991; 61(2): 125-32.
15. Vonderahe G. Postretention status of maxillary incisors with root-end resorption. Angle Orthod, 1973; 43: 247-55.
16. Xu T, Baumrind S. The relationship between apical root resorption and orthodontic tooth movement in growing subjects. Zhonghua Kou Qiang Yi Xue Za Zhi, 2002; 37(4): 265-8.
17. Fernandes M, De Ataide I, Wagle R. Tooth resorption part II-external resorption: Case series. J Conserv dent: JCD., 2013 Mar;16(2): 180.
18. Malmgren O, Goldson L, Hill C, Orwin A, Petrini L, Lundberg M. Root resorption after orthodontic treatment of traumatized teeth. Am J Orthod. 1982 Dec 1; 82(6): 487-91.
19. Spurrier S, Hall S, Joondeph DR, Shapiro PA, Riedel RA. A comparison of apical root resorption during orthodontic treatment in endodontically treated and vital teeth. Am J Orthod Dentofacial Orthop., 1990; 97(2): 130-4.

20. Remington DN, Joodeph DR, Artun J, Riedel RA, Chapko MK. Long term evaluation of root resorption occurring during orthodontic treatment. Am J Orthod Dentofacial Orthop, 1989; 96(1): 43-6.
21. Esteves T, Ramos AL, Pereira C M, Hidalgo M M. Orthodontic Root Resorption of Endodontically Treated Teeth. J Endod, 2007; 33: 119 – 122.
22. Llamas-Carreras JM, Amarilla A, Solano E, Velasco-Ortega E, Rodríguez-Varo L, Segura-Egea JJ. Study of external root resorption during orthodontic treatment in root lled teeth compared with their contralateral teeth with vital pulps. Int Endod J., 2010; 43: 654-62.
23. Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: Part 2. Literature review. American Journal of Orthodontics and Dentofacial Orthopedics, 1993 Feb 1; 103(2): 138-46.
24. Dougherty HL. The effects of mechanical forces upon mandibular bucal segments during orthodontic tretment. Part I. Am J Orthod, 1968; 54: 29-49.
25. Pereira AAC. Influência da gravidez e dos anticoncepcionais na reabsorção radicular e na remodelação óssea conseqüente à movimentação dentária induzida. Avaliação microscópica [Dissertação de Mestrado]. Bauru: USP, Faculdade de Odontologia; 1995. 144p.
26. Reitan K. Effects of force magnitude and direction of tooth movement on different alveolar bone types. The Angle Orthodontist, 1964 Oct; 34(4): 244-55.
27. Linge L, Linge BO. Patient characteristics and treatment variables associated with apical root resorption during orthodontic treatment. A J Orthod Dentofacial Orthop, 1991 Jan 1; 99(1): 35-43.
28. Goldie RS, King GJ. Root resorption and tooth movement in orthodontically treated, calcium-deficient, and lactating rats. Am J Orthod., 1984 May 1; 85(5):424-30.
29. Cholia SS, Wilson PH, Makdissi J. Multiple idiopathic external apical root resorption: report of four cases. Dento maxillofacial Radiol, 2005 Jul; 34(4): 240-6.
30. Liu L, Igarashi K, Haruyama N, Saeki S, Shinoda H, Mitani H. Effects of local administration of clodronate on orthodontic tooth movement and root resorption in rats. Eur J Orthod, 2004 Oct 1; 26(5): 469-73.
31. Igarashi K, Mitani H, Adachi H, Shinoda H. Anchorage and retentive effects of a bisphosphonate (AHBuBP) on tooth movements in rats. Am J Orthod Dentofacial Orthop, 1994 Sep 1; 106(3): 279-89.
32. Verna C, Hartig LE, Kalia S, Melsen B. Influence of steroid drugs on orthodontically induced root resorption. Orthod Craniofacial Res., 2006 Feb; 9(1): 57-62.
33. Al-Qawasmi RA, Hartsfield Jr JK, Everett ET, Flury L, Liu L, Foroud TM, Macri JV, Roberts WE. Genetic predisposition to external apical root resorption. Am J Orthod Dentofacial Orthop., 2003 Mar 1; 123(3): 242-52.
34. Hartsfield Jr JK. Pathways in external apical root resorption associated with orthodontia. Orthodontics & craniofacial research., 2009 Aug; 12(3): 236-42.
35. Pereira S, Lavado N, Nogueira L, Lopez M, Abreu J, Silva H. Polymorphisms of genes encoding P 2 X 7R, IL-1 B, OPG and RANK in orthodontic-induced apical root resorption. Oral diseases, 2014 Oct; 20(7): 659-67.
36. Iglesias Linares A, et al. Interleukin 1 receptor antagonist (IL1RN) genetic variations condition post-orthodontic external root resorption in endodontically-treated teeth. Histol histopathol. 2013.
37. Alfuriji S, Alhazmi N, Alhamlan N, Al-Ehaideb A, Alruwaithi M, Alkatheeri N, Geevarghese A. The effect of orthodontic therapy on periodontal health: a review of the literature. Int J Dent. 2014; 2014.
38. Owman-Moll P, Kurol J, Lundgren D. Continuous versus interrupted continuous orthodontic force related to early tooth movement and root resorption. Angle Orthod, 1995 Dec; 65(6): 395-401.
39. Chan E, Darendeliler MA. Physical properties of root cementum: part 7. Extent of root resorption under areas of compression and tension. Am J Orthod Dentofacial Orthop, 2006 Apr 1; 129(4): 504-10.
40. Barbagallo LJ, Jones AS, Petocz P, Darendeliler MA. Physical properties of root cementum: Part 10. Comparison of the effects of invisible removable thermoplastic appliances with light and heavy orthodontic forces on premolar cementum. A microcomputed-tomography study. Am J Orthod Dentofacial Orthop, 2008 Feb 1; 133(2): 218-27.
41. Han G, Huang S, Von den Hoff JW, Zeng X, Kuijpers-Jagtman AM. Root resorption after orthodontic intrusion and extrusion: an intraindividual study. Angle orthod, 2005 Nov; 75(6): 912-8.
42. Graber LW, Vanarsdall RL, Vig KW, Huang GJ. Orthodontics-E-Book: current principles and techniques. Elsevier Health Sciences; 2016 Jul 15.
43. McNab S, Battistutta D, Taverne A, Symons AL. External apical root resorption of posterior teeth in asthmatics after orthodontic treatment. Am J Orthod Dentofacial Orthop, 1999 Nov 1; 116(5): 545-51.
44. Beck BW, Harris EF. Apical root resorption in orthodontically treated subjects: analysis of edgewise and light wire mechanics. Am J Orthod Dentofacial Orthop, 1994 Apr 1; 105(4): 350-61.
45. Clifford PM, Orr JF, Burden DJ. The effects of increasing the reverse curve of Spee in a lower archwire examined using a dynamic photo-elastic gelatine model. Eur J Orthod, 1999 Jun 1; 21(3): 213-22.
46. Reukers E, Sanderink G, Kuijpers-Jagtman AM, Van't Hof M. Assessment of apical root resorption using digital reconstruction. Dentomaxillofacial Radiol, 1998 Jan; 27(1): 25-9.

47. Meeran NA. Iatrogenic possibilities of orthodontic treatment and modalities of prevention. J Orthod Sci., 2013 Jul; 2(3): 73.
48. Brin I, Tulloch JC, Koroluk L, Philips C. External apical root resorption in Class II malocclusion: a retrospective review of 1-versus 2-phase treatment. Am J Orthod Dentofacial Orthop., 2003 Aug 1; 124(2): 151-6.
49. Vonderahe G. Postretention status of maxillary incisors with root-end resorption. Angle Orthod, 1973 Jul; 43(3): 247-55.