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Research Article

Reliability of Assessments of Apical Root Resorption during Treatment with Removable Orthodontic Appliance in Children

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Abstract

Aims

Apical Root Resorption (ARR) of the maxillary incisors is an adverse effect in patients during treatment with orthodontic appliance. Limited number of prospective investigations on ARR in patients with Removable Orthodontic Appliance (ROA) is available and the reliability of assessments of ARR in periapical radiographs has not been evaluated. The aims were to investigate 1) Observer agreement regarding assessment of ARR in radiographs obtained during treatment with ROA in children and 2) The extent and severity of ARR in children during treatment with ROA.

Material and Methods

One hundred ten children, with Angle class II malocclusion or anterior cross bite suitable for treatment with ROA were consecutively recruited. Periapical radiographs of maxillary incisors were obtained before (T0) and after six month of treatment (T1). The contour of the roots was scored as 0, 1, 2, 3 or 4 according to a modified Levander and Malmgren index, by five observers. Score 0 represent normal root contour, score 4 severe root resorption. Inter- and intra-observer agreement was calculated as overall agreement and kappa values.

Results

In the 110 patients, 49 females, 61 males, the mean age was 10.6 years. Totally 439 roots were available for assessment. Kappa values for pair wise inter-observer agreement during treatment ranged between -0.01 and 0.27. Kappa values for intra-observer agreement ranged between -0.09 and 0.45 before treatment and -0.22 and 0.48 after treatment.

Conclusion

Reliability in assessing root morphology/resorption in periapical radiographs obtained in children during treatment with removable appliance is low. ARR seems to be of minor extent, however, the low reliability indicates difficulties in evaluating the severity and thereby the clinical importance in this young patient group.

Keywords: Apical root resorption; Assessment reliability; Children; Removable orthodontic appliance

Introduction

External root resorption seems to be an inevitable adverse effect of the mechanical forces produced by orthodontic appliances [1,2]. The Swedish Council on Health Technology Assessment (SBU) in health care concluded in a previous systematic review on risks and complications of orthodontic treatment that Apical Root Resorption (ARR) occurs in 97-100% of the patients and resorption up to one-third of the root length occurs in 11-28% of the patients [3]. The scientific evidence of the conclusions was however stated low due to study design. Apical root resorption in patients with fixed appliances seems to aggravate during treatment in those patients who presented resorption early in treatment [4,5]. Thus, to identify patients at risk of more severe root resorption during treatment, an additional radiographic examination after six months of treatment has been recommended [4].

There is limited numbers of investigations on children treated with removable orthodontic appliance and development of ARR compared to studies on adolescents treated with fixed appliance and ARR. In a retrospective study on children with removable functional appliance, approximately 9% of the patients had minor resorption of the maxillary incisors after treatment [6]. In another retrospective investigation, apical root resorption was studied on patients treated with removable or a combination of fixed and removable appliance. Even though, treatment with fixed appliance showed significantly more apical root resorption than removable appliance, the latter caused minor root resorption [7]. Janson et al. [8], investigated the amount of apical root resorption that occur after treatment with two removable

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appliances and compared the amount of resorption with an untreated control group. They found that apical root resorption was significantly more common in children treated with one of the removable appliances (Fränkel function regulator) compared to the controls. Nevertheless, Apajalathi and Peltola [9], didn't find any correlation between root resorption and treatment with removable appliances. Thus, available results regarding treatment with removable appliance and apical root resorption in children seems to be contradictory.

In most clinical studies, root resorption is assessed by means of periapical radiography of the maxillary incisors. This imaging method has certain shortcomings regarding image distortion and tissue overlapping, even when efforts are made to ensure accurate technique concerning receptor positioning and tube angulations. Furthermore, irrespective if root resorption has been assessed during treatment with fixed or removable appliances, in many studies not more than one or two observers performed the assessments [6-10]. However, the validity of an imaging method is dependent on both accuracy and reliability [11]. Investigating the agreement between and within observers provides information about the amount of error inherent in a diagnosis or score and the observer agreement may represent an "upper boundary" for diagnostic accuracy efficacy [12].

The aim of this study was therefore to investigate observer agreement in the assessment of root resorption in periapical radiographs of upper maxillary incisors during treatment with removable orthodontic appliance in children. An additional aim was to investigate if any apical root resorption of maxillary incisors occurs and if it does the frequency and severity during six months of treatment.

Material and Methods

One hundred ten healthy children, (49 females, 61 males) with a high objective treatment need, referred to the department of Orthodontics at Malmö University, Sweden, were consecutively recruited during a two year period. The patients were suitable for treatment with; a) Removable appliance to correct an Angle class I malocclusion with large over jet (>6 mm with insufficient lip closure) or b) Anterior cross bite. The sample size was based on the occurrence of apical root resorption of clinical interest (>2 mm <one-third of the root length) reported in previous studies on patients with removable appliances [6,8]. Individuals with a history of known trauma to the anterior maxilla, nails biting and patients not cooperating from start were excluded. All guardians of the patients signed an informed consent form before the study and in addition, the patients had to give their oral consent to take part in the study. The Ethical Review Board in Lund, Sweden, approved the study (Dnr.2008/245).

The patients with the Angle class I malocclusion were treated with a van Beek activator with a buccal shield of acrylic covering the entire clinical crowns of the maxillary incisors. The children and their custodians were informed to use the activator for 12 to 14 hours a day [13]. The patients with anterior cross-bite were treated with an expansion plate equipped with buccal spring and protrusion elements on the lingual surfaces of the maxillary incisors. The participants were informed to use the plates for 22 to 24 hours a day. Treatment progression and adherence to given instructions were checked every 4 to 6 weeks.

The Guidelines for Reporting Reliability and Agreement Studies (GRRAS) was used [12].

Radiographic Examination

Two or three periapical radiographs of the maxillary incisors were obtained at two occasions; before the start of treatment (T0) and following treatment of six months (T1). The X-ray unit used was a Prostyle Intra Planmeca (Planmeca Oy, Helsinki, Finland) with exposure settings 60 kV and 16 mAs. A digital sensor (Planmeca ProSensor, Planmeca Oy, Helsinki, Finland) was used for image capture. Care was taken to place the sensor as parallel as possible to the incisor roots with the X-ray beam perpendicular to the long axis of the teeth as well as to the sensor (right-angle technique). The X-ray unit was equipped with a long spacer cone. Standard quality criteria for periapical radiography were used and, wherever possible, inadequate radiographs were repeated. All radiographic examinations were performed at the Department of Oral Radiology, Faculty of Odontology, Malmö University, Malmö, Sweden.

Assessment of Root Resorption

The two series (T0, T1) of radiographs from each patient were projected on a monitor (Hewlett Packard ProBook 6650b, Palo Alto CA, USA) in a dark room and interpreted under standardized conditions. Five observers independently assessed and scored the root contour and, when present, the degree of apical root resorption of the maxillary lateral and central incisors according to a modified index by Levander and Malmgren [14], score; 0 = intact root contour; 1 = irregular root contour; 2 = slight loss of dental tissues (<2 mm); 3 = root resorption (>2 mm <one-third of the root length); 4 = root resorption (>one-third of the root length). When in doubt, the lower score was chosen. Two of the observers were specialists in orthodontics with professional experiences of six and 23 years respectively, two observers were specialists in oral and maxillofacial radiology with professional experiences of three and 26 years, respectively. Finally, one observer was a resident in oral and maxillofacial radiology. None of the observers was involved in the treatment of the patients. Prior to the assessment, the observers had a joint discussion and calibration on how to assess the radiographs. The assessment criteria were discussed and written down in a protocol that the observers had at hand during their assessments. To simulate the everyday clinical situation, serie 0 (T0) was primarily assessed followed by serie 1 (T1). The observers were blinded regarding type of the two appliances used in the treatments during the assessments of the root resorption.

In order to calculate intra-observer agreement all observers assessed a random sample of 20 series of radiographs about four weeks after the first observation in order to minimize observer recall bias.

Observer agreement was calculated in two ways; 1) for the exact scoring of 0 to 4 of all roots and 2) grouped scoring when the five scores (0 to 4) were cut-off and divided into two groups. One group comprised assessments of score 0, 1 and 2 representing regular/irregular contour or minor resorption. The other group, scores 3 and 4, representing severe and extreme resorption of the roots.

In addition, the individual observer assessment of progression of root resorption exceeding more than one score during treatment (T0 to T1), was calculated.

Statistical Evaluation

Inter and intra-observer agreement were calculated as overall agreement and Kappa value and interpreted according to Landis and

Koch [15,16]. The assessment of progression of root resorption exceeding more than one score during treatment, was calculated and presented as frequency of root resorption in percent and tooth category (tooth 12, 11, 21, 22).

Results

In the 110 children, recruited to the study, the mean age was 10.6 years at start of treatment (T0). Additional demographic characteristics and treatment information are presented in Table 1. All patients adhered to the given instructions how to use the appliances, and checked clinically to evaluate treatment progression. In total, 439 teeth in 110 patients were available for assessment (one patient had one missing lateral incisor) resulting in 2195 assessments for all observers together, including before start of treatment (T0) as well as during treatment (T1). For all observers together and all available sites (roots) for assessments there were 56 roots in 24 patients that were not measurable before start of treatment (T0) and the corresponding figures during treatment (T1) was 27 roots in 13 patients. These figures represent 2.5% and 1.2%, respectively, of the total number of available assessments (Table 2).

	Mean Age (Range) (T0)	Mean Age (Range) (T0)	Type of Appliance (n)
Female	10.7 (7.4 - 13.8)	11.4 (8.1 - 14.2)	Van Beek Activator (31), Expansion plate (18)
Male	10.4 (8.3 - 13.8)	11.1 (8.9 - 15.4)	Van Beek Activator (38), Expansion plate (23)
All	10.6 (7.4 - 13.8)	11.2 (8.1 - 15.4)	Van Beek Activator (69), Expansion plate (41)

Table 1: Gender and mean age before start of treatment (T0), during treatment (T1) and type of removable appliance.

Tooth	Assessment	Assessments According to Score 0 to 4 N= Number of Assessments (%)					
		Score 0 N (%)	Score 1 N (%)	Score 2 N (%)	Score 3 N (%)	Score 4 N (%)	N.P.A.*
12	T0	292 (53.1)	190 (34.5)	53 (9.6)	2 (0.4)	0 (0.0)	13 (2.4)
	T1	153 (27.8)	237 (43.1)	131 (23.8)	19 (3.5)	1 (0.2)	9 (1.6)
11	T0	206 (37.5)	231 (42.0)	94 (17.1)	12 (2.2)	0 (0.0)	7 (1.3)
	T1	80 (14.5)	229 (41.6)	193 (35.1)	45 (8.2)	3 (0.5)	0 (0)
21	T0	202 (36.7)	238 (43.3)	84 (15.3)	16 (2.9)	0 (0)	10 (1.8)
	T1	76 (13.8)	225 (40.9)	206 (37.4)	32 (5.8)	3 (0.5)	8 (1.4)
22	T0	289 (52.5)	174 (31.6)	60 (10.9)	1 (0.2)	0 (0.0)	26 (4.2)
	T1	137 (24.9)	244 (44.3)	141 (25.6)	16 (2.9)	2 (0.4)	10 (1.8)
Total	T0	989 (45.0)	833 (37.9)	291 (13.3)	31 (1.4)	0 (0.0)	56 (2.5)
	T1	446 (20.3)	935 (42.5)	671 (30.6)	112 (5.1)	9 (0.4)	27 (1.2)

Table 2: Inter observer agreement, all observers, presented as percentage of agreement (%) for the assessment of apical root morphology/resorption in periapical radiography of maxillary incisors before start of treatment (T0) and during treatment (T1).

Note: *N.P.A. Not possible to assess

Before start of treatment (T0) score 0, 1, and 2 were observed in 96.2% of the assessments, when taking all observers assessments into account. One point four per cent was assessed as score 3 and no root was assessed as score 4. During treatment (T1), 93.4% of the roots were assessed as score 0, 1, and 2 and 5.5% as score 3 and 4 (Table 2).

Similar numbers of root resorptions were observed in patients during treatment with van Beek activator as well as in patients with expansion plate. Eight roots in seven patients were assessed as having score 3 by three of the five observers. Four of these patients were treated with van Beek activator and three with expansion plate. In one patient treated with van Beek activator one tooth were assessed as score 4 by two observers.

Observer Agreement Exact Scoring

Pairwise inter-observer agreement for scoring 0, 1, 2, 3, and 4 varied between 27% and 67% before start of treatment (T0) and between 13% and 59% during treatment (T1) (Table 3). Agreement was generally lower in the assessments during treatment (T1). Due to too few assessments of scores 3 and 4 it was not possible to calculate kappa values for pair wise inter-observer agreement before start of treatment (T0). Kappa values for pair wise inter-observer agreement during treatment (T1) varied between -0.01 and 0.27 interpreted as no to fair agreement [15].

Pairs of Observers	Tooth	12	11	21	22
		Agreement (%)	Agreement (%)	Agreement (%)	Agreement (%)
1/2	T0	53	54	55	55
	T1	43	55	53	35
1/3	T0	62	50	48	50
	T1	37	28	26	35
1/4	T0	46	44	41	53
	T1	39	24	32	35
1/5	T0	61	53	52	63
	T1	54	45	48	59
2/3	T0	48	38	32	40
	T1	16	20	17	13
2/4	T0	40	32	27	41
	T1	29	25	25	22
2/5	T0	46	31	28	45
	T1	23	23	28	26
3/4	T0	65	51	45	67
	T1	43	33	33	44
3/5	T0	61	65	66	56
	T1	53	55	53	45
4/5	T0	49	52	47	59
	T1	40	35	37	45

Table 3: Pairwise inter observer agreement presented as percentage of agreement (%) for the assessment of root morphology/resorption in periapical radiographs of the maxillary incisors before start of treatment (T0) and during treatment (T1).

The scoring represents an exact score, 0 to 4.

1: Observer 1; 2: Observer 2; 3: Observer 3; 4: Observer 4; 5: Observer 5.

Intra-observer agreement for scoring 0 to 4 varied between 30% and 80% before start of treatment (T0). The percentages during treatment (T1) varied between 37% and 75%. Kappa values ranged between -0.09 and 0.45 (T0) and -0.22 and 0.48 (T1), interpreted as no to moderate agreement [15].

Observer Agreement Grouped Scoring

Pair wise observer agreement expressed as overall agreement in percentage was noticeably higher when the cut-off was made, varying

between 91% and 100% before start of treatment (T0) and between 75% and 98% during treatment (T1) (Table 4). Kappa values during treatment (T1) varied between -0.01 and 0.66, interpreted as no to substantial agreement [15].

Pairs of Observers	Tooth	12	11	21	22
		Agreement (%)	Agreement (%)	Agreement (%)	Agreement (%)
1/2	T0	100	94	94	99
	T1	93	88	89	94
1/3	T0	100	96	93	99
	T1	95	85	88	96
1/4	T0	99	95	93	99
	T1	92	75	86	95
1/5	T0	100	96	93	99
	T1	96	87	89	98
2/3	T0	100	94	91	100
	T1	92	87	90	92
2/4	T0	99	93	91	100
	T1	90	76	86	91
2/5	T0	100	94	91	100
	T1	93	86	89	94
3/4	T0	99	99	100	100
	T1	95	84	91	95
3/5	T0	100	100	100	100
	T1	99	97	97	98
4/5	T0	99	99	100	100
	T1	96	85	92	97

Table 4: Pairwise inter observer agreement presented as percentage of agreement (%) for the assessment of root morphology/resorption in periapical radiographs of the maxillary incisors before start of treatment (T0) and during treatment (T1).

The scoring 1 to 5 were grouped into two groups of scores, 1 to 3 and scores 4 and 5.

1: Observer 1; 2: Observer 2; 3: Observer 3; 4: Observer 4; 5: Observer 5.

During treatment (T1) the agreement values varied between 85% and 100% and the Kappa values between -0.18 and 1.0, interpreted as no to almost perfect [15].

It was not possible to calculate kappa values for all observer pairs prior to treatment or intra-observer agreement in percentage and kappa values before start of treatment (T0), due to too few assessments in the group at scores 3 and 4.

The individual observers' assessments of root resorption exceeding more than one score before start of treatment (T0) and during treatment (T1) varied between 2% and 23% for tooth 12, between 5% and 25% for tooth 11, between 4% and 24% for tooth 21 and finally between 3% and 29% for tooth 22. One observer assessed the change in root morphology to be noticeably more than the other observers. Another observer assessed this change to be noticeably less than the other observers did.

Discussion

The overall finding of the present multi-observer study on apical root resorption assessed in periapical radiographs performed before and during treatment with removable orthodontic appliance, demonstrated that inter- and intra-observer agreement varied truly. The rational for the five-observer performance approach was to create conditions similar to an everyday clinic situation, thus the observers represented different professional experiences as well as different time lengths of expertise. Inter-observer overall agreement varied substantially, even though the observers jointly discussed and wrote down assessment criteria to serve as a calibration (Table 2). Specially, pair wise inter-observer agreement for exact scoring was low (no agreement to fair agreement). The highest disagreement was found between one senior oral-and maxillofacial radiologist and one senior orthodontist (observer 2/3) (Table 3). This might be explained by the different professional experience and different expectations to detect apical root resorptions. The largest difference could also be seen between the same two observers in assessment of progression of root resorption.

The intra-observer agreement was low when using the five exact scores (0, 1, 2, 3, and 4) to assess apical root resorptions, score 1 and 2 were especially difficult to assess. It is important to remember that radiography is an imprecise tool for detection of small differences in tissue loss, which might be one explanation for the low agreement. However, the higher intra-observer agreement when dividing the five scores into the two groups (scores 0 to 2 and scores 3, 4), suggests that the index used in this study might be even further modified when root resorptions are less pronounced in the population. The higher intra-observer agreement when dividing the five scores into the two groups indicate however that no apical root resorption of major clinical importance of the maxillary incisors occurred, as no single tooth was assessed by all five observers in agreement as having severe apical root resorption (scores 3 or 4) during treatment.

When assessing root morphology/resorption the diagnostic efficacy of periapical radiographs is dependent both on accuracy and observer performance [11]. In this study, using periapical radiographs to assess root resorption during treatment, it was not possible to obtain any reference standard. However, the reliability estimations are useful in determining the extent to which the inaccuracy of a diagnostic method is due to decision-making errors. Unfortunately, reliability studies are generally neglected and do not appear in the different stages of evaluating studies of diagnostic methods [16] or in studies where diagnostic methods are used to evaluate treatment outcomes [17]. Other radiological methods like Cone Beam Computed Tomography (CBCT) may result in more reliable assessments, however, this method cannot in the current situation be justified due to higher radiation dosage.

The clinical consequences of root resorption can be discussed [18]. It has been stated that the degree of root loss in most situations is clinically insignificant while others believed that roots with severe resorption could be at risk for tooth mobility or never resist the stress of function as well as un-resorbed roots [19,20]. Mohandesan et al. [10], used external apical root resorption of 1 mm at 12 months of active treatment period as the cut-off to determine the clinical importance of root resorption. In present study we have assumed that loss of root tissue exceeding 2 mm (scores 3 and 4) is of clinical importance in the way that it might change how the treatment will continue.

Several studies on root resorption during treatment with removable orthodontic appliance are performed retrospectively by limited numbers of observers [6-9]. The patient history might then be unknown as well as that the image quality might not have been carefully taken into account when the radiographs were obtained. The strength

with a prospective study is that the diagnostic quality of the radiographs will be under control with optimal vertical angulation to depict the apex clearly, a prerequisite for assessment of root contours and resorption. Despite the ambition to obtain images of optimal quality in this study, for some roots the apical part was not possible to assess (2.5% at T0 and 1.2% at T1). A possible explanation is that in some patients the apical part of the root of a maxillary incisor is curved in the bucko-palatinal direction and consequently blurred in the image. Treatment with removable appliance results in more intermittent loading on the maxillary incisors compared to treatment with fixed appliance [6]. In present study two different types of removable appliances was used, the expansion plate and the van Beek activator. The plate was provided with active protrusive elements tipping the anterior incisors in a labial direction.

The activator, equipped with headgear, force together with the muscle tension transferred to maxillary teeth the incisors in palatal direction. In both types of appliances, the size of the forces on the maxillary incisors was unknown. The force of the springs of the expansion plate will certainly decrease after a couple of weeks, thus exposing less compression of the periodontal membrane. The intermittent loading created by the appliances might cause less damage to the most compressed areas of the periodontal membrane. Applications with less force create smaller hyaline zones and a more favorable environment for bone remodeling without involving root damages [21]. These intermissions in loading might explain why apical root resorption was less evident in the present study compared with studies on fixed appliances. An interesting finding was also that similar numbers of apical root resorptions were assessed, by three of the five observers, in patients treated with the van Beek activator and the expansion plate. Thus, the direction of the forces, palatal or labial, might be of minor importance. An additional explanation for the low occurrence of apical root resorption in the present study might be that the roots of children have wider apical foramina of the maxillary incisors with areas of high vascularity, which prevent damages of the roots compared to adolescents, having a more developed and narrow apical foramina [22,23]. Factors as gender, age, habits, trauma and certain ethnicities as predispose factors for root resorption could be interesting to investigate, but was out of topic of the present study. These factors have been highlighted in some previous studies on fixed appliance [23-27].

Conclusion

Reliability in assessing root morphology/resorption in periapical radiographs obtained in children during treatment with removable appliance is low. ARR seems to be of minor extent; however, the low reliability indicates difficulties in evaluating the severity and there by the clinical importance in this young patient group.

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