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RESEARCH ARTICLE

A CLINICAL RISK PREDICTION MODEL OF ORTHODONTICALLY INDUCED ROOT RESORPTION FOLLOWING FIXED APPLIANCE THERAPY

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ABSTRACT

Purpose: This paper aims to study the role of five variables in the susceptibility to orthodontically induced root resorption in order to obtain an integrative model to predict the occurrence of this complication following fixed appliance therapy.

Materials and Methods: Pre and post treatment records of 34 patients treated with MBT 0.022 slot appliances for a minimum of one year were studied. Root resorption was measured in the four maxillary and mandibular incisors using pre and post treatment orthopantomograms and lateral cephalograms. Statistical analysis was done to assess the role of five variables in the susceptibility of orthodontically induced root resorption

Results: Among the variables studied; gender, treatment duration, age and alveolar bone thickness significantly contributed to orthodontically induced root resorption.

Conclusion: Among the variables studied that are potential contributors for orthodontically induced root resorption, four variables associated with root resorption were identified.

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INTRODUCTION

Orthodontically induced root resorption (OIRR) can be defined as a shortening or blunting of the root apex (Malmgren and Levander, 2004). It typically attacks the root tip and travels coronally, creating a "shed roof" effect to the root (Rudolph, 1940). As orthodontically induced root resorption is believed to be irreversible when involving dentin, it is imperative to identify factors that may predispose individuals to clinically significant OIRR caused by loss of cementum (Andreasen, 1985). Root resorption occurs when the pressure on the cementum exceeds its reparative capacity and dentin is exposed, allowing the multinucleated odontoclasts to degrade the root substance. Biological factors described in literature include genetic susceptibility (Harris *et al*., 1997; Al-Qawasmi *et al*., 2003; Weltman *et al*., 2010; Gulden *et al*., 2009), gender (Brezniak and Wasserstein, 2002; Mohandesan *et al*., 2007; Iglesias-Linares *et al*., 2012; Tomoyasu *et al*., 2009), age (Iglesias-Linares *et al*., 2012; Linge and Linge, 1991; Mirabella *et al*., 1995; Mavragani *et al*., 2002; Brin *et al*., 2003), tongue thrust, existence of anterior open bite, type of malocclusion (Brin *et al*., 2003) and systemic diseases (Brezniak and Wasserstein, 2002; Hartsfield *et al*., 2004). Environmental factors concern mechanical or orthodontic treatment variables like treatment duration (Iglesias-Linares *et al*., 2012; Brin *et al*., 2003), type of orthodontic appliance (Brezniak and Wasserstein, 1993), tooth extraction (Mohandesan *et al*., 2007; Iglesias-Linares *et al*., 2012), intrusive movement, root torque and force magnitude. Polymorphisms in interleukin 1 gene have also been implicated, but results remain controversial (Gulden *et al*., 2009; Iglesias-Linares *et al*., 2012; Tomoyasu *et al*., 2009; Al-Qawasmi *et al*., 2003). Malmgren and Levander have proposed the evaluation of root resorption using ordinal scales (Levander and Malmgren, 1988), whereas others have assessed it by means of measuring root lengths (Linge and Linge, 1991; Mavragani *et al*., 2002; Linge and Linge, 1983). In clinical orthodontics, orthopantomograms and lateral cephalograms are routinely ordered as the primary diagnostic tool. Although being less accurate than periapical films, panoramic radiographs have advantages like less radiation exposure and visualization of the complete dentition, besides being less time-consuming for the operator and more patient-friendly. Panoramic films may overestimate by approximately 20% the amount of root loss (Sameshima and Asgarifar, 2001) but this magnification factor is relatively constant in the vertical axis (Larheim and Svanaes, 1986; Wyatt and Farman, 1994), which is clinically the most important aspect in analyzing OIRR (Gher and Richardson, 1995). This overestimation can be overcome using the percentage of root/tooth length variation instead of direct measurement of root length. Due to image distortion, comparison of panoramic

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with periapical films has revealed maximum differences in the lower incisors, but minimum in the maxillary incisors (Sameshima and Asgarifar, 2001), which are the most frequently affected teeth (Brezniak and Wasserstein, 1993). Three dimensional imaging systems are known to be the best way to evaluate OIRR, though not easy to apply in clinical practice due to higher expenses involved. The aim of proposing this prediction model was to evaluate the contribution of several treatment factors to orthodontically induced root resorption in order to create an integrative model that would predict the risk of developing this common orthodontic complication.

MATERIALS AND METHODS

This study consisted of patients who had undergone orthodontic treatment at K.V.G. Dental College and Hospital, Sullia, Karnataka, India for a minimum of 12 months. Thirty-four patients aged 12 years and more who underwent fixed appliance therapy with MBT 0.022 slot sliding mechanics were randomly selected. The selection criteria were as follows; the existence of complete records of the malocclusion; treatment plan and treatment history; a pre- and posttreatment panoramic radiograph taken within 1 month of debonding; and a pre- and post-treatment lateral cephalometric radiograph using a cephalometric radiography equipment with a standardized technique. The dental records were reviewed and the patients with a history of systemic illness, craniofacial abnormalities, trauma to teeth, endodontically treated teeth, impacted teeth, carious teeth, teeth with an existing periapical pathology, genetic or developmental defect of the root and absence of one or more incisors, either congenitally or due to history of extraction were excluded from the study. A total of 34 patient records were obtained which m*et al*l the above mentioned criteria with the age range of 12-26 years,out of which 17 were males and 17 females. Overbite and overjet were measured with the pre- and post-treatment lateral cephalometric radiographs to calculate the changes in overbite and overjet. Of the 34 patients, 26 patients were treated with extraction and 8 without extraction. The duration of their orthodontic treatment ranged from 12 to 28 months.

Root resorption measurement

Orthopantomograms were used to measure the root resorption. The crown length was measured from the cementoenamel junction to the incisal edge and the root length from the cementoenamel junction to the root apex with a digital caliper (accurate to 0.01 mm). Total tooth length was calculated by adding values of the crown length with the root length for each tooth. These measurements were performed on both pre- and post-treatment panoramic images. Root resorption was calculated by the difference of the tooth length between the images.

The following method was used to correct the differences in enlargement and angulations (Mohandesan *et al*., 2007).

R=TL1-TL2xCL1/CL2, where
R – resorption;
TL1 – pre-treatment total tooth length;
TL2 – post-treatment total tooth length;
CL1 – pre-treatment crown length;
CL2 – post-treatment crown length.

The tooth length was measured for the left and right permanent central and lateral incisors in both jaws. The pre and post-treatment lateral cephalograms were analysed with the help of cephalometric analyses for the linear and angular measurements of the distance between upper incisor to NA and lower incisor to NB.

Reference points on the lateral cephalograms include-

PointA- The most posterior point in the concavity between ANS and maxillary alveolar process
Point B- Most posterior point in the concavity between the chin and the mandibular alveolar process
ANS- The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening
PNS- The posterior spine of the palatine bone constituting the hard palate
Nasion- Anteriormost point on the frontonasal suture
W1- Alveolar bone thickness at the CEJ level of the U1
W2- Alveolar bone thickness at 3mm from the CEJ around the U1
W3- Alveolar bone thickness at the CEJ level of the L1
W4- Alveolar bone thickness at 3mm from the CEJ around L1

All the data was recorded by a single examiner by using the methods stated above.

Statistical analysis

Descriptive statistics was performed in the form of mean, standard deviation and frequencies. Comparison of the root length and comparison of skeletal and dental measurements pre and post treatment was done using the Paired t test. Correlation between root resorption and extraction/non-extraction and the correlation between root resorption and gender was done using the Mann Whitney U test. Correlation between the duration of treatment and age and amount of root resorption was done using Spearman's correlation test.

RESULTS

In the first step, for each tooth, OIRR values were analyzed in all the 34 patients. Root resorption was significant for each of the eight incisors ($p < 0.05$). On average, %OIRR ranged from 11.91% (tooth 31) to 15.32% (tooth 11). The correlation between OIRR and five variables was assessed. Comparison of all the skeletal and dental measurements pre and post treatment were significant ($p < 0.05$) except for the LI to NB-linear measurement ($p > 0.05$) (Table 1) Correlation between the change in root length and extraction vs non-extraction of premolars was calculated for which the results were not significant ($p > 0.05$) Correlation between gender and root resorption was significant for the maxillary right central incisor ($p < 0.05$) (Table 2) Correlation between age and root resorption was calculated and found to be not significant ($p < 0.05$) Correlation between duration of treatment and root length was calculated and found to be significant for the maxillary right lateral incisor ($p = 0.003$) (Table 3) Correlation between the alveolar bone thickness and root resorption was calculated. Results were significant for alveolar bone thickness around the mandibular lateral incisors at the level of the CEJ and at the crestal level (3 mm above the CEJ) ($p < 0.05$) (Table 3)

Table 1. Comparison of skeletal and dental measurement before and after treatment

		Mean	SD	95% CI of the difference		Paired t test		
				Lower	Upper	t	df	p-value
UI TO NA-LINEAR	Pre	8.059	2.5099	.8937	3.3122	3.538	33	0.001*
	Post	5.956	2.8798					
UI TO NA-ANGULAR	Pre	32.000	8.3811	2.0599	8.0578	3.432	33	0.002*
	Post	26.941	7.2109					
LI TO NB-LINEAR	Pre	6.794	2.3999	-.3024	1.2436	1.239	33	0.22(NS)
	Post	6.324	1.8985					
LI TO NB-ANGULAR	Pre	31.500	7.1106	1.1767	6.4703	2.939	33	0.006*
	Post	27.676	4.9465					
Alveolar bone thickness around UI-CEJ(W1)	Pre	6.603	.7154	.3998	.9825	4.827	33	<0.001*
	Post	5.912	.6682					
Alveolar bone thickness around UI-crestal level(W2)	Pre	9.074	1.0160	.5850	1.1503	6.245	33	<0.001*
	Post	8.206	.8449					
Alveolar bone thickness around LI-CEJ(W3)	Pre	5.485	.7735	.6086	1.3031	5.601	33	<0.001*
	Post	4.529	.5633					
Alveolar bone thickness around LI-crestal level(W4)	Pre	6.574	1.0811	.9018	1.5099	8.069	33	<0.001*
	Post	5.368	.9154					

*P<0.05 statistically significant
p>0.05 non significant, NS

Table 2. Comparison of change in crown length, root length and skeletal measurement according to gender

	Male		Female		Mann Whitney U test		
	Mean	SD	Mean	SD	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)
Diffroot 11	0.72	0.88	1.43	1.89	86.5	-1.985	0.047*

*P<0.05 statistically significant
p>0.05 non significant, NS

Table 3. Correlation between age, duration, skeletal changes and root length

		Root							
		11	21	12	22	31	41	32	42
Age	Correlation Coefficient	.178	.152	.052	.284	.262	.279	.135	.105
	p-value	.31(NS)	.39(NS)	.76(NS)	.10(NS)	.13(NS)	.11(NS)	.44(NS)	.55(NS)
Duration	Correlation Coefficient	-.008	.186	.489	.302	-.055	-.102	.134	.244
	p-value	.96(NS)	.29(NS)	.003*	.08(NS)	.759(NS)	.56(NS)	.44(NS)	.16(NS)
UI TO NA-LINEAR -diff	Correlation Coefficient	.294	.168	.082	.148	.101	.125	.019	.069
	p-value	.09(NS)	.34(NS)	.64(NS)	.40(NS)	.57(NS)	.48(NS)	.91(NS)	.69(NS)
UI TO NA-ANGULAR -diff	Correlation Coefficient	.242	.059	.051	.085	.244	.194	-.014	-.011
	p-value	.16(NS)	.74(NS)	.77(NS)	.63(NS)	.16(NS)	.27(NS)	.93(NS)	.95(NS)
LI TO NB-LINEAR-diff	Correlation Coefficient	.207	.211	.266	.194	.042	.054	-.094	-.103
	p-value	.23(NS)	.23(NS)	.12(NS)	.27(NS)	.81(NS)	.76(NS)	.59(NS)	.56(NS)
LI TO NB-ANGULAR-diff	Correlation Coefficient	.202	.273	.160	.145	-.050	-.098	-.160	-.147
	p-value	.25(NS)	.11(NS)	.36(NS)	.41(NS)	.78(NS)	.58(NS)	.36(NS)	.40(NS)
Alveolar bone thickness around	Correlation Coefficient	.101	.192	.295	.157	.183	.054	-.020	-.009
UI-CEJ(W1)-diff	p-value	.57(NS)	.27(NS)	.09(NS)	.37(NS)	.30(NS)	.76(NS)	.91(NS)	.96(NS)
Alveolar bone thickness around	Correlation Coefficient	-.076	.094	.084	-.123	-.261	-.308	-.099	-.167
UI-crestal level(W2)-diff	p-value	.66(NS)	.59(NS)	.63(NS)	.48(NS)	.13(NS)	.07(NS)	.57(NS)	.34(NS)
Alveolar bone thickness around	Correlation Coefficient	.137	.266	.217	.108	-.274	-.246	-.436	-.391*
LI-CEJ(W3)-diff	p-value	.44(NS)	.12(NS)	.21(NS)	.54(NS)	.11(NS)	.16(NS)	.01*	.02*
Alveolar bone thickness around	Correlation Coefficient	-.055	.102	.215	.062	-.087	-.008	-.352*	-.392*
LI-crestal level(W4)-diff	p-value	.75(NS)	.56(NS)	.22(NS)	.72(NS)	.62(NS)	.96(NS)	.04*	.02*

*P<0.05 statistically significant
p>0.05 non significant, NS

DISCUSSION

OIRR is a multifactorial phenotype, resulting from a combination of biological and mechanical risk factors, which remains highly controversial. In the present study, the role of five variables in the susceptibility to OIRR was analyzed. There is no ideal method for root measurement. Though periapical films have been found better to observe the root details, OPGs are still considered the most suitable as it is systematically ordered in orthodontics and allows the immediate evaluation of the entire dentition without extra radiation exposure. The aim of the present study was to propose a model that could be implemented by clinicians in their clinical practice. As widely observed in literature, the most frequently affected teeth were the maxillary incisors, especially the lateral incisors. Gender, treatment duration, age and alveolar bone thickness were the main factors that independently contributed to OIRR. Gender has also been previously described as a significant predictor of OIRR and males were found to be more susceptible in our study. According to other studies males, when compared to females, had more root resorption, but the differences were not statistically significant (Kaley and Phillips, 1997; Sameshima and Sinclair, 2001; Linge and Linge, 1991). Some researchers have registered more root resorption in females (Levander and Malmgren, 1988). In line with our results, some authors have identified treatment duration as a very significant variable predicting OIRR although others have not. According to them, the possible correlation between the duration of active treatment and the incidence and severity of OIRR was controversial (Mirabella and Artun, 1995; Levander and Malmgren, 1988; Baumrind *et al.*, 1996; Kaley and Phillips, 1991; Sameshima and Sinclair, 2001; Kurol *et al*., 1996; Janson *et al*., 2000). Some studies concluded that the duration of treatment might be correlated to the extent of OIRR (Sharpe *et al*., 1987; McFadden *et al*., 1989; Vlaskalic *et al*., 1998), while others found no significant association between OIRR and treatment duration (Mirabella and Artun, 1995; Beck and Harris, 1994). The duration of treatment was most often correlated with the apical root resorption in meta analysis of the treatment-related factors of external apical root resorption (Segal *et al*., 2004). According to the results of the present study, there was no significant difference in the amount of root resorption between the extraction and non-extraction groups which is in accordance with the earlier works of many authors (Baumrind *et al*., 1996). But in disagreement with certain other studies (Mohandesan *et al*., 2007; Baumrind *et al*., 1996). Measurement of the alveolar bone thickness at two levels around the respective tooth was done to understand the impact of the amount of alveolar bone on the extent of root resorption. From the study it was observed that the amount of alveolar bone significantly altered the extent of OIRR in the lower incisor. Thinner the alveolar bone around the tooth, more was the resorption and more was the tendency of the root tips to come very close to the cortical plate. The thickness of alveolar bone as a factor affecting root resorption hasn't been studied in great detail in the previous studies.

Conclusion

The above detailed clinical risk prediction model identifies, four variables affecting the extent of orthodontically induced root resorption which are treatment duration, gender, age and thickness of alveolar bone. The limited impact of these variables in root resorption suggests the existence of other, probably multiple, low penetrance factors that need to be looked into. Genetic predisposition to OIRR has long been suggested but as for other complex diseases, it is not clear if a patient's genetic profile will significantly improve risk evaluation. Hence, further studies are warranted to confirm our observations and evaluate more factors that can possibly cause directly or indirectly the roots to resorb during the orthodontic treatment. The idea behind presenting this risk prediction model is to sensitize the clinicians and equip them with sufficient knowledge about OIRR and to ponder about the same. It is expected to help the present day orthodontist to evaluate the patient based on various factors before beginning the treatment and plan a customized protocol to achieve longstanding clinical success.

Disclosure

This research paper was presented in the category of Clinical Paper by Dr.Namrata Ramesh, Postgraduate student under the guidance of the Head of the Department, Dr.Sharath Kumar Shetty and Professor, Dr.Mahesh Kumar Y. at the 1st International Orthodontic Conference conducted by the Sri Lanka Orthodontic Society at Colombo, Sri Lanka from Feb 5-8,2016.

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