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Research Article

Multidimensional Scaling for Orthodontic Root Resorption

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The paper investigates the risk factors for the severity of orthodontic root resorption. The multidimensional scaling (MDS) visualization method is used to investigate the experimental data from patients who received orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, "Carol Davila" University of Medicine and Pharmacy, during a period of 4 years. The clusters emerging in the MDS plots reveal features and properties not easily captured by classical statistical tools. The results support the adoption of MDS for tackling the dentistry information and overcoming noise embedded into the data. The method introduced in this paper is rapid, efficient, and very useful for treating the risk factors for the severity of orthodontic root resorption.

1. Introduction

Root resorption is defined as the biological process characterized by destruction of hard structure of the tooth root. Damaging may involve cementum, dentin, or both structures. Orthodontic treatment is associated with a higher frequency and severity of the pathological process of external root resorption. Frequency of orthodontic root resorption is about 100% when diagnostic techniques based on microscopy are used and around 70% when periapical or panoramic radiographs are used [1]. But generally, orthodontic root resorption severity is moderate and low, not interfering with the positive outcomes of this particular medical intervention. The meta-analysis conducted by Segal [2] identified a mean value of root shortening after orthodontic treatment of 1.421 ± 0.448 mm. Of interest are those cases where severe root resorption with root shortening is beyond 4 mm or 1/3 of root length, which are noticed in 1–5% of orthodontic patients [3]. Due to the fact that the considerable root shortening has a negative impact on tooth's prognosis, orthodontic root resorption is nowadays one of the most discussed complications of the orthodontic treatment: efforts are made in order to establish the proper preventive treatment conduct [4].

Etiopathogeny of orthodontic root resorption presents several uncertainties. It seems that higher incidence and severity of orthodontic root resorption are related mainly to patients' characteristics (individual susceptibility has the main role in root resorption appearance) and particularities of the orthodontic treatment applied [5]. It seems that a higher risk of developing external root resorption presents patients with allergies, asthma, diabetes, arthritis, endocrine disorders, Paget's disease, tooth eruption disorders (more frequently caused by pressure of the canine or wisdom teeth during eruption), hypodontia, open bite, increased alveolar bone density, particular dental morphology like reduced root diameter, and abnormal root shape in the apical part of the root, especially eroded, pointed, deviated, or bottle shape [3, 5–9]. Among particularities of the orthodontic technique seen as risk factors for root resorption are increased orthodontic treatment duration, treatment with tooth extraction, and tooth intrusion (especially when vestibular coronal torque was associated) [10, 11].

The aim of this study is to investigate the impact of several risk factors (sex of patients, orthodontic extractions, and duration of treatment) on the severity of orthodontic root resorption. The analysis is based on the formation of clusters for experimental data analysis that may indicate similar behavior in some particular clinical situations.

Given the characteristics of the biomedical data, with a plethora of different influential factors, the numerical extraction of characteristics poses difficulties to classical statistical and computer tools. In this line of thought, the adoption of advanced computational tools capable of handling the incertitude implicit in the application is imperative. Therefore, the multidimensional scaling (MDS) method which is an algorithm that does not require initial assumptions about the data is tested. MDS is a computational visualization tool that constructs maps based on comparison criteria [12–19]. The MDS plot consists of a series of points where each one represents an item. The maps can be rotated, translated, and zoomed in order to provide a better visualization of a given area [20–28]. The interpretation of the chart is based on relative position of clusters of points and takes advantage of the user intuition and experience in the particular field of application, making MDS a powerful tool for the type of data handled in this study.

Bearing these ideas in mind, the paper is organized as follows. In Section 2, the material and methods are presented. Section 3 is devoted to multidimensional scaling method for patients with and without orthodontic extractions. Section 4 presents our results and discussions. Finally, Section 5 outlines the main conclusions.

2. Materials and Methods

In order to achieve the proposed objectives, we designed and implemented a retrospective observational clinical study.

The sample was composed of patients receiving orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, "Carol Davila" University of Medicine and Pharmacy, during October 2005–October 2009. In this study, patients with fixed metallic orthodontic appliances, standard edgewise, or straight-wire technique, applied in both jaws for a period of at least 6 months were included. From this study, patients with radiological signs of root resorption before the treatment start of were excluded. According to the protocol established in the Department of Orthodontics and Dentofacial Orthopedics, all patients sign an informed consent for the use of their medical documents for teaching and scientific purposes.

External root resorption was assessed in terms of root shortening, with the changes of root length being recorded, compared to the situation before applying the orthodontic device. Measurements of upper and lower incisors were made on serial panoramic radiographs, and changes in root length were being assessed using a mathematical formula based on the one proposed by L. Linge and B. O. Linge [29] (see Figure 1):

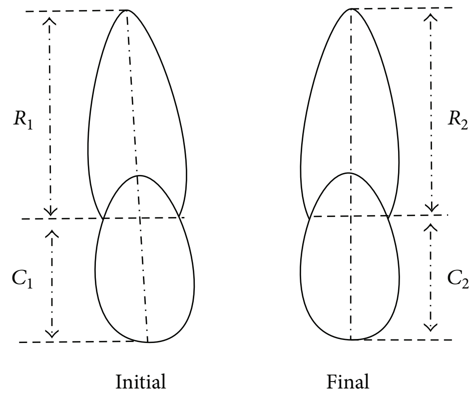


Figure 1: Calculation of the amount of root shortening (root resorption) on serial panoramic radiographs.

$$\text{Root resorption} = R_1 - R_2 \frac{C_1}{C_2}, \tag{1}$$

where R_1 and C_1 are the initial (pretreatment) root and crown lengths in the first radiograph and R_2 and C_2 are root and crown lengths in the second radiograph, respectively.

3. Experimental Setup and Mathematical Tools

In this section, the experimental cases and the mathematical tools to be adopted are briefly described.

3.1. Experiments. In the experiments, two cases were considered, namely, 1 (orthodontic treatment with tooth extraction) and 2 (orthodontic treatment without tooth extraction), denoted as cases 1 and 2 in the sequel, involving $p = 18$ patients for case 1 and $p = 37$ patients for case 2, respectively, which are studied separately. For all patients considered, $k_{\max} = 8$ measures the teeth absolute deviations that were compared by means of indices (3)-(4). In order to identify points in the MDS maps, each patient was labelled as GPP-AA-TT with G $= \{M, F\}$ for gender male/female, PP $= \{1, \ldots, p\}$ for patient number, AA $= \{10, \ldots, 30\}$ for age, in years, and TT $= \{6, \ldots, 51\}$ for treatment time, in months. For providing a better visualization, the male and female points have distinct marks (filed circle for male and open rectangle for female).

3.2. Multidimensional Scaling. Multidimensional scaling (MDS) has its origins in psychometrics and psychophysics, where it is used as a tool for perceptual and cognitive modeling. From the beginning, MDS has been applied in many fields, such as psychology, sociology, anthropology, economy, and educational research. In the last decades, this technique has been applied also in other areas such as music, finance, and biology.

MDS is a statistical technique used for visualization of information in the perspective of exploring similarities in data. MDS assigns a point to each item in an m-dimensional space and arranges the p objects in a space with a given number of dimensions m, in order to reproduce the observed similarities. Often, instead of similarities distances between the investigated p objects are considered. For two or three dimensions, the resulting locations may be displayed in a "map" that can be analyzed. We can rotate or translate the map, but the similarities between items remain the same. Therefore, the final orientation of axes in space is mostly the result of a subjective decision by the researcher, who will choose the one that can be most easily interpreted or that leads to a better visualization.

An MDS algorithm starts by defining a measure of similarity for constructing a $p \times p$ matrix $\mathbf{R}$ of item-to-item similarities. In classical MDS, the matrix is symmetric and its main diagonal is composed of "1" for similarities or "0" for distances. MDS rearranges objects so as to arrive at a configuration that best approximates the observed similarities (or, alternatively, the measured distances). For this purpose, MDS uses a function minimization algorithm that evaluates different configurations with the goal of optimizing the goodness of fit.

The most common measure used to evaluate how well a particular configuration reproduces the observed distance matrix is the raw stress defined by

$$S = \left[d_{ij} - f\left(\delta_{ij}\right)\right]^2, \quad i, j = 1, \ldots, p, \tag{2}$$

where d_{ij} denotes the reproduced distances, given the respective number of dimensions and δ_{ij} stands for the input data (i.e., the observed distances). The expression $f(\delta_{ij})$ represents a nonmetric, monotone transformation of the input data.

There are several measures that are commonly used, but most of them amount to the computation of the sum of squared deviations of observed values from the reproduced distances. Thus, the smaller the stress value S, the better the fit between the reproduced and the observed distance matrices.

We can plot S versus the number of dimensions m of the visualization, for deciding the most adequate. Usually, we get a monotonic decreasing plot, and we chose the "best dimension" as a compromise between stress reduction and dimension for the map representation. In practical terms, we chose a low dimension at the region where we have a significant variation in the stress plot.

We can also plot the reproduced distances, for a particular number of dimensions, against the observed input data (distances). This scatter plot, referred to as a Shepard diagram, shows the distances between points versus the original dissimilarities. In the Shepard plot, a narrow scatter that is around a 45-degree line indicates a good fit of the distances to the dissimilarities, while a large scatter indicates a lack of fit.

Since MDS is fed with relative distances, the maps are insensitive to rotation and translation. This means that the user can view and zoom the plots interactively in order to interpret the clusters of points that emerge in the map. Furthermore, distinct indices, capturing different characteristics, produce MDS charts, better or worse, merely in the viewpoint of easiness of interpretation in conjunction with the user own experience.

For the comparison of objects i and j, the cosine correlation [30], r_{ij} is adopted, defined as

$$r_{ij} = \frac{\sum_{k=1}^{k_{\max}} x_i(k)\, x_j(k)}{\sqrt{\sum_{k=1}^{k_{\max}} x_i^2(k) \cdot \sum_{k=1}^{k_{\max}} x_j^2(k)}}, \quad i, j = 1, \ldots, p, \tag{3}$$

where $x_i(k)$ denotes the kth measured component of the ith item and $k_{\max}$ represents the maximum number of components.

In the sequel will be adopted GGobi [31] for calculating MDS and for visualization. Other packages often used are Matlab [32] and R [33]. The GGobi package requires a $p \times p$ matrix $\Delta = [\delta_{ij}]$ of item-to-item distances (instead of similarities) and, therefore, is used:

$$\delta_{ij} = \frac{\pi}{2} - \cos^{-1}\left(r_{ij}\right). \tag{4}$$

In the experiments other metrics that lead to inferior results were tested and, therefore, are not analyzed here.

4. Results and Discussion

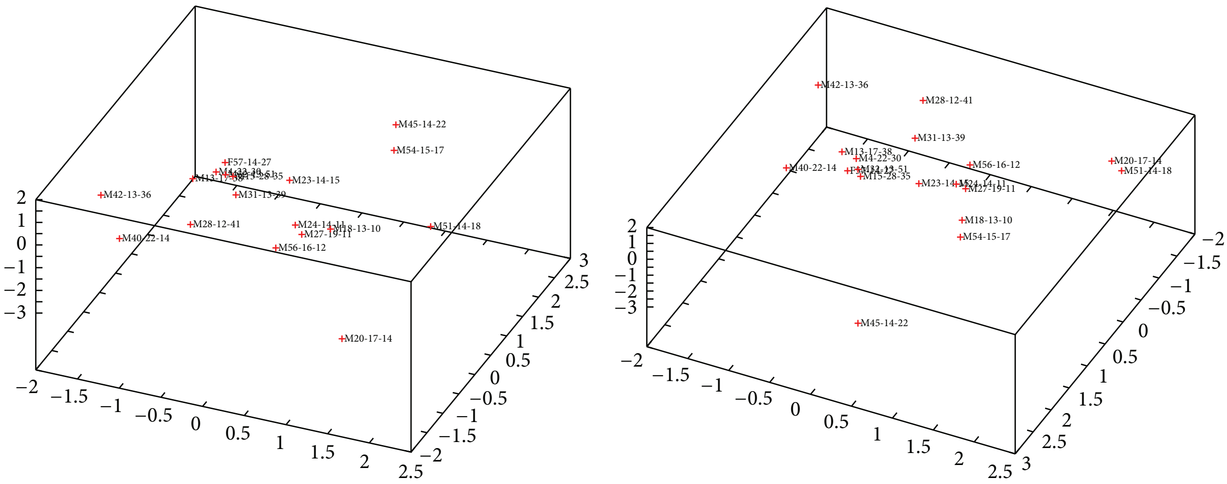
In this section, the sample of patients is described and the MDS results are analysed.

4.1. Description of the Sample. The sample included 55 patients, of which 74.5% ($n = 41$) were female and 25.5% ($n = 14$) were male, with the mean age being 15.92 years. Corresponding to the 55 patients, a total of 440 incisors were measured.

Associated with the orthodontic treatment, there was a mean reduction of 1.32 mm of tooth length. Most of the patients (67.27%, $n = 37$) had at least one incisor with root resorption exceeding 2 mm; this is often considered as the limit between low severity and medium severity of this pathological process.

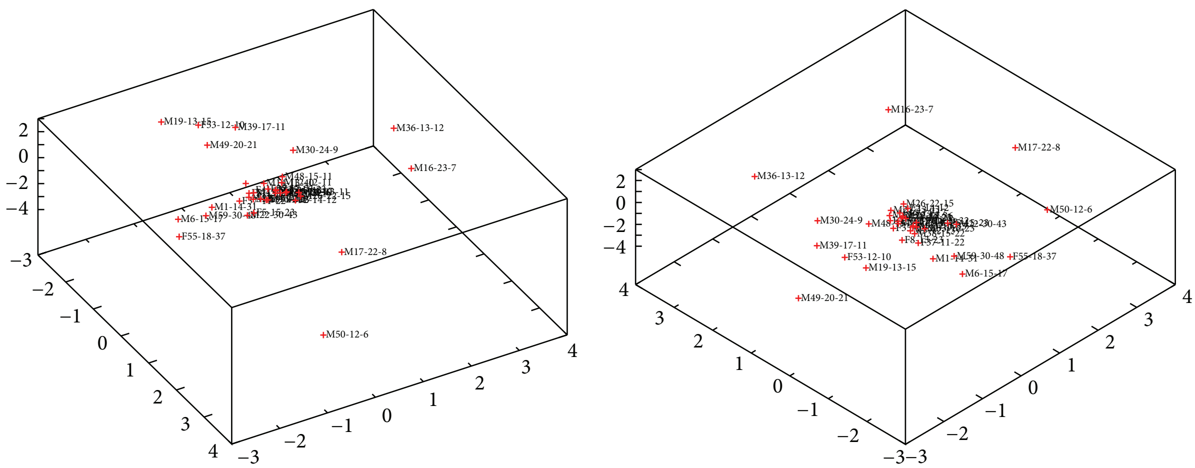
4.2. Multidimensional Scaling of Patients with and without Orthodontic Extractions. Figures 2 and 3 depict the 3-dimensional MDS maps for cases 1 and 2, respectively. The figures show two rotations views and two zoomed areas. This paper examines the formation of clusters for experimental data analysis.

In case 1 (with orthodontic extractions) mean root resorption was 1.59 mm. We cannot say anything about the implications of sex on root resorption severity due to the insignificant number of women ($n = 1$). This aspect is equivalent to the fact that more frequently the treatment plan included orthodontic extractions in male patients. Subjects presented ages between 12–28 years (mean = 16 years). Orthodontic treatment time was between 10 and 51 months (mean = 24.5 months). Important cluster points were



(a) (b)

Figure 2: Projections of the 3-dimensional MDS map for case 1 (with tooth extraction) involving $p = 18$ patients.



(a) (b)

Figure 3: Projections of the 3-dimensional MDS map for case 2 (without teeth extraction) involving $p = 37$ patients.

observed, namely, M 13-17-38, M 4-22-30, M 15-28-35, M 32-13-51, and F 57-14-27. These patients presented moderate values of root shortening (mean = 2.26 mm), indicating a higher severity than usual. It can be observed that these patients had one particular aspect in common, the extent of treatment time, which is above average. In this cluster, age did not present some clear tendency, being variable (between 13 and 28 years), but it can be noticed that mean age for the patients with orthodontic extractions was higher in subjects from the cluster (mean = 19 years) than that for the others (mean = 15 years). In consequence, we observe a tendency to form clusters with higher severity of root resorption in cases with orthodontic extractions with a greater period of orthodontic treatment time.

In case 2 (without orthodontic extractions) 37 patients were included with mean root resorption being 1.18 mm, indicating a lower severity of this pathological process. In this group, the number of males and females are comparable (13 males and 24 females). Patients presented ages between 10–30 years (mean = 16 years). Treatment time was between 6–48 months (mean = 20.21 months). We report the appearance of the clusters which shows some similarities (Figure 3). We observed a more uniform behavior compared to that of case 1. A large cluster was observed, including about 24 patients. We mention that generally patients inside the cluster presented a tendency to a more severe root resorption (mean = 1.40 mm), compared to those outside the cluster (mean = 0.77 mm). We observed also that outside the cluster, there were mostly male patients and only 2 female patients. That may suggest that females may present a tendency to a more uniform and predictive behavior related to orthodontic root resorption appearance. Also, even if there were patients of different ages outside the cluster, most of them were older than those inside the cluster. Also the mean age of patients outside the cluster

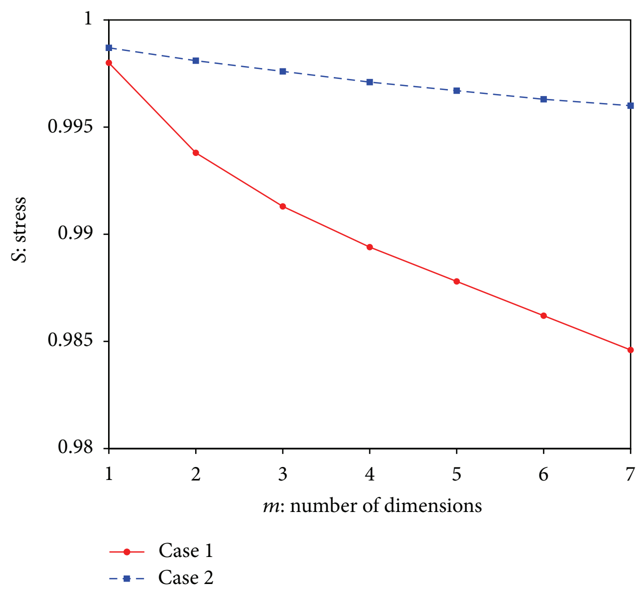


Figure 4: Stress versus the number of dimensions of the MDS representations for cases 1 and 2.

(18 years) was higher compared to that of the subjects inside the cluster (15 years). This may suggest that in older patients root resorption is a process that is less predictable.

Figure 4 shows the variation of the stress S versus the number of dimensions m of the MDS representations for cases 1 and 2. We observe that the adopted dimension $m = 3$ establishes a good compromise between precision and dimensionality reduction for visualization feasibility. Comparing the 2 situations mentioned (with and without orthodontic extractions), we observed that stress presents a higher variability in cases with extractions and a more uniform behavior in those cases without extractions. That may be related to the increased complexity of the medical intervention in the first case.

Orthodontic root resorption is one of the complications of the orthodontic treatment, knowing its etiology being an important factor in prevention of those forms with moderate and severe root shortening.

According to our results, the orthodontic extraction may be a risk for apical root resorption. More frequently it is associated with a more severe root resorption and also a more unpredictable behavior. This aspect is concordant with several clinical studies conducted on this topic [34]. Marques et al. reported that those receiving orthodontic treatment with extraction of the four first premolars, compared to patients treated without extractions, have a chance of 6.7 : 1 to present root resorption [35]. de Freitas et al. also identify a statistically significant difference in the severity of root resorption between cases with and without orthodontic extractions, with root shortening being more severe in the first case [36]. Mohandesan et al. support the same behavior that differentiated between cases with and without orthodontic extractions [37]. These observations may be explained by the larger root apex displacement in cases with orthodontic extractions and also by the increase of treatment time, with both favouring this condition. We mention that increased treatment time of the orthodontic intervention is seen, in accordance with the current knowledge, as the main risk factor of root resorption related to the orthodontic intervention [38].

5. Conclusions

Nowadays, preventive methods are seen as ensuring the best medical outcome. In this context, it is extremely important to accurately identify diseases risk factors. Interdisciplinary approach of these aspects, interpreting medical data using advanced statistical tools can offer extra knowledge. The paper studied the risk factors for the severity of orthodontic root resorption. The MDS visualization technique was adopted for exploring the data from patients receiving orthodontic treatment at the Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dentistry, Carol Davila University of Medicine and Pharmacy, during a period of 4 years. The clusters in the MDS charts reveal features not easily captured by classical statistical tools and overcome noise effects embedded into the data.

The method introduced in this paper is rapid, efficient, and very useful for identifying the risk factors for the severity of orthodontic root resorption.

References

[1] J. E. Lupi, C. S. Handelman, and C. Sadowsky, "Prevalence and severity of apical root resorption and alveolar bone loss in orthodontically treated adults," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 109, no. 1, pp. 28–37, 1996.

[2] G. R. Segal, P. H. Schiffman, and O. C. Tuncay, "Meta analysis of the treatment-related factors of external apical root resorption," *Orthodontics & Craniofacial Research*, vol. 7, no. 2, pp. 71–78, 2004.

[3] K. Lopatiene and A. Dumbravaite, "Risk factors of root resorption after orthodontic treatment," *Stomatologija*, vol. 10, no. 3, pp. 89–95, 2008.

[4] E. Lim, G. Sameshima, P. Petocz, and A. Darendeliler, "Comparison of Australian and American orthodontic clinical approaches towards root resorption," *Australian Orthodontic Journal*, vol. 28, no. 2, pp. 181–189, 2012.

[5] T. Graber, T. Eliades, and A. Athanasiou, *Risk Management in Orthodontics: Expers' Guide to Malpractice*, Quintessence, Chicago, Ill, USA, 2004.

[6] S. Ericson and J. Kurol, "Resorption of incisors after ectopic eruption of maxillary canines: a CT study," *Angle Orthodontist*, vol. 70, no. 6, pp. 415–423, 2000.

[7] J. Artun, V. R. Hullenaar, D. Doppel, and A. M. Kuijpers-Jagtman, "Identification of orthodontic patients at risk of severe apical root resorption," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 135, no. 4, pp. 448–455, 2009.

[8] I. Smale, J. Årtun, F. Behbehani, D. Doppel, M. Van't Hof, and A. M. Kuijpers-Jagtman, "Apical root resorption 6 months after initiation of fixed orthodontic appliance therapy," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 128, no. 1, pp. 57–67, 2005.

[9] C. T. Preoteasa, Ionescu, and E. Preoteasa, "Risks and complications associated with orthodontic treatment," in *Orthodontics-Basic Aspects and Clinical Considerations*, F. Bourzgui, Ed., InTech, Rijeka, Croatia, 2012.

[10] N. Fox, "Longer orthodontic treatment may result in greater external apical root resorption," *Evidence-Based Dentistry*, vol. 6, no. 1, p. 21, 2005.

[11] B. Weltman, K. W. L. Vig, H. W. Fields, S. Shanker, and E. E. Kaizar, "Root resorption associated with orthodontic tooth movement: a systematic review," *American Journal of Ortho dontics and Dentofacial Orthopedics*, vol. 137, no. 4, pp. 462–476, 2010.

[12] J. Kruskal, "Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis," *Psychometrika*, vol. 29, no. 1, pp. 1–27, 1964.

[13] J. Sammon, "A nonlinear mapping for data structure analysis," *IEEE Transactions on Computers C*, vol. 18, no. 5, pp. 401–409, 1969.

[14] J. Kruskal and M. Wish, *Multidimensional Scaling*, Sage, Newbury Park, Calif, USA, 1978.

[15] J. Tenenbaum, V. de Silva, and J. C. Langford, "A global geometric framework for nonlinear dimensionality reduction," *Science*, vol. 290, no. 5500, pp. 2319–2323, 2000.

[16] T. Cox and M. Cox, *Multidimensional Scaling*, Chapman & Hall/CRC, New York, NY, USA, 2nd edition, 2001.

[17] I. Fodor, "A survey of dimension reduction techniques," Technical Report, Center for Applied Scientific Computing, Lawrence Livermore National Laboratory, Livermore, Calif, USA, 2002.

[18] I. Borg and P. Groenen, *Modern Multidimensional Scaling-Theory and Applications*, Springer, New York, NY, USA, 2nd edition, 2005.

[19] R. N. Shepard, "The analysis of proximities: multidimensional scaling with an unknown distance function. II," *Psychometrika*, vol. 27, no. 3, pp. 219–246, 1962.

[20] W. Glunt, T. L. Hayden, and M. Raydan, "Molecular conformation from distance matrices," *Journal of Computational Chemistry*, vol. 14, no. 1, pp. 114–120, 1993.

[21] J. Tzeng, H. Lu, and W. Li, "Multidimensional scaling for large genomic data sets," *BMC Bioinformatics*, vol. 9, p. 179, 2008.

[22] G. Mao and B. Fidan, *Localization Algorithms and Strategies for Wireless Sensor Networks*, Igi-Global, Hershey, Pa, USA, 2009.

[23] J. A. Tenreiro Machado, A. C. Costa, and M. F. M. Lima, "Dynamical analysis of compositions," *Nonlinear Dynamics*, vol. 65, no. 4, pp. 399–412, 2011.

[24] J. A. T. Machado, G. M. Duarte, and F. B. Duarte, "Identifying economic periods and crisis with the multidimensional scaling," *Nonlinear Dynamics*, vol. 63, no. 4, pp. 611–622, 2011.

[25] C. M. Ionescu, J. T. Machado, and R. De Keyser, "Is multidimensional scaling suitable for mapping the input respiratory impedance in subjects and patients?" *Computer Methods and Programs in Biomedicine*, vol. 104, no. 3, pp. e189–e200, 2011.

[26] J. A. T. Machado, A. C. Costa, and M. D. Quelhas, "Analysis and visualization of chromosome information," *Gene*, vol. 491, no. 1, pp. 81–87, 2012.

[27] M. C. Hout, M. H. Papesh, and S. D. Goldinger, "Multidimensional scaling," *Wiley Interdisciplinary Reviews*, vol. 4, no. 1, pp. 93–103, 2013.

[28] C. Bécavin, N. Tchitchek, C. Mintsa-Eya, A. Lesne, and A. Benecke, "Improving the efficiency of multidimensional scaling in the analysis of high-dimensional data using singular value decomposition," *Bioinformatics*, vol. 27, no. 10, Article ID btr143, pp. 1413–1421, 2011.

[29] L. Linge and B. O. Linge, "Patient characteristics and treatment variables associated with apical root resorption during orthodontic treatment," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 99, no. 1, pp. 35–43, 1991.

[30] E. Deza and M. M. Deza, *Dictionary of Distances*, Elsevier, New York, NY, USA, 2006.

[31] GGobi, "Interactive and dynamic graphics," http://www.ggobi.org/.

[32] W. Martinez and A. Martinez, *Exploratory Data Analysis with MATLAB*, Chapman & Hall/CRC, New York, NY, USA, 2005.

[33] J. de Leeuw and P. Mair, "Multidimensional scaling using majorization: SMACOF in R," *Journal of Statistical Software*, vol. 31, no. 3, pp. 1–30, 2009.

[34] K. Nanekrungsan, V. Patanaporn, A. Janhom, and N. Korwanich, "External apical root resorption in maxillary incisors in orthodontic patients: associated factors and radiographic evaluation," *Imaging Science in Dentistry*, vol. 42, no. 3, pp. 147–154, 2012.

[35] L. S. Marques, M. L. Ramos-Jorge, A. C. Rey, M. C. Armond, and A. C. de Oliveira Ruellas, "Severe root resorption in orthodontic patients treated with the edgewise method: prevalence and predictive factors," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 137, no. 3, pp. 384–388, 2010.

[36] M. R. de Freitas, R. T. Soares Beltrão, G. Janson, J. F. Castanha Henriques, and K. Chiqueto, "Evaluation of root resorption after open bite treatment with and without extractions," *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 132, no. 2, pp. 143.e15–143.e22, 2007.

[37] H. Mohandesan, H. Ravanmehr, and N. Valaei, "A radiographic analysis of external apical root resorption of maxillary incisors during active orthodontic treatment," *European Journal of Orthodontics*, vol. 29, no. 2, pp. 134–139, 2007.

[38] M. Motokawa, T. Sasamoto, M. Kaku et al., "Association between root resorption incident to orthodontic treatment and treatment factors," *European Journal of Orthodontics*, vol. 35, no. 2, p. 273, 2013.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