



# MASTEROPPGAVE

## Fixed Appliance & Root Resorption Possible to Predict?

A Literature Review

**Dental students:  
Sesilie Beck-Hansen  
Iris Hergot Berglund**

**Supervisors:**  
Mats Larsson, Specialist in Orthodontics, TkNN  
Heidi Kerosuo, Professor, IKO

**UNIVERSITETET I TROMSØ**  
**Det helsevitenskapelige fakultet**  
Institutt for Klinisk Odontologi

Juni 2012

### **Abstract**

There are many possible causes to external apical root resorption (EARR) as a sequela of orthodontic treatment with fixed appliance. This literature review examines root morphology, age, commonly affected teeth, magnitude of force, continuous versus interrupted forces and duration of treatment, in order to evaluate if root resorption can be predicted. Qualitative analysis of a range of studies in this area has been made. Maxillary incisors seemed to be the teeth most vulnerable to EARR. All of the contributing factors above had a connection to root resorption of varying extents. It is therefore essential for a clinician to be aware of these factors, to be able to estimate the risk of root resorption individually for each patient.

**Figure 1: Root resorption in the incisors as result of orthodontic treatment with fixed appliance.**



Picture by Mats Larsson

## **Introduction**

The increasing focus on aesthetics plays an important role in today's community, with dentistry and orthodontics as a genre, as no exceptions. With increasing numbers of patients receiving orthodontic treatment and having higher expectations, the deleterious consequences of treatment should be emphasized. White spot lesions, gingival recessions and other periodontal problems are all possible complications of orthodontic treatment, but the perhaps most commonly suffered is root resorption. (Mitchell 2007) There are many orthodontic treatment options, among them removable appliances, functional appliances and fixed appliances. The focus in this assignment was root resorption as a sequelae of treatment with fixed appliances.

Root resorptions are conditions known to be associated with a physiological or pathological process that causes loss of cementum or dentin from a tooth root. The physiological process of root resorption is normal in the phase when the deciduous teeth are being shed. (D. Healy). The pathological type of root resorption however, is not normal and may for example be due to traumatic injuries or pressure from orthodontic devices, periapical infectious lesions or periodontal diseases (Brezniak and Wasserstein 2002). Sometimes the resorption process is idiopathic and the cause is unknown. When a tooth is moved, one way or the other, the orthodontic forces are transmitted from the appliance through the tooth and to the periodontal ligament. The biological process that then occurs is very complex, but the "main" result will be tension on one side of the tooth, and compression of the PDL on the other side. To the compression side,

osteoclasts will migrate and the appearance will gradually lead to bone resorption. On the tension side the opposite will happen, and bone deposition will occur due to osteoblast differentiation. When there is an imbalance between these two processes along with the loss of some of the protective mechanisms of cementum, osteoclasts and cementoclasts will be able to resorb portions of the root ( Mitchell 2007, <http://www.orthodontists.org.nz/articles/root-resorption.asp>) In orthodontics the external type of root resorption is a feared complication of orthodontic therapy. This is a surface resorption that takes place in the apical portions of the root, and the term external apical root resorption (EARR) is often used. Sameshima and Sinclair (2001) strongly suggested that; "there is some component of the root apex that has a lower threshold for irreversible change than other parts of the root." Many authors have reported that small degrees of root resorption exist in most patients, also patients that have not undergone orthodontic therapy (<http://www.orthodontists.org.nz/articles/root-resorption.asp>). This type of resorption generally arises no problems for the patients, but whenever severe, the resorption can threaten the longevity of the tooth. The frequency of severe EARR varies, but numbers of 5-20% have been reported (Mirabella and Årtun 1995, Levander 1999, Linge and Linge 1983, Thongudomporn and Freer 1998).

Root resorption as an undesirable consequence and complication of orthodontic treatment has been known for several decades, (Rudolph 1940, DeShields 1969) and although difficult to detect, there has been great improvements in equipment. Several

types of radiological examination modes, traditional x-rays, digital x-rays, CT's, CBCT's, OPG's and also scanning electron microscopes and light microscopes are only a few of the equipments that aids as diagnostic tools in the detection of EARR. DeShields (1969) claimed that intraoral radiographs are a central part of orthodontic treatment. Regular intraoral periapicals have traditionally been the preferred type of radiographic control, "since they have the highest chance of reflecting the severity of the case" (D. Healey). In the purpose of reducing the radiation dose, digital radiographic systems are being used more and more. There are several advantages with digital imaging; the dark-room process is eliminated and the clinician has immediate access to, and can manipulate the images (*Levander 1999*). Early quantifications of small alterations in the root surface are another advantage of digital vs. conventional systems (*Levander 1999*). Panoramic imaging, also called pantomography, (OPG) is a technique that produces a single tomographic picture of the facial structures and surrounding structures, and has a broad covering of both jaws. The images are not high resolution images, so sharp details cannot be studied as with periapicals. The radiation dose though is quite low, and the procedure is usually well tolerated by the patient. Today, most orthodontists require an OPG and a cephalogram before treatment start, and many also monitor the treatment situation with panoramic images. Sameshima and Asgarifar (2001) found that the loss of root surface during treatment, were overestimated by approximately 20% when analysed on

OPG's, compared to periapicals. They recommended the use of periapicals, especially in high risk patients. However, Stratomas et al. (2002) stated that OPG is a good enough method for evaluating changes in root length pre- and post treatment.

Small alterations in the root's surface are extremely difficult to detect even with digital systems, especially alterations on the buccal and lingual aspect of the root (*Brezniak and Wasserstein 2002*). Today, cone beam computed tomography or CBCT is a technique that is being used more and more. With this radiographic modality it is easier for the clinician to detect alterations on the root's surface on a detail level, which can aid in the decision making process for example when extractions have to be performed.

Several "predisposing" factors to EARR have been proposed like gender, age, roots-morphology, allergy, asthma, nutrition, trauma, genetic disposition, ethnic group, habits, anomalies in number and position of teeth, endodontically treated teeth, most commonly affected teeth, extraction therapy versus non-extractions. There are also some treatment factors that seem to have a great influence on the incidence of EARR, for example type of orthodontic movement, the distance the teeth are being moved, the amount of forces used, use of continuous versus intermittent forces, type of appliance, and finally treatment duration (table 1). The interrelations between these factors are not always clearly understood.

**Table 1: Contributory factors to root resorption**

Included factors in this review	Excluded factors
<b>1. Patient factors</b>	Gender
A: Root morphology	Systemic factors (allergy, asthma etc.)
B: Age of patient at orthodontic treatment	Trauma
C: Most commonly affected teeth	Nutrition
	Ethnic group
<b>2. Orthodontic treatment factors</b>	Habits
D: Magnitude of forces	Anomalies of teeth
E: Duration of treatment	Malocclusion
F: Continuous vs. interrupted forces	Endodontically treated teeth
	Extraction therapy vs. non- extraction
	Type of appliance
	Genetic disposition
	Idiopathic
	Etc.

### **Aim of the study**

The purpose of this assignment is to analyze the described scientific orthodontic literature for the correlation between the occurrence of root resorption and individual refractory factors on the one hand, and finally some orthodontic treatment factors on the other.

### **Material and method**

An enhancement in knowledge was first done by literature reading on the subject. The pubmed database was then used to search for information from published literature from 1930 until 2011. The search was limited to human studies. The

keywords used were “resorption” and “fixed appliance”. This search gave 136 results. In addition some of the investigations from the thesis of Levander 1999 and Owmann- Moll 1995, were used. Search through the references to included studies were also done.

In total (included the thesis) 59 studies were evaluated as relevant and valid, and included in the assignment. In addition; study literature in form of two books and lecture notes were found to be of relevance to the assignment, hence they were utilized as well.

Four of the publications were dated from the years 1930- 1960, 18 publications were from 1961- 2000 and 26 publications were from 2001-2011.

**Table 2- 3: The types of studies/ publications included in this review.****Table 2:**

Type of study	Nr of articles
Prospective	43
Retrospective	16
Reviews*	5
Meta- analysis*	1

\* Five reviews and one meta- analysis were included in the 16 retrospective studies.

**Table 3: List of journals from which the articles of the review were retrieved**

The included articles were collected from these sources	
European Journal of Orthodontics	12
American Journal of Orthodontics and Dentofacial orthopedics	8
Angle Orthodontist	7
Orthodontics and Craniofacial Research	4
American Journal of Orthodontics	3
Journal of American Dental Association	2
Stomatologija	2
American association of Orthodontists	1
Scandinavian Journal of Dental Research	1
Australian Journal of Orthodontics	1
Australian Dental Journal	1
New Zealand Association of Orthodontists	1
Mondo Orthodontics	1
Romanian Journal of Morphology and Embryology	1
Others	4

## **Results**

### *1. Patient factors*

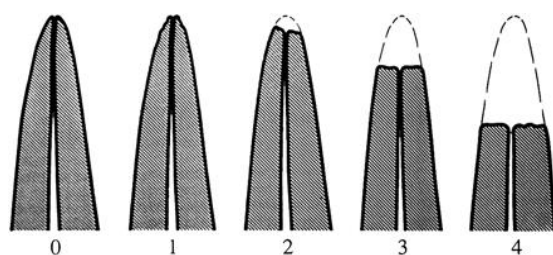
#### *A: Root morphology*

Since the 1960`s there has been a consensus that orthodontic treatment contribute to external apical root resorption, (EARR) (*De Shields, 1969*). Thongudomporn and Freer, (1998) reported that 97,3% of the patients revealed some form of EARR post-treatment. In Sameshima and Sinclair`s study from 2004, they stated that the

average root-shortening due to orthodontic tooth movement is approximately 10%, and it ranges from 1,2 -1,5 mm. A shortening of the total root length of 10% will in most cases not cause any problems for the tooth`s function. This is possibly because most of the PDL-fibers are in the upper 2/3 of the root (*Henry and Weinman 1951*).

The severity can however, be grouped into different stages as described by Levander 1999. An index-score from 1-4 is often preferred (figure 2).

**Figure 2: Root resorption index according to Levander, 1999.**



1. Irregular root contour
2. Root resorption apically, less than 2mm. (Minor.)
3. Root resorption apically, from 2mm- 1/3 of the root's length. (Severe.)
4. Root resorption exceeding 1/3 of the root's original length. (Extreme.)

When the EARR gets severe, (reaches score 3 or 4,) there is reason to concern. The numbers of reported severe EARR varies considerably in the literature. Linge and Linge reported in 1983 that 16, 5% of the patients in their study suffered from severe EARR post-treatment, while Thongudomporn and Freer (1998) found an incidence of severe EARR of approximately 40%. Whenever severe EARR, the longevity of the tooth may be compromised, and this is one of the complications most orthodontists fear the most.

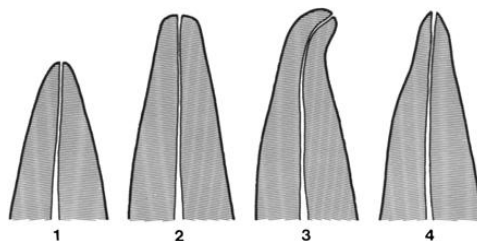
Several pre-treatment factors associated with EARR have been suggested, among them abnormal root shape (*Oppenheim 1942, Newman 1975 and Mirabella and Årtun 1995*). There are great intra- and interindividual variations regarding tooth

morphology, and the aetiology is still unknown. Bang et al. lanced a theory in 1995 that nerve-tissue is implicated in arrested tooth development, and also in anomalous root shapes. Newman, (1975) suggested that short roots may be due to a genetic component. This is in agreement with Brezniak and Wasserstein, (2002) who also claimed a strong familiar association. Nail-biting and traumatic injuries are other possible explanations (*Newman 1975*).

#### Classification

The shape of the root can be described and classified in different ways. The classification system proposed by Levander and Malmgren in 1988 has gained widespread acceptance. The shape of roots is then divided into four groups:

**Figure 3: Classification of root form according to Levander, 1999.**



1. Short
2. Blunt
3. Apically bent
4. Pipette shaped

Other authors use a slightly different classification system, and also add incomplete roots as an extra group.

Most authors found that an abnormal root form (as stated above) enhanced the risk of EARR (*Preoteasa et al. 2009; Oyama et al. 2006; Levander 1999, Thongudomporn and Freer 1998, Sameshima and Sinclair 2001 and Nigul and Jagomagi 2006*). However, Zahrowski and Jeske (2006) concluded that; "The incidence of EARR appeared unaffected by tooth morphology." Sameshima and Sinclair had similar findings. They could not find any significant relation between EARR and root form, in their article from 2004. It should be mentioned that the correlation was almost significant. Mirabella and Årtun (1995) found that an atypical root form was only a significant risk factor for the centrals, although their results indicated that EARR is linked to an abnormal root shape.

#### Normal roots

The authors all agree that a normal root form do not contribute to EARR.

#### Short roots

Levander and Malmgren (1988) found no increased risk for EARR in short roots, but emphasized the more severe

consequences if EARR were to take place in these roots. Oyama et al. (2006) concluded that there was an enhanced risk for EARR in short roots, due to the decreased crown-root ratio which in turn leads to significantly more stress, concentrated on the root's middle part. Thongudomporn and Freer (1998) and Nigul and Jagomagi (2006) also found that short roots are more exposed to EARR. A counterpart to these findings is Mirabella and Årtun's article from 1995, where they did not discriminate between the different abnormal root forms, but found long roots to be more susceptible to EARR. Their possible explanation was that in a longer root, more force is required to move the tooth. The actual displacement of the apex is bigger during tipping/torquing. The clinician would perhaps also be more reluctant to move teeth with short roots the same distance as longer roots.

#### Blunt roots

Levander and Malmgren reported in 1988 a significant higher degree of EARR in blunt roots. This view is shared by Preoteasa et al. (2009) and Thongudomporn and Freer. (2006) Sameshima and Sinclair (2001) on the contrary, concluded that blunted central incisors showed significantly less EARR, than the other root forms. This is also



postulated by Oyama et al. (2006) who reported of no significant stress concentration on these roots.

#### Apically bent roots

Mirabella and Årtun (1995) were unable to prove a significant correlation between root form and EARR. Their results, however, indicated that roots that were angulated, or roots with deviated apices had an increased risk. Preoteasa et al. (2009) found that angulated roots had the highest prevalence of EARR, and the percentage were actually 92,11%. Oyama et al. (2006) constructed FEM's, (finite element models) using a three-dimensional computer aided program, and set up five different root models, in accordance with Levander and Malmgren's classification from 1988. They then "applied" an experimental force load of 2N, at an area simulating the bracket base. Both intrusive and lingual direction of the forces was tested. For the apically bent root, the maximum stress concentration was at the root apex during both lingual and intrusive forces. The conclusion was that a bent apex induces EARR. This finding is also in agreement with several other authors. (Levander 1999 and Sameshima and Sinclair 2001). Levander and Malmgren (1988) stated that it is the bent part of the apex that will be resorbed. Once this part is resorbed, the risk of further EARR is minimal.

#### Pipette shaped roots

In their study from 1988, Levander and Malmgren reported significantly higher numbers of EARR in roots with pipette shape. This finding is shared by other authors: Pretoteasa et al. 2009, Oyama et al. 2006, Thongudomporn and Freer 1998 and Sameshima and Sinclair 2000.

#### *B: Age as a contributory factor*

The influence of age as a factor contributing to EARR, has for a long time caused some degree of disagreement among researchers. Already in the 1930's and 1940's Rudolph claimed that a young age at treatment start was beneficial in the matter of EARR. "The younger the patient at the onset of treatment, the more prolonged the treatment be without permanent loss of root tip structure" (Rudolph 1940). 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 (Reitan 1964, Brezniak and Wasserstein 1993 and Mirabella and Årtun 1995). Another influencing factor is the protective mechanisms of precementum and predentine located on the apices of young individuals (Jiang et al. 2010). Predentine is not calcified and is therefore not attacked by resorbing cells (Mavragani et al. 2002). 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 (Brezniak and Wasserstein 2002). Brezniak and Wasserstein (2002) claimed that age may not be a significant factor in the contribution of EARR. Sameshima and Sinclair, in their study from 2001 also found no such link. However, when they included the mandibular incisors, the amount of EARR was significantly higher in the adult group.

Jiang et al. (2010) found that; "age had a statistically significant correlation with resorption of all parts of the dentition," post treatment. Also Nigul and Jagomagi (2006) reported of similar findings; adult

patients had more EARR, although the difference was not statistically significant. This finding is similar to the conclusion of Preoteasa et al. (2009). They had patients older than the age of twelve with resorptions of all degrees. Of the patients under twelve years 50% had EARR, and only first degree EARR. It has been proposed that immature teeth with incomplete root formation will have the benefit of the remaining growth potential, and the result post treatment could be elongation, even with EARR (*Mavragani et al 2002*). The same study also showed that immature teeth pre-treatment reached a significant greater length post-treatment, than the teeth that had closed apices at the start of treatment. The orthodontic treatment could not be said to have any negative effects of the final root lengths of teeth with incomplete roots (*Mavragani et al 2002*).

### *C: Most commonly affected teeth*

There have been discussions among researchers of which teeth that are most susceptible to EARR, and Brezniak and Wasserstein (1993) claimed that "different teeth have different tendencies to root resorption." However, as mentioned above, maxillary incisors are thought to be the teeth most vulnerable to EARR, and therefore many researchers have concentrated their studies on these teeth. "If no apical resorption is found on the incisors, it is assumed that there is only minor risk of severe resorption in other teeth" (*Levander 1999*). This is in agreement with several other authors as well (*D. Healy, Apajalahti & Peltola 2007, Zahrowski & Jeske 2010, Thongudomporn and Freer 1998 and Sameshima & Sinclair 2000*). One plausible explanation of why incisors are more easily resorbed, were proposed by Oppenheim already in 1936. He explained that; "this may be because of

the extent of movement of these teeth are usually greater than other teeth and their root structure and relation to bone and periodontal membrane tend to transfer the forces mainly to the apex." This is in agreement with Apajalahti and Peltola's article from 2007. They claimed that maxillary incisors are the first teeth to respond when fixed appliances are activated. Hence, the duration of force will be longer and thus the potential of EARR increases. Sameshima and Sinclair (2001) pointed out that maxillary incisors are the teeth that most often show deviating root form and other developmental anomalies. Also, the erupting canine is the second most often impacted tooth, and often resorbs part of the lateral's root. Which teeth that follow the incisors when it comes to EARR "potential," have caused somewhat more controversy. Some authors claim that all maxillary anterior teeth are especially vulnerable to EARR, and that the maxillary laterals are the most often resorbed teeth followed by the centrals, mandibular centrals and then the maxillary canines (*Lopatiene and Dumbravaite 2008*). There seem to be a mutual understanding that mandibular first molars, and especially the distal root often is affected (*D. Healy, Zahrowski & Jeske 2010*). EARR in premolars are very rare, (*Lopatiene and Dumbravitaie 2008*) but Apajalahti and Peltola (2007) found that in patients with affected premolars, there was a high percentage (47%) of severe EARR. In these cases there has often been performed significantly more tooth movements due to for example extractions, and this in turn may contribute to the more severe type of EARR. Sameshima and Sinclair (2001) came to the same conclusion, but they also found that patients with only upper premolar extractions did not have more severe EARR than non extraction cases.

They could however, not explain this

## 2. Treatment factors

### D: Forces applied in orthodontic treatment

In addition to predisposing factors, forces applied during orthodontic treatment are generally regarded as an important factor that may affect the degree of root resorption. An optimal orthodontic force is characterized by a maximal cellular response from the tooth supporting

finding.

tissues at the same time as maintenance of the vitality of these tissues is secured. This includes apposition and resorption of alveolar bone (Melsen et al. 1985). In 1952 Storey and Smith introduced the “optimal force”- theory. It indicated that a pressure from 150- 200g produced the maximum tooth movement for maxillary canines in man. Since then, various suggestions of the “optimal force” are presented.

**Figure 4: List of studies on the optimal force according to Ren et. al., 2003.**

Author	Year	Ref	C	B/T	Teeth	Force (cN)	D	Results
Storey and Smith	1952	2	2	B	Cmand	175–300 400–600	9w	Optimum force range for maximum rate of movement is 150–200 cN for canines
Lee	1964	34	2	B/T	Cmax	450	>1w	Optimum force level between 150 and 260 cN
Andreasen	1967	35	2	T	Mmax	200 400	12w	Higher force yielded 2.5 times tooth displacement of the lower force
Hixon	1969	36	2	T	Cmax	300 0–1500	8w	Higher forces per unit root area increase the rate of TM
Hixon	1972	37	2	T	Cmax	300 0–1000	6w	Higher forces produce more rapid movement than lighter ones
Boester	1972	3	4	T	Cmax	55 140 225 300	10w	55 cN force yielded less TM than 140, 225, and 300 cN, whereas latter three forces produced the same amount of TM
Anderasen	1980	38	4	T	LM RM LC RC	100–150 400–500 100–150 400–500	10w	In general greater forces produced greater rate of tooth movement
Lee	1995	39	2	B/T	Cmax	35–450	7w	Maximum rates of TM is 0.78–1.34 mm/wk for tipping movement with force average 337–388 cN, and 0.86–1.37 mm/wk for bodily movement with force average 354–375 cN
Owman-Moll	1996a	40	2	T	Pmax	50 100	4–7w	No difference in TM in 50 cN group and 100 cN group
Owman-Moll	1996b	41	2	T	Pmax	50 200	7w	TM increased 50% with 200 cN as compared to 50 cN
Lundgren	1996	42	2	T	Pmax	50	7w	Horizontal movement of the tooth crown was 0.8 mm during the first week and 3.7 mm after 7w
Iwasaki	2000	43	2	B	Cmax	18 60	12w	18 cN could produce effective TM

Today’s hypothesis includes that a certain magnitude of force and forces characteristics (continuous vs. intermittent, constant vs. declining, etc.) would be able to produce a maximum rate of tooth movement without adverse tissue effects and with maximum patient comfort. Ren et al. (2003) concluded in

their systematic review that: “...from current literature, no evidence-based force level could be recommended for the optimal efficiency in clinical orthodontics” (Figure 4). The “optimal force” may differ from each tooth, movement type (intrusion, bodily movement etc.), for each individual patient, type of appliance etc.

*D: The degree of EARR when the magnitude of forces increases (Table 4)*

**Table 4: EARR when the magnitude of force increases— a summary table**

Year	Author	Duration of study (in weeks)	Nr of teeth	Tooth	Magnitude of force	Type of force	EARR rate	EARR Severity (surface expansion and depth)	Tooth movement	Ind. variations in EARR
1970	Stenvik and Mjör	4 to 35 days	35	Max./mand .1. Prem. In most cases	From 35g to 25g	Intrusive forces	More with <100g than > 100g.	–	–	–
1982	Harry and Sims	14- 70 days	18	Premolars	40g- 220g	Intrusive forces	More with high force	More with high force	–	Yes, on the control teeth
1996	Owmann- Moll et al.	4 and 7	32	Max 1.prem	50g and 100g	Tipping movement	More with 50g than 100g	Not sign. difference	Not. sign increased	Great
1996	Owmann- Moll et al.	7	16	Max. 1.prem.	50g and 200g	–	Not sign. difference	Not sign. difference	Increased	Great
2004	Darendeliler et al.	4	36	Max./mand .1. Prem.	0g, 25g, 225g	Buccaly directed forces	Not sign. difference	Not sign. difference	–	<b>Great</b>
2005	Chan and Darendeliler	4	36	Premolars	0g, 25g and 225g	–	–	Not sign. difference	–	–
2006	Harris, Jones and Darendeliler	4	54	Max. 1. prem.	0g, 25g and 225g	Intrusive forces	More with 25g than 0g and more with 225g than 25g.	More with 25g than 0g and with 225g than 25g.	–	–
2011	Zahrowski and Jeske	–	–	–	–	–	More with high forces (225g)	More with high forces (225g)	–	–

Do increased forces applied by the orthodontist increase the risk for EARR?

Many studies have demonstrated the relationship between the magnitude of applied forces during treatment with fixed appliance and root resorption: Reitan 1964, Stenvik and Mjör 1970, Harry and Sims 1982, Vardimon et al. 1991, Owmann- Moll et al. 1994, Chan and Darendeliler 2005, Zahrowski and Jeske 2011, among others.

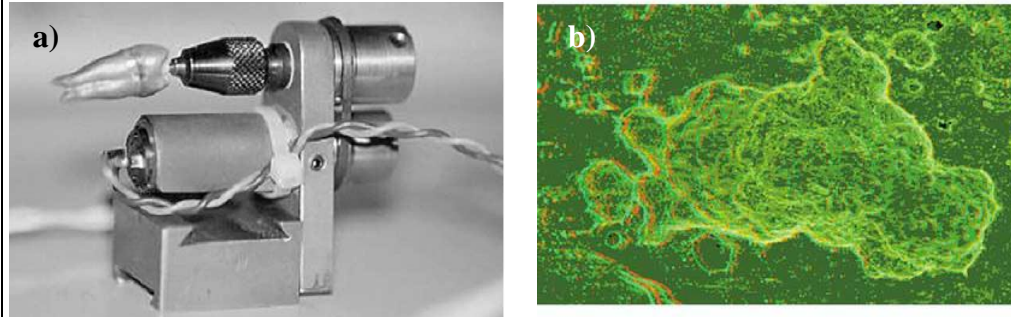
It is logical to think that the degree of resorption is greater with increasing magnitude of forces, and that is the finding from these studies: Reitan 1964.

Darendeliler et al. 2004, Chan and Darendeliler 2005, Chan E and Darendeliler 2006, Darendeliler et al. 2006 and Zahrowski and Jeske 2011, among others. Light forces have therefore long been recommended.

For example in the study by Chan and Darendeliler from 2005 the investigators extracted 36 human premolars, and made scanning electron microscope images of them (Figure 5). The teeth had been exposed to light or heavy buccaly directed forces for 28 days. In the same patients, the contra lateral premolars were used as controls.

**Figure 5 (adopted from Chan and Darendeliler, 2005)**

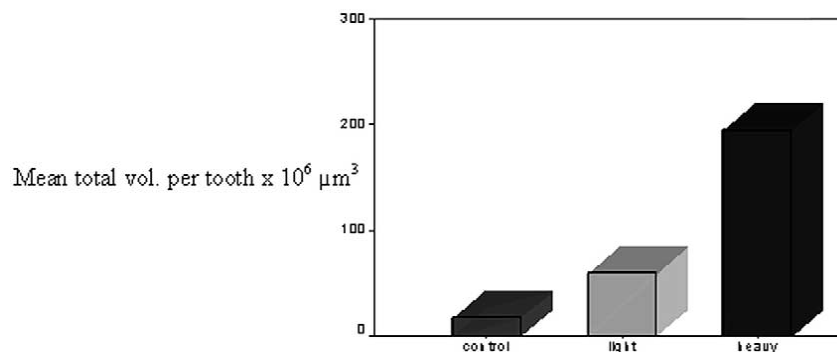
- a) Premolar mounted to be placed in SEM chamber for imaging.  
 b) 3D red-green analysis of resorption crater.



After 3-dimensional quantitative volumetric analysis with commercial software they recorded resorption in light-force (25 g) and heavy-force (225 g)

groups. The heavy-force group had 3.31-fold greater total resorption volume than the light-force group (Figure 6).

**Figure 6: Comparison of resorption per tooth in control, light-force, and heavy-force groups, from Chan and Darendelilers study from 2005.**



Similar results were found when Harris, Jones and Darendeliler (2006) used intrusive forces. The heavy-force group had more and larger root resorption craters than the light-force group. They found that the volume of the root resorption was directly proportional to the magnitude of the intrusive force applied (0g, 25g and 225g).

corresponding conclusion. They investigated literature on the subject from 1950- 2008. They used evidence from 13 valid studies, among them 11 RCT's. The result showed that the severity of root resorption increased particularly with heavy forces and intrusive movements. Thus the authors support the use of light orthodontic forces, especially with incisor intrusion.

Zahrowski and Jeske published a systematic review in 2011 with

There has been some evidence however, that do not support this conclusions. Owmann- Moll et al. published two articles in 1996 that showed no significantly increase in the rate of EARR when the forces increased. This was the result even when they four- fold the controlled, continuous forces from 50g to 200g. In fact, in one of the studies, the EARR were more frequent in the 50g- group when compared with the 100g- group both after four weeks and after seven weeks. The difference after seven weeks was significant. The severity of EARR (surface extension and depth) did not show any significant difference between the different forces applied, in these two studies.

Similar results were showed by Stenvik and Mjör in 1970. They used intrusive forces and found that in the force- group with magnitude < 100g resorption was present in fifteen out of eighteen teeth. In the group with magnitude >100g however, resorption was found in only six out of seventeen teeth.

#### *E: Duration of treatment*

Some investigators suggest duration of orthodontic treatment to be a more important factor than the magnitude of forces to prevent adverse tissue reactions (Stenvik and Mjör 1964 and Harry and Sims 1982). Sameshima and Sinclair (2001) concluded that a prolonged treatment was significantly associated with increased root resorption (n= 868 patients, retrospective study). In Levander and Malmgrens investigation from 1988, they found that root resorption after six to nine months of orthodontic treatment was detected in 34% of the teeth, meanwhile in the end of orthodontic treatment that had lasted for 19 months, root resorption increased to 56%.

In a Finnish study average treatment length for patients without root resorption was 1.5 years and for the patients with severe root resorption 2.3 years (Apajalahti and Peltola 2007) (n= 601 patients, retrospective study).

#### *F: Continuous versus intermittent orthodontic force*

The orthodontic force may be continuous or intermittent during treatment. Orthodontic treatment with fixed appliances is usually associated with continuous forces. With removable, and especially functional appliances continuous force is intermitted by brief or extended periods of rest.

Ballard et al. (2009) showed that discontinuous forces might give rise to a smaller amount of EARR than continuous forces, in their experimental study. The maxillary first premolar on one side received interrupted orthodontic forces: 14 days of force application (225g), then three days of rest and finally four days of force application (225g). This was repeated repeated five times. The first premolar on the other side received continuous forces of 225g for eight weeks. The analyze was performed with a micro-CT scan system to make direct volumetric measurements. Discontinuous forces gave significant less EARR. As a conclusion the investigators suggests that: "...intermittent forces might be a safer method to prevent significant root resorption. This regimen, however could, compromise the efficiency of tooth movement".

Levander et al. (1994) showed that an interruption of treatment for two- three months gave less EARR on initially resorbed maxillary incisors than if the treatment was continued. The investigator is therefore recommending this

interruption period for patients that shows EARR early in treatment. Brezniak and Wasserstein (1993) stated in their review that a pause in treatment allows the resorbed cementum to heal and prevents further resorption.

Owman- Moll et al. (1994) also investigated maxillary first premolars but they applied only 50 grams of orthodontic force. Two groups of eight patients in each received both continuous and interrupted forces. One group had a test period of four weeks and the other group had a test period of seven weeks. The four-week group received on one side an applied force for three weeks and then a rest period for one week with a passive wire. The seven-week group had the same treatment on one side plus another three new weeks with force application. At the

same time the authors applied continuous forces to the premolars on the contralateral side in both groups. The investigators found no significant difference in number or severity of EARR. More tooth movement was achieved in the continuous force group.

The authors of this article implied that the use of continuous forces may be more effective and safer than the use of interrupted forces, however with a degree of caution. The great amount of individual variations in this investigation may have overshadowed the resorption effects of the different force systems. It is possible that a longer observation period and/or a larger sample size would have revealed a more significant difference between the groups with continuous and interrupted forces.

**Table 5: A summary of results from reviews and meta-analysis studying EARR and different predisposing factors.**

Year	Author	Type of study	Nr of studies included	Tooth	Predisposing factors					
					Root morphology	Type of teeth most related to EARR	Age	Force magnitude	Duration of treatment	Continuous versus interrupted force
2004	Segal et al	Meta-analysis	9	Max. incisors	—	Max. incisors	—	—	EARR increases with duration/high correlation	—
1993	Brezniak and Wasserstein	Review	—	Max. 1.premolar	Deviating roots, blunt-pipette shaped roots: more EARR, especially pipette-shaped roots.	Max. laterals then max. centrals	EARR increases with age. Fully developed roots have a higher risk of EARR.	—	—	A pause in treatment reduced the risk of EARR
2008	Lopatiene and Dumbraivaite	Review	24	—				More EARR with high forces	EARR increases with duration/high correlation	
2011	Zahrowski and Jeske	Systematic Review	13	Max. incisors	Unaffected	—	—	More EARR with high forces (225g)	—	

## **Discussion**

During the PubMed- search only the keywords “fixed appliances” and “resorption” were used. Thus the 59 relevant articles for this review were searched out manually. A method using more keywords would have reduced the time spent on the search process. On the other hand this could have excluded valuable studies. The main part of the investigations consisted only of one or a few of the contributory factors (to EARR) of interest. The use of more keywords within the same search may therefore have ignored these studies. This could however have been avoided by performing multiple searches with only one or two of them in each. Authors often use different terms to describe the same phenomenon. For example EARR is also known as ERR or even OIRR (orthodontically induced root resorption). Also in this context this search method assured that relevant articles were not left out. The main part of the included articles was published between 2001 and 2011. The information in this review could therefore be regarded as updated, at the same time as the necessary historical perspectives are taken into consideration.

This review has evaluated if there are certain factors that could have an effect on root resorption. Several studies for each of these factors have been found with sometimes contradictory results. However, some important conclusions have been possible to make on the basis of this assignment.

### *1. A: root morphology*

Apart from Zahrowski and Jeske, (2006) it seems to be an agreement that there exists a correlation between abnormal

root shape and EARR, although not always a significant correlation.

Why anomalous roots are resorbed more easily is not known, 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 (*Preoteasa et al. 2009*). Sameshima and Sinclair, (2001) 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. This view is supported by both Levander (1999), Sameshima and Asgarifar (2001) and Apajalahti and Peltola (2007). They also recommend an x-ray control after active treatment of six months, when total treatment time exceeds this limit. In the early 1980`s Hollender et al. 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 (*Brezniak and Wasserstein 1993*).

### *B: Age and root development*

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. It therefore seems likely that young age at treatment start would be beneficial in the matter of evolving EARR.

### *C: Most commonly affected teeth.*

Of the articles that were included in this assignment, there seemed to be a mutual understanding that the maxillary incisors are the teeth that most often suffer from EARR during orthodontic treatment. It seems therefore likely to believe that maxillary incisors are the teeth most prone to EARR during orthodontic treatment.

### *2. D: Magnitude of force*

As it appears in table 5 the results are divergent from each other. The methods vary between the different resorption studies. This makes it difficult to compare the different results and to analyze their validity. For example the magnitude of force applied (Table 5: 25g- 225g), the measurement method for detecting EARR and the type of test teeth used varies. Different type of forces used may also give divergent results. Bodily movement induces less risk for root resorption than tooth tipping (*Brezniak and Wasserstein 1993*). Han (2005) noted: "It was established that teeth intrusion causes four times more root resorption than extrusion".

After evaluation of the individual studies, the reviews and the meta- analyzes on this issue, it seems that the risk of EARR is higher when increasing magnitude of force is applied. The higher value of N used, the more adverse effect may be expected. Owmann- Moll et al. (1996) though did not have corresponding results. The reason for that could be, as

Owman- Moll et al. (1996) suggested, individual variations. The great variations in the different studies may have interfered with possible adverse effects of increased magnitude of force.

Another important consideration is that these latter studies used light microscope to detect resorption craters. Chan and Darendeliler (2005), Darendeliler et al. (2004) and Harris et al. (2006) used scanning electron microscope (SEM). The entire buccal and lingual surfaces were analyzed, and the SEM pictures were taken in stereo pairs. Reitan (1964) enlighten that SEM provides higher resolution and more details than histological models prepared and analyzed through light microscopy. SEM studies can detect resorption cavities after a relatively short period of force application. It can therefore be questioned if small resorption craters might have been missed to a higher degree in investigations were they used 2D measurements instead of SEM. Chan and Darendeliler compared these methods in a review published 2004. They could not find a significant difference between 2D- and 3D- measurements of EARR over 28 days, but suggested that a longer experimental period could increase the resorption craters, thus find SEM to be favorable.

### *E: Duration*

According to studies included in this paper the length of treatment period was significantly associated with root resorption, and showed higher severity of resorption with increasing duration. The risk was higher after 1,5 year of treatment. This was partly based on retrospective studies (*Samenshima and Sinclair 2001, Apajalahati and Peltola 2007*). The high sample size (n= 868 and

601 patients respectively) may have been beneficial for the validity of the result.

#### F: Continuous versus interrupted forces

The variety of investigation methods makes comparison very difficult. The included articles of continuous versus discontinuous forces used rest periods from three days to three months, with or without reapplication of force. The results were quite contradictory.

Ballard et al. (2009) applied forces of 225 grams, whereas Owmann- Moll et al. (1994) used only 50 grams. It is likely that this disparity in levels of force contributes to the differences in result. The sample sizes of both of the studies mentioned above are only 16 teeth (eight patients). Levander (1999) on the other hand had a more representative sample size of 62 teeth (40 patients).

It seems as if an interruption in force application can have a beneficial outcome in terms of EARR, but as long as investigation methods are not standardized enough, it is not possible to make a reliable conclusion on this issue.

The results of this review suggest that EARR still is highly unpredictable. Further investigations on this matter, including larger samples, standardized research-methods and prolonged test—and observation—periods, would be preferable.

### **Conclusion**

The clinicians should have in mind that abnormal root morphology may increase the risk of root resorption. This is specially valid for pipette-shaped roots.

Maxillary incisors seem to be the teeth most likely to suffer from EARR.

From the root resorption point of view orthodontic treatment should begin as early as possible since there is less risk of root resorption in young and developing teeth.

Light orthodontic forces seem to present a smaller risk of resorption than heavy forces. The use of interrupted forces seems to give less root resorption than continuous forces.

If initial resorption is detected, a pause in treatment of two-three months should be considered. With sustained quality, treatment duration should always be as short as possible.

It is very important that the patient is fully informed that root resorption can be a consequence of his/her orthodontic treatment with fixed appliance.

### **References**

1. Apajalahti S, Peltola JS. Apical root resorption after orthodontic treatment—a retrospective study. *Eur J Orthod.* 2007; 29: 408-12.
2. Ballard DJ, Jones AS, Petocz P, Darandeliler MA. Physical properties of root cementum: Part 11. Continuous vs intermittent controlled orthodontic forces on root resorption. A microcomputed-tomography study. *Am J Orthod Dentofacial Orthop.* 2009; 136: 8e1-8, discussion 8-9.
3. Bang E, Kjær I, Rosèn Christensen L. Etiologic aspects and orthodontic treatment of unilateral localized arrested tooth development combined with hearing loss. *Am J Orthod Dentofacial Orthop.* 1995; 108: 154-61.
4. Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: part 1. Litterature review. *Am J Orthod Dentofacial Orthop.* 1994; 105: 23A.
5. Brezniak N, Wasserstein A. Orthodontically induced inflammatory

- root resorption. Part II: The clinical aspects. *Angle Orthod.* 2002; 72: 180-4.
6. Chan E, Darendeliler MA. Exploring the third dimension in root resorption. *Orthod Craniofacial Research.* 2004; 7: 64-70.
  7. Chan E, Darendeliler MA. Physical properties of root cementum: Part 5. Volumetric analysis of root resorption craters after application of light and heavy orthodontic forces. *Am J Orthod Dentofacial Orthop.* 2005; 127: 186-95.
  8. 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; 129: 504-10.
  9. Darendeliler MA, Kharbanda OP, Chan EKM, Srivicharnkul P, Rex T, Swain MV, Jones AS, Petocz P. Root resorption and its association with alterations in physical properties, mineral contents and resorption craters in human premolars following application of light and heavy controlled orthodontic forces. *Orthod Craniofacial Research.* 2004; 7: 79-97.
  10. DeShields. A study of root resorption in treated class II, div. 1 malocclusions. *Angle Orthod.* 1969; 39: 231-45.
  11. Han G, Shengfu H, WVHoff JWH, Zeng X, Kuijpers- Jagtman. Root Resorption after Orthodontic Intrusion and Extrusion: An Intraindividual Study. *Angle Orthod.* 2005; 75: 912-8.
  12. Harris DA, Jones AS, Darendeliler MA. Physical properties of root cementum: Part 8. Volumetric analysis of root resorption craters after application of controlled intrusive light and heavy orthodontic forces: A microcomputed tomography scan study. *Am J Orthod Dentofacial Orthop.* 2006; 130: 639-47.
  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; 111: 301-9.
  14. Harry MR, Sims MR. Root resorption in bicuspid intrusion. A scanning electron microscope study. *Angle Orthod.* 1982; 52: 235-58.
  15. Healey D. Root resorption. *New Zealand Association Orthod.*
  16. Henry, Weinman. The pattern of root resorption and repair of human cementum. *J Am Dental Association* 1951; 42: 270-90.
  17. 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.
  18. Jiang R, McDonald JP, Fu M. Root resorption before and after orthodontic treatment: a clinical study of contributory factors. *Eur J Orthod.* 2010; 32: 693-7.
  19. Levander E. Studies on orthodontically-induced apical root resorption. *Thesis, Karolinska Institutet* 1999.
  20. Linge BO, Linge L. Apical root resorption in upper anterior teeth. *Eur J Orthod.* 1983; 5: 173-83.
  21. Lopatiene K, Dumbravaite A. Risk factors of root resorption after orthodontic treatment. *Stomatologia Dent Maxillofacial J.* 2008; 10: 89-95.
  22. Mavragani M, Bøe OE, Wisth PJ, Selvig KA. Changes in root length during orthodontic treatment: advantages for immature teeth. *Eur J Orthod.* 2002; 24: 91-7.
  23. Melsen B, Fotis V, Burstone CJ. Biomechanical principles in orthodontics. *Mondo orthod.* 1985; 10: 61-73.
  24. Mirabella AD, Årtun J. Risk factors for apical root resorption of maxillary anterior teeth in adult orthodontic patients. *Am J Orthod Dentofacial Orthop.* 1995; 108: 48-55.
  25. Mitchell L. An introduction to Orthodontics. Third edition. *Oxford University Press* 2007; 4, 47.
  26. Mohandesan H, Ravenmehr H, Valaei N. A radiographic analysis of external apical root resorption of maxillary incisors during active orthodontic treatment. *Eur J Orthod.* 2007; 29: 134-9.
  27. Newman WG. Possible etiologic factors in external root resorption. *Am J Orthod.* 1975; 67(5): 522-39.
  28. Nigul K, Jagomagi T. Factors related to apical root resorption of maxillary incisors in orthodontic patients. *Stomatologija* 2006; 8: 76-9.

29. Oppenheim A. Abiological orthodontic therapy and reality. *Angle Orthod.* 1936; 6: 69-116.
30. Owmann- Moll P, Kurol J, Lundgren D. Effects of a doubled orthodontic force magnitude on tooth movement and root resorptions. An inter-individual study in adolescents. *Eur J Orthod.* 1996; 18: 141-50.
31. Owmann- Moll P, Kurol J, Lundgren D. The effects of a four- fold increased orthodontic force magnitude on tooth movement and root resorptions. An intra-individual study in adolescents. *Eur J Orthod.* 1996; 18: 287-94.
32. Owmann-Moll P. Orthodontic tooth movement and root resorption with special reference to force magnitude and direction. *Thesis, Swedish Dental J Supplement 105.* 1995.
33. 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: 113-7.
34. 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: 257-62.
35. Reitan K. Effects of force magnitude and direction of tooth movement on different alveolar bone types. *Am J Orthod.* 1964; 32: 244-255.
36. Ren Y, Maltha JC, Kuijpers-Jagtman AM. Optimum force magnitude for orthodontic tooth movement: A Systematic Literature Review. *Angle Orthod.* 2003; 73: 86-92.
37. Rudolph. An evaluation of root resorption occurring during orthodontic treatment. *Scandinavian J Dent Res.* 1940; 19: 367-371.
38. Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: Periapicals vs. Panoramic films. *Angle Orthod.* 2001; 71: 185-9.
39. Sameshima GT, Sinclair PM. Predicting and preventing root resorption: Part I. Diagnostic factors. *Am. Association Orthod.* 2001; 119: 505-10.
40. Sameshima GT and Sinclair PM. Predicting and preventing root resorption: Part II. Treatment factors. *Am J Orthod Dentofacial Orthop.* 2001; 119: 511-5.
41. Sameshima GT, Sinclair PM. Characteristics of patients with severe root resorption. *Orthod Craniofacial Research* 2004; 7: 108-14.
42. Segal GR, Schiffman PH, Tuncay OC. Meta analysis of the treatment-related factors of external apical root resorption. *Orthod Cranofacial Research.* 2004; 7: 71-8.
43. Stenvik A, Mjör IA. Pulp and dentin reactions to experimental tooth intrusion: a histologic study of the initial changes. *Am J Orthod.* 1970; 57: 370-85.
44. Storey E, Smith R. Force in orthodontics and its relation to tooth movement. *Aust Dent J.* 1952; 56: 11-18.
45. Stratomas S, Geenty JP, Petocz P, Darendeliler MA. Accuracy of linear and angular measurements on panoramic radiographs taken at various positions in vitro. *Eur J Orthod.* 2002; 24: 43-52.
46. Thongudomporn U, Freer TJ. Anomalous dental morphology and root resorption during orthodontic treatment: a pilot study. *Aust J Orthod.* 1998; 15: 162-7.
47. Vardimon AD, Gaber TM, Voss LR, Lenk J. Determinations controlling iatrogenic external root resorption and repair during and after palatal expansion. *Angle Orthod.* 1991; 61: 113-22.
48. White SC, Pharoah MJ. Oral radiology. Principles and interpretation. *Sixth edition .Mosby Elsevier* 2009; 175, 225-237.
49. Zahrowski J, Jeske A. Apical root resorption is associated with comprehensive orthodontic treatment but not clearly dependent on prior tooth characteristics or orthodontic techniques. *J Am Dental Association.* 2011; 142: 66-8.

Web- sides:

<http://www.ncbi.nlm.nih.gov/pubmed/>  
<http://www.orthodontists.org.nz/articles/root-resorption.asp>