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Turkish Orthodontic Society

TURKISH JOURNAL of ORTHODONTICS

ORIGINAL ARTICLES

Evaluation of ANN & NB Vertebral Ratios Models

Occlusal plane changes produced by Pendulum appliance

FEM Analysis of Three Different RME Appliances

Effect of Laser Therapy on Miniscrews

Skeletal Maturity and Calcification of the Teeth

Smile Esthetics & ABO Objective Grading

Age and Gender Differences in Genial Tubercle

The Psychological Well-Being of Orthodontic Patients

REVIEW

COVID-19: Challenges Today and Tomorrow

CASE REPORT

Horizontally Impacted Maxillary Canine

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TURKISH JOURNAL of ORTHODONTICS

Aims and Scopes

Turkish Journal of Orthodontics (Turk J Orthod) is an international, scientific, open access periodical published in accordance with independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of Turkish Orthodontic Society and it is published quarterly on March, June, September and December.

Turkish Journal of Orthodontics publishes clinical and experimental studies on on all aspects of orthodontics including craniofacial development and growth, reviews on current topics, case reports, editorial comments and letters to the editor that are prepared in accordance with the ethical guidelines. The journal's publication language is English and the Editorial Board encourages submissions from international authors.

Journal's target audience includes academicians, specialists, residents, and general practitioners working in the fields of orthodontics, dentistry, medicine and other related fields.

Turkish Journal of Orthodontics is currently indexed in PubMed Central, Web of Science-Emerging Sources Citation Index, Scopus and TÜBİTAK ULAKBİM TR Index.

The editorial and publication processes of the journal are shaped in accordance with the guidelines of the International Committee of Medical Journal Editors (ICMJE), World Association of Medical Editors (WAME), Council of Science Editors (CSE), Committee on Publication Ethics (COPE), European Association of Science Editors (EASE), and National Information Standards Organization (NISO). The journal is in conformity with the Principles of Transparency and Best Practice in Scholarly Publishing (doaj.org/bestpractice).

Processing and publication are free of charge with the journal. No fees are requested from the authors at any point throughout the evaluation and publication process. All manuscripts must be submitted via the online submission system, which is available at turkjorthod.org. The journal guidelines, technical information, and the required forms are available on the journal's web page.

All expenses of the journal are covered by the Turkish Orthodontic Society.

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Book Section: Suh KN, Keystone JS. Malaria and babesiosis. Gorbach SL, Barlett JG, Blacklow NR, editors. Infectious Diseases. Philadelphia: Lippincott Williams; 2004.p.2290-308.

Books with a Single Author: Sweetman SC. Martindale the Complete Drug Reference. 34th ed. London: Pharmaceutical Press; 2005.

Editor(s) as Author: Huizing EH, de Groot JAM, editors. Functional reconstructive nasal surgery. Stuttgart-New York: Thieme; 2003.

Conference Proceedings: Bengisson S. Sothemin BG. Enforcement of data protection, privacy and security in medical informatics. In: Lun KC, Degoulet P, Piemme TE, Rienhoff O, editors. MEDINFO 92. Proceedings of the 7th World Congress on Medical Informatics; 1992 Sept 6-10; Geneva, Switzerland. Amsterdam: North-Holland; 1992. pp.1561-5.

Scientific or Technical Report: Cusick M, Chew EY, Hoogwerf B, Agrón E, Wu L, Lindley A, et al. Early Treatment Diabetic Retinopathy Study Research Group. Risk factors for renal replacement therapy in the Early Treatment Diabetic Retinopathy Study (ETDRS), Early Treatment Diabetic Retinopathy Study Kidney Int: 2004. Report No: 26.

Thesis: Yılmaz B. Ankara Üniversitesindeki Öğrencilerin Beslenme Durumları, Fiziksel Aktiviteleri ve Beden Kitle İndeksleri Kan Lipidleri Arasındaki Ilişkiler. H.Ü. Sağlık Bilimleri Enstitüsü, Doktora Tezi. 2007.

Manuscripts Accepted for Publication, Not Published Yet: Slots J. The microflora of black stain on human primary teeth. Scand J Dent Res. 1974.

Epub Ahead of Print Articles: Cai L, Yeh BM, Westphalen AC, Roberts JP, Wang ZJ. Adult living donor liver imaging. Diagn Interv Radiol. 2016 Feb 24. doi: 10.5152/dir.2016.15323. [Epub ahead of print].

Manuscripts Published in Electronic Format: Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis (serial online) 1995 Jan-Mar (cited 1996 June 5): 1(1): (24 screens). Available from: URL: http:/ www.cdc.gov/ncidodlEID/cid.htm.

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January 2020 - December 2020

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Original Article

Evaluation of the Artificial Neural Network and Naive Bayes Models Trained with Vertebra Ratios for Growth and Development Determination

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Cite this article as: Kok H, Izgi MS, Acilar AM. Evaluation of the Artificial Neural Network and Naive Bayes Models Trained with Vertebra Ratios for Growth and Development Determination. Turk J Orthod 2021; 34(1): 2-9.

Main points:

- The neural network models are more successful than the naive Bayes models in our developed models.
- The neural network model determination success was 0.95 for training-test set ratio: 70%-30%.
- The increases in the number of ratios did not increase success.
- The vertebral superior border, anterior border, and depth measurements affected success.

ABSTRACT

Objective: This study aimed to evaluate the success rates of the artificial neural network models (NNMs) and naive Bayes models (NBMs) trained with various cervical vertebra ratios in cephalometric radiographs for determining growth and development.

Methods: Our retrospective study was performed on 360 individuals between the ages of 8 and 17 years, whose cephalometric radiographs were taken. According to the evaluation of cephalometric radiographs, growth and development periods were divided into 6 vertebral stages. Each stage was considered as a group, each group had 30 girls and 30 boys. Twenty-eight cervical vertebral ratios were obtained by using 10 horizontal and 13 vertical measurements. These 28 vertebral ratios were combined in 4 different combinations, leading to 4 different datasets. Each dataset was split into 2 parts as training and testing. To prevent the overfitting, a 5-cross fold validation technique was also used in the training phase. The experiments were conducted on 2 different train/test ratios as 80%-20% and 70%-30% for both NNMs and NBMs.

Results: The highest determination success rate was obtained in NNM 3 (0.95) and the lowest in NBM 4 (0.50). The determination success of NBM 1 and NBM 3 was almost similar (0.60). The success of NNM 2 did not differ much from that of NNM 1 (0.94). The determination success of stage 5 was relatively lower than the others in NNM 1 and NNM 2 (0.83).

Conclusion: The NNMs were more successful than the NBMs in our developed models. It is important to determine the effective ratio and/or measurements that will be useful for differentiation.

Keywords: Artificial intelligence, bone age measurement, cephalometry, cervical vertebrae

INTRODUCTION

Growth and development (maturation) and bone age determination play an important role in shedding light on medical and legal issues in many disciplines such as anthropology, pediatrics, forensic medicine, orthopedics, endocrinology, and dentistry. In dentistry, craniofacial growth, growth-development, and bone age determination have an important place, not only in the sciences of pedodontics and orthodontics but also in determining the implantation time in surgery. Active growth in the head-neck area, the timing of treatment, and determination of remaining growth helps dentists in identifying the treatments to be applied diagnostically (1-3). In orthodontic treatment, the determination of growth and development periods is extremely important for the

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timely and effective resolution of functional anomalies in sagittal, transversal, and vertical planes (4, 5).

In determining bone age and growth-development, morphological, histological, and radiological methods are used; however, the radiological method is often preferred (6, 7). In orthodontics, panoramic, cephalometric, and hand-wrist radiographs are used for growth and development determination (8-13). Although hand-wrist radiographs have been proved to be valid, skeletal maturation can also be detected from the cervical vertebrae. It was first reported by Lamparski (9) that vertebrae could be used, and their reliability was evaluated by hand-wrist radiographs by many researchers (9-17). In addition to routine use in diagnosis and treatment, cephalometric radiographs provide benefits such as ease in recording and evaluating and not causing extra radiation (14-16). Although several studies have reported high levels of accuracy and reproducibility of the cervical vertebra maturation (CVM) method, Gabriel et al. (18) and Zhao et al. (19) reported moderate or low intra-observer and inter-observer agreement. Predko-Engel et al. (20) stated that experienced clinicians who use the CVM method routinely, made better diagnosis, were more consistent than the inexperienced clinicians who do not use the CVM method or use it rarely.

Computers are now indispensable in our daily lives. The ability of computers to learn and make decisions like a human being has led to their increased use in a wide array of areas. Artificial intelligence involves the use of a computer-controlled machine or when a computer performs tasks associated with higher mental activities, such as understanding past experiences, reasoning, generalization, and learning, which are generally considered to be human-specific qualities (21, 22). Artificial neural networks (ANNs) are computer programs developed as mathematical models of human cognition and neural biology by imitating human neural networks, characterized by its architecture, training or learning algorithms, and activation functions (23). Naive Bayes (NB) is one of the oldest statistical classification algorithms that calculates the probability of each state for an element and classifies it based on the highest probability value. The ANNs and NB are both developed using artificial intelligence techniques. Researchers have aimed at achieving more objective results by taking advantage of computer software and digital images. There are few studies on ANN in orthodontics. Raith et al. (24) reported that ANN could classify teeth according to geometrical features. Xie et al. (25) set up an ANN in determining whether extraction or non-extraction treatment was best for malocclusion and was effective with 80% accuracy. Larson et al. (26) studied pediatric hand radiographs with a convolutional neural network (CNN) model and reported their accuracy value similar to that of an expert radiologist (26). Wand et al. (27) used CNNs to analyze hand-wrist radiographs in which the radius classification was with 92% accuracy, and the ulna classification was with 90% accuracy. Kök et al. (28) and Amasya et al. (29) used artificial intelligence algorithms for CVM assessment. Kök et al. (28) evaluated the success of seven different algorithms on a model consisting of linear measurements. Amasya et al. (29) proposed machine learning classifier models used for the prediction of cervical vertebrae morphology.

In light of this information, the purpose of our study is to evaluate the success rates of the artificial neural network models (NNMs) and naive Bayes models (NBMs) trained with various cervical vertebra ratios in cephalometric radiographs for determining growth and development.

METHODS

Our retrospective study was performed on 360 individuals between the ages of 8 and 17 years, whose cephalometric radiographs were taken. According to the cephalometric radiographs' evaluation, the growth and development periods were divided into 6 vertebral stages (10). The patients' radiographs were evaluated by a senior orthodontist (HK) and divided into 6 vertebral stages. Thereafter, the radiographs of 30 girls and 30 boys were selected for each maturation level randomly. Written consent was obtained from all patients who applied to the clinic for treatment purposes, indicating that their radiographs or materials can be used in scientific articles. Ethics committee approval was received for this study from the Ethics Committee of Necmettin Erbakan University. Individuals with any disease that could prevent bone development and also who had any systemic diseases and syndromes, growth and development retardation, an anomaly that can prevent craniofacial growth, endocrine disorders, and/or malnutrition, or a long-term infectious disease, were not included in our study.

A total of 28 cervical vertebral ratios were obtained by using 10 horizontal and 13 vertical measurements on the second vertebra (C2), the third vertebra (C3), the fourth vertebra (C4), and the fifth vertebra (C5). All measurements were taken by an orthodontist (MSI), twice at 15-day intervals. These 28 vertebral ratios were combined in 4 different combinations; so, 4 different datasets that were used for training the NNM (NNM 1-4) and the NBM (NBM 1-4) were obtained (Figure 1). For example, NNM 1 and NBM 1 trained with Dataset 1, and so on.

MLP Classifier, Gaussian NB, Standard Scaler, train test split, Grid Search CV, metrics, cross val score, confusion matrix, accuracy score, classification report functions of the scikit-learn,

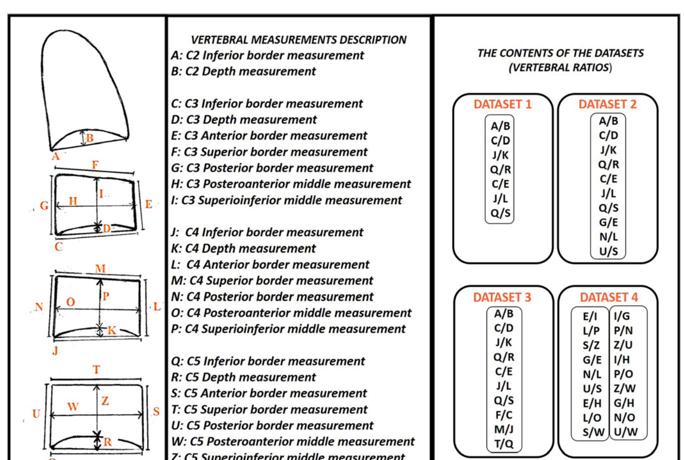

Figure 1. Description of the vertebral measurements and the contents of the datasets

and a machine learning library in Python 3.7, were used in this study. Multi-Layer Perceptron Classifier (MLP Classifier) library was used for training the ANN models. Logistic was used as an activation function. Alpha value, learning rate, and epoch (maximum iteration) were taken as 0.1, 0.001, and 200, respectively. One hidden layer was used, and for determining the appropriate neuron numbers in the hidden layer, experiments were conducted for each ANN model. It was explored between 5 and 30 neurons. Twenty-five for NNM 1 and NNM 2; 20 for NNM 3, and 15 for NNM 4 were found. L-BFGS solver, an optimizer based on the quasi-Newton methods, was chosen as the optimizer. As the dataset used in this study consists of continuous data, Gaussian Naive Bayes Classifier (Gaussian NB) library was used.

Statistical Analysis

The intraclass correlation coefficients (ICCs) were evaluated for all measurements. Each dataset was split into 2 parts as training and testing. To prevent the overfitting, a k-fold cross-validation technique was also used in the training phase. In this study, k was chosen as 5. First, the dataset was partitioned into training and test set. Then, 5-fold cross-validation (5-fold cv) was applied to the training set. In 5-fold cv, the training dataset is split into 5 portions. Each time, 1 of the 5 partitions is used as a validation set, and the other 4 portions compose the training set. (Figure 2) The mean accuracy of the training and validation sets are the results of 5-fold cv.

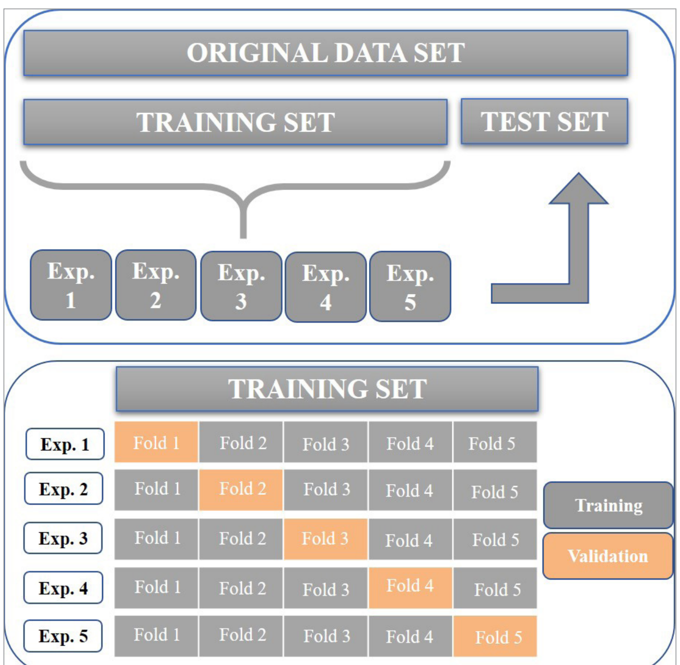

Figure 2. Description of the 5-fold cross-validation

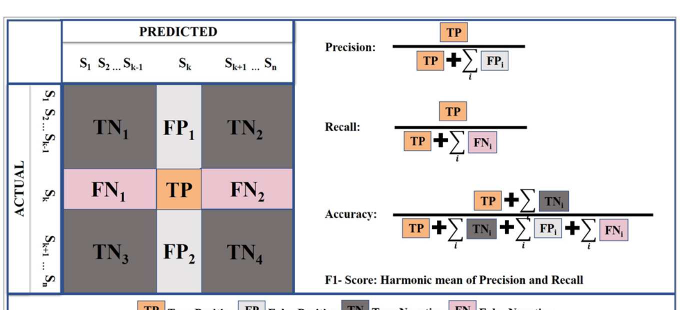

Figure 3. Structure of a confusion matrix for multiclass and graphic representations of the performance metrics

The experiments were conducted on 2 different train/test ratios as 80%-20% and 70%-30% for both NNMs and NBMs. The function "train test split" was used from the scikit-learn library to split the dataset randomly. The test size was given as an input parameter to the function. 0.3 (for 70/30) and 0.2 (for 80/20) were used as test size. To be compatible with the real-life problem, random splitting was used. There is no outside intervention during the test set formation. We added this explanation to the statistical analysis part. The results of NNMs and NBMs were evaluated using the Precision, Recall (Sensitivity), Accuracy, and F1-score performance metrics, which were calculated via the confusion matrix and kappa coefficients. A confusion matrix is basically a tabular summary representation of how well the model was performed. The structure of a confusion matrix for multi-classification (in our study, there were 6 classes called Stage 1 (S1), Stage 2 (S2), Stage 3 (S3), Stage 4 (S4), Stage 5 (S5), and Stage 6 (S6), respectively) process and the graphic representations of the performance metric equations of the are given in Figure 3.

The performance metrics and kappa values of the models are presented in Table 1 and Table 2. Precision is the ratio of correctly predicted positive determinations to the total predicted positive determinations. Recall (sensitivity) is the ratio of correctly predicted positive determinations to all determinations in the actual class. Accuracy is the ratio of correctly predicted determi-

NNM 1 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	19	0	0	0	0	0	15	0	0	0	0	0
	S2	1	20	1	0	0	0	0	14	1	0	0	0
	S3	0	0	14	0	0	0	0	1	6	0	0	0
	S4	0	0	0	21	0	0	0	0	0	13	0	0
	S5	0	0	0	1	10	1	0	0	0	0	8	0
	S6	0	0	0	0	2	18	0	0	0	0	3	11
NNM 2 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	19	0	0	0	0	0	15	0	0	0	0	0
	S2	0	21	1	0	0	0	1	14	0	0	0	0
	S3	0	1	13	0	0	0	0	1	6	0	0	0
	S4	0	0	0	21	0	0	0	0	0	13	0	0
	S5	0	0	0	1	10	1	0	0	0	0	8	0
	S6	0	0	0	0	2	18	0	0	0	0	2	12
NNM 3 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	19	0	0	0	0	0	15	0	0	0	0	0
	S2	0	20	2	0	0	0	0	14	1	0	0	0
	S3	0	0	14	0	0	0	0	1	6	0	0	0
	S4	0	0	0	21	0	0	0	0	0	13	0	0
	S5	0	0	0	0	11	1	0	0	0	1	6	1
	S6	0	0	0	0	2	18	0	0	0	0	2	12
NNM 4 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	8	7	0	0	0	0	15	0	0	0	0	0
	S2	6	7	2	0	0	0	0	14	1	0	0	0
	S3	1	1	2	2	1	0	0	1	6	0	0	0
	S4	0	1	3	6	3	0	0	0	0	13	0	0
	S5	0	0	1	3	3	1	0	0	0	1	6	1
	S6	0	0	0	0	1	13	0	0	0	0	2	12

Figure 4. The confusion matrices of the artificial neural network models (NNMs) for vertebral stage determination (70%-30% and 80%-20%)

nation to the total determinations. The F1-score is the harmonic mean of Precision and Recall and calculated as F1 = 2 (Recall × Precision) / (Recall + Precision). In all the metrics, a higher value means a better estimation result.

RESULTS

The ICCs of all measurements provided in Table 3 indicated excellent reliability (ICC>0.9). Performance metrics of NNMs and NBMs for the determination of vertebral stages (S1-S6) on the test sets are given in Table 1 and Table 2, respectively. The confusion matrices are also given for the NNMs in Figure 4 and the NBMs in Figure 5. Mean accuracy and standard deviations of train and validation sets are provided in Table 4 to assess the overfitting situation of NNMs and NBMs.

DISCUSSION

To determine skeletal age without the need for hand-wrist radiography using the cervical vertebrae on the cephalometric radiograph, which are taken for every patient in orthodontic treatment, has attracted orthodontists' attention. Studies indicate that the evaluation of chronological age phases according to the cervical vertebrae development periods is as reliable as the periods of hand-wrist development (30-32). For this reason, our study was carried out on cephalometric radiographs. Moreover, with the digitalization of the cephalometric radiographs, which is one of the routine orthodontic recordings, we think that it will be beneficial to provide a clinician decision support or a system that can be integrated into cephalometric evaluations.

Table 1. Performance metrics of the artificial NNMs for the vertebral stage determination (70%-30% and 80%-20%)

		70%-30%			80%-20%		
Model no.	**Vertebra stage**	**Precision**	**Recall**	**F1-score**	**Precision**	**Recall**	**F1-score**
NNM 1	Stage 1 (S1)	0.95	1.00	0.97	1.00	1.00	1.00
	Stage 2 (S2)	1.00	0.91	0.95	0.93	0.93	0.93
	Stage 3 (S3)	0.93	1.00	0.97	0.86	0.86	0.86
	Stage 4 (S4)	0.95	1.00	0.98	1.00	1.00	1.00
	Stage 5 (S5)	0.83	0.83	0.83	0.73	1.00	0.84
	Stage 6 (S6)	0.95	0.90	0.92	1.00	0.79	0.88
NNM 1 accuracy			0.94			0.93	
NNM 1 kappa			0.95			0.94	
NNM 2	Stage 1 (S1)	1.00	1.00	1.00	0.94	1.00	0.97
	Stage 2 (S2)	0.95	0.95	0.95	0.93	0.93	0.93
	Stage 3 (S3)	0.93	0.93	0.93	1.00	0.86	0.92
	Stage 4 (S4)	0.95	1.00	0.98	1.00	1.00	1.00
	Stage 5 (S5)	0.83	0.83	0.83	0.80	1.00	0.89
	Stage 6 (S6)	0.95	0.90	0.92	1.00	0.86	0.92
NNM 2 accuracy			0.94			0.94	
NNM 2 kappa			0.94			0.93	
NNM 3	Stage 1 (S1)	1.00	1.00	1.00	1.00	1.00	1.00
	Stage 2 (S2)	1.00	0.91	0.95	0.93	0.93	0.93
	Stage 3 (S3)	0.88	1.00	0.93	0.86	0.86	0.86
	Stage 4 (S4)	1.00	1.00	1.00	0.93	1.00	0.96
	Stage 5 (S5)	0.85	0.92	0.88	0.75	0.75	0.75
	Stage 6 (S6)	0.95	0.90	0.92	0.92	0.86	0.89
NNM 3 accuracy			0.95			0.92	
NNM 3 kappa			0.92			0.94	
NNM 4	Stage 1 (S1)	0.58	0.79	0.67	0.53	0.53	0.53
	Stage 2 (S2)	0.69	0.50	0.58	0.44	0.47	0.45
	Stage 3 (S3)	0.46	0.43	0.44	0.25	0.29	0.27
	Stage 4 (S4)	0.58	0.52	0.55	0.55	0.46	0.50
	Stage 5 (S5)	0.42	0.42	0.42	0.38	0.38	0.38
	Stage 6 (S6)	0.91	1.00	0.95	0.93	0.93	0.93
NNM 4 accuracy			0.63			0.54	
NNM 4 kappa			0.44			0.50	

NNM: Neural Network model

Researchers aimed to achieve more objective results by taking advantage of digital images with computer software and wanted to automate the vertebral evaluation. Mito et al. (33), Alhadlaq and Al-Maflehi (34), and Beit et al. (35) evaluated vertebral age determination with the help of vertebral ratios by regression analysis. In regression analysis, a formula was drawn, and the vertebral age of the patients was calculated. Mito et al. (33) and Alhadlaq and Al-Maflehi (34) used ratios of C3 and C4, and Beit et al. (35) preferred ratios of C2, C3, and C4. We conducted our study on C2-C5. In our study, Dataset 1 had 7 ratios, Dataset 2-Dataset 3 had 10 ratios, and Dataset 4 had 18 ratios. Baptista et al. (36) studied 7 ratios by 10 lines with the NB to evaluate the 2 examiners' and NB's bone age assessments using cervical vertebral maturation. The highest accuracy rate was seen at NB1 (55.85%). Considering a deviation of 1 adjacent stage, the accuracy rate of NB1 was 90.42%. The researchers stated that the NB repeated the examiner's performance and predicted the vertebral stages. We preferred to study both NB and ANNs. Because ANNs work just like a human learning system that cannot be formulized or standardized. They learn the relationships between events from examples and then make decisions about examples they have never seen using the information they have learned before (37-39). Similar to Random Forest, NB can perform well in some classifications, despite its naive design and oversimplified assumptions. Through its essential multiclass method, NB is also well suited for medical application and allows examples to be classified into more than 2 categories without changing the parameters. When a new one is submitted, the learned classifier assigns it to the most probable stage (36, 40, 41).

Table 2. Performance metrics of the NBMs for the vertebral stage determination (70%-30% and 80%-20%)

		70%-30%			80%-20%		
Model no	**Vertebra stage**	**Precision**	**Recall**	**F1-score**	**Precision**	**Recall**	**F1-score**
NBM 1	Stage 1 (S1)	0.47	1.00	0.64	0.50	1.00	0.67
	Stage 2 (S2)	0.09	0.05	0.06	0.00	0.00	0.00
	Stage 3 (S3)	0.33	0.29	0.31	0.25	0.29	0.27
	Stage 4 (S4)	1.00	0.62	0.76	1.00	0.54	0.70
	Stage 5 (S5)	0.83	0.83	0.83	0.78	0.88	0.82
	Stage 6 (S6)	0.90	0.90	0.90	0.92	0.86	0.89
NBM 1 accuracy			0.60			0.60	
NBM 1 kappa			0.52			0.51	
NBM 2	Stage 1 (S1)	0.47	1.00	0.64	0.50	1.00	0.67
	Stage 2 (S2)	0.25	0.05	0.08	0.00	0.00	0.00
	Stage 3 (S3)	0.61	0.79	0.69	0.55	0.86	0.67
	Stage 4 (S4)	1.00	0.67	0.80	1.00	0.62	0.76
	Stage 5 (S5)	0.83	0.83	0.83	0.78	0.88	0.82
	Stage 6 (S6)	0.90	0.90	0.90	0.92	0.86	0.89
NBM 2 accuracy			0.68			0.67	
NBM 2 kappa			0.61			0.60	
NBM 3	Stage 1 (S1)	0.49	1.00	0.66	0.50	1.00	0.67
	Stage 2 (S2)	0.10	0.05	0.06	0.00	0.00	0.00
	Stage 3 (S3)	0.38	0.36	0.37	0.38	0.43	0.40
	Stage 4 (S4)	0.93	0.62	0.74	1.00	0.62	0.76
	Stage 5 (S5)	0.75	0.75	0.75	0.75	0.75	0.75
	Stage 6 (S6)	0.90	0.90	0.90	0.86	0.86	0.86
NBM 3 accuracy			0.60			0.61	
NBM 3 kappa			0.52			0.53	
NBM 4	Stage 1 (S1)	0.48	0.63	0.55	0.53	0.60	0.56
	Stage 2 (S2)	0.00	0.00	0.00	1.00	0.07	0.12
	Stage 3 (S3)	0.26	0.57	0.36	0.15	0.43	0.22
	Stage 4 (S4)	0.59	0.62	0.60	0.53	0.62	0.57
	Stage 5 (S5)	0.50	0.08	0.14	0.50	0.12	0.20
	Stage 6 (S6)	0.80	1.00	0.89	0.82	1.00	0.90
NBM 4 accuracy			0.50			0.50	
NBM 4 kappa			0.40			0.40	

NBM: Naive Bayes model

According to our results, all NNMs were observed to be more successful than all NBMs. When Table 1 and Table 2 were examined, it was seen that NNM 1 had high success and consistent model for determining vertebral stages (the accuracy values were 0.94 and 0.93 for Training-Test set ratio:70%-30% and 80%-20%, respectively). NBM 1 determination success was low (0.60), and slightly increased in NBM 2 (0.68 and 0.67 for Training-Test set ratio: 70%-30% and 80%-20%, respectively). The success of NNM 2 did not differ much from NNM 1 (0.94). NNM 3 determination success was increased 0.95 for Training-Test set ratio: 70%-30%, whereas NBM 3 success decreased to 0.60 for both Training-Test set ratio: 70%-30% and 80%-%20. The determination success of S5 was relatively low than the others in NNM 1 and NNM 2 (F1-score: 0.83 for Training-Test set ratio: 70%-30%). It was observed that NNM 4 and NBM 4 determination success were quite low, although more vertebral ratios were used in Dataset 4. The accuracy value of NNM 4 was 0.63 and 0.54 for Training-Test set ratio: 70%-30% and 80%-20%, respectively. NBM 4 accuracy value was 0.50. For this reason, it was observed that the ratios in Dataset 4 were not effective and efficient in separating the stages. We could say that the vertebral superior border, anterior border, and

Table 3. The ICC values of all the measurements

Measurements	ICC	Measurements	ICC
A	0.973	M	0.999
B	0.988	N	0.998
C	0.984	O	0.999
D	0.999	P	0.999
E	0.987	Q	0.999
F	0.988	R	0.992
G	1.000	S	0.992
H	0.990	T	0.997
I	1.000	U	0.999
J	0.999	W	0.910
K	0.999	Z	0.999
L	1.000		

ICC: Intraclass correlation coefficient

NBM 1 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	19	0	0	0	0	0	15	0	0	0	0	0
	S2	21	1	0	0	0	0	15	0	0	0	0	0
	S3	0	10	4	0	0	0	0	5	2	0	0	0
	S4	0	0	8	13	0	0	0	0	6	7	0	0
	S5	0	0	0	0	10	2	0	0	0	0	7	1
	S6	0	0	0	0	2	18	0	0	0	0	2	12
NBM 2 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	19	0	0	0	0	0	15	0	0	0	0	0
	S2	21	1	0	0	0	0	15	0	0	0	0	0
	S3	0	3	11	0	0	0	0	1	6	0	0	0
	S4	0	0	7	14	0	0	0	0	5	8	0	0
	S5	0	0	0	0	10	2	0	0	0	0	7	1
	S6	0	0	0	0	2	18	0	0	0	0	2	12
NBM 3 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	19	0	0	0	0	0	15	0	0	0	0	0
	S2	20	1	0	0	1	0	15	0	0	0	0	0
	S3	0	9	5	0	0	0	0	4	3	0	0	0
	S4	0	0	8	13	0	0	0	0	5	8	0	0
	S5	0	0	0	1	9	2	0	0	0	0	6	2
	S6	0	0	0	0	2	18	0	0	0	0	2	12
NBM 4 Confusion Matrices		PREDICTED (70%-30%)						PREDICTED (80%-20%)					
		S1	S2	S3	S4	S5	S6	S1	S2	S3	S4	S5	S6
ACTUAL	S1	12	1	6	0	0	0	9	0	6	0	0	0
	S2	12	0	10	0	0	0	7	1	7	0	0	0
	S3	1	1	8	2	0	2	1	0	3	2	0	1
	S4	0	0	6	13	1	1	0	0	3	8	1	1
	S5	0	1	1	7	1	2	0	0	1	5	1	1
	S6	0	0	0	0	0	20	0	0	0	0	0	14

Figure 5. The confusion matrices of the naive Bayes models (NBMs) for vertebral stage determination (70%-30% and 80%-20%)

Table 4. Mean and standard deviation of training and validation sets for the artificial NNMs and the NBMs

			Test sets		Train sets	
	Model no.	5-fold cv (train set ratio)	Mean	Standard deviation	Mean	Standard deviation
Neural network	NNM 1	5-fold cv (70%-30%)	0.928	0.026	1	0
		5-fold cv (80%-20%)	0.930	0.028	1	0
	NNM 2	5-fold cv (70%-30%)	0.940	0.030	0.987	0.003
		5-fold cv (80%-20%)	0.944	0.029	0.993	0.003
	NNM 3	5-fold cv (70%-30%)	0.928	0.019	1	0
		5-fold cv (80%-20%)	0.934	0.036	1	0
	NNM 4	5-fold cv (70%-30%)	0.626	0.056	0.802	0.013
		5-fold cv (80%-20%)	0.642	0.063	0.792	0.017
Naive Bayes	NBM 1	5-fold cv (70%-30%)	0.686	0.097	0.720	0.085
		5-fold cv (80%-20%)	0.666	0.046	0.706	0.078
	NBM 2	5-fold cv (70%-30%)	0.714	0.085	0.758	0.064
		5-fold cv (80%-20%)	0.698	0.032	0.745	0.055
	NBM 3	5-fold cv (70%-30%)	0.694	0.116	0.726	0.078
		5-fold cv (80%-20%)	0.663	0.024	0.710	0.077
	NBM 4	5-fold cv (70%-30%)	0.606	0.045	0.665	0.021
		5-fold cv (80%-20%)	0.579	0.080	0.654	0.015

NBM: Naive Bayes model; NNM: Neural Network model depth measurements were important for the determination success of the NNM. Because Dataset 3 consisting of the ratios, that had been determined based on the shape changes that could be observed in the vertebrae with growth development, had the highest success in NNM. Amasya et al. (29) evaluated five different algorithms and reported that the success of ANN increased in the models for determining the presence of concavity. The success of the algorithms in determining the stages in this study is CS1 (90.91%), CS2 (90.48%), CS3 (88.89%), CS4 (83.78%), CS5 (87.5%), and CS6 (80%), respectively. The model's average was 86.93%. Moraes et al. (42) used only C3 concavity and declared that their results were promising in the determination of bone age by the help of the ANN. They reported only one feature (C3 concavity) has a high correlation with bone age. Also, Santiago et al. (43) studied a multinomial logistic regression model for the cervical vertebral geometry assessment and its relationship to skeletal maturation. They declared that the satisfactory prediction was observed in the model that included age, gender, and four parameters of the vertebral measurements. The knowledge of age and gender were not included in our models. Although these parameters were meaningful clinically and could be increased the models' success rate, we just focused on radiographic data (the vertebral ratios) and wanted to see their success level.

ANN is designed to generalize the relationship between input-output data. Stated in other words, it learns enough about the past to generalize to the future. At the end of the ANN training process, the perfect fit of the learned weight values to the training set is overfitting. Overfitting corresponds to a model that has learned the training data very well, so the training accuracy will be close to 100%. When this model run on the test data, the accuracy results will probably be very low compared with the training data. To prevent overfitting via choosing the proper model structure, cross-validation, a standard tool in statistics, could be used (39). According to these results, we could say that NNM 1, NNM 2, NNM 3 were acceptable models. When the results of all NBM 4 were inspected, it was seen that these models mean accuracy values lower than the others. It has been observed that the vertebral ratios used in the NBM 4 were not discriminatory in the classification.

Our study consists of individuals belonging to a specific population. It will be necessary to study different and multiracial communities. In our research, we investigated 4 models based on vertebral ratios used in the literature. The method's performance could also be improved by increasing the number of individuals included in the study and the number of models obtained with different combinations of measurements. In addition, our research did not focus on automating the landmarks. Reviews on this subject are promising and are progressing rapidly. Obtaining measurement data fully automatically will be clinically beneficial. These are the limitations of our study, and further studies are needed on these aspects.

CONCLUSION

1. The NNMs were more successful than the NBMs in our developed models.
2. The increase in the number of ratios did not increase success.
3. The vertebral superior border, anterior border, and depth measurements affected success.
4. It is important to determine the effective ratio and/or measurements that will be useful for differentiation.

Ethics Committee Approval: This study was approved by Ethics committee of Necmettin Erbakan University, (Approval No: 2017.02).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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Original Article

Occlusal Plane Changes After Molar Distalization With a Pendulum Appliance in Growing Patients with Class II Malocclusion: A Retrospective Cephalometric Study

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Main points:

- This study aimed to demonstrate the efficacy of pendulum appliance in distalizing the maxillary molars to correct a Class II malocclusion and provide a propaedeutic molar relationship before the final correction of the occlusion with fixed orthodontic treatment.
- A noteworthy result was the concordance of the data of this study with those of the previous ones; this emphasizes the environmental protocol and provides a further starting point for future investigations for the use of the pendulum appliance.
- Of particular interest was the maintenance of the occlusal plane inclination in the distalizing phase that could be achieved by the pendulum appliance compared with other distalizing techniques that do not allow a vertical control of the maxillary molars with consequent change in the occlusal plane and bite opening.
- The absence of changes in the inclination of the occlusal plane seems to not interfere with the normal maxillary and mandibular growth, which could be a strategy to achieve an improved Class II correction.

ABSTRACT

Objective: This study aimed to evaluate the skeletal and dental changes after distalization with a pendulum appliance in growing patients with Class II malocclusion, focusing on the occlusal plane (OP).

Methods: The sample included 24 patients with Class II malocclusion (10 boys, 14 girls); their mean age was 12.1 years. All patients underwent molar distalization and had 2 serial cephalograms traced at baseline (T1) and after distalization (T2). Angular and linear dental changes were calculated by taking the sella-nasion (SN), palatal plane (PP), and pterygoid vertical as reference. OP inclination was compared with SN, PP, and mandibular plane. The collected data were computed for all the tested variables, and one-way paired t-test was used to assess the significance of the differences between the time points. α was set at 0.05. Multiple linear regressions were used to predict the OP changes.

Results: The mean total treatment time was 8±2 months to obtain a super Class I molar relationship. In T1-T2 interval, statistically significant incisor buccal tipping of 5°±3.6° ($p<0.05$), first molar distal tipping of 8.9°±8.3° ($p<0.001$), and second molar tipping of 8.2°±8.1° ($p<0.001$) were observed. The maxillary first and second molars moved significantly backward by 2.8±3.2 mm ($p<0.05$) and 3.7±2.7 mm ($p<0.001$), respectively. Only the premolars showed a statistically significant anchorage loss of 2.7±3.3 mm ($p<0.05$); overjet increased significantly at 1.3±1.2 mm ($p<0.05$). Regarding the OP, none of the tested variables showed any statistically significant changes between T1-T2.

Conclusion: The pendulum appliance showed efficacy in distalizing the maxillary first and second molars at the expense of anterior anchorage loss. The OP did not show statistically significant changes after molar distalization.

Keywords: Cephalometry, Class II Angle malocclusion, molar distalization, occlusal plane, pendulum appliance

INTRODUCTION

Class II malocclusion is one of the most frequent orthodontic problems, which dentists diagnose and treat, with a mean worldwide distribution of 19.56% in permanent dentition and 23.11% in mixed dentition (1). Depending on the diag-

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nosis, Class II malocclusions can be treated by several methods, for example, functional orthopedic appliances, extraoral and intraoral devices for tooth distalization, camouflage treatment, or orthognathic surgery. If there are no significant skeletal discrepancies and tooth crowding, maxillary prognathism that involves Class II molar relationship can be completely corrected by maxillary molar distalization.

Molar distalization is a generally used non-extraction treatment to establish a Class I molar and canine relationship, especially using non-compliance devices (2). In fact, although the majority of intraoral and extraoral devices are effective for achieving molar distalization, they are often highly dependent on patient compliance. Among several intraoral distalizing devices, since its development in 1992, the pendulum appliance might be considered among one of the most investigated non-compliance and efficient tools in compensating a Class II molar relationship, especially those related with maxillary prognathism (3, 4).

The occlusal plane (OP) is a cephalometric line connecting the point bisecting the first molar cusp height and the point bisecting the overbite (5). Many factors change this plane inclination during craniofacial growth to achieve a harmonic function of the masticatory system. The OP reduces its inclination with respect to the maxilla and anterior cranial bases owing to an anterior rotation taking place during growth; this phenomenon is caused by a larger eruption of the upper molars than upper incisors (6). The cant of the OP is usually related to a malocclusion describing a vertical morphologic feature, which then affects the sagittal-mandibular position. Class III shows a flat OP, whereas Class II shows a steep one. Furthermore, orthodontic treatment changes the position and angulation of the involved teeth, and it is acknowledged that slight dental angular variations can result in significant alteration of the occlusion (7).

From a clinical perspective, treatment of the sagittal component of malocclusions, that is, distalizing techniques, could aim at changing the vertical position of the posterior teeth and subsequently the OP inclination and potentially advance the mandible toward a corrective position (8). OP is often strictly related to treatment, and a great part of the treatment effort is involved with its correction. A correct plane of occlusion allows protrusion without posterior interferences, enabling good function between the maxilla and mandible, whereas uncontrolled changes in the OP might lead to worsening of the malocclusion in some cases or difficulties in performing desired movements.

Several studies have evaluated the cephalometric changes after distalization with a pendulum from different perspectives (9). Nevertheless, the OP changes after distalization in Class II malocclusion are still not completely clarified, and this aspect is relevant. This study aimed to evaluate the skeletal and dental changes after upper molar distalization with a pendulum device in terms of potential changes in OP inclination in growing patients with a Class II malocclusion.

METHODS

Sample Selection and Exclusion Criteria

Ethical approval was obtained from the ethics committee of the University of Insubria (#18/2014); the protocol followed adhered to the World Medical Association Declaration of Helsinki. Before starting treatment, an informed consent for releasing radiological diagnostic records for scientific research was obtained. Because the primary purpose of this study was to evaluate the effectiveness of molar distalization and its correlation with possible changes of the OP variables, the sample size was calculated on the cephalometric values of 5 patients, selecting the distance between the upper first molar centroid and the pterygoid vertical (PtV-Ctr1M) changes before and after distalization (mean=–2.7; standard deviation [SD]=3.2) as the main outcome. A sample size of at least 23 subjects was necessary to retrieve a power of 0.8 (β=0.20) with α set at 0.05. An initial sample of 30 patients was selected according to the following inclusion criteria:

1) Skeletal Class I or mild Class II malocclusion (ANB≤6°)
2) Bilateral Class II molar relationship
3) Sella-nasion (SN)-mandibular plane (MP) <37°
4) Unerupted or incompletely erupted second maxillary molars
5) No previous orthodontic treatment and non-extraction treatment
6) Use of the pendulum appliance
7) High-quality radiographs with clear landmark visualization

Table 1. Sample selection and exclusion criteria

Initial sample	30
Primary exclusion criteria	
1) Poor film quality	2
2) Incomplete records	1
Secondary exclusion criteria	
1) Treatment time >12 months	3
Final sample	24

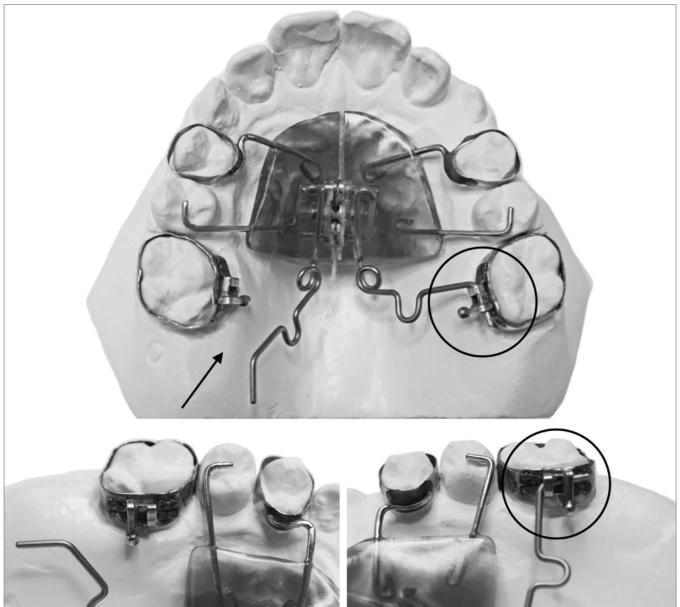

Figure 1. Pendulum appliance design and activation. Occlusal and lateral views of the appliance showing activation of the wire on the right upper molar (arrow) and the wire already inserted in the slot band on the left upper molar (circle). Once inserted, the wire has a wire/slot play (circle) that allows to apply tip bend to correct tipping of the molar during its distalization

A total of 6 patients were excluded according to defined criteria as summarized in Table 1. The final sample included 24 patients, 10 boys and 14 girls (mean age of 12.1 years; range, 10.5-14.2 years) with 2 serial cephalograms available at the observation times: baseline (T1) and after molar distalization (T2).

Clinical Management

In this study, a modified pendulum appliance was used with first molars bands, occlusal rests on premolars, and titanium-molybdenum alloy (TMA) springs (Figure 1); 45° to 60° activation angle of the TMA springs was customized on model casts to exert 200 to 250 g. Owing to compensation of the palatal and coronal forces applied toward the center of resistance, uprighting bends (25°-30°) were added to the end of the TMA wire to avoid excessive molar tipping; toe-in bends were also added (10-12). The pendulum was left *in situ* until a super Class I molar relationship was achieved.

Cephalometric Analysis

Lateral cephalograms were traced by a dedicated software (Delta-Dent; Outside Format, Cremona, Italy) by the first operator (CE) with verification of anatomy and landmarks by the second one (SM). In case of overlapping structures (for example, gonial angle and teeth), a single averaged tracing was made. A conventional cephalometry, including skeletal and dental measurements, was used. Initial cephalometric measures at T1 are summarized in Table 2.

The centroid point was obtained as the midpoint between the greatest mesial and distal convexity of the crowns of the maxillary first and second molars and the first premolars; the incisor tip was pointed at the incisal edge. The lines passing through the centroid and furca points and through the centroid/tip and apex were used as molar and premolar/incisor axes, respectively. SN (anterior cranial base plane), palatal plane (PP) (plane formed by the line connecting the anterior and posterior nasal spine), MP (plane formed by connecting gonion to gnathion points), and

Table 2. Mean and SD of cephalometric measurements at T1 and T2 and statistical comparison (paired t-test) with p values of T2-T1 period

	T1		T2		ΔT2–T1		
Cephalometric measurement	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p**
Skeletal							
SNA (°)	81.2	2.5	80.8	3.3	–0.4	2.1	NS
SNB (°)	77.4	2.9	77.8	3.1	0.4	2.1	NS
ANB (°)	3.6	1.8	3.1	1.7	–0.5	1.3	NS
SN-PP (°)	7.7	3.0	7.8	3.6	0.1	2.3	NS
SN-MP (°)	30.6	3.8	31.4	4.6	0.8	3.0	NS
PtV-A (mm)	55.5	2.8	55.6	3.1	0.1	2.1	NS
PtV-B (mm)	55.3	4.4	56.1	4.7	0.7	2.8	NS
ANS-Me (mm)	65.3	5.4	67.1	6.0	1.8	1.8	NS
Dental							
SN-AxU1 (°)	103.2	8.3	108.2	8.1	5.0	3.6	<0.05
SN-Ax1Pm (°)	84.0	4.5	86.5	6.3	2.5	5.1	NS
SN-Ax1M (°)	67.9	5.1	59.0	9.6	–8.9	8.3	<0.001
SN-Ax2M (°)	60.9	3.2	52.7	4.8	–8.2	8.1	<0.001
PtV-TipU1 (mm)	56.2	3.7	57.7	3.9	1.5	2.8	NS
PtV-Ctr1Pm (mm)	40.2	3.3	42.8	4.3	2.7	3.3	<0.05
PtV-Ctr1M (mm)	22.3	3.5	19.5	3.6	–2.8	3.2	<0.05
PtV-Ctr2M (mm)	13.1	3.1	9.4	2.7	–3.7	2.7	<0.001
PP- TipU1 (mm)	29.0	3.0	29.5	3.5	0.5	1.4	NS
PP-Ctr1Pm (mm)	21.0	2.8	22.3	3.2	1.4	1.8	NS
PP-Ctr1M (mm)	17.5	2.8	17.4	2.7	–0.1	1.6	NS
PP-Ctr2M (mm)	12.1	4.6	12.2	4.0	0.1	2.4	NS
OVJ (mm)	3.9	1.6	5.2	2.1	1.3	1.2	<0.05
OVB (mm)	3.2	1.9	2.8	2.1	–0.4	1.9	NS
OP							
SN-OP (°)	19.8	4.3	19.3	3.9	–0.5	2.3	NS
PP-OP (°)	11.7	4.1	11.2	4.1	–0.5	0.1	NS
OP-MP (°)	15.8	3.1	16.8	4.3	1.0	3.4	NS

NS: Not significant (p>0.05); SD: Standard deviation; Ax1M: Maxillary first molar axis; Ax2M: Maxillary second molar axis; OP: Occlusal plane; PP: Palatal plane; MP: Mandibular plane; SN: Sella-nasion plane; TipU1: Upper central incisor tip; Ctr1Pm: Maxillary first premolar centroid; Ctr1M: Maxillary first molar centroid; Ctr2M: Maxillary second molar centroid; PP: Palatal plane; PtV: Pterygoid vertical; OVJ: Overjet; ANS: Anterior nasal spine; OVB: Overbite

PtV (line perpendicular to the Frankfort plane at the posterior margin of the pterygomaxillary fissure) were used as horizontal and vertical reference planes for angular and linear parameters (Figures 2 and 3). OP was evaluated using the angular measurements of SN-OP, PP-OP, and OP-MP as shown in Figure 2.

Statistical Analysis

Descriptive statistics was calculated for cephalometric measurements at T1 and T2 for all the subjects. Mean differences and SDs between T1 and T2 were also calculated. The Statistical Package for Social Sciences version 22.0 software (IBM Corp.; Armonk, NY, USA) was used for statistical analysis. The Shapiro-Wilk test confirmed the normal distribution of the data for the tested sample, and parametric tests were used to compare the mean differences among different timepoints. Data were computed for all the tested variables, and the paired t-test was used to assess significance of the differences among the timepoints. Significance level (p) was set at 0.05.

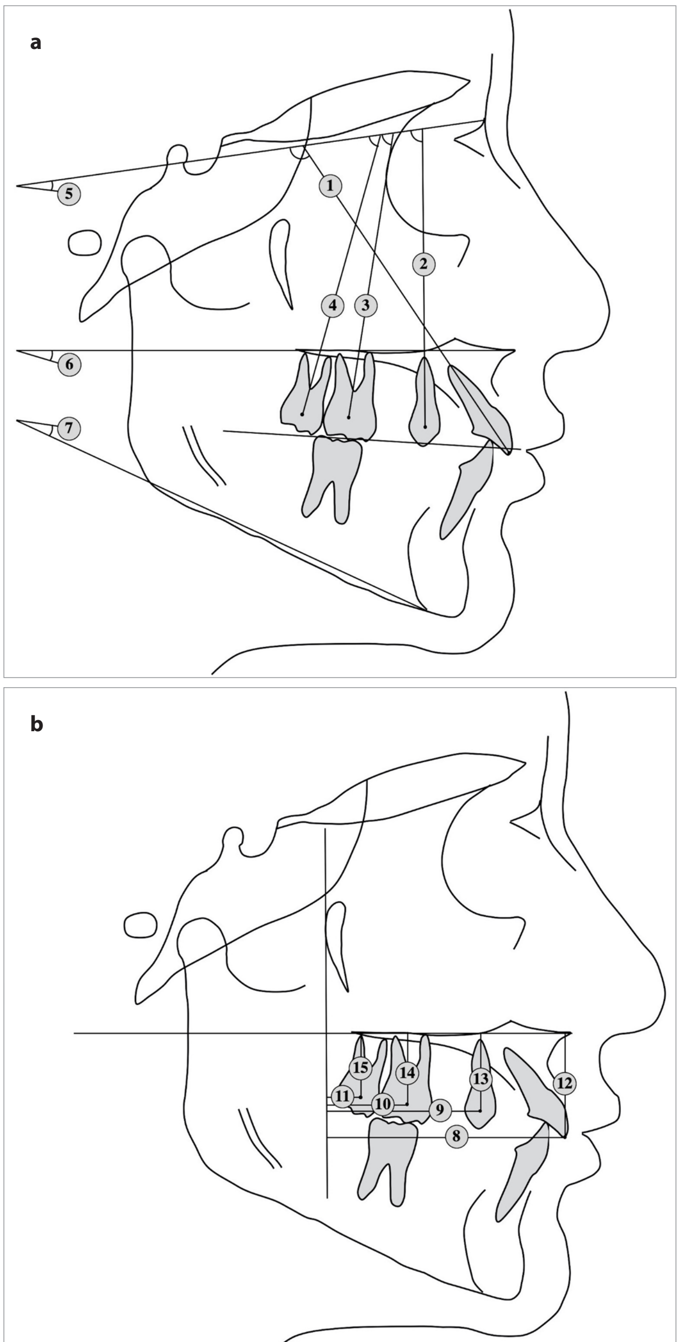

Figure 2. a, b. (a) Cephalometric analysis for evaluation of maxillary tooth and occlusal plan changes. 1) SN-AxU1; 2) SN-Ax1Pm; 3) SN-Ax1M; 4) SN-Ax2M; 5) SN-OP; 6) PP-OP; 7) MP-OP (b) Cephalometric analysis of the evaluation of maxillary tooth and occlusal plane changes. 8) PtV-TipU1; 9) PtV-Ctr1Pm; 10) PtV-Ctr1M; 11) PtV-Ctr2M; 12) PP-TipU1; 13) PP-Ctr1Pm; 14) PP-Ctr1M; 15) PP-Ctr2M

The Pearson correlation coefficient (r) was employed to evaluate the strength of the relationship between several tested parameter (SN-MP; SN-Ax1M; SN-Ax2M; PtV-Ctr1M; PtV-Ctr2M; PP-Ctr1M; and PP-Ctr2M) changes after distalization and the changes in SN-OP. Finally, the multiple backward linear regressions were used to estimate the association of each tested parameter with the SN-OP changes.

Method Error

The method error was quantified with the method of moments variance estimator. A total of 10 lateral cephalograms were randomly selected and retraced by a third orthodontist (CA). A paired t-test showed no significant differences between the 2 series of cephalometry. The mean error and 95% confidence interval among the repeated data were 0.7 (0.5-0.8) mm for linear measurements and 0.8° (0.6°-0.9°) for angular measurements; reliability coefficient (r) for linear and angular measurement ranged from 94% to 98% and from 92% to 97%, respectively.

RESULTS

The mean treatment time from the maxillary molar distalization to achieving a super Class I was 8±2 months. Mean and SD and paired t-test results of the skeletal, dental, and occlusal changes are reported in Table 2. The most significant changes are reported below.

Skeletal Changes

Changes in skeletal measurements were observed. SNA (Sella-Nasion-Point A) decreased 0.4°±2.1° and SNB (Sella-Nasion-Point B) increased 0.4°±2.1°; PtV-A (Pterygoid Vertical-Point A) and PtV-B (Pterygoid Vertical-Point B) increased 01±2.1 mm and 0.7±2.8 mm, respectively. An increase in SN-MP (Sella-Nasion Plane-Mandibular Plane) of 0.8°±3° accompanied by an increase in ANS-Me (Anterior Nasal Spine-Menton) of 1.8±1.8 mm was also observed. Inferential statistical analysis showed that none of these changes were significant ($p>0.05$).

Dental Changes

Statistically significant changes were observed in SN-Ax1M (Sella-Nasion plane-First maxillary molar axis), which decreased at 8.9°±8.3° in the T1–T2 interval ($p<0.001$), whereas SN-Ax2M (Sella-Nasion plane-Second maxillary molar axis) insignificantly tipped distally by 8.2°±8.1°. SN-AxU1 (Sella-Nasion plane-Maxillary central incisor axis) also increased significantly at 5°±3.6° after distalization ($p<0.05$). Linear changes in teeth position in the case of PtV (Pterygoid Vertical) and PP (Palatal Plane) were observed. In the T1-T2 interval, the distances decreased by 2.8±3.2 mm for PtV-

Ctr1M (Pterygoid Vertical-Maxillary first molar centroid) ($p<0.05$) and 3.7±2.7 mm for PtV-Ctr2M (Pterygoid Vertical-Maxillary second molar centroid) ($p<0.001$). Vertical extrusion was reported on all the analyzed teeth but without any statistically significant difference. OVJ (Overjet) increased significantly by 1.3±1.2 mm ($p<0.05$). Both angular and linear changes were also observed on anchorage-loss teeth; the incisor and first premolars moved and tipped mesially, but only PtV-Ctr1Pm (Pterygoid Vertical-Maxillary first premolar centroid) was statistically significant with a mesial movement of 2.7±3.3 mm ($p<0.05$). The main dental movements after molar distalization are resumed in Figure 4.

Occlusal Plane Changes

None of the tested variables related to the OP (Occlusal Plane) showed statistically significant differences between the 2 time-points; OP-MP (Occlusal Plane-Mandibular Plane) was increased by 1°±3.4°, whereas both SN-OP (Sella-Nasion plane-Occlusal Plane) and PP-OP (Palatal Plane-Occlusal Plane) showed a decrease of 0.5°±2.3° and 0.5°±0.1°, respectively. In addition, results of multiple backward linear regressions (Table 3) showed that the tested parameters (SN-MP, SN-Ax1M, SN-Ax2M, PTV-Ctr1M, PTV-Ctr2M, PP-Ctr1M, and PP-Ctr2M) accounted for 68% of the changes in SN-OP after molar distalization. Moreover, none of the differences in the tested parameters were significantly associated with SN-OP changes in the multiple linear regressions.

Table 3. Results of the multiple backward linear regression to estimate association of the tested parameters with the SN-OP changes after distalization (T1-T2)

Explanatory variable	B	t	P
SN-MP	0.32	1.21	0.26
SN-Ax1M	−0.21	−0.65	0.53
SN-Ax2M	−0.17	−0.47	0.65
PtV-Ctr1M	0.02	0.06	0.95
PtV-Ctr2M	0.15	0.35	0.73
PP-Ctr1M	−0.70	−2.58	0.03
PP-Ctr2M	−0.01	−0.03	0.97

β correlation coefficients; R square of the model, 0.68. Level of significance: $p<0.05$.

MP: Mandibular plane; SN: Sella-nasion plane; Ax1M: Maxillary first molar axis; Ax2M: Maxillary second molar axis; Ctr1M: Maxillary first molar centroid; Ctr2M: Maxillary second molar centroid; PP: Palatal plane; PtV: Pterygoid vertical

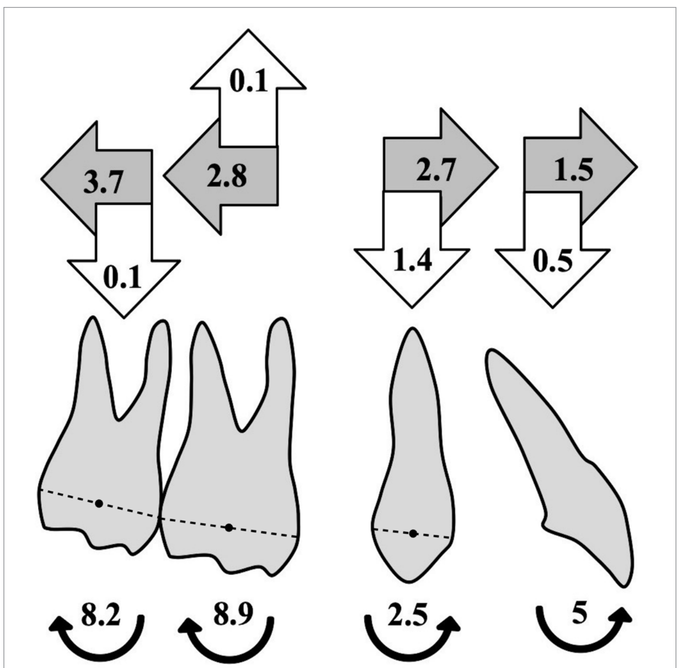

Figure 3. Main results after distalization of dentoalveolar measurements. Gray arrows, sagittal movements (mm); white arrows, vertical movements (mm); black arrows, mesiodistal (molars and premolar) and buccolingual (incisor) inclination movements (°)

DISCUSSION

This retrospective study described the result of 24 growing patients treated with a pendulum device. Pendulum is a largely studied non-compliance device, and it has been compared with similar tools that provide a combination of distal body movement and distal crown tipping (9). This phenomenon is accompanied by loss of anchorage and extrusion in the premolars and incisors. The mean treatment time for achieving a Class I molar relationship was about 8±2 months, consistent with the treatment time of previous systematic reviews that report a range of 6 to 10 months, which probably depended on the full cusp or end-to-end molar relationship of the sample before treatment (13). Several studies have also evaluated the influence of the pendulum in relation to the soft tissue and dentoskeletal improvement (13). The results of this study are assumed to be in accordance with the mean values of the previous studies on distalizing devices (14). However, till date, there are no studies regarding the use of the pendulum and its influence on the OP. Therefore, the purpose of this study was to evaluate the OP changes after maxillary molar distalization in growing patients.

Skeletal Changes

In terms of the skeletal changes, no statistical significance was found in the T1-T2 period. SNA decreased by 0.4°±2.1°, whereas SNB increased by 0.4°±2.1° in T1-T2. PtV-A and PtV-B increased by 0.1±2.1 mm and 0.7±2.8 mm, respectively. SNA reduction was like in other studies, corresponding more to a normal growth than any orthopedic influence of the appliance used (15). The pendulum causes primarily a dentoalveolar effect, but secondary mandibular growth can be essential for the correction of Class II malocclusion in growing patients (16). This provides a correction of the molar relationship because of molar distalization, whereas a favorable growth pattern drives the mandible forward as expected by the increase in SNB and PtV-B. Nevertheless, a period of approximately 8 months necessary for molar distalization seems to be too short to observe any remarkable and statistically significant cranial changes compared with the use of functional orthopedic appliances (17). Therefore, increase in the mandibular length was similar to the measurements reported in untreated patients and is variable according to mean treatment time (18).

The increase in SN-MP is often evaluated because of the risk of producing an anterior open bite (19). Class II correction by conventional molar distalization is not always suggested. It can be stated that mandibular rotation is related to changes in the distalization, corrective orthodontic mechanics, and craniofacial growth and development (20). In fact, in open bite patients, extrusion and distalization could assess a backward mandibular rotation, increasing the anterior lower facial height and resulting in a worse molar relationship. In this study, SN-MP was increased only by 0.8°±3°, and lower anterior face height was increased by 1.8±1.8 mm, although without any statistical significance. The vertical increase in facial height seems to represent only a temporary effect, which could be completely compensated by a favorable counterclockwise mandibular growth (2). The variability of results in the literature may be related to differences in sample size, mean age, vertical facial pattern, and criteria used to classify the patients (21). Because of these considerations and to prevent bite opening, it has been speculated that distalization techniques are more suitable in patients with normal or reduced divergence, as was the case in the sample collected for our study.

Dental Changes

In this study, the mean distal shift of the first and second maxillary molars was 2.8±3.2 mm and 3.7±2.7 mm, respectively. Previous studies have reported a mean molar distal movement ranging between 2 and 6.4 mm, depending on the presence or absence of the upper second molar. Our results are also in accordance with the mean of 3.1 mm for palatal distalizing appliances described in previous studies (9, 14). The pendulum appliance can achieve a large amount of molar distalization, but it depends on many factors, the first being the eruption stage of second maxillary molars (22). The authors agreed with the idea that the presence of completely erupted second molars decreased the efficiency of distalization, increased the treatment time, required a higher force, and produced a larger anchorage loss but with less tipping than bodily movement of the first molar. The best time to start the pendulum treatment is when the second molars are unerupted, although more crown tipping can be expected (23). Owing to the mean age, the sample of this study had incompletely erupted second molars; therefore, distal tipping of the first maxillary molars seemed to be greater than bodily movement, probably because of the unerupted second molars, which acted as a distal crown fulcrum instead of the center of rotation.

It is important to define in detail what distal movement is in comparison with that in other studies on the basis of the reference point, for example, centroid of the radiological crown as used in this study or the tip of a cusp and the distance between it and the center of rotation changes. The closer the reference point is to the center of rotation, the smaller the amount of distal movement that will be obtained (24). Therefore, data will have to be carefully compared not only in terms of the reference point but also the reference plane.

The pendulum should ideally provide a bodily distal displacement, but distal tipping is often produced by distalizing appliances. Significant changes were observed in the first and second molar tipping that increased distally by 8.9°±8.3 and 8.2±8.1°, respectively. A previous systematic review has reported a molar distal tipping from 8.4° to 14.5° (9). This shows that the pendulum is not effective in pure distalization. As mentioned earlier, the eruption stage of the second molars can be a discriminating factor in the tipping amount. Furthermore, the ratio between the reference point and the center of rotation must be considered. The uprighting bends on the TMA loop also can be a reason for a decrease in the final molar tipping. Therefore, comparison with other studies is not always possible without a strict similarity of mechanical and environmental conditions.

Upper molars, first premolars, and upper incisors have vertically changed insignificantly. The pendulum is used to prevent molar extrusion by rigid bonding and intrusive forces exerted by the tongue. Maxillary molar eruption at the mean age of 12 years during the 8 months of distalizing treatment did not show statistically significant changes. The first molars intruded 0.1±1.6 mm and second molars extruded 0.1±2.4 mm using PP as a reference line, and these values seem to be insignificant, especially in the bite opening (SN-MP), which was 0.8°±3°. The mean values reported in the literature show an intrusion variable from 0.1 to 1.7 mm; it has been demonstrated that the pendulum does not create critical molar extrusion (9, 25). The design and activation of the modified pendulum provide an explanation for the result obtained because of the trajectory of the TMA loop, which contrasts with the normal eruption of the maxillary molar eruption during growth. The first premolars extruded 1.4±1.9 mm and incisors extruded 0.5±1.4 mm; these results are comparable with the incisor extrusion caused by the patient's growth and are in accordance with the previous studies that report extrusion on the premolar and incisor region (14). An explanatory statement is that the appliance itself rotates the maxilla around its center of rotation between the molars and premolars but without changing the opening of the skeletal bite. This rotation helps to prevent an increase in the vertical dimension despite a modified pendulum promoting bodily distal movement and smaller distal tipping.

The major disadvantage of distalizing techniques, common to all intraoral tooth-bonded distalization devices, is the forward drift of the anchoring units (21). The resulting loss of anchorage is stated by an uncontrolled mesial movement of the medial and anterior segments. The first premolars anchorage loss found was 2.7±3.3 mm mesial movement and 2.5°±5.1° mesial tipping. The mean distance obtained by molar distalization and anchorage loss was 5.5 mm, and the premolar anchorage loss represents 49% of the space opened. The systematic revision used as reference indicates a range between 24% and 46% of anchorage loss (9); a greater anchorage loss is probably because of uprighting bends that had been added to the TMA springs. Another effect of this device is incisor anchorage loss; the forces transmitted to anterior teeth and the movements exercised by the activated springs cause a movement of the anchored incisors (2). The amount of anchorage loss of the incisors in this study was 1.5±2.8 mm and 5°±3.6°. Throughout distalization, the upper incisors are proclined as a result of reaction forces that act first on the bonded premolars before being conducted to the incisor segment. Therefore, the pendulum could be more appropriate in Class II patients with a reduced incisor buccal inclination. Furthermore, the variability of results may be influenced by the early use of uprighting bends that provide a greater bodily movement, and the position of second molars could be an obstacle to first molar distalization at the expense of anchorage loss and time (23). Skeletal anchorage could be a strategy to prevent anchorage loss with the use of an anchored pendulum.

OP Changes

Numerous authors have attempted to explain the factors responsible for a successful Class II treatment, which could be the changes in the level of occlusal line and growth. The cant of the OP also describes a vertical trait, which may affect the mandibular position and solve a skeletal discrepancy. In fact, changes in the inclination of the OP can, in part, compensate for unfavorable skeletal factors outside the bite to create a normal occlusion (26). To date, no study has analyzed the relationship between the use of pendulum and OP changes, although some data are available. There are only a few studies available to compare the OP changes (3, 19, 20, 27-29). There is a wide agreement between the longitudinal data reported in the literature and data of this study, showing progressive horizontalization of the occlusal plan followed by simultaneous reduction in the mandibular plane angle as the mandible adapts.

The line that forms the OP is influenced by molar and incisal vertical position. Changes in the vertical position of both maxillary and mandibular teeth result in changes in the OP; as a result, the definition of OP can be the first discriminating factor, for example, bisected or functional OP (30). In addition, changes in the OP could depend on the changes in the reference plane: SN, PP, and MP.

A comparison of changes in the OP inclination between treated and untreated patients should be made, comparing the normal changes observed in growing patients by age. It is reported that between the age of 12 and 13 years, and SN-OP, PP-OP, and OP-MP have values of 19.4°, 10°, and 15°, respectively (6). Our study reported corresponding values of 19.8°, 11.7°, and 15.8°, respectively, at T1 and 19.3°, 11.2°, and 16.8°, respectively, at T2, after a mean time of 8 months of distalization. It is interesting to observe the trend of changes of these values before and after the pubertal growth spurt; as reported, SN-OP and PP-OP decrease, whereas OP-MP increases constantly. On an average, a counterclockwise rotation of the mandible and OP is expected with age, implying a correlation between OP inclination and mandibular repositioning during growth and skeletal development (31).

These changes in the orientation of OP play an important role in the anterior rotation that takes place during growth. It has been also reported that the OP rotates upward and forward an average of 6.1° between the ages of 6 and 16 years, which allows to manage and to possibly solve spontaneously a third of Class II discrepancies (7). As mentioned earlier, the pendulum itself rotates the maxilla around its center of rotation, whereas the maxillary teeth change their vertical position, and the combination of both events, concurrently normal growth of the dentofacial complex, does not seem to influence the natural tendency of the OP to rotate forward. The use of a distalizing appliance that does not influence the cant of the OP could be a strategy to not influence normal growth and favor not only dental but also skeletal correction of the Class II malocclusion.

PP-OP decreased 0.5°±0.1° after molar distalization. A reduction in this angle was also observed in growing patients with Class II; nevertheless, these values seem to be less important in the craniofacial complex development (31). OP-MP could be more meaningful, more expressive of type, and more expressive on the vertical positions of the teeth within the dentofacial complex; this angle is a measure of relative posterior alveolar height and also correlates with SN-MP (32). In this study, OP-MP increased insignificantly by 1°±3.4° after molar distalization, starting with a value of 15.8°±3.1°. The position of the occlusal line is determined principally by the vertical growth of both upper and lower teeth, and its inclination is defined mostly by the development of the dentoalveolar bone (31). It has been speculated that a control of extrusion in the mandibular arch prevents clockwise rotation of the mandible, which can lead to a worse vertical dimension and aggravate both skeletal and dental Class II discrepancies.

The cant of the OP is difficult to correlate with the changes produced by orthodontic treatment or normal growth, because it is necessary to consider many dental and skeletal values, including mandibular ones, and the function must also be considered. For clinicians, orthodontic treatment of the anteroposterior components of malocclusion could aim at changing the OP inclination, reducing it, possibly facilitating the adaptation of the mandible for an improved skeletal relationship with the maxilla (8). It is reasonable to assume that any variation in the occlusion would alter the jaw position in relation to the maxillary occlusal surfaces (31). Therefore, the main clinical implication could be to not tip the OP by raising the posterior end when a patient starts with high SN-MP values to prevent bite opening.

The main limitation of this study was the absence of a control group to compare the OP changes; unfortunately, there were no previous studies that evaluated the correlation between Class II malocclusion and its potential correction related to OP changes. As a preliminary study, the authors did not include a control group. Further studies are needed with a control group for comparison. Another limitation of this study was the observation time of the sample; all the patients were treated with a fixed orthodontic appliance after a period of approximately 4 months after molar distalization and Nance button retention. It may be interesting to evaluate the changes in the OP in patients treated only with distalization and following the craniofacial growth. Limitations of this study also include the evaluation of 3D landmarks on bidimensional cephalograms and potential bias from converting bilateral structures to single outlines; hence, 3D analysis should be addressed in further studies.

CONCLUSION

The pendulum appliance was effective in distalizing the first and second maxillary molars with negligible extrusion, moderate distal tipping, and moderate anterior anchorage loss. The pendulum appliance seems to take advantage of its biomechanics in not producing significant changes in OP inclination. Further long-term and controlled studies are needed to compare the present data.

Ethics Committee Approval: This study was approved by Ethics committee of University of Insubria of Varese (Italy), (Approval No: 18/2014).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – A.C.; Design – M.S., E.C.; Supervision – R.F., A.C.; Materials – E.C., A.C.; Data Collection and/or Processing – E.C., R.F.; Analysis and/or Interpretation – M.S., R.F.; Literature Search – M.S., E.C.; Writing Manuscript – M.S.; Critical Review – R.F., A.C.

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Original Article

Evaluation of Initial Stress Distribution and Displacement Pattern of Craniofacial Structures with 3 Different Rapid Maxillary Expansion Appliance Models: A 3-dimensional Finite Element Analysis

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Main points:

- All the appliances showed similar stress distributions.
- The maximum posterior expansion was achieved with the Hyrax appliance.
- The maximum anterior expansion was observed with the double-hinged appliance.
- Inferior maxillary displacement was the greatest with the Hyrax appliance.
- Anterior maxillary displacement was the greatest with the double-hinged appliance.

ABSTRACT

Objective: This study aimed to describe the displacement of anatomical structures and the stress distributions caused by the Hyrax, fan-type, and double-hinged expansion screws via the 3-dimensional (3D) finite element method (FEM).

Methods: The 3D FEM was based on the computed tomography data of a 12-year-old patient with a constricted maxilla. The Hyrax model included 1,800,981 tetrahedral elements with 2,758,217 nodes. The fan-type model included 1,787,558 tetrahedral elements with 2,737,358 nodes. The double-hinged model included 1,777,080 tetrahedral elements with 2,722,771 nodes. The von Mises stress distributions after 0.2 mm of expansion and displacement patterns after 5 mm of expansion were evaluated.

Results: The highest stress accumulation was observed in the sutura zygomatico maxillaris area with all 3 appliances. An increase in stress was noted at the pterygomaxillary fissure, the medial and lateral pterygoid process of the sphenoid bone, and the nasal areas. The wedge-shaped skeletal opening was observed with all 3 appliances. In the transverse plane, maximum posterior expansion was achieved with the Hyrax appliance, whereas the maximum anterior expansion was observed with the double-hinged appliance. The maxilla moved inferiorly and anteriorly with all the 3 appliances. The greatest inferior displacement of the maxilla was recorded with the Hyrax appliance, whereas anterior maxillary displacement was the greatest with the double-hinged appliance.

Conclusion: All the appliances showed similar stress distributions. The use of double-hinged screw caused a slight anterior displacement of point A. The fan-type and double-hinged appliances were shown to be more effective on anterior maxillary constriction, whereas the Hyrax appliance might be chosen for resolving maxillary posterior constriction.

Keywords: Finite Element Method, rapid maxillary expansion, transverse maxillary deficiency

INTRODUCTION

Rapid maxillary expansion (RME) is often needed to correct transverse discrepancies. RME is also used to correct the axial inclinations of the posterior teeth before functional jaw orthopedic or orthognathic surgery to mobilize the circummaxillary sutures, to reduce nasal resistance, and to broaden the smile (1).

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The positional changes of the skeletal and dental structures after RME have been evaluated and documented in previous studies (2-4). Some authors have reported that the anatomical resistance areas are the dentoalveolar complex, midpalatal suture, zygomatico maxillary buttress, and circummaxillary sutures (4, 5). Isaacson (1964) and Wertz (1970) (2, 6) have stated that the resistance occurring during RME is caused by the neighboring tissues, such as zygomatic and sphenoid bones, and not the suture itself.

In recent years, the finite element method (FEM) has been proven to be a great research method to solve various biomechanical problems in orthodontics (7, 8). The possibility of simulating different clinical conditions without subjecting the patients to possible harmful adverse effects is one of the most important advantages of this method (9).

For anterior constriction, 2 different screw designs, the fan-type (10, 11) and the double-hinged type (12,13), were introduced instead of the conventional expansion Hyrax screw, which has been reported to expand the anterior part compared with the posterior part of the maxilla (4, 14). Multiple FEM studies have analyzed the effects of RME on the craniofacial complex and dentition; however, the effects of the fan-type and double-hinged expansion screws have not been evaluated with FEM yet (7-9).

This study aimed to analyze the stress concentration areas and displacement of the bony units with 3 different RME appliances on the same patient-based 3-dimensional (3D) FEM.

METHODS

The digital imaging and communications in medicine data were imported into the Mimics version 10.01 software (Materialise, Leuven, Belgium), and the bone tissue was calibrated (15). A computer-aided model was constructed based on the dental volumetric tomography scan of a 12-year-old male patient presenting with maxillary constriction. The cone-beam computed tomography image was taken with an Iluma Imtec Imaging machine (3M, Ardmore, OK, USA [X-ray tube, 120 kV; X-ray tube current, 1-4 mA; scanning time, 40 seconds maximum and 7.8 seconds minimum; field of view, 14.2x21.1 cm; voxel size, 0.0936 mm; greyscale, 14 bit]) with the patient sitting in an upright position. The model containing only the nasomaxillary complex and the cranial bones was obtained by subtracting the mandibular and vertebral masks from the main mask (Figure 1).

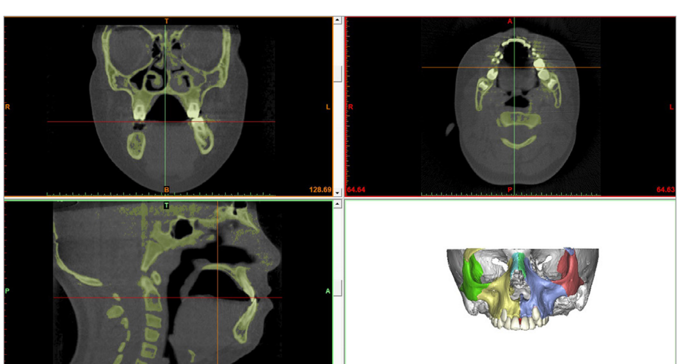

Figure 1. The digital imaging and communications in medicine images on Mimics software

Data of the models of the bony structures, teeth, and periodontium were exported to Geomagic Design X (Rock Hill, USA) and SOLIDWORKS 2016 software (SOLIDWORKS Corp, Waltham, Massachusetts, USA). Surface meshes were created; unwanted parts, such as overlaps, irregularities, roughness, and holes on the surface mesh structure, were arranged; and solid models were created for finite element analysis.

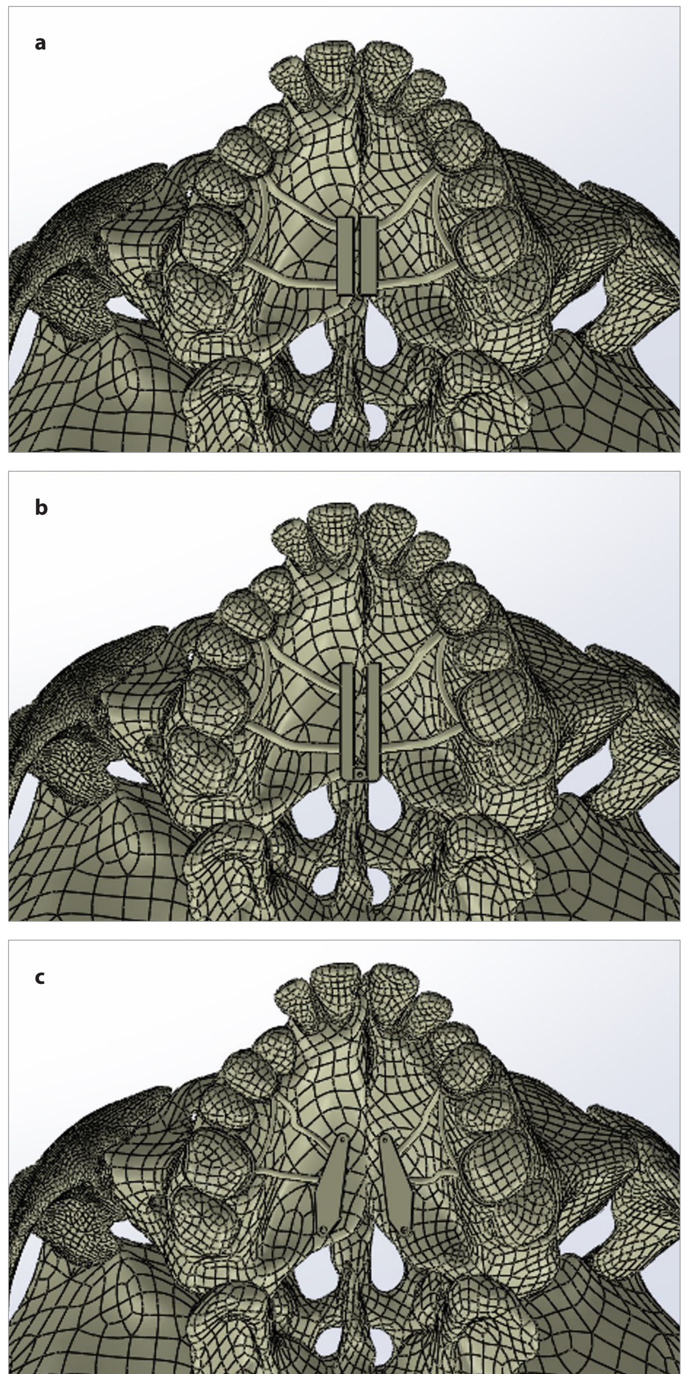

Figure 2. a-c. Modeling of the Hyrax appliance (a), modeling of the fan-type appliance (b), modeling of the double-hinged appliance (c)

Hyrax (Leone, Florence, Italy), fan-type (Leone, Florence, Italy), and double-hinged expanders (Bestdent, Kaoshiung, Taiwan) were modeled using SOLIDWORKS 2016. The screws were positioned parallel to the midpalatal suture, as close to the palate as possible (Figure 2a-2c).

ANSYS version 17.0 (Canonsburg, PA, USA) was used for the finite element analysis. The resulting volumetric Hyrax model included 1,800,981 tetrahedral elements with 2,758,217 nodes; the fan-type model included 1,787,558 tetrahedral elements with 2,737,358 nodes; And the double-hinged model included 1,777,080 tetrahedral elements with 2,722,771 nodes. Each element had a tetrahedral shape and included 10 nodes (Figure 3).

The teeth, cortical and cancellous bones, sutures, periodontal ligament, and stainless steel were considered to be homogenous and isotropic. The material properties, which were determined from the data of the previous studies, are shown in Table 1 (16-21).

Table 1. Young's modulus and Poisson's ratio used in this study

	Young's modulus (MPa)		Poisson's ratio
Compact bone	13,700	1	0.3
Cancellous bone	1,370	2	0.3
Suture	10	3	0.49
Tooth	20,290	4	0.3
PDL	0.68	5	0.49
Stainless steel	210,000		0.3

PDL: fibrous connective tissue that surrounds the root and connects to the alveolar bone

Nodes along the foramen magnum were determined as the boundary condition, and all the displacements were restricted to this area (Figure 4) (7, 8, 22). The 2 parts of the maxilla were separated so that they could move with expansion forces laterally with respect to the vertical plane of symmetry (7).

This study was approved by the ethics committee of the Bezmialem Vakıf university clinical research (15.09.2015-17/18). Using the data extracted from the archival dental volumetric tomog-

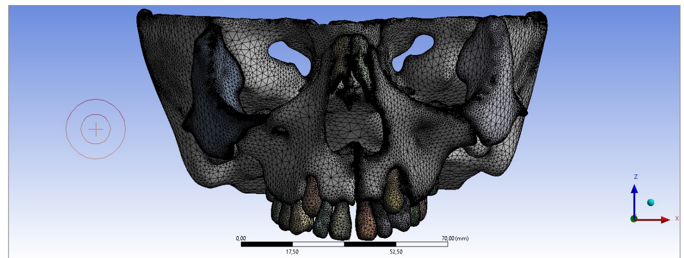

Figure 3. Finite element analysis solid model

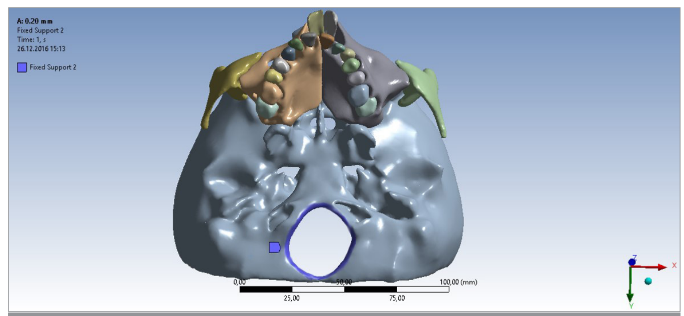

Figure 4. Boundary conditions

Table 2. Displacement of various skeletal structures (mm)

	Hyrax				Fan-type				Double-hinged		
Skeletal structures	X	Y	Z		X	Y	Z		X	Y	Z
Internasal suture	0.07	-0.26	-1.3	5.1	0.05	0	-0.61	5.2	-0.01	0.03	-0.47
Frontonasal suture	0.05	-0.36	-1.19	5.3	0.05	-0.07	-0.52	5.4	0.06	-0.01	-0.34
Frontomaxillary suture	0.02	-0.27	-1.05	5.5	0	-0.03	-0.43	5.6	-0.04	0.02	-0.24
Nasomaxillary suture	-0.03	-0.23	-1.15	5.7	-0.07	-0.02	-0.45	5.8	-0.16	-0.01	-0.28
Frontal process	-0.14	-0.2	-0.97	5.9	-0.21	-0.03	-0.3	5.10	-0.31	-0.03	-0.08
Zygomatico maxillary suture	-0.58	0.2	-0.19	5.11	-0.54	0.28	0.21	5.12	-0.73	0.15	0.47
Inferior orbital rim	-0.5	0.12	-0.23	5.13	-0.5	0.22	0.18	5.14	-0.71	0.22	0.46
Infraorbital foramen	-0.64	0.1	-0.5	5.15	-0.62	0.13	-0.01	5.16	-0.82	0.04	0.22
Zygomatic process	-0.76	0.34	-0.18	5.17	-0.67	0.29	0.17	5.18	-0.87	0.21	0.4
Lateral nasal cavity wall	-0.75	-0.13	-1.04	5.19	-0.79	-0.1	-0.33	5.20	-1.08	-0.22	-0.13
ANS	-1.24	-0.2	-1.34	5.21	-1.13	-0.24	-0.59	5.22	-1.44	-0.44	-0.39
Point A	-1.38	-0.1	-1.28	5.23	-1.23	-0.18	-0.53	5.24	-1.54	-0.38	-0.32
PNS	-0.63	-0.25	-1.11	5.25	-0.55	-0.26	-0.49	5.26	-0.73	-0.47	-0.37
Pterygomaxillary fissure	-0.38	0.25	-0.11	5.27	-0.31	0.16	0.15	5.28	-0.46	0.08	0.3
Medial pterygoid (inferior)	-0.47	0.17	-0.26	5.29	-0.36	0.05	0.01	5.30	-0.5	-0.08	0.09
Medial pterygoid (superior)	-0.05	-0.05	-0.21	5.31	-0.06	-0.05	0		-0.1	-0.01	0.02
Lateral pterygoid (inferior)	-0.43	0.23	-0.07	5.32	-0.32	0.12	0.14	5.33	-0.46	0.02	0.25
Lateral pterygoid (superior)	-0.16	0.11	-0.08		-0.16	0.09	0.12		-0.22	0.04	0.19

ANS: Anterior point on maxillary bone; PNS: Posterior point of palatine bone

Table 3. Displacement of various dentoalveolar and dental structures (mm)

	Hyrax				Fan-type				Double-hinged		
Dentoalveolar and dental structures	**X**	**Y**	**Z**		**X**	**Y**	**Z**		**X**	**Y**	**Z**
Apical region of incisor	-1.5	0	-1.21	6	-1.32	-0.14	-0.48	7	-1.75	-0.4	-0.34
Apical region of canine	-1.13	0.04	-0.91	8	-1	-0.02	-0.26	9	-1.29	-0.17	-0.04
Apical region of premolar	-1.3	0.33	-0.56	10	-1.07	0.19	-0.04	11	-1.39	0.04	0.19
Apical region of molars	-0.96	0.41	-0.23	12	-0.78	0.29	0.14	13	-1.02	0.18	0.35
Incisal edge of incisor	-2.01	0.16	-1.33	14	-1.8	-0.08	-0.54	15	-2.21	-0.41	-0.31
Palatinal cusp tip of canine	-1.67	0.36	-0.82	16	-1.31	0.1	-0.16	17	-1.72	-0.12	-0.04
Palatinal cusp tip of molar	-1.55	0.37	-0.53		-0.84	0.26	-0.03		-1.35	0	0.11

Table 4. Von Mises stress distribution of various skeletal structures (MPa)

	Von Mises (Mpa)		
Skeletal structures	**Hyrax**	**Fan-type**	**Double-hinged**
Internasal suture	1.12	1.72	2.23
Frontonasal suture	1.27	1.57	1.59
Frontomaxillary suture	2.63	2.17	2.36
Nasomaxillary suture	2.51	2.07	2.16
Frontal process	1.55	0.53	0.58
Zygomatico maxillary suture	6.39	4.32	4.46
Inferior orbital rim	0.07	0.01	0.33
Infraorbital foramen	1.24	0.74	1.88
Zygomatic process	1.97	0.92	2.13
Lateral nasal cavity wall	1.2	0.87	1.22
ANS	0	0	0
Point A	0.01	0	0
PNS	0.04	0.01	0.05
Pterygomaxillary fissure	4.86	3.66	4.26
Medial pterygoid (inferior)	0.18	0.05	0.11
Medial pterygoid (superior)	3.19	1.49	2.54
Lateral pterygoid (inferior)	0.18	0.1	0.12
Lateral pterygoid (superior)	2.52	1.39	2

ANS: Anterior point on maxillary bone; PNS: Posterior point of palatine bone

Table 5. Von Mises stress distribution of various dentoalveolar and dental structures

	Von Mises (Mpa)		
Dentoalveolar and dental structures	**Hyrax**	**Fan-type**	**Double-hinged**
Apical region of incisor	0	0	0
Apical region of canine	0.45	0.63	0.71
Apical region of premolar	0.29	0.37	0.44
Apical region of molar	0.88	0.23	0.53
Incisal edge of incisor	0	0	0
Palatinal cusp tip of canine	0.06	0.11	0.13
Palatinal cusp tip of molar	0.26	0.19	0.19

raphy scan images of a 12-year-old male patient with maxillary transverse deficiency, 3D finite element models were generated with institutional review board approval. The parents/legal guardian of the patient previously signed an informed consent form stating that his archival data could be used for scientific purposes.

RESULTS

The 3D coordinates were recorded for various craniofacial structures before and after the screw activation in all 3 dimensions (X-axis-positive value: lateral movement, X-axis-negative value: medial movement, Y-axis-positive value: posterior movement, Y-axis-negative value: anterior movement, Z-axis-positive value: inferior movement, Z-axis-negative value: superior movement). Positive changes indicated lateral, posterior, and inferior displacements. The von Mises stress distribution was recorded after 0.2 mm of expansion, and the displacement of the structures was evaluated after 5 mm of expansion (Tables 2-5).

In this study, the von Mises stress distributions were investigated after the initial 0.2 mm of activation as in previous studies (28). In the literature, there are many of finite element analysis studies that have investigated the skeletal effects with different amounts of maxillary expansion (7, 8, 22, 28-30). In some of these studies, displacement patterns were investigated based on moderate maxillary transverse deficiency after 5 mm expansion as in our study (15). A similar method was followed to allow the comparison of the results.

Displacement Pattern in the X-axis

A wedge-shaped opening was observed with all 3 appliances. In the transverse plane, the maximum posterior expansion was achieved with the Hyrax appliance (1.55 mm), whereas the maximum anterior expansion was observed with the double-hinged appliance (2.21 mm).

In the internasal and front maxillary suture area, slight medial displacement was observed with the Hyrax and fan-type appliances, whereas slight lateral displacement was observed with the double-hinged appliance.

The lateral nasal walls showed lateral displacement with all 3 appliances; 0.75 mm, 0.79 mm, and 1.08 mm lateral displacements were observed with the Hyrax, fan-type, and double-hinged appliances, respectively.

The inferior parts of the pterygoid plates showed greater displacements than the superior parts (Tables 2 and 3).

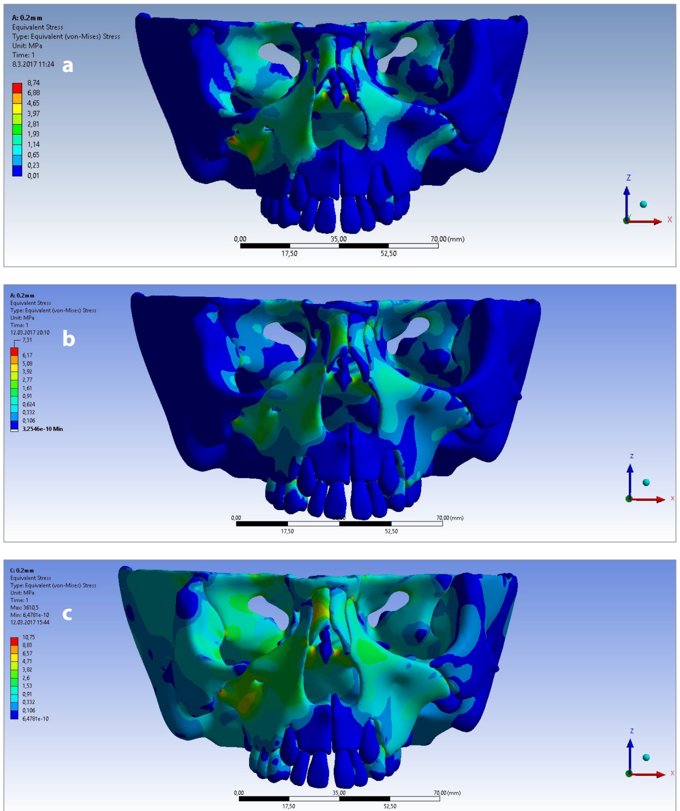

Figure 5. a-c. Stress distribution for the Hyrax appliance (a), stress distribution for the fan-type appliance (b), stress distribution for the double-hinged appliance (c)

Displacement Pattern in the Y-axis

The maxilla moved anteriorly with all 3 appliances. The greatest anterior displacement of the maxilla was recorded with the double-hinged appliance (1.44 mm).

The lateral nasal walls showed anterior displacement with all 3 appliances; 0.13 mm, 0.1 mm, and 1.22 mm anterior displacements were observed with the Hyrax, fan-type, and double-hinged appliances, respectively.

The dentoalveolar complex moved posteriorly with the Hyrax appliance (central incisor-0.16 mm), whereas anterior displacement was recorded with the fan-type (central incisor-0.08 mm) and double-hinged appliances (central incisor-0.41 mm) (Tables 2 and 3).

Displacement Pattern in the Z-axis

The maxilla moved inferiorly with all 3 appliances. The greatest inferior displacement of the maxilla was recorded with the Hyrax appliance (1.34 mm).

The maxilla rotated posteriorly with anterior nasal spine (ANS) showing more inferior displacement than posterior nasal spine (PNS) with the Hyrax and fan-type appliances, whereas parallel movement occurred with the double-hinged appliance.

The lateral nasal walls showed inferior displacement with all 3 appliances; 1.04 mm, 0.33 mm, and 0.13 mm inferior displacements were observed with the Hyrax, fan-type, and double-hinged appliances, respectively.

When all the anatomical structures were evaluated in the vertical plane, greater inferior displacement was recorded with the Hyrax appliance than the fan-type and double-hinged appliances (Tables 2 and 3).

Von Mises Stress Pattern

The stress distribution with the initial 0.2 mm of expansion is presented in a color band, with different colors representing various stress levels, where red indicates areas with the highest stress and blue indicates the lowest stress (Figure 5a, b, and c.)

The highest stress accumulation was observed in the sutura zygomatico maxillaris area (Hyrax=6.39 MPa, fan type=4.32 Mpa, double-hinged=4.46 MPa) with all 3 appliances.

An increase of stress was noted at the pterygomaxillary fissure and medial and lateral pterygoid plates of the sphenoid bone and the nasal areas. When all the anatomical structures were evaluated overall, the stress distributions were found to be the highest with the Hyrax expansion screw, and the lowest values were recorded with the fan-type expansion screw (Tables 4 and 5).

DISCUSSION

Previous orthodontic FEM studies used shell elements for meshing the models (7, 8). However, we used tetrahedral elements with 10 nodes, which have previously been proven to provide better stress transmissibility and bending deformations, for mesh generation (22).

The number of elements that constitute the working model and the number of nodes that each element includes are important factors affecting the sensitivity and reliability of the finite element analysis. In previous studies, Işeri et al. (7) used 2,349 elements and 2,147 nodes; Jafari et al. (8) used 6,951 elements and 7,357 nodes; and Gautam et al. (22) used 108,799 elements and 193,633 nodes. The models used in this study included approximately 1,800,000 volumetric elements and 2,750,000 nodes.

In our study, the wedge-shaped opening was observed with all 3 appliances. In the transverse plane, the maximum posterior expansion was achieved with the Hyrax appliance and the maximum anterior expansion was observed with the double-hinged appliance. Several studies have explained the wedge-shaped opening in the anteroposterior plane as a result of the resistance generated in the pterygomaxillary connection (2, 6). The difference between the opening patterns is thought to be related to the screw design.

The maxilla moved inferiorly and anteriorly with all 3 appliances in the vertical and sagittal planes. The inferior and anterior movement of the maxilla resulting from the RME procedure has been previously reported in many studies (2, 7, 8, 22, 23). Sicher (24) reported that the maxillocranial sutures produce inferior and anterior movement of the maxilla after the RME. Wertz (2) suggested that separation of the maxillary complex from the pterygoid process could allow significant anterior movement of the maxilla. Gardner and Kronman (23) related the anterior maxillary displacement to the opening of the spheno-occipital synchondrosis. However, Da Silva Filho et al. (25) found no sagittal movement related to the maxilla, but they reported changes in the vertical plane and inferior displacement.

Taking into account the displacement pattern of the maxilla, Dr. Liou (12) designed the double-hinged expansion screw. He stated that the double-hinged appliance provided a greater anterior displacement of the maxilla with less chance of bone resorption behind the maxillary tuberosity. He also stated that the double-hinged appliance significantly displaced the maxilla more anteriorly compared with the Hyrax appliance in an experimental study in 14 cats (13). This finding is similar to that of our study. The highest anterior displacement was observed with the double-hinged screw. We believe that the design of the double-hinged screw moves the center of rotation of the maxilla during opening behind the area of tuberosity, causing the forward movement of the maxilla.

Doruk et al. (10) compared the effects of the Hyrax and fan-type appliances and reported that the maxilla moved inferiorly and anteriorly in both the groups. Their findings showed that the fan-type appliance also forced the maxilla anteriorly more than the Hyrax appliance. The authors argued that the fan-type appliance had a buttressing effect on the skeletal structures behind the maxilla, which explained the rotational opening (10). In this study, the greatest maxillary inferior displacement was recorded with the Hyrax appliance, whereas the anterior maxillary displacement was the greatest with the double-hinged appliance.

The maxilla rotated posteriorly with the Hyrax and fan-type appliances, whereas parallel movement occurred with the double-hinged appliance. Other studies reported varying degrees of anterior or posterior rotation. Işeri et al. (7) and Gautam et al. (8) reported the posterior rotation of the maxilla with RME in contrast with Jafari et al. (22) who found anterior maxillary rotation.

In the nasal area, a slight medial displacement was observed with the Hyrax and fan-type appliances, whereas slight lateral displacement was observed with the double-hinged appliance. Multiple studies have reported medial displacement of the nasal structures after REM (7, 22). Medial displacement of the nasal area might lead to compression of the tissues. This phenomenon explains the frequent dizziness and the pressure and tension in the nasal bridge, under the eyes, and around the cheekbones reported during palatal expansion therapy (4, 22).

The lateral nasal walls were displaced laterally, inferiorly, and anteriorly with all 3 appliances. These findings show similarities with previous reports, and the movement of the lateral nasal walls and inferior movement of the nasal floor could cause a reduction in the airway resistance (4, 7, 8, 22).

With all 3 appliances, the lateral and medial pterygoid plates showed lateral bending; the inferior portion was displaced more than the superior part, in agreement with the results of previous research (7, 8, 22). This is because the pterygoid plates are more resistant to bending in the parts that are closer to the cranial base (3). Similarly, in our study, lower stress levels were noted for the inferior parts of the plates, and higher stress levels were reported for the superior parts.

Doruk et al. (10) reported that Hyrax caused palatal tipping of the upper incisors, whereas the fan-type appliance caused labial tipping of upper incisors. Similarly, in this study, palatal tipping of the upper incisors was recorded with the Hyrax appliance and labial tipping of upper incisors was recorded with the fan-type and double-hinged appliances (10).

When all the anatomical structures were evaluated in the vertical plane, a tendency toward inferior displacement was recorded with the Hyrax appliance. This is in agreement with the findings of previous studies (2, 25). However, some studies reported that expanded vertical dimensions decrease after the retention phase and the changes that occur are not permanent (26, 27).

Previous studies reported that the main resistance to RME occurred not only in the median palatal suture but also in the sphenoid and zygomatic bones (8, 14).

Işeri et al. (7) observed large amounts of stress accumulation in the canine and molar areas in the maxillary arch, on the lateral sides of the inferior nasal cavity, on the pterygoid plates of the sphenoid bone, and on the zygomatic and nasal bones with RME. Jafari et al. (8) reported that the greatest stress accumulation was seen in the internasal, nasofrontal, and nasomaxillary sutures. Gautam et al. (22) found maximum stress accumulation along the frontomaxillary, nasomaxillary, and frontonasal sutures.

In this study, the maximum stress accumulation was observed in the sutura zygomatico maxillaris area with all 3 appliances. An increase of stress was noted at the pterygomaxillary fissure, medial and lateral pterygoid plates of the sphenoid bone, and the nasal areas. The overall stress distribution values were found to be the highest with the Hyrax expansion screw, and the lowest values were recorded with the fan-type expansion screw.

Similar to the results of our study, Matsuyama et al. (28) found the highest stress levels in the zygomatic process, pterygomaxillary fissure, and tuberous maxilla area with RME. Lee et al. (29) found the highest stress levels in the zygomatico maxillary suture. Mac Ginnis et al. (30) reported high stress levels in the zygomatico maxillary suture, zygomatic process, lateral pterygoid plate, and palatine bone.

Although RME is mainly performed for correcting transversal problems, different vertical and sagittal effects may occur depending on the choice of the appliance. This study aimed to shed light on the selection of the most appropriate expansion appliance according to the skeletal and dental relationship of the patients, either in the vertical or sagittal planes. However, the limitations of the FEM studies, especially the absence of soft tissue, should be considered. Further studies modeling soft tissues also should be performed to better simulate the clinical scenario. A similar study could be performed *in vivo* with identical triplets presenting with similar maxillary constriction, although it would be difficult to find suitable patients.

Despite all its advantages, it should be noted that finite element analysis is a simulation scenario created by researchers. It requires a computer with sufficient hardware equipped with expensive software that needs regular updates. Another disadvantage is that it requires some presumptions (homogeneous, linear, and isotropic) to simplify the real situation as it is not possible to model all of the complex anatomical structures or to consider all their mechanical properties. There are also other disadvantages, such as the need for detailed information transfer regarding the material properties, loading of the applied forces into the system, and the extensive time required to perform the analysis. In this study, only the initial displacements and stress distributions were studied, which could be considered a limitation considering the dynamic nature of the real clinical application.

CONCLUSION

The following conclusions can be drawn per the results of our study:

1. A wedge-shaped opening was observed, and the maxilla moved inferiorly and anteriorly with all 3 appliances.
2. The maxilla rotated posteriorly with the Hyrax and fan-type appliances, and parallel movement occurred with the double-hinged appliance.
3. The dentoalveolar complex moved posteriorly with the Hyrax appliance, whereas anterior displacement was recorded with the fan-type and double-hinged appliances.
4. The maximum stress was found in the sutura zygomatico maxillaris with all 3 appliances.

Some clinical projections to be considered are the use of fan-type and double-hinged expansion appliances in cases where the maxillary constriction is located more anteriorly. However, the Hyrax appliance may be preferred in patients with excessive posterior constriction. The double-hinged and fan-type appliances seem to be more advantageous for providing vertical control compared with the Hyrax appliance and thus should be preferred in patients with increased vertical height. Considering the displacement of the dental structures, it might be hypothesized that the Hyrax appliance could play an auxiliary role in camouflage treatment of dental Class II malocclusion and the double-hinged appliance in the treatment of the dental Class III malocclusion. Nevertheless, these suggestions need to be justified with further clinical studies.

Ethics Committee Approval: This study was approved by Ethics Committee of Bezmialem Vakif University, (Approval No: 15.09.2015-17/18).

Informed Consent: Verbal and written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – B.Y., S.İ.R.; Design – B.Y., S.İ.R., M.S.; Supervision – B.Y., S.İ.R.; Resources – M.S.; Materials – M.S.; Data Collection and/or Processing – M.S.; Analysis and/or Interpretation – M.S.; Literature Search – B.Y., M.S.; Writing Manuscript – B.Y., M.S.; Critical Review – B.Y., S.İ.R.

Conflict of Interest: The authors have no conflict of interest to declare.

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Original Article

Effect of Low-Level Laser Therapy on Peri-Miniscrew Fluid Prostaglandin E2 and Substance P Levels: A Controlled Clinical Trial

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Main points:

- Inflammation, which can damage the bone surrounding the neck of the miniscrew, is one of the main causes of miniscrew loosening.
- In this study, the biostimulatory effects of low-level laser therapy were evaluated for its clinical efficacy.
- It was concluded that gallium-aluminum-arsenide diode laser therapy has no effect on inflammation and pain around the miniscrews.

ABSTRACT

Objective: This study aims to evaluate the effect of low-level laser therapy on peri-miniscrew fluid prostaglandin E2 (PGE2) and substance P (SP) levels during orthodontic treatment.

Methods: A total of 15 individuals were included in this study. Miniscrews were inserted to the inter-radicular region of the maxillary right and left second premolar and the first molar teeth, and diode lasers were randomly applied to the right or left side. Irradiation was performed at 940 nm wavelength using a gallium-aluminum-arsenide diode laser with 100 mW power output, 0.125 cm2 spectral area, 8 J/cm2 energy density, and 10 seconds of exposure time. Peri-miniscrew fluid samples were collected on the 1st, 3rd, and 7th days, and PGE2 and SP levels were assessed. For statistical comparison, two-way (factors) analysis of variance with repeated measurements on one-factor levels was used at statistical significance (p) of <0.05.

Results: PGE2 levels on the 1st, 3rd, and 7th days were 160.64±10.05, 135.17±37.18, and 98.57±22.94, respectively, in the control group and 150.75±9.08, 87.17±40.67, and 78.10±16.50, respectively, in the laser group. SP levels on the 1st, 3rd, and 7th days were 79.90±12.05, 64.61±10.05, and 70.05±9.10, respectively, in the control group and 76.32±11.39, 60.25±9.08, and 65.71±5.59, respectively, in the laser group. The differences in PGE2 and SP levels between the laser and control groups were not statistically significant at all time intervals.

Conclusion: Low-level laser therapy cannot be recommended as a clinical adjunct therapy to reduce inflammation and pain around the miniscrews.

Keywords: Inflamation, miniscrew, pain, PGE2, SP

INTRODUCTION

Anchorage, which has a critical role in the success of orthodontic treatment, is defined as resistance to undesired tooth movement (1). Because the use of traditional anchorage enhancement methods, such as headgear and intra-oral elastic, are patient dependent, the use of dental implants, miniplates, and miniscrews that require less patient cooperation have become more widespread (2, 3). In addition, miniscrews have advantages over miniplates and dental implants, such as their small size, availability of many inserting regions in the oral cavity, low cost, and easy application and removal (4). However, early loss is the most common clinical challenge in using miniscrews (5).

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Inflammation, which can damage the bone surrounding the neck of the miniscrew, is one of the main causes of miniscrew loosening (6, 7). Immediately after miniscrew insertion, the traumatized area suffers ischemic injury and deficiency of nutrients and oxygen supply, which may cause apoptosis of the injured cells (8, 9). To achieve tissue integrity, the healing process must include an inflammatory response and tissue formation and remodeling (8).

The use of low-level laser therapy, carried out with appropriated protocols, increases collagen synthesis and fibroblast proliferation and influences cellular and subcellular processes needed to increase the formation of messenger RNA, adenosine triphosphate synthesis, and lymphocytic action to initiate and promote the healing process (10, 11). Furthermore, low-level laser therapy decreases inflammatory reactions and pain by increasing local blood circulation, inhibiting inflammatory substance secretion, inducing neurotransmitter release, altering the conduction and excitation of the peripheral nerves, and stimulating endorphin release (12, 13).

Clinical, histological, biomechanical, and biochemical examinations are based on the evaluation of miniscrew stabilization. Biochemical examination is a non-invasive and simple method in which the peri-miniscrew fluid is used for evaluating the build-up and destructive levels of the tissues surrounding the miniscrew (14). Only 1 study in the literature has used biochemical assessments to explore the effect of low-level laser therapy on miniscrew stability (15). In this study, interleukin-6 (IL-6) levels elevated in the later stage of the inflammatory response were explored. Furthermore, IL-8 levels, which can be detected at high levels in healthy and diseased periodontal tissues, were analyzed (16). However, no study has evaluated prostaglandin E_2 (PGE_2) and substance P (SP) levels. PGE_2 is known to affect the fibroblasts and osteoclasts that induce the synthesis of IL-1β and other cytokines. In addition, SP released from nerve endings plays an important role in inflammation (17, 18).

In light of this information, we aimed to study the effect of low-level laser therapy on peri-miniscrew PGE_2 and SP levels, which are important cytokines in the inflammatory and pain responses. The alternative hypothesis was that low-level laser therapy may reduce inflammation and pain around the miniscrews.

METHODS

A total of 15 individuals to be treated with fixed orthodontic appliances at Van Yüzüncü Yıl University, Faculty of Dentistry, Department of Orthodontics, were included in this study. The following inclusion criteria were applied: no previous fixed orthodontic treatments, cephalometric evaluation and model analysis indicating upper 2 premolar teeth extraction, good general health conditions, healthy periodontal tissues, and individuals younger than 18 years with completed permanent dentition. Individuals who were pregnant or lactating, had used antibiotics within the previous 6 months, and had poor oral hygiene were excluded from the study.

The study was conducted after the approval of Van Yüzüncü Yıl University, Faculty of Medicine, Ethics Committee (08.10.2015/07). After a detailed explanation of the study, informed consent was obtained from all participants.

Miniscrews (ACR, Seoul, Korea, 1.6 mm wide, 7 mm length) were inserted in the inter-radicular region of the maxillary right and left second premolar and molar teeth (19). Stainless steel wire (0.017 inch×0.025 inch) was passively bent between the miniscrew and auxiliary tube of the maxillary first molar to increase the anchorage in the posterior region. Subsequently, maxillary first premolar teeth extractions were performed, and fixed orthodontic treatment using 0.018-slot Roth brackets (Victory Series, 3M Unitek, Monrovia, California) was carried out.

The upper jaws of patients irradiated by the diode laser represented the laser group, and patients with non-irradiated jaws represented the control group. The sealed-envelope technique was used to select whether the right or left side would be irradiated. The soft tissue surrounding the miniscrew was irradiated with a 940 nm wavelength of gallium-aluminum-arsenide diode laser with 100 mW power output, 0.125 cm^2 spectral area, 8 J/cm^2 energy density, and 10 seconds of exposure time (Figure1). The tip was held perpendicular and in contact with the mucosa during the laser procedure. Diode laser irradiation was applied by a single investigator over the miniscrew insertion area on the buccal and palatinal surfaces on days 1, 3, and 7.

Figure 1. Diode laser device

Figure 2. Collection of peri-miniscrew fluid

Table 1. Descriptive statistics for patient age (years)

	n	Age (mean±SD)	Maximum	Minimum	p
Female	8	17.40±1.45	18	14	0.495
Male	7	16.85±1.57	18	14	
Total	15	17.15±1.48	18	14	

SD: Standard deviation

Table 2. PGE_2 levels (pg/mL) in control and laser groups

	Control group (mean±SD)	Laser group	p
1st day	160.64±10.05	150.75±9.08	0.915
3rd day	135.17±37.18	87.17±40.67	0.397
7th day	98.57±22.94	78.10±16.50	0.478

*Two-way (factors) analysis of variance with repeated measurements on one-factor levels (interaction is not statistically significant)
PGE_2: prostaglandin E2; SD: Standard deviation

Table 3. SP levels (pg/mL) in control and laser groups

	Control group (mean±SD)	Laser group	p
1st day	79.90±12.05	76.32±11.39	0.833
3rd day	64.61±10.05	60.25±9.08	0.483
7th day	70.05±9.10	65.71±5.59	0.703

*Two-way (factors) analysis of variance with repeated measurements on one-factor levels (interaction is not statistically significant)
SP: Substance P; SD: Standard deviation

Peri-miniscrew fluid samples were collected on the 1st, 3rd, and 7th days by placing paper strips of standard size (Periopaper, Gingival Fluid Collection Strips, Oraflow, Smithtow, NY, 11787) onto the mesiobuccal and distobuccal regions of the miniscrew. During the sampling process, the region was dried with sprayed air for a short time and then isolated with cotton rolls to avoid contamination from saliva and blood (Figure 2). The samples contaminated with blood and exudate were excluded from the study. All periopapers were kept in the crevice for 30 seconds and then put into sterile Eppendorf tubes containing 500 µL phosphate-buffered saline (pH 7.0) and stored at –40°C until the day of analysis.

A PGE_2 Enzyme Immunoassay (EIA) kit and an SP EIA kit (Cayman Chemicals, AnnArbor, MI) were used to determine PGE_2 and SP levels. Analysis of samples was carried out according to the manufacturer's recommended protocol using enzyme-linked immunosorbent assay method. Peri-miniscrew fluid samples were collected from the laser and control groups on days 1, 3, and 7. The stability of miniscrews at all time intervals was also evaluated clinically, and no failure was observed.

Statistical Analysis

Sample size calculation

Because the standard deviation (SD) (s) of IL-1β levels ranged from 2.5 to 3.2 pg/mL in a previous study, this study established these levels as 2.8 pg/mL (20). Furthermore, for the 0.05 type I error rate, the effect size and Z value were assumed to be 1.5 and 1.96, respectively. On the basis of this information and according to the sample size equation ($n=Z^2s^2/d^2$), the minimum sample size was calculated to be 13.38 (@13). To account for a 20% follow-up loss, we rounded up the number to 15 participants.

The Statistical Package for the Statistical Package for Social Sciences version 23.0 software (IBM Corp.; Armonk, NY, USA) was used for statistical analysis. The results were expressed as means and SD, as well as maximum and minimum values. The Kolmogrov-Smirnov test was applied to assess whether the data were normally distributed. To compare the groups (independent factors: control and laser) and time (dependent factors: 1st, 3rd, and 7th days), two-way (factors) analysis of variance with repeated measurements on one-factor level was performed. The significance level in the calculations was taken as 5%.

RESULTS

A total of 8 patients in the study group were women (mean age: 17.40 years, SD: 1.45 years) and 7 men (mean age: 16.85 years, SD: 1.57 years). There was no statistically significant difference between sexes in terms of mean age and patient count (Table 1).

In the control group, means and SDs of PGE_2 levels were 160.64±10.05 pg/mL, 135.17±37.18 pg/mL, and 98.57±22.94 pg/mL on days 1, 3 and 7, respectively. In the laser group, means and SDs of PGE_2 levels were 150.75±9.08 pg/mL, 87.17±40.67 pg/mL, and 78.10±16.50 pg/mL on days 1, 3, and 7, respectively. The differences in PGE_2 levels between the laser and control groups on days 1, 3, and 7 were not statistically significant ($p>0.05$) (Table 2).

In the control group, means and SDs of SP levels were 79.90±12.05 pg/mL, 64.61±10.05 pg/mL, and 70.05±9.10 pg/mL on days 1, 3, and 7, respectively. In the laser group, means and SDs of SP levels were 76.32±11.39 pg/mL, 60.25±9.08 pg/mL, and 65.71±5.59 pg/mL on days 1, 3, and 7, respectively. The differences in SP levels between the laser and control groups were not statistically significant (Table 3).

DISCUSSION

The results of this study that investigated the effect of low-level laser therapy on peri-miniscrew PGE_2 and SP levels led to insignificant differences between the laser and control groups. Therefore, the alternative hypothesis was fully rejected.

In recent years, the application of low-level lasers has become popular for their biostimulatory effects, such as acceleration of healing, reduction of inflammation, and alleviation of pain (21). The biostimulatory effect might be influenced by the optical properties of tissues and the type, wavelength, energy density, power, and exposure time of the lasers (22). The gingiva contains fibrous connective tissue and associated extracellular matrix components, as well as a high content of water and melanin (23). Moreover, deeper penetration of the lasers into the soft tissue depends on the wavelength or low absorption coefficient in water (21). Therefore, among the carbon dioxide (CO_2), neodymium: yttrium-aluminum-garnet, and diode lasers that could be used in soft tissues, we preferred diode lasers in our study because of their low absorption coefficient in water compared with that of the CO_2 laser, good absorption by pigmented tissue, and selective targeting of inflamed tissue (23, 24).

The most suitable wavelength range for biostimulation is reported to be 600–1,000 nm (11, 13). Moreover, because low-power output and longer exposure time are known to best reduce the inflammatory process and pain, dosages of 1–20 J/cm^2, light powers of 10–100 mW, and durations from 10 seconds to 2.7 minutes irradiation are recommended (13, 25). The 940-nm gallium-aluminum-arsenide diode laser used in this study with 100 mW power output, 8 J/cm^2 energy density, and 10 seconds of exposure time was observed to be within the recommended ranges.

Although the measurement intervals of peri-miniscrew pro-inflammatory cytokines vary among studies, Sari et al. (20) found a significant increase in IL-1β levels on the 1st day and a decrease to the baseline level on the 7th day. Furthermore, Yanaguizawa et al. (15) reported significant increases in IL-6 and IL-8 levels in the first 3 days, indicating the beginning of inflammatory response. Therefore, in this study, peri-miniscrew fluid evaluations were performed on days 1, 3, and 7.

Human studies exploring the effect of low-level laser therapy on miniscrew stability exhibit conflicting results. Although miniscrew stability was evaluated clinically in 3 of them, it was examined biochemically through cytokines in 2 studies (8, 11, 15, 26). Osman et al. (8), who evaluated miniscrew stability using a periotest device, concluded that diode laser therapy (910 nm, 0.7 W, 60 s) can be recommended as a clinical adjuvant to increase the success of miniscrews. Similarly, the results of another study using a periotest device have also shown an increase in the secondary stability of miniscrews after diode laser therapy (635 nm, 100 mW, 100 s) (11). However, in a study by Abohabib et al. (26), which evaluated miniscrew stability with an Osstell implant stability quotient device, the effect of diode laser therapy (940 nm, 1.7 W, 60 s) was not shown to be clinically useful. The controversial findings between the study results might be owing to the different laser parameters and measurement devices. In our study, miniscrew stability was evaluated clinically without a measurement device, and no failures were observed in either group.

When the studies in which miniscrew stability was evaluated biochemically through cytokines were examined, it was determined that among the pro-inflammatory cytokines, IL-1β, IL-2, IL-6, and IL-8 were explored (15, 20, 27). Besides, only in the study by Yanaguizawa et al. (15) evaluating IL-6 and IL-8 levels, the effect of diode laser therapy (660 nm, 40 mW, 1 min, 2.4 J of total energy) on initial infection was examined at 24, 48, and 72 hours. The results showed a significant increase in IL-8 levels in the control group at all time intervals, as well as an increase in IL-6 levels in the laser group 24 hours after miniscrew application (15).

No study in the literature has evaluated the peri-miniscrew PGE_2 and SP levels after laser therapy. In our study, the effect of gallium-aluminum-arsenide diode laser therapy (940 nm, 100 mW, 0.125 cm^2, 8 J/cm^2, 10 s) on PGE_2 and SP levels, which are important cytokines in inflammation and pain, was evaluated at 1, 3, and 7 days. As a result, insignificant differences were determined between the laser and control groups at all time intervals.

A short observation period, small sample size, and lack of information on the clinical periodontal status of patients were the main limitations of this study. Therefore, further studies involving a larger sample size and a longer follow-up period and using different laser wavelengths, energy densities, application periods, and protocols are recommended.

CONCLUSION

Although a decrease in PGE_2 and SP levels was observed in the laser group, the differences between the groups were not statistically significant. Considering the limitations of this study, it appears that gallium-aluminum-arsenide diode laser therapy has no effect on inflammation and pain around the miniscrews, which was evaluated by means of PGE_2 and SP levels.

Ethics Committee Approval: This study was approved by Ethics committee of Van Yüzüncü Yıl University, (Approval No: TSA-20186757).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

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Original Article

Assessment of the Relationship between Skeletal Maturity and the Calcifications Stages of Permanent Canines and Second Premolars

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Main points:

- Evaluation of tooth calcification stages is an alternative approach for identifying individual skeletal maturity.
- The calcification stages of permanent canines and second premolars show satisfactory demonstrative performance of assessing the pre-pubertal phase.
- The subjects of this study showed precocious puberty.

ABSTRACT

Objective: This study aimed to evaluate the relationship between the calcification stages of permanent maxillary and mandibular canines and second premolars and skeletal maturity in both sexes.

Methods: This study included 138 patients (82 females, 56 males) who were treated in the Department of Orthodontics, Altınbaş University. The mean age of the patients was 12.31±1.76 years, ranging from 7.8 years to 15.8 years. Dental maturity stages of canines and second premolars were evaluated according to the Demirjian index on digital panoramic radiograph. The skeletal maturation stage was determined using the cervical vertebral maturation (CVM) index. The Pearson correlation analysis was performed to assess the association among CVM stages and calcification stages of canines, second premolars, sex, and chronological ages.

Results: A statistically significant correlation was found between CVM and the calcification stages of the canines and second premolars ($p<0.05$). The calcification stages of the canines and second premolars had the highest distribution of Stage F and Stage G at CVM2 ($p<0.01$). For the canines and second premolars, Stage H corresponded to CVM3 in female patients and a high percentage of Stage G corresponded to CVM3 in the male group.

Conclusion: A significant correlation was found between the calcification stages of maxillary and mandibular canines, second premolars, and skeletal maturity in both sexes. It was observed that calcification stages and cervical maturations were advanced in female subjects compared with male subjects.

Keywords: Tooth calcification stages, digital panoramic radiography, skeletal maturity

INTRODUCTION

Skeletal maturity plays a key role in orthodontics and dentofacial orthopedics when treating growing orthodontic patients. In various malocclusions, optimal treatment time is critical. For instance, early Class III treatment using protraction facemasks with skeletal expansion is more efficiently performed at the pre-pubertal period, whereas the functional appliances for Class II treatment are more efficient at the growth peak stage when incorporated in the treatment. Nevertheless, as there are notable variations regarding the development among children of the same age, the role of chronological age in the evaluation of skeletal maturation does not matter (1). Discrepancies between chronological and biological ages showed a need for maturity indicators, such as morphological age, skeletal age, sexual age, and dental age (2). The most commonly used

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techniques for growth evaluation are physical indicators, which are based on the overall body changes, such as the appearance of sexual characteristics and the evaluation of the hand-wrist radiographs, lateral cephalometric radiographs, or digital panoramic radiographs (3-6).

Numerous researchers have evaluated the cervical vertebral maturation (CVM) index, which determines the growth stage according to morphological shapes of the second, third, and fourth cervical vertebrae in lateral cephalometric radiographs (7, 8). Similarly, hand-wrist radiographic evaluation is an important diagnostic tool used in ascertaining whether pubertal growth has started, is still occurring, or has finished (9). Tooth calcification is a more dependable indicator of dental maturity than tooth eruption because it is not influenced by factors such as early loss of primary teeth, missing spaces, maturation, caries, ankyloses, and malocclusions, in addition to genetic control (10).

The most widely used method for estimating dental maturation or dental age was described in 1973 by Demirjian et al. (10). This method is based on the development of 7 left permanent mandibular teeth. Most of the studies using Demirjian's method have reported overestimation (11, 12). For Turkish population, there are studies that have shown both overestimation and convenience (13-15).

The CVM method is accepted as a precise method for evaluating the growth stage; however, it requires a lateral cephalogram to be taken from every patient, which is currently controversial (16, 17). In recent research, lateral cephalometric radiographs have not been taken routinely. Instead, digital panoramic radiographs are routinely obtained in orthodontic practice and are beneficial for evaluating dental maturity. It could be said that the evaluation of dental maturity is an alternative to the CVM method (18-20).

An established link between permanent tooth calcification stages and CVM may assist in ascertaining the skeletal maturity of the patient on the digital panoramic radiograph. Numerous studies have been performed using a similar method (18-22). Permanent canines have primary roles in determining functional occlusion and disturbances of normal development and its eruption may have major consequences (23).

This study aimed to evaluate the correlation between calcification stages of permanent canines and second premolars and skeletal maturity to assess whether this correlation among those teeth may be used as a reliable diagnostic tool for skeletal maturity assessment. The null hypothesis of the study is that no correlation exists between calcification stages of the permanent canines, second premolars, and CVM.

METHODS

The protocol of this retrospective research was evaluated and approved by the clinical sciences ethical board of Altınbaş University (2020/6). Signed informed consents of the patients treated at the Department of Orthodontics at Altınbaş University between December 2018 and January 2020 were obtained. The study group included 138 Caucasian orthodontic patients (82 females, 56 males) treated in the Department of Orthodontics, Altınbaş University. To determine whether the correlation between the calcification stages of the canines and premolars and skeletal maturity, power analysis was performed with G*Power Ver. 3.1.9.7 (Franz Faul, Universität Kiel, Germany) software (with the two-tailed hypothesis, α=0.05, f=0.30, power=0.95). The mean age of the patients was 12.31±1.76 years, ranging from 7.8 years to 15.8 years. The mean age of the female and male patients was 12.32±1.72 and 12.35±1.83 years, respectively. The minimum age of the patients was 7.8 years and maximum age was 15.6 years. The exclusion criteria were as follows: presence of any congenital anomalies, no congenitally missing mandibular second premolar, development/systemic disorders, nutritional deficiencies, and prolonged illnesses and patients who were undergoing or had previously undergone orthodontic treatment. An experienced orthodontist analyzed pretreatment digital panoramic radiographs and lateral cephalometric radiographs of the patients, which were taken according to the standard technique for evaluating cranial structures, using a NewTom-Giano Imaging System machine (CeflaGroup, Verona, Italy) by the same technician.

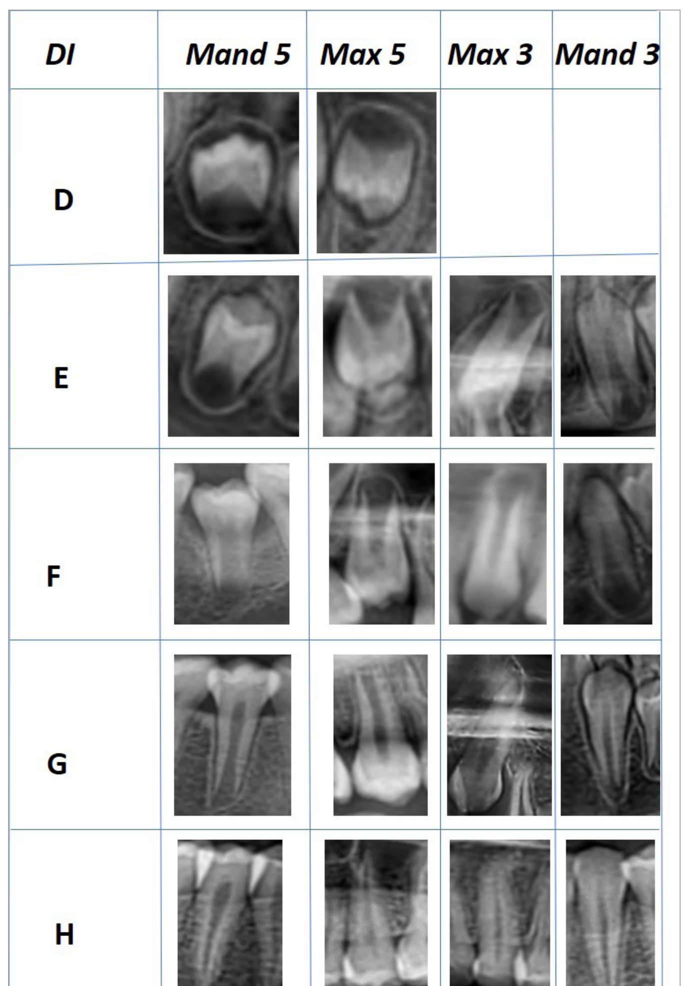

Figure 1. Classification of the dental maturation stages used in this study according to the Demirjian index method (10)

The calcification stages of canines and second premolars were evaluated. We chose canines and second premolars because, usually, these teeth are the last erupted teeth. The maxillary canine should erupt at the same time as the second premolar (24).

The calcification stages of the canines and second premolars were evaluated according to the Demirjian method (DI), in which 1 of the 8 stages of calcification (A to H) was assigned to the tooth (10) (Figure 1).

Evaluation of skeletal maturity was carried out using CVM index, and, the method proposed by Baccetti et al. (7), lateral cephalograms. The second, third, and fourth cervical vertebrae (C2, C3, and C4) were examined according to their shapes and grouped into 1 of the 6 stages in CVM (Figure 2).

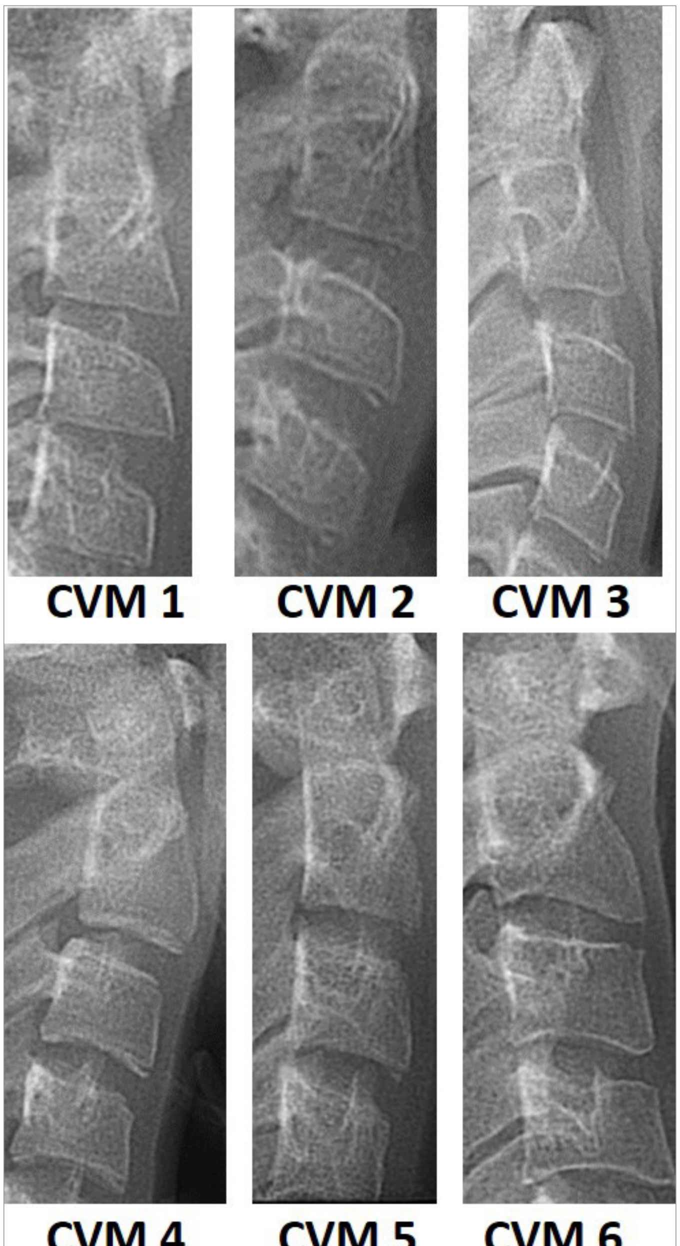

Figure 2. Evaluation of skeletal maturity stages used according to the method described by Baccetti et al. (7)

Statistical Analysis

Analysis of the data was conducted using the package program Statistical Package for the Social Sciences (SPSS) version 16 (SPSS for Windows, SPSS Inc., Chicago, IL, USA). The mean, standard deviation, frequency, and percentage of the DI stages and CVM were calculated, and the Shapiro–Wilk normality test was applied to the data. The Pearson correlation analysis was adopted to assess the association among CVM stages of canines, second premolars, sex, and chronological ages., evaluation of randomly selected. The lateral cephalometric and digital panoramic radiographs of 10 randomly selected patients were re-evaluated at an interval of 15 days to determine intra-rater reliability, and Pearson correlation coefficients were calculated as being in the range of 0.780–0.864. Statistical significance was set at $p<0.05$.

RESULTS

Table 1 shows chronological distribution of the CVM stages for the female and male groups. According to the results, maturation of the female group was earlier than that of the male group. In all the CVM stages, the average maturation age of the female group was lower than that of the male group.

Table 2 shows the distributions between the CVM stages and the calcification stage of the maxillary canines. Stage G DI showed the highest percentage distribution (50%) for female patients at CVM2 (pre-peak of pubertal growth spurt), whereas Stage F was observed in 66.67% of the male patients at CVM2. In the CVM3 (peak of pubertal growth spurt) stage calcification, Stage G was observed in 52.63% of the male patients, whereas Stage H was observed in 69% of the female patients. In contrast, the highest percentages were observed between the DI Stage H and CVM4 (deceleration of growth spurt), CVM5, and CVM6 stages (post-peak of pubertal growth spurt) in both male and female groups.

Table 1. Chronological distribution of CVM stages for female and male groups

			Ages (years)	
CVM Stages	**Sex**	**N**	**Mean**	**Standard deviation**
CVM1	Female	5	8.93	0.49
	Male	5	10.34	1.19
CVM2	Female	8	9.94	1.22
	Male	9	10.52	1.84
CVM3	Female	13	11.88	1.01
	Male	19	12.31	1.03
CVM4	Female	17	12.45	0.89
	Male	12	13.02	1.27
CVM5	Female	34	13.16	1.45
	Male	11	14.01	1.12
CVM6	Female	5	13.60	0.66
	Male	1	15.80	0.00

CVM: Cervical vertebral maturation; N: number of patients

Table 2. The distributions between CVM stages and calcification stages of maxillary canines; descriptive statistic was used

CVM stages		Calcification stages, n (%)				Total
		E	F	G	H	
CVM1	Female	4 (80)	1 (20)			5 (100)
	Male	1 (20)	1 (20)	3 (60)		5 (100)
CVM2	Female	1 (12)	3 (38)	4 (50)		8 (100)
	Male	1 (11.11)	6 (66.67)	2 (22.22)		9 (100)
CVM3	Female			4 (31)	9 (69)	13 (100)
	Male		3 (15.79)	10 (52.63)	6 (31.58)	19 (100)
CVM4	Female			3 (18)	14 (82)	17 (100)
	Male			3 (25)	9 (75)	12 (100)
CVM5	Female			3 (9)	31 (91)	34 (100)
	Male			1 (10%)	9 (90)	10 (100)
CVM6	Female				5 (100)	5 (100)
	Male				1 (100)	1 (100)
Total	Female	5	4	14	59	82
	Male	2	10	19	25	56

CVM: cervical vertebral maturation

Table 3. The distributions between CVM stages and calcification stages of mandibular canines; descriptive statistic was used

CVM stages		Calcification stages, n (%)				Total
		E	F	G	H	
CVM1	Female	2 (40)	3 (60)			5 (100)
	Male		3 (60)	2 (40)		5 (100)
CVM2	Female		4 (50)	3 (37.5)	1 (12.5)	8 (100)
	Male		4 (44.44)	5 (55.56)		9 (100)
CVM3	Female			6 (46.15)	7 (53.85)	13 (100)
	Male		1 (5.26)	11 (57.90)	7 (36.84)	19(100)
CVM4	Female			1 (5.88)	16 (94.12)	17 (100)
	Male		3 (25)	9 (75)	12 (100)	3 (25)
CVM5	Female			3 (8.83)	31 (91.17)	34 (100)
	Male				10 (100)	10 (100)
CVM6	Female			3 (8.83%)	31 (91.17)	34 (100)
	Male				1 (100)	1 (100)
Total	Female	2	7	13	60	82
	Male		8	21	27	56

CVM: Cervical vertebral maturation

Table 3 shows the percentage distributions between DI stages of mandibular canines and CVM stages. DI Stage F included the highest distribution (50%) at CVM2. Similar to the other CVM stages, Stage H was found in both sexes (male, 36.84%; female, 53.85%) for mandibular canine.

Tables 4 and 5 present the relations of the DI stages and CVM stages for mandibular and maxillary second premolars. Both tables show the DI Stage H at CVM4, CVM5, and CVM6 (from 76.47% to 100% for female and from 83.3% to 100% for male), while observing the differences at the CVM2 stage.

The correlations between the CVM stages, calcification stages of the canines and second premolars, sex, and chronological ages are shown in Table 6. A significant correlation was found between the calcification stages of the maxillary canine and the second premolar ($r=0.911$, $p\leq0.01$).

DISCUSSION

This study was performed to determine the relationship between the CVM stage and the calcification stages of permanent canine and second premolars and whether these stages can be used as indicators to determine the skeletal maturity of the CVM in both sexes.

Skeletal maturation exhibited fluctuation compared with chronological age**.** As a result, the effectiveness of chronological

Table 4. The distributions between CVM stages and calcification stages of maxillary premolars; descriptive statistic was used

		Calcification stages, n (%)					
CVM stages		**D**	**E**	**F**	**G**	**H**	**Total**
CVM1	Female	3 (60)	2 (40)				5 (100)
	Male	1 (20)	1 (20)	1 (20)	2 (40)		5 (100)
CVM2	Female		4 (50)	1 (12.5)	3 (37.5)		8 (100)
	Male	1 (11.11)	2 (22.22)	2 (22.22)	4 (44.44)		9 (100)
CVM3	Female			3 (23.08)	4 (30.77)	6 (46.15)	13 (100)
	Male		1 (5.26)	1 (5.26)	10 (54.6)	7 (36.84)	19 (100)
CVM4	Female				4 (25.53)	13 (76.47)	17 (100)
	Male				2 (16.67)	10 (83.33)	12 (100)
CVM 5	Female				5 (14.71)	29 (85.29)	34 (100)
	Male					10 (100)	10 (100)
CVM 6	Female					5 (100)	5 (100)
	Male					1 (100)	1 (100)
Total	Female	3	6	4	16	53	82
	Male	2	4	4	18	28	56

CVM: Cervical vertebral maturation

Table 5. The distributions between CVM stages and calcification stages of mandibular premolars; descriptive statistic was used

		Calcification stages, n (%)					
CVM stages		**D**	**E**	**F**	**G**	**H**	**Total**
CVM 1	Female	1 (20)	2 (40)	2 (40)			5 (100)
	Male	1 (20)		2 (40)	2 (40)		5 (100)
CVM 2	Female		2 (25)	4 (50)	2 (25)		8 (100)
	Male	1 (11.11)	3 (33.33)	2 (22.22)	3 (33.33)		9 (100)
CVM 3	Female		1 (7.69)	3 (23.08)	2 (15.39)	7 (53.85)	13 (100)
	Male		1 (5.26)	2 (10.52)	10 (52.64)	6 (31.58)	19 (100)
CVM 4	Female			1 (5.88)	8 (47.06)	8 (47.06)	17 (100)
	Male				7 (58.33)	5 (41.67)	12 (100)
CVM5	Female			1 (2.94%)	8 (23.53)	25 (73.53)	34 (100)
	Male				3 (30)	7 (70)	10 (100)
CVM6	Female					5 (100)	5 (100)
	Male					1 (100)	1 (100)
Total	Female	1	5	11	20	45	82
	Male	2	4	6	25	19	56

CVM: Cervical vertebral maturation

age regarding the assessment of the maturation status is ambiguous (25, 26).

Digital panoramic and cephalometric radiographs are used as routine diagnostic methods in orthodontic treatment. It is easy to assess dental maturation using digital panoramic radiographs (5, 18), and the DI could be used for evaluating the maturation of tooth calcifications (10). DI is based on shape criteria and the proportion of root length. In this study, DI stages of teeth were considered instead of eruption because calcification stages are anticipated as a more reliable criterion for assessing dental maturation (10).

The CVM method was used for evaluating skeletal maturity, as stated by Baccetti et al. (7), on lateral cephalograms. Researchers have found that CVM is an efficient method for assessing skeletal maturity (8, 18-21). In this study, skeletal maturation was evaluated using the method by Baccetti et al. (7) instead of the method by Hassel and Farman (8). The method by Baccetti et al. is the modified and refined version of the CVM and is valid for the appraisal of mandibular skeletal maturity in light of the findings of recent studies.

Kumar et al. (20) have revealed that each cervical stage consistently appears earlier in females than in males. These findings are similar to those of this study. In contrast, the association between CVM and DI is examined separately for male and female patients. Previous studies have shown that DI stages in male patients tend to be earlier than cervical stages in female patients (5,

Table 6. Correlation between the CVM, calcification of maxillary canine and second premolar, sex, and ages; Pearson correlation coefficients were performed

		max canine	mand canine	max premolar	mand premolar	sex	age
CVM	Pearson correlation	0.724**	0.692**	0.709**	0.649**	-0.262**	0.688**
	Sig. (two-tailed)	0.01	0.01	0.01	0.01	0.002	0.01
max canine	Pearson correlation	1.000	0.886**	0.911**	0.826**	-0.084	0.673**
	Sig. (two-tailed)		0.01	0.01	0.01	0.326	0.01
mand canine	Pearson correlation	0.886**	1.000	0.875**	0.785**	-0.046	0.589**
	Sig. (two-tailed)	0.01		0.01	0.01	0.595	0.01
max premolar	Pearson correlation	0.911**	0.875**	1.000	0.866**	0.020	0.595**
	Sig. (two-tailed)	0.01	0.01		0.01	0.818	0.01
mand premolar	Pearson correlation	0.826**	0.785**	0.866**	1.000	-0.003	0.601**
	Sig. (two-tailed)	0.01	0.01	0.01		0.976	0.01
sex	Pearson correlation	-0.084	-0.046	0.020	-0.003	1.000	-0.028
	Sig. (two-tailed)	0.326	0.595	0.818	0.976		0.739
age	Pearson correlation	0.673**	0.589**	0.595**	0.601**	-0.028	1.000
	Sig. (two-tailed)	0.01	0.01	0.01	0.01	0.739	

CVM: Cervical vertebral maturation; ** p≤0.01

20, 27, 28). It was also discerned that at the same cervical stage, male patients had more advanced trends in DI than female patients in this study.

According to the recent studies, the associations between the CVM indicator and maxillary and mandibular canine and second molar calcification are acceptable for both female and male patients; these teeth could be indicators for growth stages (19, 20). This finding of the present study is consistent with previous studies. Canines and second premolars can be used as indicators of skeletal maturation.

Obvious correlations were observed between the DI of canines and second premolars. Kumar et al. (20) have assessed the maturation stages of maxillary canines. They found that the DI Stage E of maxillary canines was essentially distributed for CVM2 and was indicative of growth status in the early stages (pre-pubertal; Stage F). However, in our study, the DI stages of maxillary and mandibular canines were between Stages G and F at CVM2 in the female group. It was found that mandibular and maxillary second premolars were in DI Stage E by the time CVM2 was reached. The highest distribution of Stage F at CVM2 was revealed at the pre-peak phase of the mandibular growth spurt. In this study, the Stage F calcification of the mandibular canine and second premolar coincided well with the CVM Stage 2. Džemidžić et al. (21) and Mittal et al. (29) have reported similar results in their studies. This means that the Stage F calcification of mandibular canines and second premolars could be used for assessing the pre-pubertal phase.

Kamal et al. (13) have reported that mandibular canines are in the DI Stages G and H by the time CVM3 was reached. They also pointed out that the second premolars were found to be in Stages F and G with CVM3. Mittal et al. (29) have found that the second mandibular premolars, which were in Stage F of the DI, corresponded to CVM3. In our study, the Stage G calcification of the second mandibular premolar was observed at CVM3 in male patients. Moreover, a high percentage was found in Stage H at CVM3 in the female group, whereas the DI Stage G was at CVM3 in the male group for maxillary canines. However, for female patients, the Stage H calcification of the mandibular canine showed the highest percentage of distribution at CVM3. These results comply and are parallel to the results obtained by Džemidžić et al. (21*)*. In contrast, the calcification stages, which are advanced in this study compared with those in the previous studies, revealed that Stage F corresponded to CVM3 (18, 20, 27, 29). According to the method described by Baccetti et al. (7), growth at CVM3 is still accelerating toward peak velocity, whereas at CVM4, adolescent growth begins to decelerate. In this study, canine and second premolar root formation was complete (Stage H) in the majority of female patients at CVM3. Observing Stages G and H in CVM3 in children aged 7-9 years may be the result of precocious puberty. It is presumable that the reason for such precocious puberty is exposure to pharmacological insecticides and, especially for females, the use of cosmetic products (30).

Stage H calcification of maxillary and mandibular canines coincided well with CVM4, CVM5, and CVM6 for both sexes in our study. The DI Stage H suggests insignificant or no remaining adolescent growth. These results are consistent with the results of other similar studies (20, 21).

Uysal et al. (31) have argued that the second molar teeth were the most correlated teeth with the skeletal maturity stage in terms of calcification stage. They showed that the highest correlation was in the third molar teeth. However, the authors have suggested that completion of the mandibular canine and the first premolar root formation can be used as an indicator of maturity for a pubertal growth spurt. Krailassiri et al. (28) have demonstrated that the second premolar was the tooth showing the highest correlation with skeletal maturity. Trakinienè et al. (19) have found that maxillary canines and mandibular second molars and third molars were good predictors of the growth phase. Our findings corresponded with the findings of other studies: the mineralization stages of canines and second premolars were a good predictor of skeletal maturity. In this study, a correlation was found between the calcification stages of canines and second premolars.

Determination of the pubertal growth stage is very important for planning orthopedic force application. Functional appliances could have a greater skeletal effect when they are used in this period, whereas they have greater dental changes after the growth has ended. In this study, canine maturation occurred earlier in female patients than in male subjects. In addition, studies have revealed that the relationship between the dental calcification stages and skeletal maturity indicators in patients with cleft lip palate may potentially allow determination of the stages of the pubertal growth period on panoramic radiograph; the findings of this study can be used in such patients in the future (32, 33).

Numerous studies have been performed to determine the reliability of the DI for Turkish children in different regions of Turkey. Özveren and Serindere (13) have studied in the Aegean region of Turkey; Sen Tunç and Koyutürk (34) have studied in Northern Turkey; and Çelikoğlu et al. (14) have studied Eastern Turkey; thus, they have stated that DI may not be suitable for Turkish children in the specific regions. However, Apaydın and Yaşar (15) have shown that DI is appropriate and recommended for Turkish children ranging in age from 5 to 15 years. Our study was conducted in Turkey's largest city; it is not representative of any ethnic regions.

This study was limited by a number of factors, including a small number of patients and the limitations owing to the nature of DI. The DI is based on the shape and proportion of root length, using its relative value to crown height rather than its absolute length. Thus, the panoramic distortions of the developing teeth will not affect the reliability of estimation. Another limitation of DI is the tendency toward overestimation of a patient's age (35). It can be recommended that periapical dental radiograph could be used for evaluation of DI in future studies.

CONCLUSION

A significant correlation was found between the calcification stages of maxillary and mandibular canines and second premolars and skeletal maturity in both sexes. The calcification stages of maxillary and mandibular canines and second premolars showed a satisfactory diagnostic performance to assess skeletal maturity. The evaluation of sexes showed that females reach skeletal maturity earlier than males do.

The calcification stages of canines and second premolars had the highest distribution of Stages F and G at CVM2. This means that Stage F calcification of mandibular canines and second premolars could be used for assessing the pre-pubertal phase.

It was found that Stage H corresponds to CVM3 in female patients and a high percentage of Stage G corresponds to CVM3 in the male group.

Observing the DI Stage H at CVM4 demonstrated the deceleration of the pubertal growth spurt; CVM5 and CVM6 represented post-peak pubertal growth spurts. For both sexes, canine root formation was complete (Stage H) in the majority of patients at CVM5 and CVM6. This means that the majority of patients in this study were at precocious puberty. The findings of this study indicate that the time to commence orthodontic treatment might be earlier in female than in male patients. In contrast, owing to precocious puberty, orthodontic treatment can be started at the beginning of CVM2.

Ethics Committee Approval: The study was approved by the Clinical Sciences Ethical Board of Altınbaş University (Approval No: 2020/6).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – E.O., S.A.; Design – E.O, S.A.; Supervision – E.O., S.A; Resources – E.O.; Materials – S.A.; Data Collection and/or Processing – S.A..; Analysis and/or Interpretation – E.O.; Literature Search – E.O, S.A.; Writing Manuscript – E.O; Critical Review – S.A.

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Original Article

The Relationship between Posttreatment Smile Esthetics and the ABO Objective Grading System: Class I Extraction versus Non-Extraction Cases

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Main points:

- The goal of this study was to evaluate the relationship between the American Board of Orthodontics (ABO) objective grading system and post-treatment smile esthetics in Class I extraction versus non-extraction cases.
- Extremely poor Pearson correlation coefficients were found between the components of the ABO grading system and the average Q-scores of smiles.
- The total scores of both groups acquired from the ABO grading system and Q-scores of the captured smile showed no relevance at all.
- Combined results presented weak correlations among the parameters of the ABO grading system and smile esthetics. Logistic regression showed that a beautifully articulated dental cast with parallel roots did not necessarily result in an attractive smile.
- There was no relationship between smile esthetics and ideal post-treatment occlusion in Class I extraction vs non-extraction cases.

ABSTRACT

Objective: This study aimed to evaluate the relationship between the components of the objective grading system developed by the American Board of Orthodontics (ABO) and smile esthetics in Class I extraction vs non-extraction cases.

Methods: A total of 40 extraoral smile images of orthodontically treated (20 extraction and 20 non-extraction) cases in the age group of 13-30 years and Class I skeletal malocclusion with an average mandibular plane angle were selected. Smile images were rated only by the orthodontist, and this panel included 12 members. Scoring of post-treatment dental casts and panoramic radiographs of each patient was performed by 1 investigator per the guidelines of the ABO grading system. The Pearson correlation coefficient and logistic regression analysis were used to ascertain whether the scores of the ABO grading system could foretell whether a smile would be "attractive" or "unattractive."

Results: The correlation between all the criteria of the ABO grading system and attractiveness of the smile was extremely weak. The r values ranged from -0.53 to 0.37 for extraction cases and -0.63 to 0.003 for non-extraction cases ($p>0.05$). Neither individual parameters nor total scores of the ABO grading system could predict whether the smile was attractive or unattractive in either group.

Conclusion: No correlation was found between post-treatment ABO grading and smile esthetics in patients with extraction or non-extraction. Hence, this study recommends that ancillary soft tissue variables have to be incorporated into the grading system to evaluate a smile.

Keywords: ABO Objective Grading System, smile esthetics, Q-Sort

INTRODUCTION

A beautiful smile can act as a powerful communication tool. With the advent of digitization, patients are becoming more aware and specific with their treatment outcomes, especially their smile esthetics. Proper alignment of teeth with good occlusion is thought to be a fundamental component of an attractive smile (1). Smile esthetics

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encompasses various factors, including dentition and surrounding soft tissues (2). It is also one of the critical factors in evaluating orthodontic treatment outcome.

A common treatment modality in orthodontics is tooth extraction. There is almost always a dispute concerning the outcome of smile esthetics after extraction and non-extraction orthodontic therapy. Usually, we presume that extraction results in narrowing of the dental arches, thereby increasing the buccal corridors, and resulting in an unesthetic smile. Johnson and Smith (3) stated that the smile esthetic scores obtained and visible dentition while smiling were the same in patients with both extraction and non-extraction. Unlike non-extraction treatment, extraction treatment did not result in the narrowing of the intercanine arch width. Previous studies have evaluated frontal smile esthetics in post-treatment frontal smiling photos and found that the esthetic scores of both the extraction and non-extraction groups were insignificant (4-8).

Evaluation of the orthodontic treatment outcome helps to set certain treatment goals, establish orthodontic treatment standards, and achieve a measurable finish for patients after completion of their orthodontic treatment (9,10). The American Board of Orthodontics (ABO) grading system is a valid and reliable index to assess the post-treatment occlusal outcomes according to 8 different occlusal and radiographic components (11). Soft tissue components are not considered in the ABO grading system. No other studies have yet compared the outcome of smile esthetics with post-treatment results between extraction and non-extraction orthodontic treatment cases. Hence, this study aimed mainly to evaluate the relationship between the components of the ABO objective grading system and smile esthetics after orthodontic treatment in Class I extraction and non-extraction cases. Clinical significance of this study is that smile esthetics is not dependent on ideal occlusion or post-treatment outcome (ABO Grading System) in either extraction or non-extraction groups. The hypothesis is that when the outcomes of smile esthetics using post-treatment ABO grading system between extraction and non-extraction orthodontic treatment cases are correlated, they should show a significant difference between the 2 groups, whereas the null hypothesis is that there is no significant difference between the 2 groups.

METHODS

Patient Selection

The study protocol was reviewed and approved by the institutional ethical board. Ethical clearance was obtained from the institutional ethical committee before the commencement of the study (Ref: CODS/2427/201819). All the patients enrolled in this study were from the Department of Orthodontics and Dentofacial Orthopedics at College of Dental Sciences, Davangere who appeared during a regular post-treatment consultation. Written informed consent was procured from the patients who participated in this study; for patients below the age of 18 years, a legal guardian was asked to sign their consent form.

Inclusion criteria for the study included: age group of 13-30 years; skeletal Class I malocclusion; average mandibular plane i.e., the angle between the sella-nasion line and the mandibular plane (SN/MP=32°); completion of orthodontic treatment within the previous 6 months, either with non-extraction therapy or with 4 premolar extraction therapy; full set of post-treatment diagnostic records; South Indian Ethnicity .

To determine the sample size, power analysis was conducted on the basis of the previous study (12), a two-tailed test with $\alpha \leq 0.05$ which provided 90% power to detect the difference between the means at a significance level of 5% using a 2-sided t test; intra-class correlation coefficient of 0.94 and 95% confidence interval was also achieved to ensure an adequate sample size. A sample size of 40 patients with completed orthodontic treatment (20 extraction and 20 non-extraction) who met the inclusion criteria was selected. The extraction group included 14 men and 6 women with an average age of 18.25±4.4 years. The non-extraction group included 16 men and 4 women with an average age of 20.25±1.8 years, and the mean difference between the 2 groups was 2 years.

All the patients were treated with Gemini MBT prescription pre-adjusted edgewise brackets with 0.022x0.028 inch slots (3M Unitek Corporation, Monrovia, California, USA).The sequence of archwire was: nickel titanium, 0.014-inch, 0.016-inch, 0.018x0.025 inch, 0.019x0.025 inch; stainless steel (SS) 0.019x0.025 inch. During space closure, an elastic chain with SS 0.025-inch ligature wire was tied on the first molar hook to the anterior arch hook placed between the canine and lateral incisor and used for en-masse retraction of the anterior teeth using sliding mechanics in extraction cases, and elastomeric chains were used for space closure in non-extraction cases. The elastic chains were changed on a monthly appointment basis followed by finishing and detailing of the case.

Capturing of 40 Extraoral Smile Images of Orthodontically Treated Patients

All the images were captured by the same photographer. This study used only extra-oral smile images. A mounted Nikon FM10 SLR camera (Nikon Corporation, Cosina, Japan) 35 mm was used. A distance of 36 inches was fixed between the lens and the subject. A lighting source of 1 strobe was used to indirectly illuminate the patient using flash, a photographic umbrella was used to avoid any reflective diffusion, and all of this was connected to the camera. The patient was instructed by the photographer to "smile" before taking the photo. A posed smile is voluntary, and it is far more reproducible. Hence used for research purposes.

The photograph was imported using a software program for image editing (Adobe Systems Incorporated, San Jose, California, USA). Standardization of size and location on all the images were performed by designing a 3x5 inch template (Figure 1).Superimposition of the template on top of the photograph was performed by Adobe Photoshop software version 7.0 (Adobe Systems Incorporated, San Jose, California, USA).Superimposition was performed by enlarging the smile images until the outer commissures of the lips matched with the vertical tick marks inset, which were three-quarters of an inch from the border of the template. Then smile photograph were positioned such that maxillary incisal edges coincided with the templates' horizontal line.

Healing brush tool in Adobe Photoshop was used to erase any skin aberration, blemishes, or spots in the resulting photograph so that this would not influence the rater when evaluating them. A 4-digit unique number was randomly chosen to label the finished images. Compressed photograph of 150 KB was achieved at the end of complete editing, and this was saved as joint photographic expert's group file type. The images were shown to the raters in a random order on a Microsoft Office PowerPoint 2007 presentation (Microsoft, Redmond, WA, USA).

Rater Selection

Smile images were rated only by the orthodontist. Clinical experience of the empaneled orthodontists ranged from 1 to 5 years, and there were 8 men and 4 women in this panel aged between 26 and 36 years (they were selected from the institution's orthodontic program and were graduates of the same university).

Q-sort Method

In 1953,Stephenson (13) first proposed this method, which was an alternative approach for large samples and could create

Figure 1. A standardized smile photograph using the 3x5 inch template

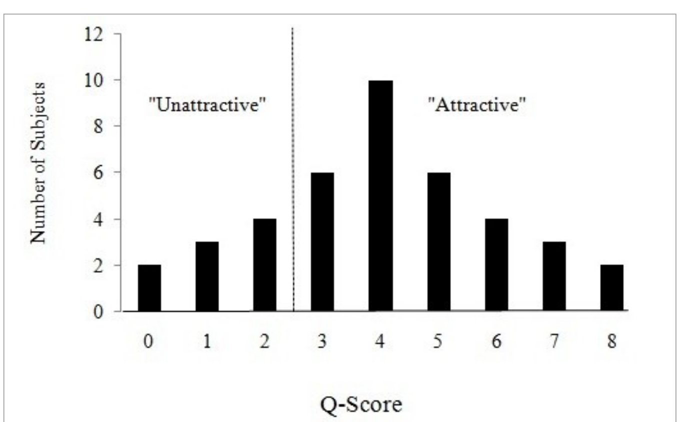

Figure 2. Q-sorting: assignment of scores to the cutoff point used to separate "attractive" from "unattractive" smiles in the Q-sort distribution. Note: A line between columns 2 and 3 is given a numeric score of 2.5

9-category ordinal ranking according to a variety of subjective criteria. To generate a quasi-normal distribution of the sample, it used the progressive forced choice winnowing to make anesthetic scale "least pleasing" to "most pleasing" for rating the smile images in this study.

The panelists were asked to rate the clinical images of 40 patients for the attractiveness of smile images and then to apply the Q-sort technique to those images.

A specific order was employed by each of the panelist to select and organize the images (Figure 2). From these 40 images, the 2 most attractive and the 2 least attractive smiles were found and placed in their columns. The 3 most attractive and 3 least attractive smiles were selected similarly,4 smile images then followed by 6 smile images from each extreme, leaving only 10 smile images, presumably of neutral attractiveness. Between the 2 columns, there was a cutoff point separating the "unattractive" from the "attractive" smiles established by a survey performed by each rater.

Figure 2 depicts the score assigned for each Q-sort distribution. In a given group, each photograph was assigned a score, which is represented by the X-axis, and the number of patients is represented by the Y-axis. For each image, a score of 0–8 was given with 2 images each that were perceived least attractive as 0 and 2 images each that were perceived most attractive as 8. Overall, the Q-score for each patient was generated by calculating the average from the scores obtained for that patient by various raters.

A numeric value was given as a cutoff point, which separates the unattractive images from the attractive ones. Esthetic boundary for a panel member was represented by a score. For example (Figure 2), in a Q-sort distribution, if a line was drawn between columns 2 and 3, then it was given a scoring of 2.5, which indicated that particular panel member's esthetic boundary. Overall, a demarcation between attractive and unattractive images was generated by averaging the cutoff points received from the various raters.

Assessment of ABO Grading System

One of the best ways to assess a finished case is with the use of the ABO objective grading system. Per the guidelines of the ABO objective grading system, the principal author was initially trained in the ABO objective grading system using an ABO calibration kit as well as with a tutorial using the ABO gage. Only 1 investigator evaluated all the cases and scored panoramic radiographs and post-treatment dental casts of all the patients using the special gage (11).The occlusal outcome of each patient for either extraction or non-extraction case was measured using the scores obtained from each of the 8 components and total scores generated from the ABO objective grading system for that particular patient. The ABO objective grading system is an objective clinical examination tool that has been judged reproducible depending on its extensive inter- and intra-examiner reliability testing by various investigators (14).

Statistical Analysis

All the data were analyzed using the **Statistical Package for Social Sciences version 24.0 software (IBM Corp.; Armonk, NY, USA) for Windows.** The results were presented as means and standard deviations for age, criteria of the ABO objective grading system, esthetic boundary cutoff scores, and Q-sort scores. The Pearson correlation coefficients were calculated to evaluate the relationship between the occlusal outcome and perceived smile attractiveness of patients with extraction and non-extraction treatment. Specifically, the individual criteria and total combined scores of the ABO grading system were evaluated against the average combined Q-scores of smiles captured with clinical photography. To evaluate whether the individual criteria or total combined scores of the ABO grading system could predict whether a smile would be attractive or unattractive in patients with extraction vs. non-extraction treatment, logistic regression was used; $p<0.05$ was established as a level of significance for all the statistical tests.

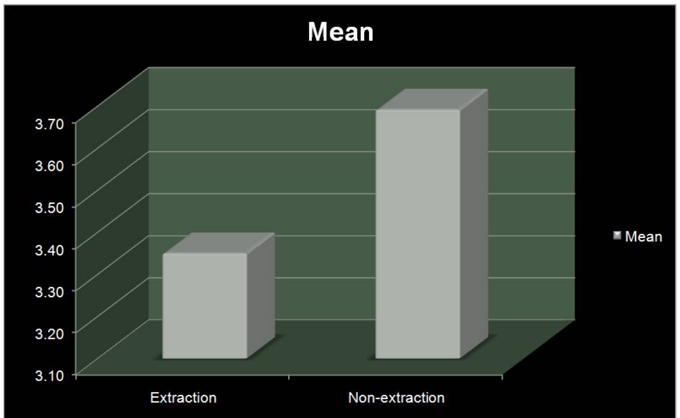

Figure 3. Comparison of mean Q-sort scores between the extraction and non-extraction groups

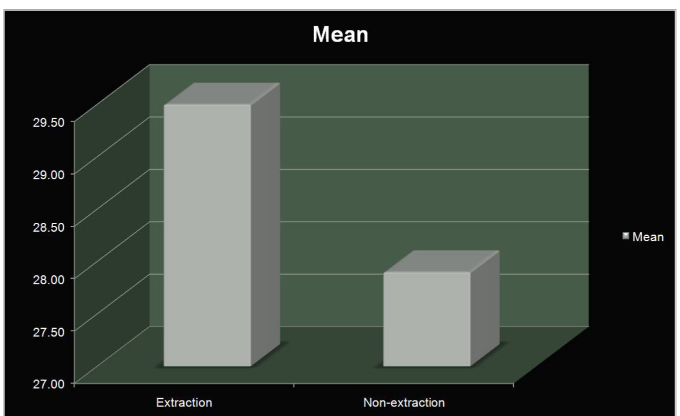

Figure 4. Comparison of mean total deductions of American Board of Orthodontics score between the extraction and non-extraction groups

RESULTS

Comparison of the mean Q-sort scores between Class I extraction and non-extraction cases showed differences in the mean scores as 3.35 and 3.69, respectively, which were statistically non-significant (Figure3). Similarly, comparison of mean total deductions of the ABO scores between extraction and non-extraction groups were 29.50 and 27.90, respectively, which were statistically non-significant (Figure 4). Table 1 represents the descriptive statistics of the ABO grading system in the extraction and non-extraction cases. Table 2 represents the descriptive statistics calculated for the average Q-scores. A combined result of all 12 raters for each photograph was calculated to determine the average Q-scores. Esthetic boundary scores were represented by an average cutoff point demarcation between the unattractive and attractive smile images during the Q-sort assessment. Because of the ordinal nature and normal distribution of the Q-sort, 4 would be the mean Q-sort score when all the patient scores were combined. The scores ranged from 0 to 8 between Q-sort scores and esthetic boundary.

To distinguish the relationship between the average Q-scores of smiles and the 8 criteria of the ABO grading system for extraction and non-extraction cases, the Pearson correlation coefficients were calculated (Table 3). A score of 0 in the ABO grading system means a perfect occlusal outcome; a score of 1 would mean a perfect correlation between optimal occlusion and an attrac-

Table 1. Descriptive statistics of the citeria of American Board of Orthodontics objective grading system in extraction and non-extraction cases with point deductions of criteria and total scores

ABO Criteria	Extraction				Non-extraction			
	Range				Range			
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD
Alignment	2	7	4.30	1.38	1	7	4.15	1.66
Marginal ridge	2	7	4.15	1.42	2	8	4.45	1.76
Buccolingual inclination	1	7	3.85	1.93	1	7	3.50	1.47
Occlusal relationship	1	6	2.90	1.45	0	5	2.45	1.23
Occlusal contacts	2	10	4.85	2.56	0	7	4.55	1.85
Overjet	1	3	1.70	0.73	1	5	1.90	1.02
Interproximal contacts	0	7	3.75	2.02	0	5	2.60	1.67
Root angulation	2	6	4.20	1.54	0	9	4.20	2.61
Total deductions	16	43	29.50	9.26	17	43	27.90	7.90

SD: Standard deviation; ABO: American Board of Orthodontics tive smile. Between all the factors of the ABO grading system and perceived smile attractiveness, extremely weak positive and negative relationships (r values ranging from -0.53 to 0.37 for extraction cases and -0.63 to 0.003 for non-extraction cases) were found. Although individual components, such as occlusal relationship (-0.53) and interproximal contact (-0.46), showed significance for extraction group and buccolingual inclination (-0.48), occlusal contacts (-0.62) and root angulations (-0.63) showed significance for non-extraction cases. Moreover, total deductions between the 2 groups showed significance.

Logistic regression equation predictors: regression coefficients (B) and probabilities (P) for individual parameters and combined total scores of the ABO grading system with “attractive” and “unattractive” smiles in an extra-oral smile photograph as the dependent variable are presented in Table 4. Whether the smile was attractive or unattractive could not be predicted, by either the individual score or the total scores obtained from components of the ABO grading system.

DISCUSSION

A large number of adult patients seek orthodontic treatment for esthetic reasons. However, these patients also demand a high level of comfort, greater treatment efficiency, and better esthetic results, especially smile esthetics and faster treatment. No other studies have yet compared the outcome of smile esthetics with post-treatment results between the extraction and non-extraction orthodontic treatment cases. Hence, this study was undertaken to analyze the relationship between the occlusal outcomes of the ABO grading system and post-treatment smile esthetics in Class I extraction vs non-extraction cases.

A previous study evaluating the smile esthetics found that the Q-sort technique indicated a higher reliability than that of the visual analog scale(15).The same study reported that both patients’ parents and orthodontists agree on whether the smiles are attractive or unattractive. Therefore, our study participants were only orthodontists. The results from previous studies comparing the smile esthetics between the extraction and non-extraction cases reported that the differences were of no significance (4-8).

Johnson and Smith (3) evaluated the smile esthetics in patients with completed orthodontic treatment with or without extraction of the first 4 premolars. The mean esthetic score of patients with extraction and non-extraction treatment was insignificant. The results showed that there was no predictable relationship between the esthetics of a smile and the extraction of the premolars. This correlates with the results of our study.

Table 2. Descriptive statistics for average Q-sort and esthetic boundary scores of the various raters for each image type

Smile photo			Range	
Variable and Rater	**Mean**	**SD**	**Minimum**	**Maximum**
Average Q-sort score (range 0-8)[a] Orthodontist	4	1.4	0.5	6.7
Average esthetic boundary (range,0-8) Orthodontist	3.2	1.3	0.5	6.5

[a]The normal distribution of the Q-sort score results in a mean of 4 when patients are combined
SD: Standard deviation

Table 4. Logistic regression: regression coefficients (B) and probabilities (p) for individual ABO criteria and total scores with “attractive” and “unattractive” smiles captured with clinical photograph as the dependent variable

ABO Criteria	Regression coefficient (B)	SE (B)	p
Alignment	0.20	0.79	0.80
Marginal ridge	0.71	0.72	0.33
Buccolingual inclination	0.40	0.87	0.65
Occlusal relationship	-0.70	0.81	0.38
Occlusal contacts	0.39	0.62	0.53
Overjet	0.36	0.78	0.64
Interproximal contacts	-0.05	0.72	0.95
Root angulation	-0.25	0.70	0.73
Total deductions	-0.31	0.63	0.62

ABO: American Board of Orthodontics; SE: Standard error of the coefficient

Table 3. Pearson correlation coefficients between the criteria of the American Board of Orthodontics objective grading system and average Q-sort scores of smiles captured with clinical photography between the extraction and non-extraction groups

	Extraction group		Non-extraction group	
ABO Criteria	**Correlation coefficient* with Q-sort scores**	**p**	**Correlation coefficient* with Q-sort scores**	**p**
Alignment	-0.19	>0.05	–0.32	>0.05
Marginal ridge	-0.26	>0.05	-0.09	>0.05
Buccolingual Inclination	-0.43	>0.05	-0.48	<0.05*
Occlusal relationship	-0.53	<0.05*	-0.09	>0.05
Occlusal contacts	-0.26	>0.05	-0.62	<0.01*
Overjet	0.37	>0.05	0.003	>0.05
Interproximal contacts	-0.46	<0.05*	-0.36	>0.05
Root angulation	-0.26	>0.05	-0.63	<0.01*
Total deductions	-0.49	<0.05*	-0.62	<0.01*

*Statistically significant at p<0.05; ABO: American Board of Orthodontics

Kim and Gianelly (6) studied the dental casts and frontal smile images of the patients treated with and without extraction of the first 4 premolars to as certain changes in the arch width. The esthetics of the smile was judged by 50 laypeople. The results of their study showed that both extraction and non-extraction treatment did not have any preferential effect on smile esthetics, and no constriction of the arch was seen in patients with extraction treatment. Isiksal et al. (7) compared the esthetics of a smile between patients with extraction and those with non-extraction treatment and a control group, who were judged by orthodontists, plastic surgeons, artists, general dentists, dental professionals, and parents. The mean esthetic scores for all the 3 groups were non-significant. The results of these 2 studies are similar to those of our study.

Extremely poor Pearson correlations were found between the components of the ABO grading system and average Q-scores of smiles (the r values ranged from -0.53 to 0.37 for extraction and -0.63 to 0.003 for non-extraction cases).Individual components of the ABO grading, such as occlusal relationship (-0.53) and interproximal contact(-0.46), showed significance for the extraction group. This may be explained by the larger space available for precise positioning of the teeth after extraction. Buccolingual inclination (-0.48), occlusal contacts (-0.62), and root angulations (-0.63) showed significance for non-extraction cases. This may be because of the tipping movement of the teeth and owing to the lack of available space for a perfect tooth placement. The total ABO scores procured from both the groups and the captured smile Q-scores bear no relevance at all, although total deductions between the 2 groups showed significance. A study by Anthopoulou et al. (16) found similar results. They found that for a patient with Class I malocclusion, the same quality of results was achieved as assessed by the ABO objective grading system, irrespective of extraction and non-extraction treatment.

Neither the individual parameters nor the combined total scores obtained from the ABO grading system in logistic regression could predict whether a smile would be considered unattractive or attractive in patients with or without extraction. Combined results presented weak correlations among the parameters of the ABO grading system and smile esthetics. Logistic regression analysis shows that a beautifully articulated dental cast with parallel roots does not necessarily result in an attractive smile. None of the soft tissue parameters were evaluated in the current objective grading system; hence, these results are not surprising. Schabelet al. (17) and Cheng and Wang (18) have found similar results, which are in accordance with our study.

Irrespective of the other parameters that could affect a clinician's decision regarding the treatment protocol, extraction or non-extraction did not have any significance when evaluated. This result was not in accordance with the study conducted by Vaidya et al. (19).

The results of this study suggest that there is no relationship between ideal post-treatment occlusion and smile esthetics. Overall, majority of people use smile as a factor to judge whether their treatment was successful (20).Orthodontists should endeavor to create an ideal smile with facial and occlusal outcomes, which would satisfy and benefit the patient the most (21).

CONCLUSION

This study comprehensively evaluated the relationship between the ABO objective grading system and post-treatment smile esthetics in Class I extraction versus non-extraction cases and found no significant relationship between them. The ABO objective grading system could not predict whether the smile was attractive or unattractive after orthodontic treatment in both groups. Soft tissue parameters, neither intraoral nor extraoral, were assessed in the objective grading system. Therefore, our study suggests that when assessing the overall post-treatment orthodontic outcomes, inclusion of ancillary soft tissue variables into the grading system is necessary to evaluate the smile esthetics.

Ethics Committee Approval: This study was approved by Ethics committee of College of Dental Sciences affiliated with Rajiv Gandhi University of Health Sciences (Approval No: CODS/2427/201819).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Supervision – G.S., N.S.; Design – V.K., N.S.; Resources – V.K., G.S.; Materials – V.K., N.S.; Data Collection and/or Processing – V.K., G.S.; Analysis and/or Interpretation – V.K., G.S.; Literature Search – V.K., N.S.; Writing Manuscript – V.K., N.S.; Critical Review – V.K., G.S.

Conflict of Interest: The authors have no conflict of interest to declare.

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Original Article

Comparison of Genial Tubercule Anatomy Based on Age and Gender

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Main points:

- The anatomy of the genial tubercle differs between genders and ages.
- Men have larger genial tubercles compared to women, regarding vertical and horizontal dimensions.
- As the age of the patients increases, the vertical dimensions of the genial tubercle decrease.
- Three-dimensional evaluation of the genial tubercle can be used in forensic dentistry for age-gender determination and preoperative planning of mandibular osteotomy.

ABSTRACT

Objective: In our study, it was aimed to determine whether there were differences in genial tubercle dimensions depending on age and gender.

Methods: In this study, 220 cone beam computed tomography (CBCT) images of patients (110 female and 110 male) between the ages of 20-80 years were obtained from the archive of İzmir Katip Çelebi University Faculty of Dentistry. All patients were divided into decade groups according to their age, and each decade group was divided into two subgroups according to gender. The genial tubercle was defined radiologically using axial, coronal and sagittal sections as well as 3D reconstruction image with NNT software program. Sagittal, vertical and horizontal dimensions of the genial tubercle were measured and statistically analyzed.

Results: There was a weak negative correlation between age groups and vertical values (r=-0.142; p=0.036) whereas the correlation coefficients between age groups and sagittal and horizontal values were not statistically significant (r=-0.043; p=0.530 and r=-0.039; p=0.563). There was a strong positive correlation between vertical and sagittal values in men (r=0.705, p<0.001) and women (r=0.714, p<0.001) in the whole group. There was a weak positive correlation between horizontal and sagittal, horizontal and vertical values in men (r=0.362, p<0.001; r=0.231, p<0.001) and women (r=0.304, p<0.001; r=0.257, p=0.007) in the whole group.

Conclusion: The vertical and horizontal dimensions of genial tubercle of men were higher than that of women. As the age of the patients increased, a decrease in the vertical values of the genial tubercle was observed.

Keywords: Age, chin, forensic dentistry, gender

INTRODUCTION

During the growth process, the mandible grows downward and forward as a whole (1). The corpus region of the mandible, which contains the genial tubercle, grows forward with the effect of the ramus and the alveolar bone of the upper jaw (2).

The aging process, which begins after the development is completed, causes morphological changes in the bone structure of the face and bones are subject to remodeling (3). Microstructural changes are observed in the bone

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matrix as a result of the change of mineral components during the aging process. The aging process has a significant impact on bone mineral density and calcium concentration. In order to reveal age-related changes in skull structure, studies have been carried out on skulls of young and old individuals and Computed Tomography (CT) data (4). Aging of the craniofacial structure is not only due to bone atrophy, but also due to bone expansion and changes in dynamics due to bone loss (5).

Facial bones, which loose their density and thickness due to age, cause some changes in face shape. Bone quantity loss belonging to age groups are as follows (6):

20-30 age group: A small percentage of bone loss is seen in this age group.

30-40 age group: The base of the nose gets bigger. Some changes are observed in the chin area.

40-50 age group: The chin area continues to expand. Eye sockets begin to widen.

50-60 age group: Menopause effects in women. There is a decrease in bone density due to the combination of low growth hormone and estrogen levels.

The genial tubercle is located on the midline on the lingual face of the mandible and slightly above the lower margin as four bone ledge called spina mentalis; The two upper protrusions are called spina mentalis superior, and the lower two protrusions are called spina mentalis inferior. The genioglossus muscle attaches to the upper protrusions, and the geniohyoideus muscle to the lower protrusions (7).

There are studies reporting that defining the morphology of the genial tubercles is valuable for different dental applications, and the morphology, position and dimensions of the genial tubercle are important in some cases (8-11). Some studies have reported that genial tubercle dimensions are important in complete denture stability in the mandible (12, 13). Genial tubercles can also be used as a reference in the assessment of mandibular asymmetry (11). It can also be a guide in determining a safe area in the mental foramina region in the mandible before implant surgery. Besides, it is reported that genial tubercles are an anatomical hard tissue parameter that can be used in the surgical treatment of Obstructive Sleep Apnea (OSA) (14).

The muscles attached to the genial tubercle are closely related to the function and support of the tongue and its associated soft tissues (15). The first of these is the genioglossus muscle, which is the main muscle that protrudes the tongue, and its contraction expands and stabilizes the area of the upper airway most prone to collapse. The other is the geniohyoideus muscle; It is a narrow muscle located superior to the medial border of the mylohyoid muscle and originates from the spina mentalis inferior, behind the mandibular symphysis, and moves back and slightly downward, inserting into the anterior part of the body of the hyoid bone. It is in contact with its fellow of the other side. The geniohyoid muscle, which belongs to the group of suprahyoid muscles, pulls the hyoid bone forward and upward (16). And by expanding the upper airway, it helps breathing (17). In the first stage of swallowing, as the food mass moves from the mouth to the pharynx, the hyoid bone and accompanying tongue is pulled up and forward by the anterior bellies of the digastric muscle, the mylohyoid muscle, and geniohyoid muscle. It also helps to lower the mandible (18). The tongue prevents posterior collapse by contracting the genioglossus muscle during sleep (19). Especially during the REM period of sleep, relaxation of the genioglossus and the geniohyoid muscles has been reported to play a role in OSA (18).

In order to better understand its morphology, it is useful to use CBCT to measure the height and width of the tubercle in individuals of different ages and genders. Studies in the literature also show that CBCT is an accurate method for evaluating the morphology, dimensions and position of the genial tubercle (19). Studies have shown that it provides acceptable precision in linear measurements on alveolar bone and mandible (20).

Another area of use where the awareness of the importance of knowing the location of the morphology of genial tubercles is increasing in forensic dentistry. As in forensic medicine, x-ray records are used in many parameters (age and gender) related to identification in forensic dentistry and radiology science is used. X-ray records are one of the important evaluation criteria used by forensic medicine and forensic dentistry, as they shed light on many issues both in determining the current situation and in comparisons with the past (21). Forensic dentistry is not only concerned with the identification of the dead and the finding of the disappeared, but also deals with the forensic cases in the living. In this case, the forensic odontologist can assist in the investigation by narrowing the age group in which the deceased may be included, in the light of the data obtained (22).

In this study, we aimed to examine the genial tubercles of patients by making 3D measurements on the CBCT images in the archive of Izmir Katip Çelebi University Faculty of Dentistry. We aimed to investigate whether there are age- and gender-related differences in the genial tubercle dimensions.

METHODS

In our cross-sectional study, tomography data which was previously taken and kept ready at our university in order to observe the changes in the bones, teeth, soft tissues and airways of the patients were used. In the study, 220 CBCT images (110 female and 110 male) were obtained from the archive of İzmir Katip Çelebi University Faculty of Dentistry Department of Oral and Maxillofacial Radiology. All patients were divided into ten-year groups according to their age, and each ten-year group was divided into two subgroups according to gender. Patients who did not show asymmetry were selected considering the criteria defined by Wang et al. (23)

The study was approved by the "İzmir Katip Çelebi University Non-Interventional Clinical Research Ethics Committee"

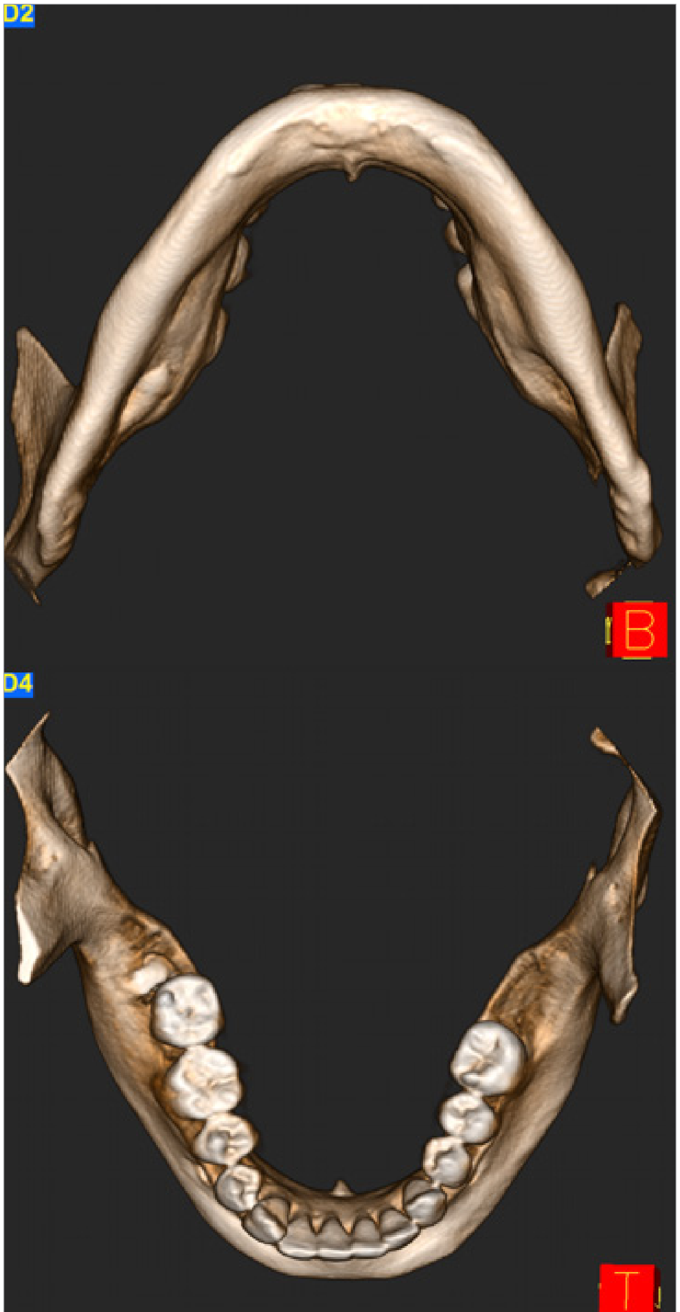

Figure 1. The images of the genial tubercle on 3D reconstruction

(Date:04.09.2020, Approval Number: 2020-GOKAE-0175). CBCT images included in this retrospective study were determined according to the following criteria:

Inclusion criteria:
1. Being twenty years old or older,
2. No dental anomaly or tooth loss in the anterior mandible,
3. No craniofacial deformity (i.e. any bone related disorders) and/or facial asymmetry observed.

380 individuals who met the general criteria determined by measuring cephalometric radiographs of 1100 individuals who had previously registered for diagnosis and treatment purposes in the archives of X University Faculty of Dentistry Department of Oral and Maxillofacial Radiology were selected and their CBCT images were screened. Among the individuals whose CBCT images were screened, CBCT images of 220 persons who comply with the inclusion criteria of the study were included in the study. The study did not have a control group. In our study, there are a total of 18 groups; 6 main groups and 12 subgroups.

All CBCT images were obtained with NewTom 5G (QR, Verona, Italy) flat panel CBCT device using 110 kVp and 1-20 mA parameters, 15x12 FOV (Field Of View) field and 0.2 mm voxel size. Images were analyzed using the NNT (QR-NNT V9.1, Verona, Italy) software program. The head orientation is standardized so that the Frankfurt horizontal plane is perpendicular to the ground and the Porion plane (the line passing through the right and left Porion points) is parallel to the ground, because CBCT device in the Radiology Department of the hospital takes images in the supine position.

The genial tubercle was defined radiologically using axial, coronal and sagittal sections as well as 3D reconstruction image (Figure 1); and it has been identified as the center of the four genial tubercles of the mandible. Genial tubercle dimensions were calculated in axial and sagittal sections. In the axial section, the most concave points were identified on the lingual surface of the anterior segment of the mandible near the genial tubercle. A line was obtained by combining these two points and this line was measured in millimeters. The horizontal width of the genial tubercle was calculated using this line. In the sagittal section, first the most concave points on both sides of the genial tubercle were marked and a line was formed between these two points. Through this line, the vertical width of the genial tubercle was calculated in millimeters. Then, a point was marked at the top of the genial tubercle and a second line was drawn perpendicular to the vertical width line from this point and terminating on this line to measure the height of the genial tubercle in millimeters. (Figure 2).

Statical Analysis

The data were evaluated by The Statistical Package for Social Sciences version 25.0 software (IBM Corp.; Armonk, NY, USA). The normal distribution of the data was analyzed using the Shapiro Wilk test. Homogeneity of variances was evaluated by Levene's test. Since the data for sagittal, vertical and horizontal values had a skewed distribution, logarithmic transformation of the data was performed. Descriptive statistics were given as geometric mean (GM) and 95% confidence limits of the real values, since the data were transformed logarithmically. Independent samples t-test was used to compare sagittal, vertical and horizontal values according to gender, and one-way analysis of variance was used for comparison of age groups. Comparison of sagittal, vertical and horizontal values in age groups by gender was made by two-factor analysis of variance from general linear models. The Sidak test was used as a multiple comparison test in the two-factor analysis of variance. The relationship between sagittal, vertical and horizontal values was evaluated by Pearson correlation analysis. p value of <0.05 was considered statistically significant.

Table 1. Comparison of sagittal, vertical and horizontal values by gender groups

	Gender	Geometric Mean	95% Confidence Limits		Test Statistics	
					t	p
Sagittal	Male	1.77	1.62	1.93	1.374	0.171
	Female	1.61	1.45	1.78		
Vertical	Male	5.58	5.22	5.97	2.46	0.015
	Female	5	4.72	5.3		
Horizontal	Male	8.16	7.70	8.64	5.094	<0.001
	Female	6.54	6.13	6.97		

Table 2. Comparison of sagittal, vertical and horizontal values by age groups

	Age Groups	Geometric Mean	95% Confidence Limits		Test Statistics	
					f	p
Sagittal	20-30	1.84	1.61	2.09	1.256	0.284
	30-40	1.65	1.41	1.93		
	40-50	1.71	1.44	2.04		
	50-60	1.57	1.33	1.84		
	60-70	1.53	1.29	1.81		
	70-80	2.03	1.57	2.63		
Vertical	20-30	5.81	5.21	6.48	1.686	0.139
	30-40	5.4	4.75	6.14		
	40-50	5.42	4.95	5.93		
	50-60	4.87	4.41	5.37		
	60-70	4.88	4.35	5.47		
	70-80	5.48	4.84	6.2		
Horizontal	20-30	7.5	6.67	8.44	0.771	0.572
	30-40	7.37	6.61	8.24		
	40-50	6.93	6.18	7.77		
	50-60	7.31	6.54	8.17		
	60-70	7.01	6.39	7.69		
	70-80	8.14	7.07	9.37		

RESULTS

Sagittal, vertical and horizontal values of men and women in all age groups with logarithmic transformations showed normal distribution. Sagittal values did not differ according to gender ($p=0.171$). Vertical values of men were statistically higher than women ($p=0.015$). Horizontal values of men were statistically higher than women ($p<0.001$) (Table 1).

Sagittal, vertical and horizontal values were compared according to age groups. Sagittal, vertical and horizontal values were not statistically different according to age groups ($p<0.05$) (Table 2).

When the model statistics were examined, sagittal values were similar according to age and gender groups. Considering the average values, the sagittal values of female patients in the 60-70 age group were higher than that of men; and also, in other age groups, although the sagittal values of men were higher than that of women, the differences were not statistically significant (Table 3). According to the model and test statistics, the vertical values of male patients in the 40-50 age group were statistically higher than women. The differences between vertical values between male and female patients in other age groups were not statistically significant (Table 3). According to the model and test statistics, the horizontal values of male patients in the 20-30, 40-50 and 60-70 age groups were statistically higher than that of women. In the 30-40 and 70-80 age groups, the values of men were high and the difference with women is close to statistical significance (Table 3).

When the relationships between age groups and sagittal, vertical and horizontal values were evaluated, there was a weak negative correlation between age groups and vertical values ($r=-0.142$; $p=0.036$). As the age of the patients increased, a decrease in the vertical values was observed. The correlation coefficients between age groups and sagittal and horizontal values were not statistically significant ($r=-0.043$; $p=0.530$ and $r=-0.039$; $p=0.563$).

According to correlation coefficients between age groups and sagittal, vertical and horizontal values were not statistically significant ($r=-0.037$; $p=0.701$; $r=-0.109$; $P=0.257$ and $r=-0.023$;

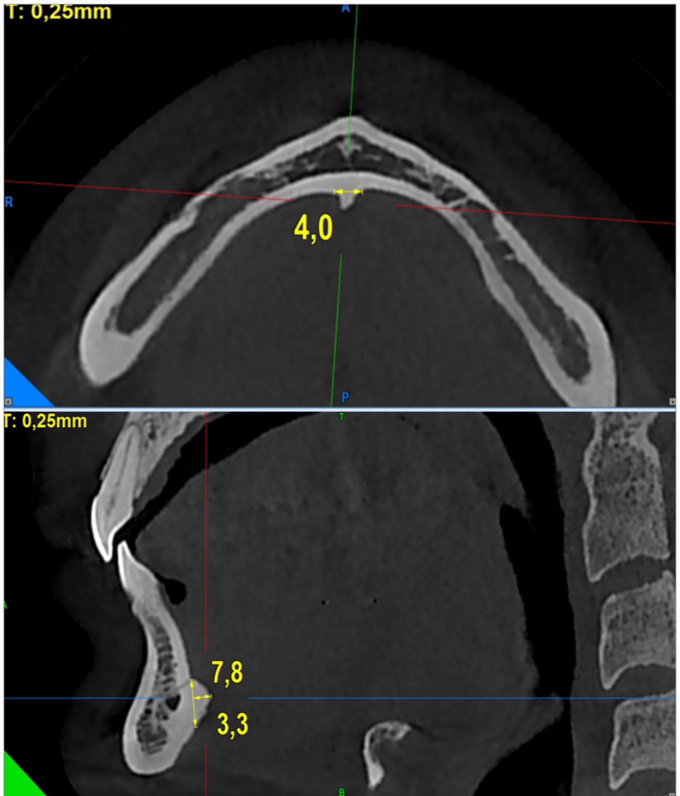

Figure 2. Measurement of the genial tubercle in the axial, horizontal and vertical direction in the sections

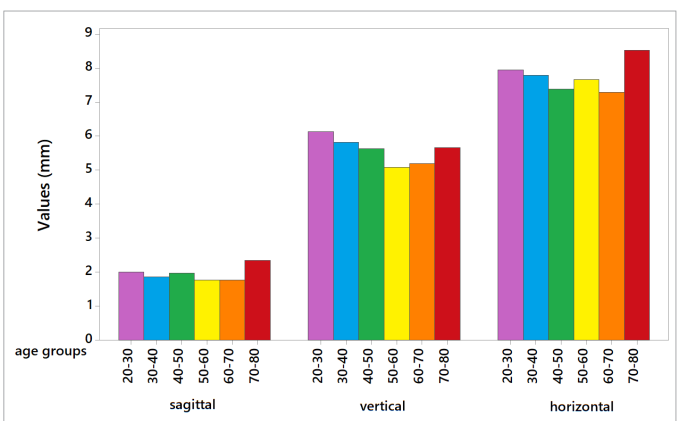

Figure 3. Graphical illustration of the sagittal, vertical and horizontal values by different age groups.

p=0.809). In males, there was a weak negative correlation between age groups and vertical values (r=-0.211; p=0.027). As the age of male patients increased, a decrease in vertical values was observed. Correlation coefficients between age groups and sagittal and horizontal values in males were not statistically significant (r=-0.049; p=0.611 and r=-0.083; p=0.386).-

In the whole group, there was a weak positive correlation between horizontal and sagittal, horizontal and vertical values in men and women (Table 4; Figure 3, 4). In the whole group, there was a strong positive correlation between vertical and sagittal values in men and women (Figure 5).

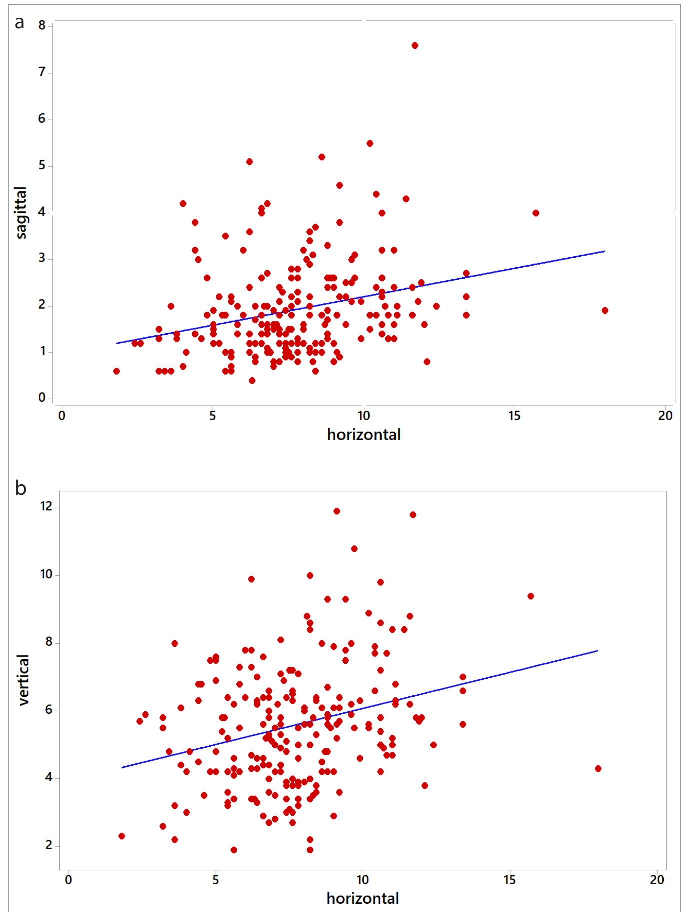

Figure 4. Graphs showing positive correlation between (a) sagittal and horizontal and (b) vertical and horizontal values in the pooled sample (men and women).

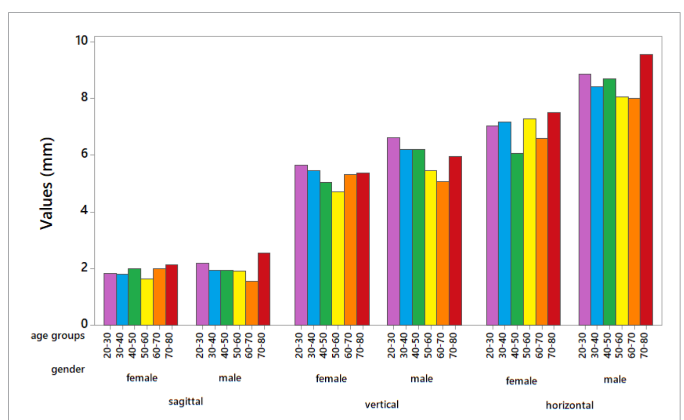

Figure 5. Graphical illustration of the sagittal, vertical and horizontal values by different age groups.

DISCUSSION

Although the genial tubercles are defined as four tubercles bilaterally surrounding the lingual foramina in pairs on the lingual side of the mandible, on the right and left sides of the midline, it is stated that the morphology and dimensions of these anatomical structures are still controversial (24).

Table 3. Comparison of sagittal, vertical and horizontal values according to group and age variables

Direction	Age Groups	Gender	Geometric Mean	95% Confidence Limits		Test Statistics f	Test Statistics p	Model Statistics
SAGITTAL	20-30	Male	2.01	1.66	2.43	1.294	0.257	Age groups effect: f= 1.250; p= 0.287; Gender effect: f=2.360; p= 0.126; Age groups* gender effect F= 0.646; p= 0.665
		Female	1.68	1.38	2.04			
	30-40	Male	1.69	1.31	2.17	0.067	0.795	
		Female	1.62	1.31	2			
	40-50	Male	1.81	1.51	2.15	0.403	0.526	
		Female	1.63	1.19	2.24			
	50-60	Male	1.72	1.37	2.16	1.285	0.258	
		Female	1.44	1.13	1.83			
	60-70	Male	1.44	1.19	1.75	0.631	0.428	
		Female	1.63	1.23	2.18			
	70-80	Male	2.33	1.65	3.28	1.433	0.233	
		Female	1.78	1.15	2.76			
VERTICAL	20-30	Male	6.26	5.27	7.44	2.025	0.156	Age groups effect: f= 1.715; p=0.132; Gender effect: f=5.941; p=0.016; Age groups* gender effect: f=0.726; p=0.605
		Female	5.39	4.68	6.21			
	30-40	Male	5.58	4.42	7.03	0.352	0.554	
		Female	5.24	4.57	6			
	40-50	Male	6.01	5.3	6.83	3.890	0.049	
		Female	4.89	4.32	5.53			
	50-60	Male	5.29	4.66	6.01	2.64	0.118	
		Female	4.49	3.85	5.22			
	60-70	Male	4.78	4.02	5.68	0.168	0.682	
		Female	4.99	4.22	5.9			
	70-80	Male	5.87	5.16	6.69	0.846	0.359	
		Female	5.12	4.07	6.46			
HORIZONTAL	20-30	Male	8.52	7.39	9.82	6.125	0.014	Age groups effect: f= 0.851; p= 0.515; Gender effect: f= 24.315; p<0.001; Age groups* gender effect: f= 0.570; p= 0.723
		Female	6.61	5.5	7.95			
	30-40	Male	8.04	6.89	9.39	2.821	0.095	
		Female	6.77	5.75	7.97			
	40-50	Male	8.23	7	9.67	11.266	0.001	
		Female	5.84	5.12	6.66			
	50-60	Male	7.75	6.7	8.96	1.284	0.258	
		Female	6.9	5.77	8.25			
	60-70	Male	7.78	6.97	8.7	4.176	0.042	
		Female	6.32	5.48	7.29			
	70-80	Male	9.19	7.55	11.18	2.781	0.097	
		Female	7.22	5.87	8.88			

Many studies have shown that the anatomical linear measurements of the alveolar bone and mandible with CBCT are acceptable (21). However, cadaver studies have also been conducted to define the genial tubercle region more clearly (25). Results of a study conducted by Hueman et al. (26) showed that CBCT is a reliable method for determining the anatomical location of genial tubercles. Compared to conventional CT, CBCT has the advantages of relatively less radiation dose, low cost, accessibility, and multiplanar reconstruction images (24). Therefore, in our study, CBCT images were preferred for anatomical measurements of genial tubercles.

Studies based on cadaver dissections and radiographic imaging have found some differences among the patient population, as in many anatomical structures (25). In genioglossus advancement surgery, various studies have been conducted in various populations examining the morphology, position and dimensions of the genial tubercle to contribute to pre-surgical evaluation and planning (15, 27). Kolsuz et al. (28) examined the location and morphology of the genial tubercle using CBCT in a Turkish population. Only a few of the studies in the literature divided the total study group into groups by gender (15, 26). Nejaim et al. (15) found that the height of the genial tubercle was significantly higher in men compared to women; on the other hand, they did not find a significant difference in width. However, in the study of Kai Yin et al. (27), no statistically significant difference related to genial tubercle height between genders was found. In our study, vertical and horizontal measurements were compared both between genders and age groups.

After the development is completed and the aging process begins, there is no study that specifically compares the morphology and dimensions of the genial tubercle between different age groups. Some researchers draw attention to genial tubercle fractures observed especially in older ages, and it is not known

Table 4. Correlations between sagittal, vertical and horizontal values for the whole group and gender

	All Groups				Male				Female			
	Sagittal		Vertical		Sagittal		Vertical		Sagittal		Vertical	
	r	p	r	P	R	p	r	p	r	p	r	p
Vertical	0.704	<0.001	-	-	0.705	<0.001	-	-	0.714	<0.001	-	-
Horizontal	0.34	<0.001	0.279	<0.001	0.362	<0.001	0.231	0.015	0.304	<0.001	0.257	0.007

r: Pearson's correlation coefficient

whether there is a significant difference in genial tubercle morphology and dimensions between age groups (10, 29).

It has been reported that CBCT, which has been increasingly used in clinical dentistry practice, is especially useful in age and gender determination studies in the field of forensic dentistry and orthodontics (21, 30). Today, archive records are created with the presence of CBCT devices in imaging centers and dentistry faculties, and these records can be consulted in forensic cases when needed for the identification of individuals, age and gender determination (30). Some authors have reported that the evaluation of anatomical structures with the help of CBCT can be used in determining age and gender in forensic dentistry (21, 30). In our study, although not statistically significant, the genial tubercle values of men in the 30-40 and 70-80 age groups were found to be high, and the difference with women is close to statistical significance. In addition, according to the model and test statistics made in our study, it was observed that the vertical values of male patients in the 40-50 age group were statistically higher than women. However, according to the model and test statistics, the horizontal values of male patients in the 20-30, 40-50 and 60-70 age groups were found to be statistically higher than women. It is thought that these findings will provide important information in determining the age range and gender, especially in forensic dentistry.

According to the findings we obtained in our study, the genial tubercle vertical values of men are statistically higher than that of women. Similarly, the mean horizontal values of the genial tubercle were found to be statistically significantly higher in men than in women. These differences in the vertical and horizontal dimensions of the genial tubercles between genders can be attributed to the fact that the anatomical structures of men are physically larger than that of women. This finding is again an important finding for forensic dentistry.

Various surgical approaches have been reported to advance the mandible forward to increase the hypopharyngeal airway space in patients with mandibular retrognathie. These approaches are to position the tongue muscles forward to reduce airway resistance. However, the anatomy and morphology of these muscles are not clearly defined in the literature (31). Therefore, preoperative planning requires an important anatomical hard tissue such as genial tubercles, and the localization, morphology and dimensions of these structures gain importance. There are not many studies in the literature that associate the localization, morphology and dimensions of genial tubercles with orthodontics. In a retrospective study of 101 women and 100 men, with 201 CBCT images, Kolsuz et al. (28) concluded that the genial tubercle was different in terms of its localization, morphology, and dimensions in the study group. Although they used different measurement methods from our study, they found that the dimensions of the genial tubercle were larger in male patients compared to female patients, similar to our findings. In addition, a high positive correlation was found between vertical and sagittal values in the whole group, for men and women. In the whole group, there was a weak positive correlation between horizontal and sagittal, horizontal and vertical values in men and women. When the relationships between age groups and sagittal, vertical and horizontal values were evaluated, it was observed that there was a weak negative correlation between age groups and vertical values. These findings show that the vertical values of the genial tubercles decrease as the patients' age increases. When these current findings are evaluated together, it is thought that the age-and gender-related genial tubercle size differences obtained in our study will give more insight into the medicine; and more comprehensive studies should be conducted on this subject.

When all age-and gender-related findings are considered together, it is seen that the evaluation of the dimensions of the genial tubercles with the help of CBCT is an important anatomical parameter that can be used in determination of age-gender in forensic dentistry.

CONCLUSION

- The vertical and horizontal dimensions of genial tubercle of men were higher than that of women.
- There was a negative correlation between vertical dimensions of the genial tubercle and age.
- Our study suggests that the morphological analysis of the genial tubercles can be a valuable and effective tool in determining the morphological differences in these structures according to age and gender factors; It also shows that it can have important contributions in the preoperative planning of maxillofacial surgery and in forensic dentistry.

Ethics Committee Approval: This study was approved by Ethics committee of İzmir Katip Celebi University, (Approval No: 2020-GO-KAE-0175).

Informed Consent: Verbal/Written informed consent was obtained from the patients who agreed to take part in the study. (This was a retrospective study)

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Original Article

The Influence of Abnormalities in the Profile and Overjet on Psychological Well-Being

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Main points:

- The effect of abnormalities in the facial profile on children's psychological well-being was not significant.
- Malocclusion type was not a deterministic factor for the psychological well-being of children.
- Early treatment during childhood might be better than late treatment, as malocclusion might affect psychological well-being negatively with aging.

ABSTRACT

Objective: This study aimed to comparatively evaluate the psychological well-being and health-related quality of life of subjects having either a convex or concave profile and abnormal overjet, with subjects having a straight profile and normal overjet.

Methods: In this study, 163 children and their parents who applied to the Faculty of Dentistry were classified into 3 groups: Group 1: convex profile, Class II molar relationship, and increased overjet (n=62; 28 boys and 34 girls; mean age: 11.6 years); Group 2: concave profile, Class III molar relationship, and negative overjet (n=55; 32 boys and 23 girls; mean age: 11.2 years); and Group 3: straight profile, Class I molar relationship without crowding, and normal overjet (n=46; 24 boys and 22 girls; mean age: 11.0 years). The severity of malocclusion was evaluated using the Index of Orthodontic Treatment Need (IOTN). Self-concept, depression, and state–trait anxiety were evaluated to determine the psychological well-being of the children.

Results: No differences were found among the groups with respect to self-concept, depression levels, state–trait anxiety levels, and quality of life scores. No correlation was found between the IOTN scores and psychological well-being.

Conclusion: Abnormalities in the facial profile and negative or increased overjet have no influence on children's psychological well-being.

Keywords: Esthetics, index of orthodontic treatment need, orthodontics, psychology

INTRODUCTION

Esthetic appearance has a great influence on social interactions and psychological well-being. People satisfied with their faces are more self-confident and have higher self-esteem than those who are dissatisfied (1). As part of the facial structure, dentition plays a crucial role in facial appearance, and people are primarily concerned with their dental appearance, alignment, and arrangement (2). Malocclusion, especially related to anterior teeth, has a psychosocial effect on the well-being, self-confidence, and social life of children and adolescents (3-5). An unattractive dental appearance can hinder adolescents' professional achievements and negatively impact their self-esteem (5). In their 15-year follow-up study, Helm et al. (2) reported that malocclusion may adversely affect self-concept not only during adolescence but also in adulthood.

Gerzanic et al. (6) indicate that psychological profiles are significantly different between Class II and Class III orthognathic surgery patients. Adults with Class III malocclusion felt significantly less attractive and had slightly

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stronger feelings of insecurity regarding their facial appearance compared with Class II patients. However, some authors reported no significant differences between Class II and Class III subjects, who required orthognathic surgery, in their levels of happiness and self-perception of dentofacial attractiveness (7).

In the literature, some studies have evaluated the impact of malocclusion and its severity on the oral-health-related quality of life (OHRQoL). The severity of cases was determined using different indexes, which yielded contradictory results. Ashari and Mohamed (8) have suggested that the Dental Aesthetic Index cannot strongly predict OHRQoL, as there is a significant weak correlation between them. However, Choi et al. (9) concluded that severe malocclusion, as determined according to the Index of Orthodontic Treatment Need (IOTN) was associated with a lower quality of life.

To our knowledge, there is limited number of studies focused on quality of life and, that too, mostly on dental malocclusions, and self-perception of dentofacial attractiveness. (3, 10-12). However, none of them compared the psychological well-being of children with different types of malocclusion. Therefore, this study aimed to comparatively evaluate the psychological well-being (self-concept, depression, and anxiety levels) and health-related quality of life of subjects having a convex or concave profile and abnormal overjet with respect to a control group and to determine the effects with respect to the severity of malocclusion. The null hypothesis was that malocclusion had no effect on psychological well-being of the children.

METHODS

A total of 163 consecutive children between the ages of 8 and 13, as well as their parents who had attended the Faculty of Dentistry, participated in this study.

The participants were classified into 3 groups based on their profiles (13) and overjets, which were determined by intra- and extra-oral examinations. Overjet was measured between the most anterior point of the maxillary central incisors and the corresponding reference point on the mandibular incisor. The sagittal overjet was measured. A large angle (>10°) between the line extending from the bridge of the nose to the base of the upper lip and the second line dropped from that point downward to the chin indicates profile convexity; an angle less than 10° shows a concave facial profile, which indicates a skeletal Class III relationship. The participants considered to have a straight profile had a nearly straight line and only a slight inclination in either direction between these line segments (13).

Subjects in Group I had a convex profile, increased overjet, and Class II molar relationship (n=62; 34 girls and 28 boys; mean age: 11.6±1.47 years); subjects in Group II had a concave profile, negative overjet, and Class III molar relationship (n=55; 23 girls and 32 boys; mean age: 11.2±1.61 years); and subjects in Group III had a straight profile, normal overjet without crowding, and Class I molar relationship (n=46; 22 girls and 24 boys; mean age: 11.0±1.75 years) (Figure 1).

The Ethics Committee of the University approved the study (604.01.02/50), and informed consent was obtained from the parents of the children who agreed to participate in this study. Although a sample size of 37 patients per group at α=0.05 yields a statistical power of 0.80 for this study, the sample size was increased to at least 46 patients per group. Therefore, the realized power of this study was obtained as 87% with a significance level of 0.05 and an effect size of 0.27. Patients who had craniofacial anomalies such as cleft lip and/or palate, facial asymmetry, missing or impacted teeth except third molars, medical problems, temporomandibular joint pain, orthodontic treatment experience, untreated caries, periodontal disease, and any psychiatric diagnosis were excluded from the study.

We evaluated 10 malocclusion traits to determine the Dental Health Component of the IOTN (DHC-IOTN) (14). These traits were overjet, reverse overjet, overbite, open bite, crossbite, crowding, impeded eruption, cleft lip and palate defects or other craniofacial anomalies, Class II and Class III buccal occlusions, and hypodontia. The DHC-IOTN consists of 5 grades: grades 1 and 2 indicate no need for treatment, grade 3 indicates borderline cases, and grades 4 and 5 indicate those who need orthodontic treatment.

Clinical evaluations and the DHC-IOTN measurements were conducted by one author (E.K). After the clinical evaluations, participants were evaluated in terms of their psychological well-being (state and trait anxiety, depression, self-concept, and health-related quality of life). The Piers–Harris Children's Self-Concept Scale (PHCSC), Children's Depression Inventory (CDI), and State–Trait Anxiety Inventory for Children (STAIC) were used to assess the children's psychological well-being. To measure health-related quality of life, the Pediatric Quality of Life (PedsQL) Inventory was administered to children and parents, separately and simultaneously.

The PHCSC was developed by Piers and Harris (15) to assess self-concept in children. The PHCSC is a self-report questionnaire consisting of 80 yes/no items. The sum of the affirmative answers, with one point assigned to each, yields the final score. The higher the score, the more positive the respondent's self-image. The PHCSC is composed of 6 domain scales: behavioral adjustment, intellectual and school status, physical appearance and attributes, freedom from anxiety, popularity, and happiness

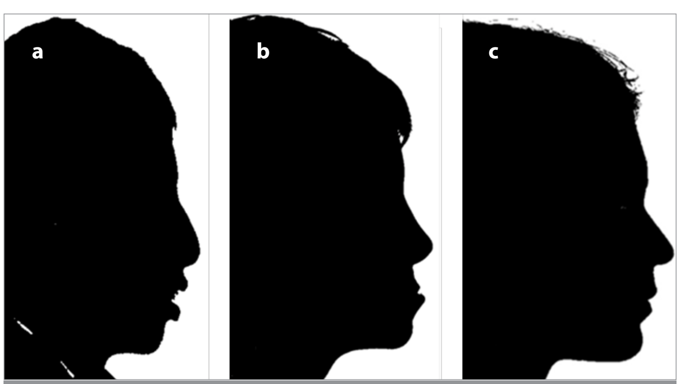

Figure 1. a-c. The facial profile silhouettes. (a) Convex. (b) Concave. (c) Straight.

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and satisfaction. The Turkish adaptation study of the PHCSC was conducted by Öner (16). The reliability coefficients of the Turkish form range from 0.81 to 0.89 (16).

CDI was used to assess the depression levels of children (17). CDI is a 27-item self-report scale, in which items are rated between 0 and 2. A higher total score demonstrates a greater severity of depressive symptomatology. The reliability and validity study of the Turkish version of CDI was verified by Öy (18). Test–retest reliability and criterion-related validity were found to be 0.80 and 0.61, respectively (18).

STAIC consists of two 20-item scales that measure state and trait anxiety in children between the ages of 8 and 14 (19). The A-State scale examines the shorter-term state anxiety that is commonly specific to situations. The A-Trait scale measures longer-term trait anxiety, which addresses how the child generally feels. The statements are rated from 1 to 3, with a total score of 20-60 for each scale. The Turkish reliability and validity study of this inventory was conducted by Özusta (20). The Cronbach's alpha coefficient was 0.82 for the State scale and 0.81 for the Trait scale (20).

The PedsQL measures the health-related quality of life in healthy children and adolescents, as well as in those with acute and chronic health conditions (21). The 23-item scale measures physical, emotional, social, and school functioning. PedsQL scales comprised child self-reports (ages 5-7, 8-12, and 13-18) and parent proxy reports, which assess parents' perceptions of their children's health-related quality of life. Physical health scores, psychosocial health scores, and total scores were obtained from the scale. Higher scores indicate better health-related quality of life. Memik et al. (22) adapted the Turkish versions of this scale. The Cronbach alpha coefficients range from 0.59 to 0.88 (22).

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences, version 16.0 software (SPSS Inc.; Chicago,IL, USA). Ages and the scores obtained from the questionnaires of the groups were statistically compared using one-way analysis of variance. The gender difference in the scores was determined with the Student *t*-test. The relationships among the IOTN scores, psychological well-being, and health-related quality of life were examined using the Spearman rank correlation coefficient. Intra-examiner reliability for the aesthetic component scale of the IOTN (AC-IOTN) was evaluated by Kappa analysis. The significance level was set to $p<0.05$.

RESULTS

The mean age was found to be similar among the groups. There was high agreement between the first and second readings for the AC-IOTN obtained by the same examiner ($r=0.89$). There was no statistically significant gender difference in terms of state and trait anxiety, depression, self-concept, and health-related quality of life scores (Table 1).

The results revealed that state and trait anxiety levels were similar in both malocclusion groups, and these values showed no differences between the malocclusion and control groups. No significant differences were found among the groups with respect to depression levels (Group 1: 7.06; Group 2: 7.56; and Group 3: 7.28) and self-concept (Group 1: 65.33; Group 2: 65.19; and Group 3: 65.28). In terms of quality of life total scores, physical health, and psychosocial health scores, the self-report of the children did not differ significantly in the 3 groups. Although parents' self-reports with regard to the quality of life total scores, physical health, and psychosocial health scores were higher in the convex profile with increased overjet cases than for the concave profile with negative overjet and control groups, there were no significant differences among the groups (Table 2).

The distribution of IOTN scores in Groups 1 and 2 is given in Table 3. In Group 1, 43.5% of subjects were in the category of grade 4, as were 56.4% of subjects in Group 2. Among the IOTN scores

Table 1. Gender differences in state and trait anxiety, depression, self-concept, and health-related quality of life scores (Student's *t*-test)

Psychological status and quality of life parameters	Male (n=84) Mean±SD	Female (n=79) Mean±SD	p	
State anxiety	29.74±6.63	29.34±6.37	0.700	NS
Trait anxiety	32.75±5.39	33.81±7.06	0.280	NS
Depression	7.73±5.72	6.91±7.07	0.420	NS
Self-concept	65.49±8.22	65.04±10.51	0.770	NS
Child report—quality of life total score	80.63±12.24	82.61±12.87	0.320	NS
Child report—physical health score	81.48±13.83	81.42±16.18	0.980	NS
Child report—psychosocial health score	79.38±14.20	82.90±13.59	0.110	NS
Parent report—quality of life total score	75.00±16.18	76.31±15.28	0.600	NS
Parent report—physical health score	75.74±18.98	75.24±19.67	0.870	NS
Parent report—psychosocial health score	75.30±15.02	76.62±15.36	0.580	NS
Parent report—psychosocial health score	75.30±15.02	76.62±15.36	0.580	NS

SD: Standard deviation; NS: Nonsignificant; *p<0.05

Table 2. The distribution of IOTN scores in Groups 1 and 2

	Group 1		Group 2		Total	
IOTN scores	n	%	n	%	n	%
2.00	11	17.7	2	3.6	13	11.1
3.00	14	22.6	19	34.5	33	28.2
4.00	27	43.5	31	56.4	58	49.6
5.00	10	16.1	3	5.5	13	11.1
Total	62	100.0	55	100.0	117	100.0

IOTN: Index of orthodontic treatment need

Table 3. The comparison of the 3 groups in terms of psychosocial well-being and quality of life of the children and their parents (one-way analysis of variance)

Psychological status and quality of life parameters	Group 1 Mean±SD	Group 2 Mean±SD	Group 3 Mean±SD	F (2,160)	p	
State anxiety	31.06±8.26	29.00±5.65	28.89±5.54	1.770	0.170	NS
Trait anxiety	34.71±6.70	32.98±6.35	32.36±5.63	1.890	0.150	NS
Depression	7.06±5.22	7.56±5.81	7.28±5.56	0.060	0.920	NS
Self-concept	65.33±10.26	65.19±9.80	65.28±8.21	0.003	0.990	NS
Child report—quality of life total score	81.47±14.63	83.47±10.94	79.53±12.37	1.420	0.240	NS
Child report—physical health score	80.76±17.98	83.99±11.00	79.10±16.03	1.610	0.200	NS
Child report—psychosocial health score	80.31±16.03	82.77±13.44	79.80±12.77	0.740	0.470	NS
Parent report—quality of life total score	74.41±8.93	78.60±11.70	73.31±16.44	1.860	0.150	NS
Parent report—physical health score	73.76±21.93	78.20±15.80	73.88±20.39	0.990	0.370	NS
Parent report—psychosocial health score	76.49±16.51	78.40±12.11	72.68±16.68	2.140	0.120	NS

SD: Standard deviation; NS: Nonsignificant; *p<0.05.

Table 4. The correlations among the IOTN scores and the psychological well-being and health-related quality of life of the patients and parents (Spearman's rank correlation coefficient)

Psychological status and quality of life parameters			State anxiety	Trait anxiety	Self-concept	Depression	Parent report—quality of life total score	Parent report—physical health score	Parent report—psychosocial health score	Child report—quality of life total score	Child report—physical health score	Child report—psychosocial health score
IOTN	Group 1	r	0.129	–0.169	0.022	0.027	–0.065	0.098	–0.203	0.018	–0.031	0.000
		p	0.318	0.189	0.866	0.833	0.615	0.446	0.114	0.887	0.810	0.997
			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Group 2	r	–0.053	–0.107	–0.077	0.191	0.057	0.068	0.036	0.030	0.112	–0.007
		p	0.702	0.436	0.579	0.162	0.678	0.623	0.794	0.829	0.415	0.962
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

IOTN: Index of orthodontic treatment need; r: correlation coefficient; NS: nonsignificant; *p<0.05

and state–trait anxiety, depression, self-concept, and health-related quality of life scores, none of the correlation coefficients were found to be significant (Table 4).

DISCUSSION

People who are dissatisfied with their facial appearance often express more displeasure with their teeth than with any other facial feature (1). Adults with severe malocclusion report feeling that they are useless, shameful, and inferior (23). Dibiase and Sandler (24) have suggested that children with certain malocclusions are more likely to be the victims of bullying, such as teasing and name-calling. It has been reported that bullying experiences can impact not only concurrent but also future psychosocial actions (25). The effect of malocclusion on health-related quality of life has been widely evaluated in the literature (3, 5, 9). However, there are few studies considering psychological well-being of subjects (3, 10-12), and to our knowledge, none of them compared psychological well-being and health-related quality of life scores of children who have various malocclusions. Therefore, this study aimed to comparatively evaluate the psychological well-being of the subjects with normal and abnormal profile and overjet, and also determine the effects of the severity of malocclusion, which was assessed with the DHC-IOTN.

Children's feelings about their dental appearance begin to emerge by about 8 years of age. They have criteria similar to those of adults regarding the self-perception of body image (3). According to Rossini et al. (26), the smile appears to be of primary esthetic importance for children younger than 10 years of age as well as for adolescents. It is critical to evaluate the effect of malocclusion on psychological well-being in this age group, as it might influence their future psychosocial life. Therefore, this study researched an age group between 8 and 13 years, which are the critical years in terms of the development of body image and self-perception.

Although some studies have reported a relationship between socioeconomic status and OHRQoL, others have shown no such association (5, 27, 28). Therefore, to eliminate the possible confounding effects of socioeconomic status on psychological well-being, only participants with similar health insurance plans were included in this study. This allowed us to standardize the socioeconomic status of the participants. However, parents' education levels, incomes, and occupations were not included in the survey, which was a limitation of our study.

Kragt et al. (29) pointed out the importance of sociocultural structures on the perception of dental esthetics. In this study, all participants were from the same country and region. Moreover, in some studies, it was reported that no significant differences were found between genders regarding the impact of malocclusion on OHRQoL (3, 30). In this study, there were also no significant differences between male and female participants in self-concept, depression, state, and trait anxiety levels. Hence, both genders were evaluated together in each group.

Few studies have examined the relation between self-concept, self-esteem, and malocclusions. Seehra et al. (31) reported that being bullied was significantly associated with a Class II Division 1 incisor relationship and increased overjet, and bullied participants reported lower levels of general self-esteem. In addition, Kenealy et al. (32) reported that malocclusions had a negative impact on the self-esteem of adolescents. Average T-scores for 11- and 12-year-old subjects were given as 51.3 (33). However, in this study, the mean self-concept scores are higher than the average score, and no significant differences were found among the groups with respect to self-concept. In accordance with our study, Phillips and Beal (10) suggested that an adolescent's self-perception of the dentofacial region has more effect on self-conception issues compared with malocclusion.

No study has evaluated the relation between malocclusion and depression. Bang et al. (34) reported a cutoff score of 15 for mildly depressed subjects. In the present study, it was found that depression scores of adolescents were low (approximately 7 for all groups), and there was no significant difference among the groups. Therefore, it could be interpreted that malocclusion was not a main factor for depression.

The State Anxiety Scale evaluates a subject's current state of anxiety, asking how subjects feel "right now," using items that measure subjective feelings of apprehension, tension, nervousness, worry, and activation/arousal of the autonomic nervous system. The Trait Anxiety Scale evaluates relatively stable aspects of "anxiety proneness," including general states of calmness, confidence, and security (35). In this study, mild state (Group 1: 31.06; Group 2: 29.00; and Group 3: 28.89) and trait (Group 1: 34.71; Group 2: 32.98; Group 3: 32.36) anxiety were observed in all groups, but no significant difference was found with respect to both anxiety scores. As all cases were referred to the clinic for a dental examination, the mild state anxiety might have been due to dental examination fear and anxiety.

Dahong et al. (36) reported that the psychosocial impacts on patients with dental malocclusions were significantly different from those with normal occlusion. However, there is a conflict in the literature about the levels of happiness, concerns and awareness, feelings of insecurity, self-perception regarding facial profile, and dental appearance of adult cases (7,36). In a previous study, adults with a mild protrusion of the lip had significantly better self-esteem and health-related quality of life scores compared to severe protrusion cases (37). This result might indicate a risk of psychosocial impairment if the patients leave without treatment.

A previous study indicated that overjet is one of the most important occlusal traits and might greatly affect the self-dental perception of patients (4). Dahong et al. (36) suggested that this trait, which can be perceived easily by patients, can further influence the psychology of young adults. The researchers reported that the psychosocial impacts of Class III and Class II/I patients were similar, but the effects of these malocclusions were found to be more severe compared with Class I cases. In addition, Johnston et al. (7) reported that psychosocial impacts occurred regardless of the type of malocclusion. In this study, no differences in the psychological well-being of children were found between children with increased, decreased, or normal overjet. The findings of this study were in agreement with those of previous studies, which found that malocclusion type was not a deterministic factor for psychological well-being. However, our findings conflict with previous studies, in which malocclusion groups were compared with control groups. This might be because of the age of the subjects. Kragt et al. (29) reported that children older than 14 years showed the greatest impact of malocclusion on OHRQoL owing to the major life changes occurring between the ages of 11 and 14 years. Choi et al. (9) reported that aging and severity of malocclusion had relatively negative effects on OHRQoL and noted that subjects in their 30s had a more negative perception. In light of the results of this study, it could be concluded that the effect of malocclusion on health-related quality of life did not seem to be significant in the early ages. Therefore, early treatment during childhood might be better than late treatment, as malocclusion might affect psychological well-being negatively with aging.

A systematic review found a missing association between DHC-IOTN or index of complexity, outcome, and need and OHRQoL, where an association was found between the AC-IOTN and the social emotional domain of OHRQoL (29). In addition, Baram et al. (38) reported a relationship between AC-IOTN and the psychosocial impact of malocclusion. In a study evaluating the relation between self-esteem and malocclusion, self-esteem was not found to be significantly different between cranial types, but there was a significant difference between the malocclusion severity levels assessed by DHC-IOTN (39). Another study reported that components of IOTN had a maximum impact on self-esteem (40). However, the cases in this study were mostly scored at grade 4, while the correlation between the DHC-IOTN scores and the state–trait anxiety, depression, self-concept, and health-related quality of life scores was found to be insignificant. This inconsistency with previous studies might be due to age difference.

In light of these findings, the null hypothesis could not be rejected because no differences were found among the groups with respect to self-concept, depression levels, state–trait anxiety levels, and quality of life scores.

We were not able to classify and statistically compare the subjects' psychological well-being according to the severity of their profile abnormalities owing to limited sample size.

CONCLUSION

Abnormalities in the facial profile and negative or increased overjet have no influence on children's psychological well-being. The null hypothesis was accepted.

No correlation was found between the severity of malocclusion and psychological well-being.

Ethics Committee Approval: This study was approved by Ethics committee of Gazi University, (Approval No: 77082166-604.01.02/50).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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Review

Coronavirus Disease 2019- Challenges Today and Tomorrow in Orthodontic Practice: A Review

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Main points:

- As uncertainty about the coronavirus disease 2019 (COVID-19) pandemic increases, it is necessary to have clear guidelines or rules that explain which emergencies orthodontists must attend to and which they can defer.
- There are many situations where an orthodontist cannot leave the patients unattended for more than 6 to 10 weeks..
- Guidelines for COVID-19 testing, the type of personal protective equipment are required in orthodontic practice.
- Creation of guidelines for obtaining consent and proper documentation are also of utmost importance when contacting patients remotely.

ABSTRACT

From the start of 2020, the world has witnessed the biggest health and humanitarian crisis in the modern century named coronavirus disease 2019. The rapid spread of infection created chaos and confusion across the globe. Like all other health professions, a timely and major reorganization of orthodontic services is challenging. Unlike other medical emergencies, an orthodontic emergency does not require immediate attention in most cases. With advances in the modern web-based communication systems, minor problems can be managed online in orthodontic practice. During an emergency, however, orthodontists have a moral obligation to treat and manage patients under the World Health Organization guidelines and protocol.

Keywords: Coronavirus, orthodontic practice, web-based communication

INTRODUCTION

The outbreak of coronavirus disease 2019 (COVID-19) has been declared as a global health crisis by the World Health Organization (WHO), and it has led to major disruptions, national emergencies, and lockdowns, leaving only the essential services to continue. The human spread of the infection is majorly through the respiratory secretions and droplets and/or direct contact by which the virus enters the mucous membranes of oral and other associated structures (1). The origin of the pneumonia-like infection of unknown causes is believed to be from bats, and the infection was first detected in the city of Wuhan in Hubei province, China (2). COVID-19 infections are caused by a variant of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which belongs to the family Coronaviridae. Other rare strains, such as Middle East respiratory syndrome coronavirus (MERS-CoV) and severe acute respiratory syndrome coronavirus (SARS-CoV) belonging to the same family, are responsible for Middle East respiratory syndrome and severe acute respiratory syndrome (SARS) diseases, respectively (3).

The degree of infection spread is high in orthodontic practice because of the characteristics of orthodontic clinics and nature of treatment. To control and reduce the transmission of coronavirus infection, it is essential to follow standard infection control guidelines and protocols and strict behavioral guidelines in addition to the correct use of personal protective equipment (PPE) (4).

Before any urgent dental care, patients who are potential carriers of the infection should be detected to prevent further spread of infection. Emergency treatment needed for a patient may be categorized on the basis of

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whether the procedure generates aerosols. During this COVID-19 period, it is better to reduce the aerosol-generating procedures (AGPs), whenever possible, because these aerosols carry a high risk of infection. Questionnaires can be used to identify high-risk groups depending on medical history and systemic conditions. Furthermore, body temperature should be measured before attempting any clinical procedure (5).

Owing to the rapidly evolving nature of the infection, orthodontists, like all other health professionals, are struggling to balance the safety of orthodontic team in their commitment to their patients. Therefore, concise protocols and safety measures are needed for managing various orthodontic emergencies (6). When dealing with a pandemic, appropriate time management and circumstance-specific protocols are the only options available to maintain the efficiency of appliances (7).

This review aimed to provide a comprehensive and detailed summary of problems faced in the field of orthodontics and to discuss the need for guidelines and protocols in the handling of various emergency orthodontic procedures.

Epidemiologic Characteristics

COVID-19 remains a highly infectious disease with a reproductive number (R0) of approximately 1.4 to 2.5 according to the WHO estimate (8). Preliminary studies conducted at the beginning of the outbreak have reported higher estimates of R0 of infection in the range of 2.24 to 3.58 (9). All the estimates of transmissibility indicate that self-sustaining progression between humans is the main reason for the magnitude of this outbreak (10, 11).

The incubation period for COVID-19 remains comparable with that of other recent epidemic viral diseases, such as SARS (2-7 days) (12) and MERS-CoV (2-14 days) (13), but it is slightly longer than that of swine flu (1-4 days) and seasonal influenza (1-4 days) (14). A recent study looking at 88 cases of travel-related infection spread has shown an average period of incubation of approximately 6.4 days (2.1-11.1 days) (15).

Clinical Signs and Symptoms

Clinical manifestations of this disease range from mild to severe illness along with other clinical conditions, such as pneumonia, acute respiratory distress syndrome (ARDS), sepsis, and multi-organ failures (16). Various signs and symptoms include fever, cough, sore throat, nasal congestion, malaise, and headache, whereas atypical symptoms can be seen in immunocompromised patients (17-21). In serious illness, it is likely to see symptoms, such as pharyngeal pain, dyspnea, dizziness, abdominal pain, and anorexia (18). In older individuals, adverse outcomes can be associated with underlying comorbidities such as diabetes, cardiovascular disease, and cerebrovascular disease (20).

The onset of ARDS is associated with severe shortness of breath that might develop within a few hours to a few days after the infection (16, 22). Significant decrease in CD4 and CD8 levels can be seen in the initial stages of infection, and chest imaging can show bilateral opacities, lobar or lung collapse, or nodules (20).

Diagnosis of Coronavirus Disease 2019

The WHO recommends that culturing of the virus must be performed in a biosafety level (BSL)-3 laboratory and the reverse transcription-polymerase chain reaction (RT-PCR) be performed in a BSL-2 laboratory (24, 25). When handling specimens of SARS-CoV-2, one must ensure that the sample is not contaminated or the healthcare worker (HCW) is not infected to minimize any risks and to ensure accuracy of diagnosis. Isolation of SARS-CoV-2 can be performed using cell lines, and diagnosis has to be confirmed by RT-PCR.

Seroconversion for the disease is evaluated by the detection of antibodies in convalescent-phase serum after a negative result in the acute-phase serum sample. Seroconversion can be confirmed by enzyme-linked immunosorbent assay or indirect fluorescent antibody test (26).

Tele-Triage and Pre-Appointment Screening

Triage should be established so that teleconsultation or web-based communication with the patient will assist the patient in resolving any urgent orthodontic problems that can be managed at home and to determine the need for a patient's visit to the orthodontic office or provide support by following the social distancing protocol. The triage team should inform patients about the preventive measures to be undertaken, such as maintaining social distance, wearing masks, washing hands, or using hand sanitizer, that must be followed in a healthcare facility.

Triage screening or self-assessment tools published by the Centers for Disease Control and Prevention (CDC) and Mayo Clinic include questions about recording a patient's body temperature, updating the patient's medical history, and asking targeted questions mandatorily (27, 28).

1. History of fever (37.3°C or higher) or use of antipyretic medications in the past 14 days?

2. Have you traveled to a country/area reporting high transmission of COVID-19 infection?

3. History of contact with COVID-19-positive patients in the past 14 days?

4. Have you recently participated in a large gathering?

5. Symptoms of any lower respiratory tract infections, such as difficulty in breathing, shortness of breath, sore throat, cough, diarrhea, or loss of smell or taste?

If patients answer yes to any of these questions, advise them to self-quarantine at home for 14 days.

For patients with a history of COVID-19 infection, any orthodontic emergencies should not be performed unless the patient has followed the CDC guidelines listed below:

1. At least 72 hours have passed since recovery (resolution of fever without the use of antipyretics and no respiratory symptoms, such as cough, shortness of breath, and difficulty in breathing).

2. One week has passed since the initial symptoms.

3. The patient should have 2 negative laboratory test results in 24 hours at least.

The orthodontist must perform the necessary measures to resolve the emergency and advice the patient to maintain optimal oral hygiene, follow a low-sugar diet, and avoid hard and sticky food that can lead to breakage of appliance.

After tele-triage, when a patient needs to be examined clinically, the triage team should ask the abovementioned screening questions (screening questions with informed consent and necessary documentation). The patient should be advised to enter the office with maximum 1 accompanying person who should not be medically compromised (29). Instruct the patient to enter the operatory room alone wearing a mask, and the accompanying person should remain in the waiting room or parking lot.

Infection Control and Management of Orthodontic Practice

Preventive Measures

The orthodontic office must maintain very high standards of infection control procedures and sterilization of instruments. The orthodontist/clinician should examine the patient by wearing PPE, which includes a face mask (fit-tested N95 masks), double gloves, eye protection, face shield, and gowns (29, 30).

Because the level of infection in human saliva is high, it is necessary to use preprocedural mouth-rinse, such as hydrogen peroxide (1%) or povidone-iodine (0.2%), to reduce the salivary load of microbial flora, because the SARS-CoV-2 is vulnerable to oxidation (4, 5). The Faculty of General Dental Practice guidelines recommends that there is no evidence of a virucidal effect.

The orthodontic team should be trained about the disease symptoms, mode of transmission of disease, and infection control procedure, such as thoroughly disinfecting all surfaces with 0.1% to 0.2% of sodium hypochlorite for 1 minute or 62% to 95% ethanol for disinfection of small surfaces (31). Medical waste should be presumed to be infectious and disposed off as infected medical waste. HCWs should be taught proper donning and doffing of PPE (29, 31).

In the operatory area, adequate ventilation with fresh air or high airflow is advised. It is necessary to have a private room or negatively pressured rooms for treating patients who may be infected. The distance between the dental units must be a minimum of 2 m if this room is not available. The room should be reorganized in a way that patients can maintain a safe distance when entering or leaving the clinic. The disinfection protocol should be repeated after each patient consultation (5). All dental staff and patients/carers should disinfect their hands when entering and leaving the room. This must be performed immediately before every episode of direct patient care. Disposable tissues and materials should be made available to the patients to cover their nose and mouth in case of coughing (32). The dental unit waterline should be flushed for at least 2 minutes using disinfectant to not only minimize the risk of infection but also improve the quality of water. Orthodontic pliers should be sterilized with steam autoclave, ultrasonic bath, and cold sterilization with 2% of glutaraldehyde or 0.25% of peracetic acid solution. Photographic retractors, debonding burs should be decontaminated with washer-disinfector (29).

Owing to the unprecedented and evolving nature of the disease, current guidelines advise limiting the use of AGPs to reduce the chance of cross-infection (4). Aerosols could be contaminated with the patient's saliva or blood and increase the concentration of microbial flora, exceeding those produced by sneezing or coughing. They may spread as far as 2 m from the patient's mouth, which could contaminate the entire operatory area.

The various AGPs include (33-37):
• high-speed air rotor or low-speed drills, including surgical drills
• three-in-one air/water syringes
• ultrasonic and sonic handpieces
• air abrasion procedures or intraoral sandblasting.

Preventive Measures to Minimize the Effect of Aerosol Production in the Orthodontic Office

Aerosol production in the orthodontic office is basically through 2 routes: bonding and debonding procedures. For orthodontic practice, this extrapolates for procedures that use slow rotary instruments or air turbine with high speed, three-in-one air/water syringe, and enamel preparation using ultrasonic or air abrasion devices. This will have a direct impact on adhesive removal from enamel and the use of air/water sprays and rotary handpieces for moisture control and cleaning. A recent study by van Doremalen et al. (38) has indicated that coronavirus can survive from 4 to 24 hours on copper and paper surfaces, whereas infectious charge is reduced only after 48 hours on a steel surface and 72 hours on plastic material.

Bonding Procedure

Aerosol production with bonding procedures involves the use of water-spray in enamel etching, increasing the likelihood of spatter and droplet formation and resulting in increased working time. Liquid gel/low-viscosity and self-etching primer should be prioritized over conventional acid etching. Light-cured resin-modified glass ionomer cement is also preferred over conventional light-cured bonding agent although it has compromised bond strength (39, 40).

Debonding Procedure

During the debonding procedure, preventive measures to minimize aerosol contamination of the operatory area should focus on minimizing the composite remnants after bracket debonding and effective grinding patterns to reduce dust, operating time, and particulate generation. Cohesive resin fracture would allow for minimal enamel remnants by identifying bracket base mesh, size, and shape with adhesive composition. One can avoid rotary instruments and reinforce the use of hand instruments for removal of resin remnants. Using tungsten carbide burs without water for removal of limited traces of resin remnants can be recommended (41).

Table 1. Various orthodontic emergency scenarios, home care, and emergency precautions

Orthodontic emergency	Home care/emergency procedure
Sharp protruding distal wire	• A cotton bud or pencil eraser can be used to flatten the wire against the tooth surface to prevent impingement. • A clean or sterile tweezer can be used to grip the wire so that it can be secured to both sides comfortably. • Relief wax can be used to prevent irritation. • A sterile or clean nail clipper can be used to remove the protruding part of the wire.
Debonded bracket	• Self-etching primer can be used, which minimizes treatment time and the amount of moisture.
Impingement from ligature wire	• If ligature wire is loose, a tweezer can be used to remove it. • Relief wax or cotton swab can be used to prevent irritation.
Irritation from the broken fixed retainer	• If part of the retainer is broken, it can be removed with the help of a clean clipper. • If the entire retainer is loose, the patient should be advised to remove it carefully with help of a tweezer and use a removable retainer (if provided). • If retention is necessary for stability, the patient should be advised to visit the orthodontic office under strict healthcare protocol.
Severe pain and/or infection from orthodontic bands or appliance embedded into the gingiva	• This requires immediate attention, which should be managed in an orthodontic setup. The patient should be cleared of all tele-triage screening. • If the patient cannot be attended to in-person, the part which is impinging or embedded within the gingiva should be removed carefully with a clipper. • The patient can be advised to use mouthwash and saltwater gargle. • Antibiotics and antipyretics can be prescribed with a digital signature by the orthodontist.
Loose removable appliance	• It can be removed or discontinued until the next visit with the orthodontist, when the clinic/practice reopens for a routine procedure. • If it is necessary for stability, the orthodontist can deliver a new set of removable appliances such as removable quad helix, if necessary.
Broken or ill-fitting aligner	• If the current aligner is broken or ill-fitting, switch to the previous aligner. If the previous aligner is also ill-fitting, have a new aligner, if possible.
Broken or loose palatal expander or transpalatal arch	• If these appliances are partially glued on, they can be placed back in position, and any screw activations should be stopped. • If it has fallen out completely, it should be kept in a safe place until further instructions from the orthodontist.
Laceration or ulcers from a broken appliance	• Mouth sores can be relieved by applying topical anesthetics, egora-bases, or dentogel.
Swallowed bracket/piece of appliance	• If swallowed, the patient should be asked about difficulty in breathing or sudden coughing. In case of severe difficulty, the patient should be admitted to the hospital as an emergency. • If no difficulty is experienced, it may pass through the digestive tract without any complication.

Use of high-volume suction in orthodontic practice has been shown to reduce a significant amount of aerosols in the environment and should be employed in all AGPs, including trimming appliances outside the oral cavity. A rubber dam can be also used to reduce the biodiversity of aerosols when multiple teeth are being treated, although practical implications in orthodontics are limited. Another alternative for the clinician would be to schedule appointments for different times or even separate days when AGPs need to be performed. A separate unit can be used for AGPs.

Filtering facepiece class 3 respirator also offers a useful method of filtration of particles as small as 0.6 µm and can be used to reduce aerosol particles in the environment (32). Furthermore, when treating any patient, it is imperative to use PPE, such as face shields and goggles, and the abovementioned common preventive measures should be followed (42).

Orthodontic Emergencies and Management

In this phase of the COVID-19 pandemic, reorganization of orthodontic services is very challenging for an orthodontist. Although most minor procedures have been postponed, it is necessary to manage acute orthodontic emergencies to avert further complications.

A true emergency in the field of dentistry is the one that is associated with swelling and infection of soft tissues, unbearable pain, bleeding, and so on. From an orthodontic perspective, emergencies may include trauma from the removable or fixed orthodontic appliance leading to severe pain and/or infection, circumstances related to dental trauma, or conditions where a lack of management would be harmful to the patient. Moreover, an orthodontist may not be able to leave a patient unattended for a long duration (10-12 weeks) to avoid further complications (43). The orthodontist should try and manage orthodontic emergencies over the phone or provide the patient with links containing audiovisual aids available on professional websites that would guide them to manage minor emergencies at home. Table 1 lists some orthodontic emergencies that can be managed remotely (31).

Immediate attention is needed in cases of discomfort associated with various fixed orthodontic appliances where orthodontic intervention is required. Overextended distal wires, detachment of buccal tube, impinging ligature ties, loose bracket leading to laceration, and loose or broken bands are some of the common orthodontic emergencies observed. Virtualized orthodontic consultations and treatment approaches can be implemented in case of emergencies.

Post-lockdown, patients who need to be addressed first are those who are undergoing treatment mechanics that are not self-limiting, such as reverse curve NiTi wires, torquing auxiliaries, springs (pendulum or canine eruption spring), fixed functional appliances (Herbst), and lose temporary anchorage devices which, if left unattended, would lead to detrimental effects, increase in treatment duration, and reduction in patient motivation.

Less often, symptomatic treatment measures can be given to patients, including pharmacological management in case of pain and minor discomfort (44). Paracetamol should be advised in preference to ibuprofen (45).

Post-lockdown, passive self-ligation offers advantages in delaying appointments and offers fewer emergencies than elastomeric rings, where loose elastomeric rings or accumulation of food and plaque around elastomeric rings leads to emergency visit (46). These appliances are more comfortable, and patient follow-up can be minimized during this pandemic. Aligner therapy has advantages such as comfort, and short treatment duration. Yunyan et al. (47) have concluded that clear aligners had an advantage in segmented teeth movement and shortened treatment duration but were less effective in controlling torque and retention.

During leveling and alignment, reciprocal forces are generated between the teeth. Usually, practitioners start with light forces with round NiTi archwires that can lead to slippage of the wire from brackets because of excess amount of play. Square or rectangular NiTi wires are preferred to avoid emergencies owing to slippage. To prevent sharp ends impinging on the soft tissues, the archwires should be cinched back. Initial few visits during leveling and alignment should be scheduled with an interval of approximately 10 weeks during this pandemic to reduce patient exposure. Stainless steel ligature is more hygienic than elastomeric rings (48).

During the second or third wave of the pandemic, expansion treatment with rapid palatal expander, open coil spring used during alignment, and fixed functional appliances (Herbst or Class II correcter) requires close monitoring and therefore should be prescribed with caution. Alternative methods of NiTi slow expander, NiTi open coil springs, and fixed twin block would be preferable during this crisis, because they have fail-safe mechanics, minimizing the chance of emergencies (48).

Space closure can be accomplished with active tie-backs, and use of elastics for space closure should be avoided, because it requires continuous monitoring. Phase II treatment with fixed appliances should be delayed, and the retentive phase should be extended by placing an upper inclined plane (48).

Looking from a financial perspective, the treatment cost might remain the same post-lockdown with an additional cost charged for PPE to ensure safety of both the patient and clinician. Teledentistry or virtual consultations should continue with WhatsApp or Zoom video, maintaining communication with patients in the immediate future. This pandemic has produced scenarios that were never envisioned before and has affected the practice of orthodontics in particular and dentistry as a whole. Virtual consultations have certain advantages, such as easier monitoring of the patient without the need for personal contact, and help the patient psychologically. They are cost-effective for patients; however, they have certain disadvantages like a lower standard of care in orthodontics, no clear rules or guidelines available for virtual orthodontic care, legal issues, and so on. We would recommend adapting orthodontic mechanics that offer more convenient and fail-safe methods whenever required.

As the uncertainty of the pandemic continues, it is evident that up-to-date recommendations are needed. These recommendations should focus on the guidelines and rules that explain emergencies that an orthodontist must attend to in their clinics; guidelines for the screening and testing of the disease; and guidelines for obtaining consent, documentation, and comprehensive protocols for virtual or web-based consultations and appointments.

CONCLUSION

Unlike medical emergencies, orthodontic emergencies do not require immediate attention in most cases. With advances in the modern web-based communication systems, management of minor problems can be done online in an orthodontic practice. However, in some cases, pain and discomfort have to be taken care of as an emergency condition. The main focus and objective of an orthodontist when the patients come in for an emergency appointment are to take into account the complete history of the patient and the problem and relieve the patient of any pain and discomfort under the proper guidelines recommended by the WHO.

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Case Report

Mini-implant and Modified Nance Button Assisted Alignment of a Horizontally Impacted Maxillary Canine - A Case Report

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Main points:

- The priorities in the management of a highly placed horizontally impacted canine are to move its crown away from the roots of the incisors and to reorient it vertically before it is erupted intraorally. The mini-implant and modified Nance button provided an appropriate point for force application to redirect the impacted canine from a horizontal to a more vertical position.
- A modified closed-eruption technique used initially to bond an attachment on the canine helped maintain intact gingival attachment at the end of treatment.
- Once the canine was palpable in the vestibule, an open eruption was planned, and a cantilever spring was used for forced eruption. The cantilever spring is a one-couple system that allows for the delivery of relatively constant optimal forces and moments, thus avoiding the need for frequent reactivations.

ABSTRACT

Orthodontic alignment of a horizontally impacted canine placed high and deep in the maxilla represents a challenging clinical scenario. This article describes a case report of a 16-year-old postpubertal male patient who was concerned about an unesthetic smile. The clinical and radiographic investigations revealed that the patient had retained deciduous canines and bilaterally impacted maxillary canines. The right impacted canine had a good prognosis. The left canine was horizontally impacted in the labial side with a Kau-Pan-Gallerano index score of 19, which indicates a "difficult" degree of treatment. The initial treatment plan was application of distal traction to the impacted left canine from reinforced anchorage unit to change its inclination from horizontal to vertical before erupting it toward occlusion. In this case report, we demonstrated the use of a mini-implant and a modified Nance button–assisted forced eruption of an impacted canine. The 12-month follow-up review showed that the results were maintained during the time, and the previously impacted teeth showed intact gingival attachments. A conservative surgical exposure of the impacted canine and well-planned biomechanics helped us achieve a desirable, esthetic outcome.

Keywords: Canine impaction, mini-implant, modified Nance button

INTRODUCTION

The canines play a crucial role in establishing an esthetic smile and functional occlusion. Canines have the longest period and deepest area of development, as well as the most devious eruptive path (1-3), making them more susceptible to impaction. This case report demonstrates the application of a modified Nance button with a mini-implant for the successful management of a horizontally impacted maxillary canine situated in a labial position in an adolescent patient.

CASE PRESENTATION

Diagnosis and Etiology

A 16-year-old male patient presented with a chief concern of an unesthetic smile (Figure 1 a-g). The extraoral examination showed a straight profile. The intraoral examination revealed Angle Class I molar relationship with

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Figure 1 (a-g). Pretreatment facial (a-b) and intraoral (c-g) photographs

6 mm of spacing in the maxillary anterior region, retained maxillary deciduous canines, missing permanent canines, increased overjet, and normal overbite. The patient had an increased facial angle with counterclockwise rotation of the mandible (decreased Frankfort-mandibular plane angle), which manifested as a mild skeletal Class III relationship (Table 1). He had proclined anterior teeth (Table 1, Figure 2a). The panoramic radiograph (Figure 2b) revealed impacted maxillary canines; the left and right canines were located in sector 4 and 1, respectively (4). A cone beam computed tomography (CBCT) image revealed that the crown of the left canine was close to the labial cortex and at the apical one-third of the central incisor root (Figure 2 c, d).

Table 1. Cephalometric data

	Normal values	Pretreatment	Post treatment
SNA (°)	82+2	80	81
SNB (°)	80+2	82	82
ANB (°)	2	-2	-1
Ao-Bo (mm)	-1	-2	0
NPg-FH (°)	89+ 3.9	92	89
Ar-Go-Me (°)	126+6	128	123
FMA (°)	25	22	22
SN-GoGn (°)	32	25	26
U1-NA (°)	22	50	33
U1-NA (mm)	4	14	8
U1-SN (°)	102+2	130	122
L1-NB (°)	25	32	26
L1-NB (mm)	4	8	6
U1-L1 (°)	125+7	100	114
IMPA (°)	90	99	95

SNA: Sella, Nasion, A-point; SNB: Sella, Nasion, B-point; ANB: A-point, Nasion, B-point; Ao-Bo: A-point and B-point to occlusal plane, NPg-FH: Nasion - Pogonion to Frankfort plane angle, Ar-Go-Me : Articulare-Gonion-Menton angle, FMA: Frankfort mandibular angle; SN-GoGn: Angle that is measured at the junction of the planes Sella -Nasion to Gonion-Gnathion , U1-NA: Angle between upper incisor inclination and NA plane; U1-SN: Angle between upper incisor inclination and SN plane, L1-NB: Angle between lower incisor inclination and NB plane, U1-L1: Angle between upper and lower incisor inclination, IMPA: Inter-incisor mandibular plane angle

The Kau-Pan-Gallerano index (5) showed a score of 8 for the right canine and 19 for the left canine, which indicates "easy" and "difficult" degrees of treatment, respectively (Figure 3 a, b).

Treatment Objectives

The treatment objectives were to (1) get both the canines in arch with minimal impact on the supporting periodontium and (2) achieve normal overjet and a Class I canine relationship.

Treatment Alternatives

As the degree of difficulty was higher for the impacted left canine, extraction of the same and replacement with the help of a fixed prosthesis or a dental implant was advised. However, the patient denied the prosthesis. Autotransplantation of the left impacted canine was not considered as the procedure's success rate was not good. Finally, we decided to attempt forced eruption and alignment of the impacted teeth with the consent of the patient and his parents.

Treatment Progress

A 0.022×0.028 inch preadjusted edgewise appliance was used. After extracting the deciduous canines, the right impacted canine erupted spontaneously. The maxillary molars were banded, and a modified Nance acrylic button with a hook extension on the palatal side was placed in the maxillary arch (Figure 4a-b). A

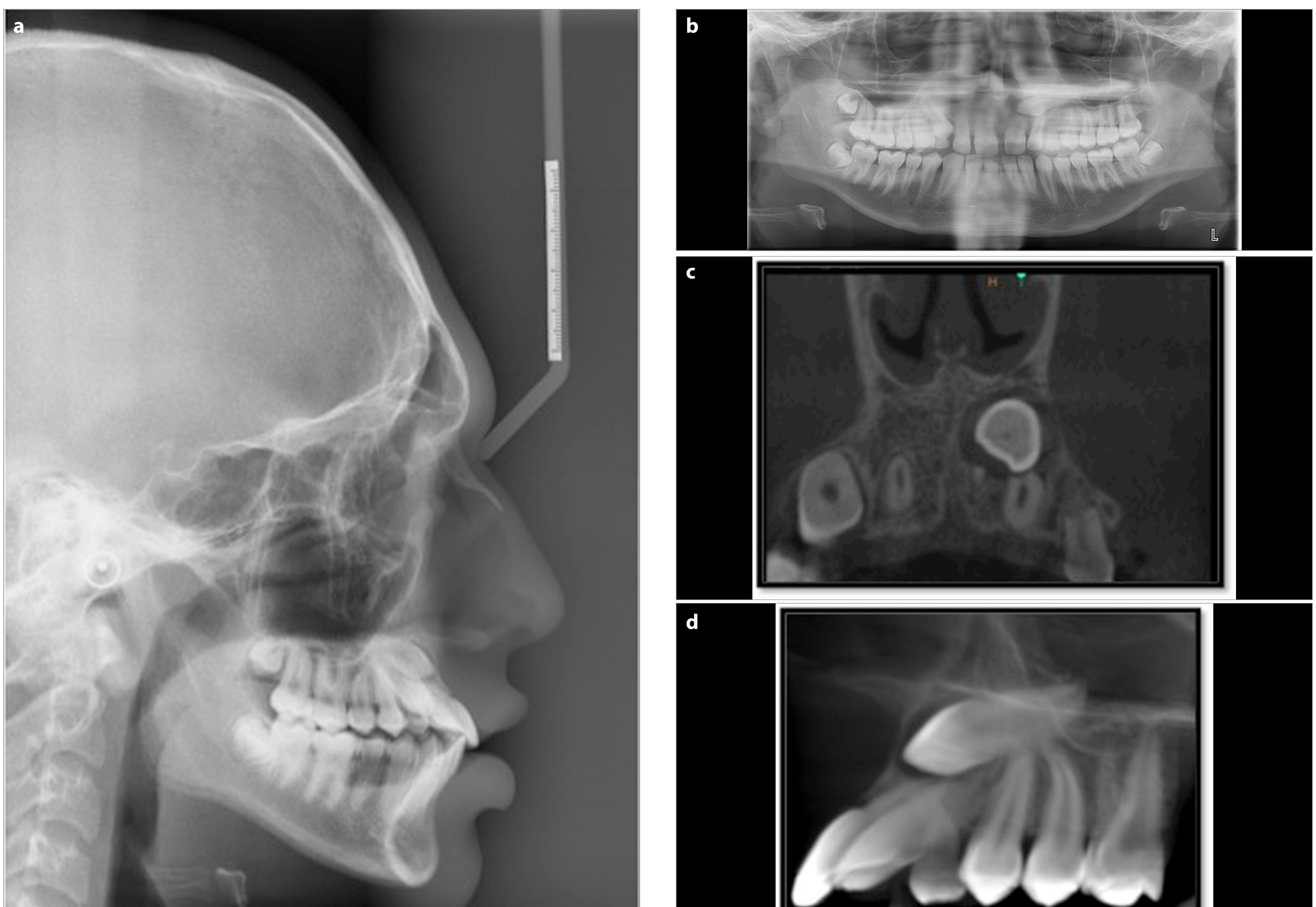

Figure 2 (a-d). Pretreatment lateral cephalogram (a), panoramic radiograph (b), coronal view of the CBCT image (c), sagittal view of the CBCT image, and the impacted left maxillary canine (d)

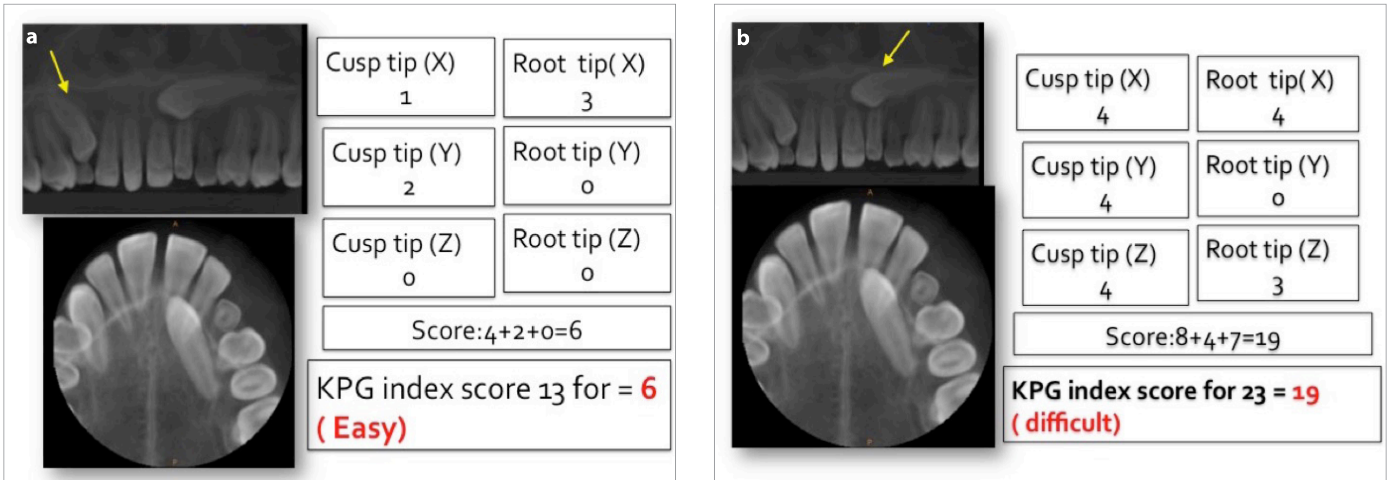

Figure 3 (a, b). Kau-Pan-Gallerano index score for the right (a) and left (b) impacted canines. Yellow arrow indicates the impacted canine

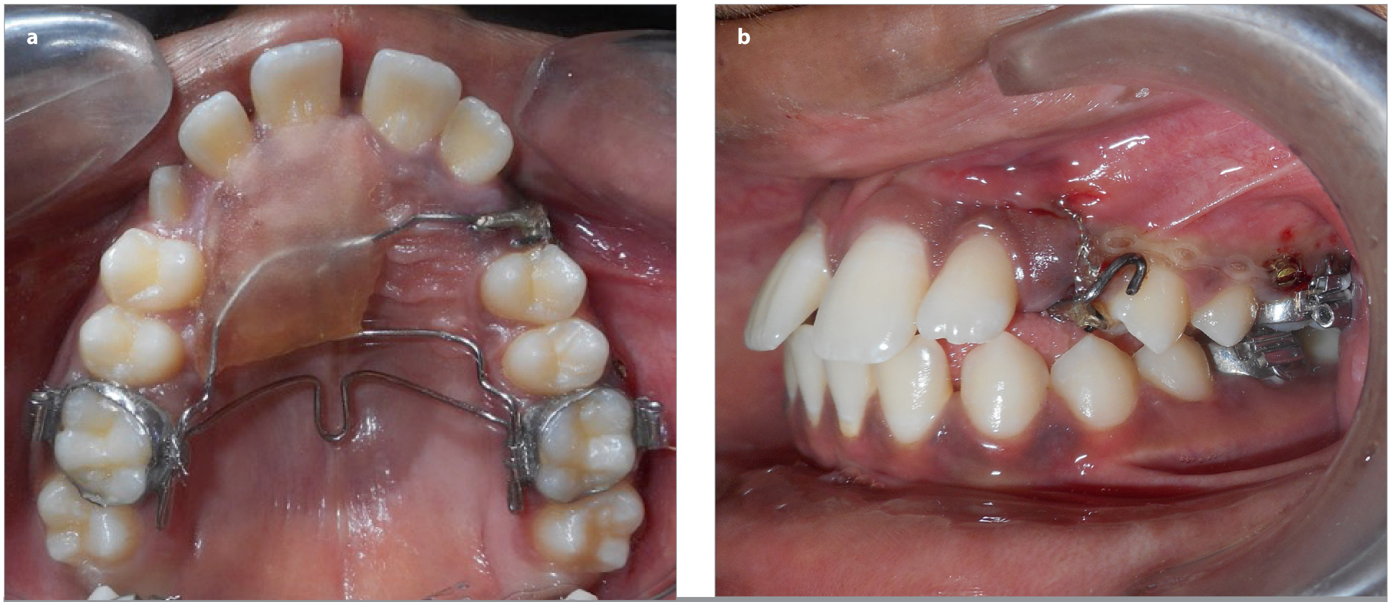

Figure 4 (a, b). Occlusal (a) and lateral (b) views show a modified Nance button used for forced eruption of the left impacted canine

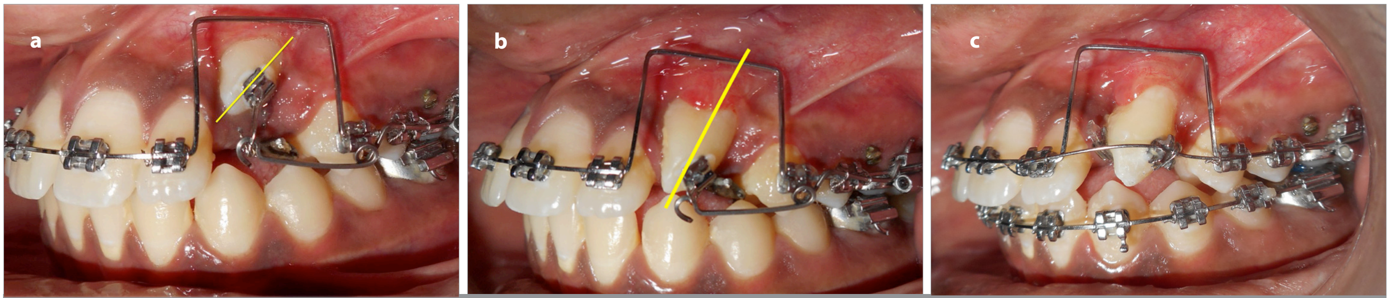

Figure 5 (a-c). Progress intraoral photographs show a cantilever spring in position at the start (a), and at the end (b) of cantilever mechanics, and a 0.014-inch nitinol archwire piggybacked on a 0.019×0.025-inch stainless steel base archwire for alignment of the impacted canine (c).
Yellow line indicates the long axis of canine

Begg's bracket with a ligature extension was bonded on the left impacted canine. This attachment was used to apply a traction force from the impacted canine to the mini-implant (diameter, 1.3 mm; length, 8 mm) placed in the interradicular space between the left second premolar and first molar. Once the angulation of the canine improved, the vertically directed force was applied on the canine from the hook of the Nance button. Subsequently, the maxillary teeth were bonded, leveling and alignment was done, and an open coil spring was used for space consolidation. As the canine approached the attached gingiva, the 0.019×0.025-inch stainless steel base archwire with a horizontal offset was placed, and a cantilever spring fabricated with a 0.017×0.025- inch beta titanium wire was used for canine extrusion (Figure 5a-b). Once the canine approached the occlusal plane, the preadjusted brack-

Figure 6 (a-g). Posttreatment facial (a-b) and intraoral photographs (c-g)

et was used to replace the Begg's bracket, and a 0.014-inch nitinol archwire was piggybacked onto the existing stainless steel base archwire (Figure 5c). As the alignment proceeded, a continuous rectangular archwire provided an additional moment to upright and torque the canine. The fixed appliance was removed after finishing and detailing of the arches, followed by placement of canine-to-canine fixed lingual retainers in both the arches.

Treatment Results

The total treatment time was 22 months. The smile esthetics improved (Figure 6 a, b). Intraorally, a well-interdigitated buccal occlusion with a Class I molar and canine relationship was established (Figures 6 c-g and 7a). The posttreatment intraoral photograph showed a slightly longer clinical crown of the maxillary left canine (Figure 6d); however, it was asymptomatic, and the gingival

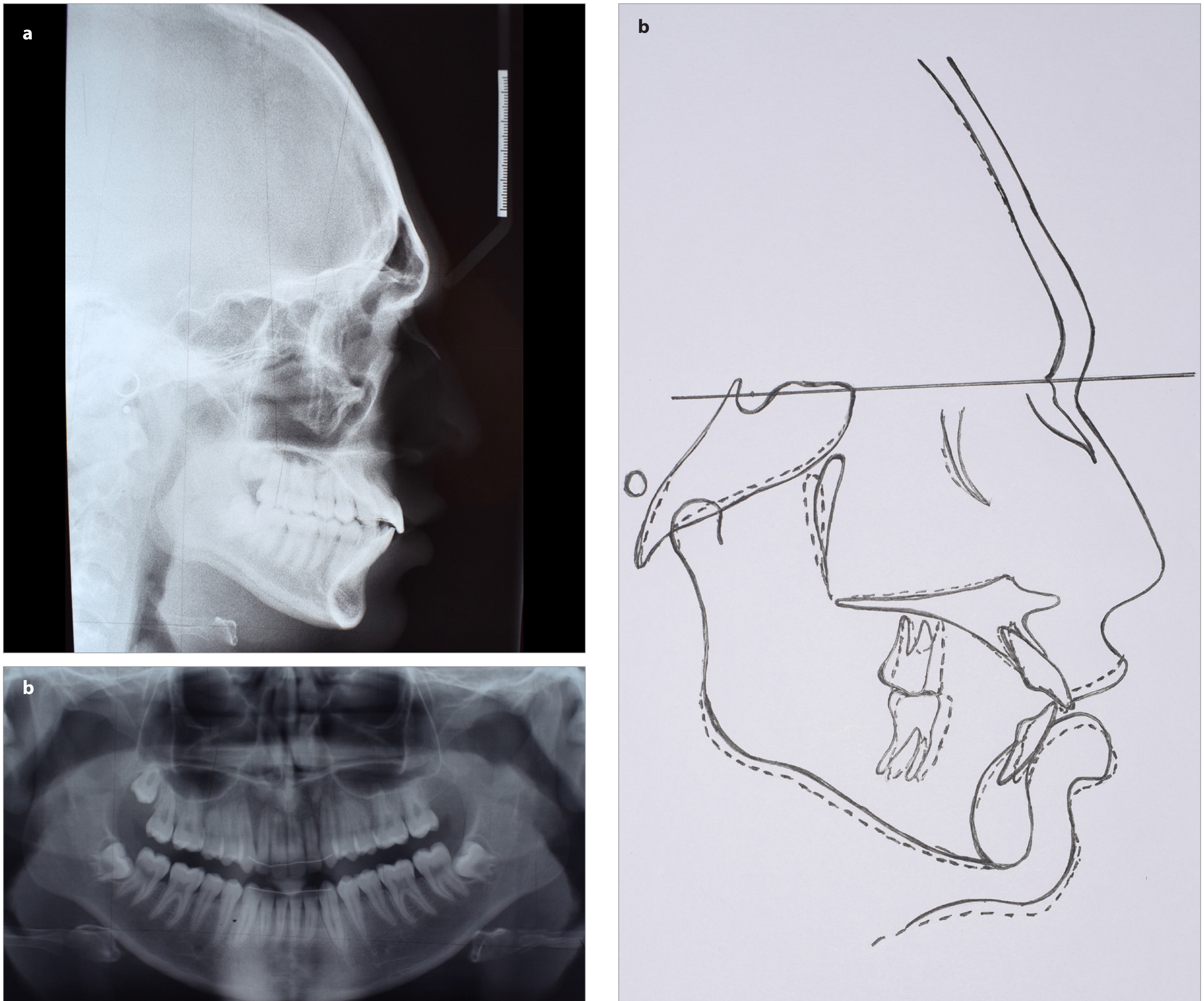

Figure 7 (a-c). Posttreatment lateral cephalogram (a), panoramic radiograph (b), and superimposition of pretreatment (solid line) and posttreatment (dotted line) cephalometric tracings on sella-nasion plane at sella (c)

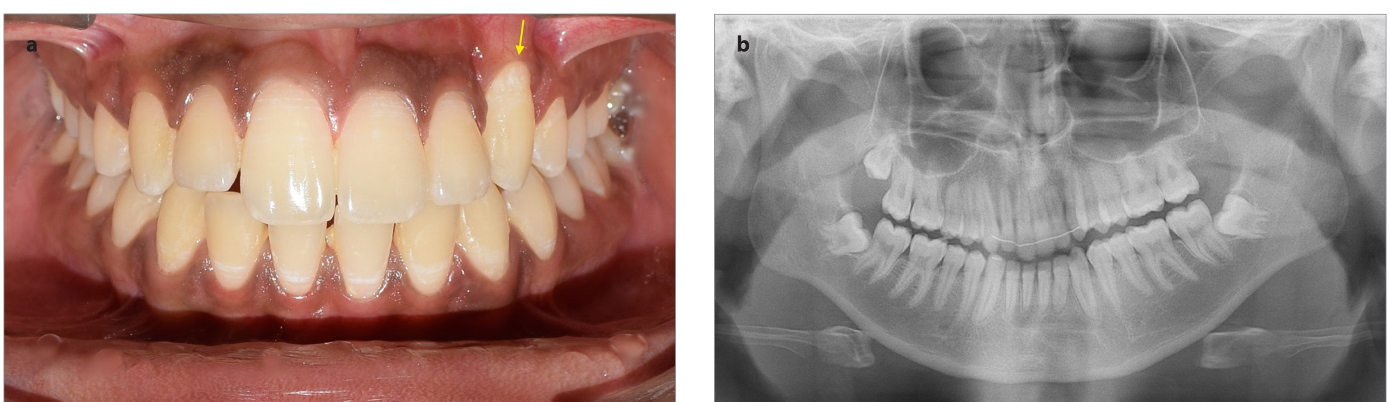

Figure 8 (a, b). The 12-month postretention intraoral frontal photograph (yellow arrow shows the gingival level of previously horizontally impacted canine) (a) and a panoramic radiograph (b)

contour was healthy. The posttreatment panoramic radiograph showed good root paralleling (Figure 7b). The superimposition showed that the patient's skeletal pattern remained unaltered by the mechanics (Figure 7c). The 12-month follow-up review showed that the results were maintained during the time, and the canines showed intact gingival attachments (Figure 8 a, b).

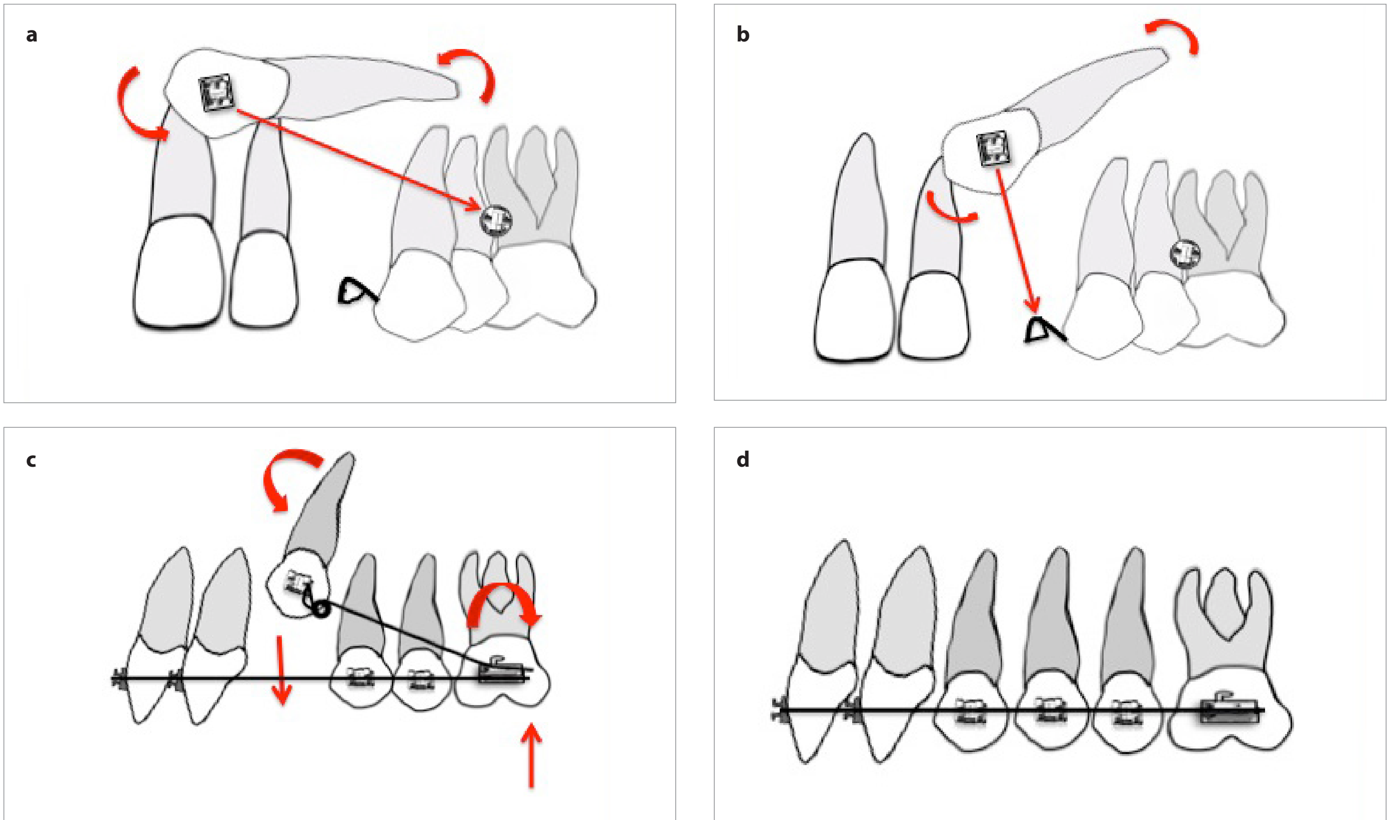

Figure 9 (a-d). Illustrations show the treatment strategy used for eruption of the impacted left canine. Distally directed elastic chain force from the impacted canine to the mini-implant (a), a vertical vector of force from the hook of a modified Nance button (b), the canine with a cantilever spring (c), and the canine in the final position (d)

DISCUSSION

In this case, a CBCT image helped us in precise localization of the impacted maxillary canine, and it was brought into alignment with meticulous planning (6-9). Several locations for the insertion of temporary anchorage devices have been suggested. The interradicular area between the second premolar and first molar in the maxilla is the safest zone in all dentoskeletal patterns (10). The pretreatment radiograph showed sufficient interradicular space in this region, which enabled the placement of a mini-implant. In this case, the canine was erupted using a modified closed-eruption technique. A small window created by the removal of an overlying soft tissue and bone was large enough to accommodate a small attachment, yet small enough for hemostasis to be secured to facilitate the immediate bonding of an attachment (11-14).

Surgical access and orthodontic traction need to be negotiated very delicately between the roots of the incisors, and no attempt at root uprighting or torque should be undertaken until the canine is well clear of both the incisors (15). Therefore, the initial alignment and early use of rectangular archwires was ruled out and was deferred to later stages of treatment (15). The mini-implant was used for initial application of distally directed horizontal force. This initial force element not only tipped the canine and changed its inclination from horizontal to slightly vertical but also pulled the crown tip away from the roots of the incisors (Figure 9a). Subsequently, a vertical vector of force was applied from the hook of the modified Nance button (Figure 9b). Once the canine bulge was palpable in the attached gingiva, an open eruption was performed with the help of a segmental approach (9). A one-couple cantilever spring was used (Figure 9c) to generate a counterclockwise moment and to upright the canine before pulling it into the oral cavity (Figure 9d). As the extrusion force is also labial to the center of resistance of the canine, a moment tends to tip the tooth, thus improving its labiolingual position (9, 16).

CONCLUSION

This case demonstrates that a proper diagnosis helps to develop an optimum treatment plan. A conservative surgical exposure with well-planned biomechanics using a simple modified Nance button–assisted with a mini-implant helped us to achieve desirable esthetic outcomes.

Informed Consent: Written informed consent was obtained from the patient/parent who agreed to take part in this case study.

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Erratum

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In the article by Camcı et al., entitled "Effect of Strontium Ranelate on Condylar Growth during Mandibular Advancement in Rats" that was published online on December 2020 issue of Turkish Journal of Orthodontics (Turk J Orthod 2020; 33 (4): 216-23, DOI: 10.5152/TurkJOrthod.2020.20014), the coressponding author's institution name was written erroneously.

The error has been corrected, and the updated version of the article is available on the journal's website.

https://www.turkjorthod.org/en/effect-of-strontium-ranelate-on-condylar-growth-during-mandibular-advancement-in-rats-163884