Ann Ist Super Sanità 2012 | Vol. 48, No. 1: 71-74
DOI: 10.4415/ANN_12_01_12

The application of X-ray microtomography for the assessement of root resorption caused by the orthodontic treatment of premolars

Monika Sawicka[(a)], Rossella Bedini[(b)], Raffaella Pecci[(b)], Cornelis Hans Pameijer[(c)] and Zbigniew Kmiec[(d)]

[(a)] *Department of Orthodontics, Medical University of Gdańsk, Poland*
[(b)] *Dipartimento di Tecnologie e Salute, Istituto Superiore di Sanità, Rome, Italy*
[(c)] *School of Dental Medicine, University of Connecticut, USA*
[(d)] *Department of Histology, Medical University of Gdańsk, Poland*

Summary. The purpose of this study was to demonstrate potential application of micro-computed tomography in the morphometric analysis of the root resorption in extracted human first premolars subjected to the orthodontic force. In one patient treated in the orthodontic clinic two mandibular first premolars subjected to orthodontic force for 4 weeks and one control tooth were selected for micro-computed tomographic analysis. The hardware device used in this study was a desktop X-ray microfocus CT scanner (SkyScan 1072). The morphology of root's surfaces was assessed by TView and Computer Tomography Analyzer (CTAn) softwares (SkyScan, bvba) which allowed analysis of all microscans, identification of root resorption craters and measurement of their length, width and volume. Microscans showed in details the surface morphology of the investigated teeth. The analysis of microscans allowed to detect 3 root resorption cavities in each of the orthodontically moved tooth and only one resorption crater in the control tooth. The volumes of the resorption craters in orthodontically-treated teeth were much larger than in a control tooth. Micro-computed tomography is a reproducible technique for the three-dimensional non-invasive assessment of root's morphology *ex vivo*. TView and CTan softwares are useful in accurate morphometric measurements of root's resorption.

Key words: orthodontic treatment, root resorption, microtomography.

Riassunto *(Applicazione della microtomografia per la valutazione del riassorbimento radicolare originato da trattamento ortodontico di premolari)*. Lo scopo di questo studio è stato quello di dimostrare le possibilità di applicazione della tomografia microcomputerizzata nell'analisi morfometrica del riassorbimento radicolare in primi premolari umani estratti soggetti a forza ortodontica. In un paziente trattato in clinica ortodontica sono stati scelti per l'analisi microtomografica due primi premolari soggetti a sforzo ortodontico per quattro settimane e un dente di controllo. Lo strumento hardware usato per questo studio è stato un desktop X-ray microfocus CT scanner (SkyScan 1072, SkyScan, Kartuizersweg, Belgium). La morfologia della superficie delle radici è stata analizzata con i software ConRec V2.23 e CTAn V1.9 (SkyScan, Kartuizersweg, Belgium) che hanno permesso l'analisi di tutte le micro scansioni, l'identificazione del riassorbimento radicolare e la misura della loro lunghezza, larghezza e volume. Le microscansioni hanno mostrato nel dettaglio la morfologia dei denti che sono stati osservati. L'analisi delle microscansioni ha permesso di identificare 3 cavità di riassorbimento radicolare in ognuna delle radici dei denti trattati ortodonticamente e solo un cratere di riassorbimento nel dente di controllo. Il volume dei crateri di riassorbimento nei denti trattati ortodonticamente si sono dimostrati essere più larghi che nel dente di controllo. La tomografia microcomputerizzata è una tecnica affidabile per l'analisi tridimensionale non invasiva della morfologia *ex vivo* delle radici, e i software ConRec e CTan sono utili nella misurazione accurata del riassorbimento radicolare.

Parole chiave: trattamenti ortodontici, riassorbimento radicolare, microtomografia.

INTRODUCTION

Orthodontic tooth movement is based on cellular activation in the periodontal ligament (PDL). Different tissue reactions are observed at the compression and tension side of surrounding tissues [1, 2]. Compression is connected with ischemia and necrosis of PDL, the affected area is called hyaline zone [3, 4]. This sterile necrotic tissue is removed by macrophages, foreign

Address for correspondence: Monika Sawicka, Department of Orthodontics, Medical University of Gdańsk, Aleja Zwycięstwa 42c, 80-210 Gdańsk, Poland. E-mail: msawicka@gumed.edu.pl.

body giant cells and osteoclasts from adjacent undamaged areas [1, 4]. These cells also resorb bone adjacent to the necrotic PDL area and remove it together with the necrotic tissue in a process termed "undermining resorption" [1, 4]. Orthodontically-induced inflammatory root resorption is a part of the hyaline zone elimination process. The initial removal takes place at the periphery of the hyaline zone, where blood supply to the periodontal ligament does not change or is even increased [4]. During the elimination of necrotic tissue, the outer surface of root, which consists of the cementoblast layer, can be damaged. In result the underlying mineralized cementum becomes exposed to odontoclasts-multinucleated cells which precursors are recruited by activated endothelium from the bone marrow [3]. Odontoclasts resorb mineralized dental tissues, *i.e.* cementum and dentin. Another mechanism of root resorption is also possible. Orthodontic force itself may directly damage the outer cemental surface [1, 2, 4]. In the clinical settings root resorption is difficult to be quantitatively assessed by the X-ray methods. In this paper we demonstrate that the microscan tomography may be applied to numerically assess root resorption in extracted teeth that were previously subjected to the action of orthodontic force.

MATERIALS AND METHODS

Three human first premolars (from child of 12 years old) scheduled for extraction for orthodontic reasons were selected for the micro-tomographic analysis. Two premolars were subjected to orthodontic force for 4 weeks, one tooth was free of any force application. After extraction the teeth were stored in 10% formalin solution. The hardware device used in this study was a desktop X-ray microfocus CT scanner (SkyScan 1072, bvba, Aartselaar, Belgium). The scanning procedure was completed for all teeth using 10W, 100 kV, 98 μA, a 1.0 mm aluminum filter and 15x magnification, resulting in a pixel size of 19.1 μm x 19.1 μm. Approximately 4 hours were needed to complete scan of one tooth. During acquisition, hundreds of two-dimensional (2D) projections through 180° of rotation were saved in a digital format. In order to gain the third dimension (3D), the data stored as projections were then transformed into new two-dimensional images (cross-sections) with a pixel size of 19.1 μm x 19.1 μm and a slice thickness of 13.0 μm. The 3D image was achieved by juxtaposition of 2D images of adjacent slices.

The morphology of all roots' surfaces was assessed by using software TView (SkyScan, bvba), which allows observing of all microscans and identification of root resorption craters. Since the beginning and the end of the crater along root's axis could be identified at single microscan, the length of the craters was measured with the accuracy up to 0.001 mm. The Computer Tomography Analyzer (CTAn) (SkyScan, bvba) software was used for the determination of crater's volume *(Figure 1)*.

RESULTS

Micro-computed tomography (micro-CT) allowed for the detection of 3 resorption craters in each premolar subjected to orthodontic force and only one resorption crater in control tooth. In our study craters of volume higher than 0.001 mm^3 were included into

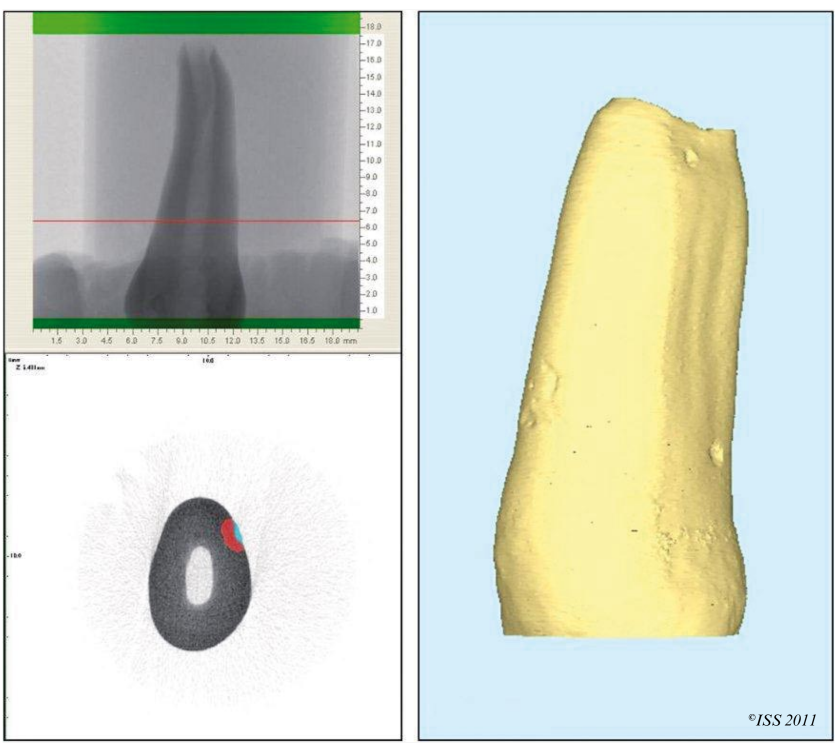

Fig. 1 | *Illustration of the micro-tomography technique for the morphometric analysis of root resorption. Upper left figure shows at low magnification the scan of a root and its part were resorption crater was found. Lower left figure shows one microscan were the red color marks the region of interest (ROI) defined as the area where one or more craters are present. The turquoise area is a measured crater area. Right figure shows one root reconstruction image with some craters.*

Table 1 | *The number, length and volume of detected craters in human premolars*

	Force application	Number of craters	Length of crater (mm)	Volume of crater (mm³)
Tooth 1	yes	3	0.843	0.048
			1.914	0.082
			1.987	0.342
Tooth 2	yes	3	0.804	0.082
			0.765	0.033
			0.995	0.019
Tooth 3	no	1	0.651	0.034

analyses because smaller craters were considered as unimportant. The length of assessed resorption craters differed from 0.651 to 1.987 mm. The volume of craters differed from 0.019 to 0.342 mm^3 *(Table 1)*.

DISCUSSION

Our pilot study showed the possible application of micro-computed tomography for the detection and analysis of root resorption craters. Orthodontically-induced root resorption has mainly been detected with 2-dimensional measurement techniques such as radiographs [5-7], light microscopy [8-10] or scanning electron microscopy (SEM) [11, 12]. Radiographs are not suitable method for the quantitative analysis of root resorption because magnification errors may lead to the underestimation or overestimation of the extent of this process [13]. The more accurate methods are micro-computed tomography [13, 14] and SEM with special software [15, 16]. Dudic *et al.* in their research compared the detection of root resorption by radiographs and micro-computed tomography and concluded that less than half of the cases with root resorption identified using a CT scanner were identified by radiography [17], some of resorption craters that were "visible" on radiographs were not identified by CT scanner. Hohman *et al.* compared the SEM method with micro-CT and concluded that in assessment of tooth morphology more easily applicable and accurate method is micro-computed tomography [18]. Although the microcomputed tomography cannot be at present used for *in vivo* clinical studies because of a long exposition time, we showed that it may serve as a precise analytical technique for the investigation of teeth morphology [19].

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

Submitted on invitation.
Accepted on 19 December 2011.

References

1. Thilander B, Rygh P, Reitan K. Tissue reaction in orthodontics. In: Graber TM, Vanarsdall RL, Vig KWL (Ed.). *Orthodontics: Current principles and techniques 2005.* Mosby, St Louis: Elsevier; 2005. p. 170-3.
2. Weltman B, Vig KWL, Fields HW, Shanker S, Kaizar EE. Root resprption associated with orthodontic tooth movement. A systematic review. *Am J Orthod Dentofac Orthop* 2010;137:462-76. DOI: 10.1016/j.ajodo.2009.06.021
3. Brezniak N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part I: the basic science aspects. *Angle Orthodontist* 2002;72:175-9. DOI: 10.1051/ odf:20074130263
4. Krishnan V, Davidovich Z. Cellular, molecular, and tissue-level reactions to orthodontic force. *Am J Orthod Dentofac Orthop* 2006;129:469e.1-60e.32.
5. Blake M, Woodside DG, Pharoah MJ. A radiographic comparison of apical root resorption after orthodontic treatment with the edgewise and speed appliances. *Am J Orthod Dentofacial Orthop* 1995;108:76-84. DOI:10.1016/j.ajodo.2009.11.009.726.e1
6. Hendrix I, Carels C, Kuijpers-Jagtman AM, Van T Hof M. A radiographic study of posterior apical root resorption in orthodontic patients. *Am J Orthod Dentofacial Orthop* 1994;105:345-9. DOI:10.1016/S0889-5406(97)70189-6
7. Mohandesan H, Ravanmehr 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.
8. Reitan K. Effects of force magnitude and direction of tooth movement on different alveolar bone types. *Angle Orthod* 1964;34:244-55. DOI: 10.1016/S0889-5406(96)80013-8
9. Reitan K. The tissue reaction as related to the functional factor. *Eur J Orthod* 2007; 29: i58-i64. DOI: 10.1093/ejo/cjl110
10. Reitan K. Tissue behavior during orthodontic tooth movement. *Am J Orthod* 1960; 46:881. DOI: 10.1111/j.1600-0765.2011.01444.x
11. Acar A, Canyurek U, Kocaaga M, Erverdi N. Continuous vs. discontinuous force application and root resorption. *Angle Orthod* 1999;69:159-63.
12. Casa MA, Faltin RM, Faltin K, Arana-Chavez VE. Root resorption on torgued human premolars shown by tartrate-resistant acid phosphatase histochemistry and transmission electron microscopy. *Angle Orthodontist* 2006;76:1015-21. DOI: 10.1016/j.ajodo.2010.01.033 e353
13. Harris DA, Jones AS, Darendeliler MA. Physical properties or root cementum: Part 8. Volumetric analysis of root resorp-

tion 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. DOI: 10.1016/j.ajodo .2007.07.005

14. Wierzbicki T, El-Bialy T, Aldaghreer S, Li G, Doschak M. Analysis of orthodontically induced root resorption using micro-computed tomography. *Angle Orthod* 2009;79:91-6. DOI: 10.4103/0970-9290.84302
15. Chan E, Darendeliler MA. Physical properties of root cementum: Part 7. Extent of root resorption under areas of compression and tension. *Am J Orthod Dentofac Orthop* 2006;129:504-10. DOI: 10.1051/odf:20074130311
16. Chan E, Darendeliler MA. Physical properties or 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. DOI: 10.1016/j.ajodo.2007.03.028. 222
17. Dudic A, Giannopolou C, Leuzinger M, Kiliaridis S. Detection of apical root resorption after orthodontic treatment by using panoramic radiography and cone-beam computed tomography of super high resolution. *Am J Orthod Dentofac Orthop* 2009;135:434-7. DOI: 10.1016/j.ajodo.2008.10.014
18. Hohmann A, Wolfram U, Geiger M, Boryor A, Sander C, Faltin R, Faltin K, Sander FG. Periodontal ligament hydrostatic pressure with areas of root resorption after application of a continuous torque moment. *Angle Orthod* 2007;77:653-9.
19. Plotino G, Grande NM, Pecci R, Bedini R, Pameijer CM, Somma F. Three-dimensional imaging using microcomputed tomography for studing tooth macromorhology. *JADA* 2006;137:1555-61.