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External apical root resorption after molar space closure with miniscrew as anchorage: a tomographic evaluation

Reabsorção radicular apical externa após fechamento de espaço do molar com uso de mini-implante como ancoragem: avaliação tomográfica

Resorción externa de la raíz apical tras el cierre del espacio molar con miniscrew como anclaje: una evaluación tomográfica

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Abstract

Objective: The purpose of this retrospective study was to evaluate and quantify external apical root resorption (EARR) in molars after masialization into atrophic alveolar ridge area. Materials and Methods: The sample consisted of 11 patients, five women and six men, and a total of 16 molars, both superior and inferior (seven in the maxilla and nine in the mandible). The age range was 19 to 55 years at the beginning of treatment (initial mean age of 36 years and 5 months), with an average treatment time of 23 months. Tooth movement was performed with mini-implant anchorage using NiTi springs, using a mean force of 300 grams. The sample was evaluated using cone-beam CT scans (CBCT) in two periods, at the beginning of the treatment (T1) and after 4 mm of movement (T2). Root resorption was measured by the difference in root lengths (T2-T1). Using the distance from the floor of the pulp chamber to the root apex as a reference. Root length was measured using specific software (OnDemand3Ddental) and was analyzed using the paired t-test, adopting a significance level of 5%. Results: There was statistically significant resorption only in the mesial and distal roots, with a mean reduction of 0.69 mm in the mesial root (-6.2%) and 0.83 mm in the distal root (-7.4%). Conclusion: Space closure after dental movement in an atrophic alveolar ridge was identified as a risk factor for ARR. However, the amount of ARR could be considered clinically irrelevant.

Keywords: Root resorption; Orthodontic anchoring procedures; Tooth movement.

Resumo

Objetivo: Avaliar e quantificar a reabsorção radicular apical nos molares mesializados por meio de mini-implantes. Metodologia: A amostra desse estudo retrospectivo foi composta por 10 pacientes (6 do sexo masculino e 4 do sexo feminino), com idades entre 19 e 55 anos, em um total de 15 dentes mesializados (6 no arco superior e 9 no arco inferior) ortodônticamente com auxílio de mini-implantes, em um tempo médio de 22,46 meses. Essa amostra foi avaliada por meio de tomografias computadorizadas de feixe cônico, em dois períodos, antes (T1) e após 4mm de mesialização (T2). Para realizar a mensuração, os molares foram verticalizados e tivemos como referência o assoalho da câmara pulpar até o ápice dentário. O comprimento das raízes dos molares foi medido em um software específico (OnDemand3Ddental) e analisados através do teste t pareado adotando o nível de significância de 5% ($p<0,05$). Resultados: A média do comprimento da raiz na fase inicial foi de 11,29 com desvio padrão de 2,46. E a média do comprimento da raiz na fase final de 10,60 com desvio padrão de 2,63. Conclusão: Houve reabsorção estatisticamente significante, com média de 0,69mm, o que corresponde a uma reabsorção de 6,1% do comprimento da raiz.

Palavras-chave: Reabsorção da raiz; Procedimentos de ancoragem ortodôntica; Movimentação dentária.

Resumen

Objetivo: El propósito de este estudio retrospectivo fue evaluar y cuantificar la reabsorción radicular apical externa (EARR) en molares después de la masialización en el área del reborde alveolar atrófico. Materiales y Métodos: La muestra estuvo conformada por 11 pacientes, cinco mujeres y seis hombres, y un total de 16 molares, tanto superiores como inferiores (siete en el maxilar y nueve en la mandíbula). El rango de edad fue de 19 a 55 años al inicio del tratamiento (edad media inicial de 36 años y 5 meses), con un tiempo medio de tratamiento de 23 meses. El movimiento dentario se realizó con anclaje de mini-implantes utilizando resortes de NiTi, utilizando una fuerza media de 300 gramos. La muestra se evaluó mediante TC de haz cónico (CBCT) en dos periodos, al inicio del tratamiento (T1) y después de 4 mm de movimiento (T2). La reabsorción de raíces se midió por la diferencia en la longitud de las raíces (T2-T1). Utilizando la distancia desde el suelo de la cámara pulpar hasta el ápice de la raíz como referencia. La longitud de la raíz se midió mediante un software específico (OnDemand3Ddental) y se analizó mediante la prueba t pareada, adoptando un nivel de significancia del 5%. Resultados: Hubo reabsorción estadísticamente significativa solo en las raíces mesial y distal, con una reducción media de 0,69 mm en la raíz mesial (-6,2%) y 0,83 mm en la raíz distal (-7,4%). Conclusión: El cierre del espacio después del movimiento dentario en un reborde alveolar atrófico fue identificado como un factor de riesgo para RRA. Sin embargo, la cantidad de ARR podría considerarse clínicamente irrelevante.

Palabras clave: Resorción radicular; Métodos de anclaje en ortodoncia; Técnicas de movimiento dental.

1. Introduction

After loss of permanent molars, the alveolar ridge undergoes a period of bone remodeling that results in reduction of alveolar bone height and disorganization of bone trabeculation (Carlsson, Lindquistm & Jemt, 2000). The rehabilitation of this region often requires the combination of surgical, orthodontic and prosthetic treatments (Taner *et al.*, 2006). The atrophic alveolar ridge, post-dental extraction, is therefore a difficult obstacle to overcome due to vestibulolingual narrowing and loss of bone height of the alveolar ridge, compromising the support of the active dental element (Taner *et al*., 2006; Rabie & Chay, 2000). These severe chronic periodontal problems coincide with increased root resorption, compromising dental support (Rodriguez-Pato, 2004).

One of the treatment options is orthodontic space closure via mesial movement of molars (Lee *et al*., 2009). However, for this movement to be optimized, a suitable anchorage unit is necessary to avoid movement of the anterior segment (Kim *et al*., 2015). In most patients, root shortening during this treatment is usually less than 2.5 mm or ranges from 6% to 13% for various teeth (Castro *et al.*, 2013; Weltman *et al*., 2010). However, in 1% to 5% of all patients undergoing orthodontic treatment, severe resorption occurs, defined as more than 4 mm or one-third of root shortening (Weltman *et al*., 2010).

Some studies reported evaluations of root resorption of orthodontically-moved teeth to overcome adjacent permanent molar loss (Kim *et al*., 2006; Winkler *et al*., 2017). However, no study has evaluated this root resorption in the atrophic alveolar ridge by cone-beam computed tomography. This is a unique advantage in our study, since it is a more accurate and reliable examination. Therefore, the purpose of this study was to evaluate, by means of cone-beam computed tomography, the magnitude of root resorption in the molars after movement using mini-implant anchors in edentulous areas with atrophic alveolar ridges.

2. Materials and methods

This is retrospective study with a quantitative character due to measurement o EARR which was measured in numerical values (Pereira, 2018). It was submitted to and approved by the Ethics Committee on Research in Human Subjects of the University XXXX. Decision No. 1986566.

Sample size determination

The sample calculation was based on the study by Winkler and co-workers from 2017 (Winkler *et al.*, 2017), where a confidence level of 95% and a maximum error of 0.1 mm were adopted. The calculated sample required for this study, using CBCT, was 16 teeth.

Sample

The sample consisted of 11 patients (initial mean age of 36 years and 5 months, being at least 19 years and the maximum of 55 years) with 16 molars, superior or inferior, adjacent to an edentulous area. Thus, patients had more than one moved tooth.

Of the 11 patients, five were female (45.4%) and six were male (54.5%). Of the total number of teeth (16), seven belonged to women (43.8%) and nine belonged men (56.2%), seven were superior (43.8%) and nine were inferior (56.2%).

Inclusion criteria

- Adult patients and young adults who had undergone initial CBCT for the purpose of pre-surgical diagnosis of the edentulous space to determine the placement of an osseointegrated implant or orthodontic closure; and a final CBCT to assess apical root resorption.
- Patients treated orthodontically with movement of molar teeth (inferior or superior).
- Dental absence in the posterior portion of the unilateral or bilateral maxilla and/or mandible occurring at least 2 years prior to characterize the atrophic ridge area, since 6 to 18 months after tooth loss there is a large amount the reduction of the alveolar ridge after extraction (Tolstunov, 2007).
- Edentulous area with a minimum mesio-distal dimension of 4 mm.

Orthodontic treatment

Orthodontic treatment was performed with fixed Roth prescription slot appliances 0.022 x 0.028 (Brand, city, country). In order to perform the space closure by molar movement, an orthodontic skeletal anchorage was used, with the fixation of mini-implants in the premolar region, according to a previously published protocol (Park, 2002).

Initial orthodontic leveling was performed, and the mechanization of movement only started when the 0.020" steel arch (Brand, city, country) was inserted In an attempt to approach the center of tooth resistance, the movement was assisted by a cantilever that was made by a 0.019" x 0.025" TMA thread segment This cantilever was positioned in the distal portion of the molar tube that would be moved and attached to the mini-implant by means of a

NiTi spring with a mean force of 300g (Roberts, Marshall, Mozsary, 1990) (Figure 1).

The activations were done with mean intervals of 30 days.

Figure 1. Clinical presentation of the mechanics of tooth movement in the maxilla and mandible.

Source: The authors.

Figure 2 shows a distended spring coil supported on a mini-screw and in a power arm placed in the orthodontic appliance. Once this coil has form memory, it will try to close and mesialize the molar thanks to the support on power arm. On the other side, since mini-screw is fixed in the alveolar bone, the entire applied strength will be delivered in the molar, improving the desired movement.

Cone-beam computed tomography

The CBCTs were performed at two time points:

- T1: at the beginning of the orthodontic treatment, for pre-surgical diagnosis of the edentulous space, to determine the placement of the osseointegrated implant or orthodontic closure.
- T2: after movement of the molars at 4 mm. This measurement was made by means of a digital caliper (stainless steel 200 mm, Total brand, 8 inches). At this time, orthodontic mechanics were interrupted pending examination.

The CBCT exams were performed on two different devices:

- I-CAT (Imaging Sciences International, Hartfield PA, USA) with FOV 17.5. We used 120 kVp and 12 mA and voxel 0.2 mm, with exposure time 40 seconds. This equipment was used for the tomographic acquisition of 10 teeth at T1 and T2.
- Prexion 3D (XP68) with FOV 81.00. We used 90 KVp and 4 mA, with exposure time 19 seconds. This equipment was used in the tomographic acquisition of 6 teeth

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at T1 and T2.

Patients were positioned in the apparatus by standardizing the position of the head such that the Frankfurt plane was parallel to the ground and the median sagittal plane was perpendicular to the ground.

All images were stored in Digital Imaging and Communications in Medicine (DICOM) format for further processing and analysis.

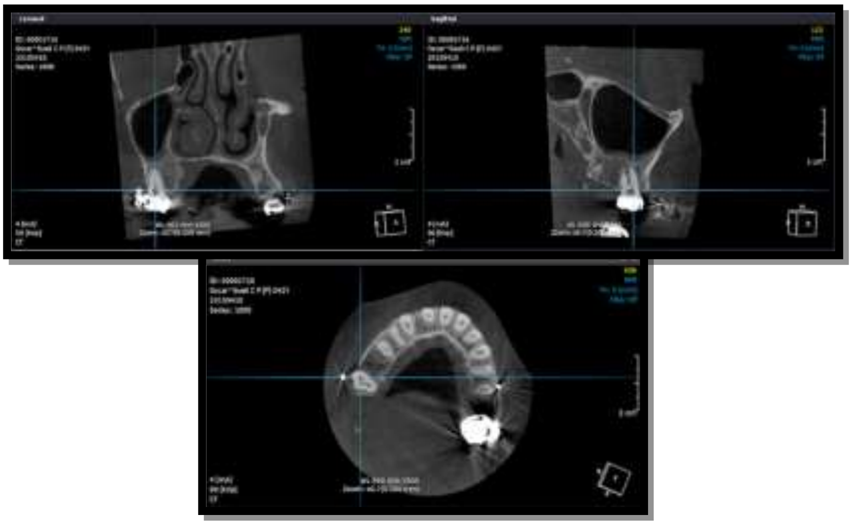
Evaluation method

For quantitative evaluation of EARR, The DICOM files were imported into the software package OnDemand3Ddental (Cibermed Inc, Yuseong, Daejeon, South Korea). The cuts used were 0.1 mm.

Measurement of vestibular roots

Using the multi-planar reconstruction (MPR) window, patient images can be viewed in axial, coronal and sagittal windows. The first step was to do the digital verticalization of the tooth to be analyzed, considering that the majority of the sample was made up of molars mesially-inclined, common movement for molars adjacent to edentulous areas (Figure 2).

Figure 2. Digital verticalization of the molars and positioning of the cursors on the vestibular roots.



Source: The authors.

Observe that in Figure 2 the cursors (in blue) I posits simultaneously in the 3 MPR windows (coronal, sagittal and axial views) on the vestibular roots. This way, we determinate that the root position will be assessed in all dimensional plans.

Root appex of the root in question and the floor of pulp chamber were used as references (red lines in Figure 3) to measure root size in T1 and T2, because the latter structure did not change positioning between T1 and T2. We did not use the cement-enamel junction as a reference (Lund *et al.*, 2012) because the moved molars often had extensive restorations, making it difficult to visualize.

In the sagittal cut, after the tooth verticalization and identification of the vestibular roots, the mesiobuccal and distobuccal roots were measured (Figure 3).

Figure 3. Measurement of the vestibular roots.

Source: The authors.

In Figure 3, it is possible to observe red lines placed in references sites determinated in the methodology. Using a software tool, it is possible to measure the distance between the lines. If there is root resorption, the line placed in the apex will be closer to the one placed on the floor of the pulp chamber.

We used these same parameters to measure the roots of the inferior molars, evaluating the mesial and distal roots of each tooth.

These same parameters were used in T1 and T2 to perform the measurements, processed by a single operator (a radiologist). The magnitude of root resorption was represented by the difference in root length of each root (T2-T1).

We did not include the palatine root in our work because of the reduced number of upper molars in the sample (n = 7).

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Statistical analysis

The data were described in tables and graphs according to mean, standard deviation and 95% confidence interval (95% CI).

All measurements passed the Kolmogorov-Smirnov normality test.

For the comparison between the initial and final phases, the paired t-test was used. To compare the amount of resorption between genders and arches, the t-test was used for independent measures.

To verify the correlation between age and time of treatment with the amount of resorption, we used Pearson's correlation coefficient.

In all tests, the significance level was set at 5% ($p < 0.05$).

All statistical procedures were performed on SPSS version 17.

All measurements were repeated 30 days after the first evaluation by the same examiner. In order to verify the systematic intra-examiner error, the paired t-test was used. For determination of casual error we used the calculation of error proposed by Dahlberg (Houston, 1983).

3. Results

On intra-examiner comparison, there was no statistically significant error (in the mesial root, p=0,483, and distal root, p=0,199).

There was thus a statistically significant resorption in the mesial and distal roots, as the "p" value was lower than 0.05, as shown in Table 1.

Table 1. Comparison of variation (EARR), between T1 and T2, for the various molar roots evaluated.

Root	Measure	Mean	SD	(95% CI)	P
Mesial	T1	11.15	2.41	9.87 to 12.43	0.001*
	T2	10.46	2.49	9.13 to 11.78	
	Variation	-0.69 (-6.2%)	0.71	-1.07 to -0.32	
Distal	T1	11.13	2.45	9.83 to 12.43	<0.001*
	T2	10.31	2.58	8.93 to 11.68	
	Variation	-0.83 (-7.4%)	0.66	-1.18 to -0.47	

* - statistically significant difference ($p < 0.05$).ns – no statistically significant difference.
Source: The authors.

According to Table 1, the mean mesial root length at T1 was 11.15 mm (maximum value: 16.52 and minimum value: 6.51) with standard deviation of 2.41 mm. At T2 it was 10.46 mm (maximum value: 15.99 mm and minimum value: 6.71 mm), with standard deviation of 2.49 mm. Thus, there was a root length reduction of 0.69 mm (-6.2% from the root length to the initial mean). At the distal root, the initial mean was 11.13 mm (maximum value: 16.52 mm and minimum value: 6.51 mm) with standard deviation of 2.45 mm, and final mean of 10.31 mm (maximum value: 15.99 mm and minimum value: 6.71 mm) with standard deviation of 2.58 mm and with a total reduction of 0.83 mm (-7.4% from the root length to the initial mean). In the palatal root, there was an initial mean of 12.69 mm (maximum value: 15.87 mm and minimum value: 9.59 mm) with a standard deviation of 2.56 mm, final mean of 12.27 mm (maximum value: 15.97 mm and minimum value: 9.23 mm) with a standard deviation of 2.79 mm, with a total reduction of 0.42 mm (-3.3% from the root length to the initial mean). There was thus a statistically significant resorption in the mesial and distal roots, as the "p" value was lower than 0.05. In the palatal root, this difference was statistically insignificant (palatal sample with only seven teeth)

There was therefore no statistically significant difference between arches and EARR (Table 2).

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Table 2. Comparison between resorption in different arches for the three root types.

Root	Group	n	Mean	SD	P
Mesial	Superior	7	-0.47	0.70	0.290 ns
	Inferior	9	-0.86	0.70	
Distal	Superior	7	-0.54	0.65	0.137 ns
	Inferior	9	-1.05	0.62	

ns – no statistically significant difference. Source: The authors.

Table 2 shows that in the upper mesial root (n = 7), the mean was -0.47 mm with a standard deviation of 0.70 mm, and in the lower mesial root (n = 9), the mean was -0.86 mm with a standard deviation of 0.70 mm. In the upper distal root (n = 7), the mean of -0.54 mm with a standard deviation of 0.65 mm, and in the inferior distal root (n = 9) the mean was -1.05 mm, with a standard deviation of 0.62 mm. There was therefore no statistically significant difference between genders and arches.

The amount of root resorption did not correlate with age, nor with the treatment time (Table 3).

Table 3. Correlation between age and time of tooth movement with resorption occurring in the three types of roots.

Correlation		Root	
		Mesial	**Distal**
Age	r	0,13	0,11
	p	0,622 ns	0,680 ns
Treatment Time	r	0,09	-0,02
	p	0,753 ns	0,942 ns

ns – correlation not statistically significant. Source: The authors.

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Table 3 shows that the amount of root resorption did not correlate with age, however it correlated with the treatment time only in the palatal root ($p < 0.05$). That is, the longer the treatment time, the greater the resorption in the palatal root (n =7).

4. Discussion

The combination of ARR with periodontal problems can result in severe loss of tooth support, making its viability questionable in the long term (Winkler *et al.*, 2017). Moved teeth present a soft crest to the apical bone (Santos *et al.*, 2017), justifying the importance of assessing this mechanism in the atrophic alveolar ridge, since these factors could compromise dental support.

In this study, we used cone-beam computed tomography (CBCT) to measure resorption because it is a validated and accurate method. Among the computerized tomographies, CBCT can acquire images with a lower dose of radiation (Walker, Enciso & Mah, 2005; Haney *et al.*, 2010). Comparing the radiation dose of CBCT with that of the initial orthodontic documentation, including complete periapical radiographs that should be requested for ARR assessment since panoramic radiography causes great distortion, CBCTs provide lower radiation doses (Lorenzoni *et al.*, 2012). This explains the request for a second CBCT used retrospectively in this study.

In addition, children are more susceptible to adverse effects of radiation (Hagmar *et al.*, 1998). In this study, the sample consisted of patients between the ages of 19 and 55 and the mean root length showed a statistically significant reduction in the mesial roots of 0.69 mm (-6.2%) and in the distal roots there was a reduction of 0.83 mm (-7.4%), with an average resorption of 0.76 mm.

The resorption of canines, premolars and mesial and distal roots of the molars in panoramic radiographs were also evaluated in a previous study (Winkler *et al.*, 2017). The authors found a statistically significant difference in the inferior molars of only -0.73 mm (mean reabsorption of the two roots).

After measuring the mesial root length of the molar adjacent to the edentulous space on the panoramic radiographs, it was observed that the root length decreased significantly after movement, with a mean ARR of 0.80 mm (Kim et al., 2015). We had a resorption very close to that of these two studies, demonstrating that this resorption, although statistically significant, was also clinically irrelevant (Levander & Malmgren, 1998). These EARR results are somewhat larger than the results found by other authors (Sameshima & Sinclair, 2001) who showed that the mean root resorption of the mandibular molars after conventional orthodontic treatment without movement was 0.42 mm. It should be noted that the molars are not the most affected by EARR as a consequence of orthodontic treatment, whereas the incisors are the most affected teeth (Sameshima & Sinclair, 2001; Linge & Linge, 1991; Brin *et al*., 2003). However, the degree of radicular resorption of the molars when they undergo major movements, including tooth movement in atrophic edentulous areas, should be considered because the tooth support in the alveolar ridge depends on the combination of bone support and root length.

In this study, the amount of resorption did not correlate with age, a result that agrees with a previous research (Kim *et al*., 2015). Current evidence is inconclusive with respect to patient age. Researchers in two studies reported that ARR was lower in children and adolescents than in adults (Sameshima & Sinclair, 2001; Mayragani *et al*., 2000). Other studies indicated that age may not play a significant role as a risk factor for ARR in adults (Baumrind, Korn & Boyd, 1996; Mirabella & Artun, 1995). In this study, we included only young adults and adults (ages 19-55). There was also no correlation with type of moved tooth (maxilla or mandible), in agreement with a previsou study (Sameshima & Sinclair, 2001).

The mean treatment time was 23 months. Previous studies (Winkler *et al*., 2017; Kim *et al*., 2015) reported a meant treatment duration time varying from 30 to 32 months. However, in our study, the treatment time between T1 and T2 (i.e., from the beginning of the treatment until the closure of 4 mm of space) was considered. In the studies cited above, the total time of treatment was considered from the beginning to the end.

Therefore, according to the magnitude of root resorption found in this study, clinically insignificant (Levander & Malmgren, 1998) and probably not affecting tooth longevity, the orthodontic option of molar movement for edentulous areas may be an alternative treatment for partial edentulous patients if the patient accepts the treatment protocol. This protocol presents advantages with respect to rehabilitation with implants or prostheses, since the patient would preserve their natural teeth. In addition, even for the installation of prostheses or implants, in most cases a previous orthodontic treatment is necessary for alignment of the adjacent teeth the areas to be rehabilitated.

These results should be confirmed with prospective randomized clinical trials, as well as other effects of treatment such as periodontal conditions and using a control group. In this study we did not use because many patients had also lost teeth on the opposite side.

5. Conclusions

According to the methodology adopted and with the data collected, it is possible to conclude:

- There was a statistically significant reduction of the mesial root length of 0.69 mm (-6.2%) and the distal root of 0.83 mm (-7.4%).
- However, this resorption should be considered clinically irrelevant,[34] thus justifying the viability of this treatment modality.

Further researches might be necessary in order to verify how support structures such as alveolar bone and periodontal ligament would respond to molar mesialization. Consequently, this mechanical can be proved as an efficient way to close spaces in a safe way.

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