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3. Mueller HJ, Freeman D. FT-IR spectrometry in materiolography. 2nd Ed., Ohio: American Society for Metal 1994, p.51-56.

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5. Hudson FB, Hawcroft J. Duration of treatment in phenylketonuria. In: Seakins J, Saunders R, editors. Treatment of inborn errors of metabolism. London: Churchill Livingstone, 1973, p.51-56.

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Figure 1. Panoramic radiograph of the patient taken 6 months after surgery, note irregular borders of the lesion.

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Table 1. *Concise explanation of the table contents (SD: standard deviation, CTA: cartilage tissue area, NBA: new bone area).*

	Control group (Mean % ± SD %)	First group (Mean % ± SD %)	Second group (Mean % ± SD %)
CTA	21.41 ± 4.2	2.5 ± 2.4	11.42 ± 4.2
NBA	11.48 ± 0.2	21.41 ± 14.22	11.41 ± 4.2

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Original research

Evaluation of patient satisfaction with pharyngeal airway changes after orthognathic surgery in patients with Class III skeletal anomalies

Purpose
The aims of our study were to determine the changes in the pharyngeal airway after treating patients with Class III malocclusion who received double jaw surgery, to determine the hard tissue and soft tissue parameters and the hyoid bone and tongue positions after surgery, to determine the changes to compare the pre-treatment and post-treatment measurements of the patients in the double jaw group with the measurements of the control group patients, and to evaluate post-operative patient satisfaction.

Materials and Methods
The study included thirty-two Class III adult patients that received double jaw surgery and twenty-five Class I patients. Cephalometric records were taken before treatment (T1) and after treatment (T2).

Results
After double jaw orthognathic surgery, there were statistically significant changes in all pharyngeal airway linear and areal parameters ($p<0.001$). There were significant superior and posterior movements of the tongue and hyoid bone post-surgery. The post-treatment analysis of the double jaw surgery group and control group were compared, with statistically significant differences in the mandibular dental parameters and pharyngeal airway measurements in patients in the double jaw surgery group.

Conclusion
Despite the narrowings detected, high satisfaction scores were observed in the patient satisfaction questionnaire and the patients did not experience respiratory problems.

Keywords: *Orthognathic surgery, Class III malocclusion, pharyngeal airway, patient satisfaction, cephalometric*

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Introduction

Class III anomalies are the most difficult and complex orthodontic deformities in terms of both diagnosis and treatment planning. These skeletal anomalies can be treated by maxillary advancement or mandibular setback, which can be preferred as a single or double jaw surgical operation (1). Orthognathic surgery aims to give patients a better aesthetic appearance, as well as a healthy occlusion and chewing function. In orthognathic surgical procedures, the movement of skeletal structures significantly affects facial aesthetics and causes changes in soft tissues such as submental and nasolabial areas. Apart from the affected areas such as the nose, lips, and chin tip, changes are also observed in the pharyngeal region (2). This complex structure consists of the soft palate, hyoid bone, tongue, epiglot-

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tis, and a group of muscles associated with them. Especially after mandibular setback procedures, the change of positions in these structures associated with the lower and upper jaws can affect the quality and efficiency of respiration. Changes in the volumes of the oral and nasal cavities cause changes in the pharyngeal airway space (3-6). Volumetric changes in the pharyngeal airway space (PAS) may be a risk factor for respiratory disturbance (6). Some patients develop Obstructive Sleep Apnea syndrome (OSAS) after mandibular setback procedures, drawing attention to the relationship between these operations and airway dimensions, with the number of studies on this issue having increased in recent years (5, 7).

Lateral cephalometric radiography continues to be an important imaging tool in orthognathic surgical. Cephalometric imaging is still used estimate skeletal deformities despite the fact that it provides only 2-dimensional images for the evaluation of the pharyngeal airway (3, 8-10). Easy access, low complexity, low cost, less radiation are among the advantages of cephalometric radiography (9, 10). Many studies examined by lateral cephalometric analysis stated that the most common anatomical changes related to OSAS are the posterior location of the hyoid bone and the base of the tongue, which results in pharyngeal airway narrowing. In these studies, it was aimed to examine the effect of orthognathic surgery on PAS. Conversely, the PAS seems to become narrow after mandibular setback, with a risk of developing OSAS (3, 8, 11).

The purpose of our study is 1) to determine the changes in the posterior pharyngeal airway of patients treated with double jaw orthognathic surgery, 2) to reveal the results of airway measurements on lateral cephalometric films with linear and areal parameters, 3) to determine the changes in hard tissue and soft tissue parameters, hyoid bone, and tongue positions after surgery, and 4) to compare the pre- and post-treatment measurements of the patients in the double jaw surgery group with the measurements of the control group patients and to evaluate post-operative patient satisfaction.

The first null hypothesis of this study was that there was no change in linear and area measurements of the pharyngeal airway space after double jaw surgery when compared to both pre-treatment and control groups.

The second null hypothesis of this study was that there was no change in post-treatment patient satisfaction after double jaw surgery compared to pre-treatment.

Material and Methods

Study design

A retrospective study design was used to address the research subject. The subjects of this study were selected from the patients treated at the Karadeniz Technical University, Faculty of Dentistry, Turkey between 2008 and 2020. Inclusion criteria were nonsyndromic adult patients older than 18 years with skeletal Class III deformities, including mandibular prognathism and maxillary retrognathism, that received orthodontic treatment prior to surgical procedures. Exclusion criteria included previous orthognathic surgery, genioplasty, and craniofacial anomalies. Thirty-two patients (19 women, 13 men) underwent a modified bilateral sagittal split ramus osteotomy (BSSRO) combined with a Le Fort I osteotomy, and twenty-five control group patients (13 women, 12 men) were selected with a Class I malocclusion. In the Le Fort I surgical technique, the maxilla was also positioned upwards. All of the patients were treated surgically with the same examiner and treatment protocol.

Cephalometric measurements

Lateral cephalograms were obtained using a standardized method by cephalostat on the same orthopantomograph (Sirona Group, Bensheim, Germany). Lateral cephalometric images were obtained pre-treatment (T1) and > 1 years post-treatment (T2) from each subject and traced by the same investigator (an orthodontist). The mean duration of treatment time was 2.8 years in the double jaw surgery group. The pre- and post-surgical cephalograms were digitized by using the Nemoceph software (NemoStudio 2020, Software Nemotec S.L. The horizontal reference plane (HOR) was defined by raising a line 7° from Sella-Nasion (S-N) and the perpendicular line drawn from S point to HOR was used as the vertical reference plane (VER). Seventeen skeletal, nine dental, two hyoidal, six pharyngeal linear, two tongue position, three pharyngeal area, and six soft tissue measurements were used in the study (Figures 1 and 2). Area measurements of the pharyngeal airway were done with an ImageJ version 1.3 software (National Institutes of Health, Bethesda, Md).

Error of the method

All measurements were repeated on 10 randomly selected radiographs. Measurements were compared and correlation coefficients (r^2) were provided. Areal measurements were re-measured three times by the same investigator to eliminate the error rate.

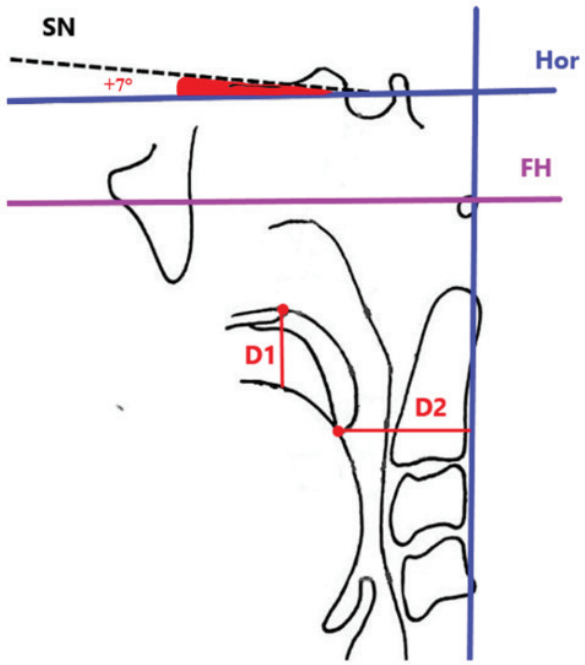

Figure 1. *D1: The line drawn from the PNS point to the dorsum of the tongue parallel to the vertical reference plane (Ver). D2: It is the distance of the point where the dorsum of the tongue cuts the mandibular plane to the line perpendicular to the Frankfort horizontal plane and passing through the Porion.*

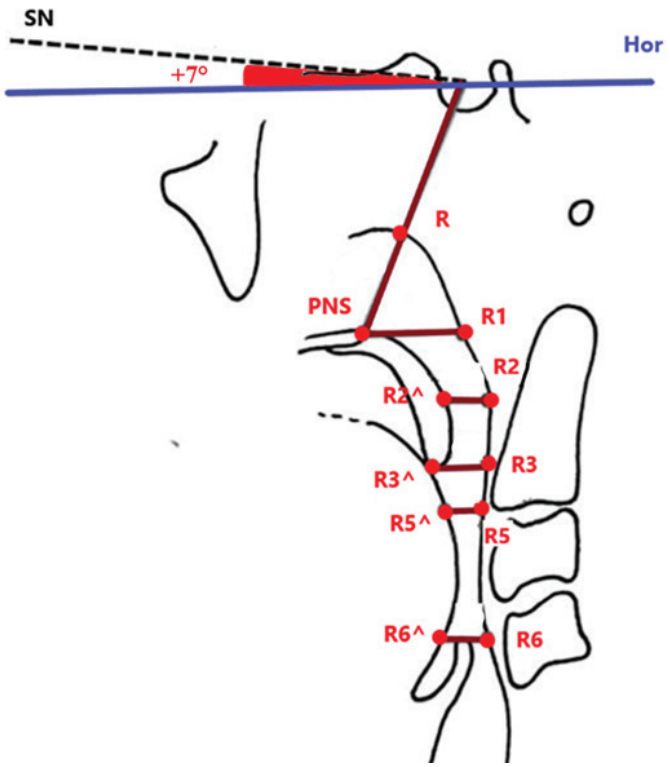

Figure 2. *Pharyngeal Linear Parameters: PNS-R: It is the distance between PNS and R points, PPS (PNS-R1): It is the distance between the PNS and R1 points (Palatal pharyngeal region). SPSS (R2-R2^): Superior posterior pharyngeal region MPS (R3-R3^): Middle pharyngeal region, IPS(R5-R5^): Inferior pharyngeal region, EPS(R6-R6^): Epiglottic pharyngeal region.*

Postoperative patient satisfaction questionnaire

In our study, all individuals were interviewed face-to-face, and they were asked to answer a 14-question questionnaire evaluating post-surgical quality of life and patient satisfaction. In our questionnaire, a 3-point Likert scale was used and the patients were asked to mark the answers as "Never", "Moderate", or "Very".

The first 4 questions were included in the questionnaire in order to evaluate the patients who had respiratory distress and related problems before orthognathic surgery.Patients who did not experience the problems mentioned before the operation were asked to pass these questions. In the 6-10th questions in the questionnaire, the existence and severity of functional problems that patients may experience after orthognathic surgery were questioned. In the 10-14th questions, awareness related to the changes in the external appearance of the patients after surgery was questioned. The views of the patients about their appearance and the people in their social circles, changes in self-confidence and social adaptation, and general satisfaction after the operation were evaluated.

Sample size calculation

In calculating the sample size, based on the Cakarne D. (12) study, alpha error=0.05, beta error=0.20, effect size 0.65, it was concluded that 22 patients for each group would be sufficient. However, considering possible data losses, it was planned to retrospectively include at least 50 patients (at least 25 in each group) in the study.

Statistical analysis

Statistical analyses were performed with SPSS for Windows 17.0 (SPSS Inc., Chicago, IL, USA). Wilcoxon Signed Ranks Test was used to evaluate the differences between skeletal, dental, pharyngeal airway parameters and area measurements performed on cephalometric radiographs between the treatment periods of the double jaw group. Mann Whitney U Test was used for comparisons between groups. Intra-class correlation coefficient (ICC) was applied to evaluate the intra-observer agreement between pre-treatment and post-treatment measurements. The p value below than 0.05 was considered as significant.

Results

The method's reliability was high, with the correlation coefficients ranging between 0.758 and 0.996. The demographic and clinical characteristics of the groups are presented in Table 1.The cephalometric outcomes for 32 patients who underwent bimaxillary orthognathic surgery were compared with 25 patients who had Class I skeletal malocclusion. The results are presented in Tables 2 and 3. There was a significant post-surgery posterosuperior movement of hyoid bone (H-Ver and H-Hor: $p<0.001$). The D1 value showed significant decreases, describing the movement of the tongue in the vertical direction, and the D2 value, which describes the movement in the sagittal direction (D1 and D2: $p<0.001$). An increase in the nasopharyngeal airway area (AREA 1) was observed ($p<0.001$). Decreases in the oropharyngeal (AREA 2), hypopharyngeal airway area (AREA 3), and dimensional measurements ($p<0.001$) were found (Table 2).

When the sagittal direction analyzes were evaluated in the comparison of the pre- jaw orthognathic surgery group and the control group, statistically significant differences were found (SNA, SNB, ANB: $p<0.001$). When pharyngeal airway linear measurements were compared, statistically significant differences were found in all parameters except the PNS-R value and in parameters expressing tongue position (D1 and D2) (PNS-R1: and SPSS: $p<0.05$ MPS, IPS and EPS: $p<0.001$, D1 and D2: $p<0.01$). Statistically significant differences were observed in the AREA 3 value from the pharyngeal airway areal parameters ($p<0.05$). While the PNS-P value was 19.74 mm in the double jaw group post-treatment, this value was 17.73 mm in the control group, and the difference between them was statistically significant ($p<0.001$). While the AREA

Table 1. *Demographic and clinical characteristics of the groups.*

Groups	Age (years)			Gender	
	Mean	Min	Max	Male	Female
Double Jaw (n=32)	21.50	18	32	13	19
Control (n=25)	19.88	18	23	12	13

Min:Minimum, Max: Maksimum

Table 2. *Comparison of Skeletal, Dental, Soft Tissue, Hyoid Bone, Tongue and Pharyngeal Airway Measurements Before and After Treatment of the Double Jaw Surgery Group.*

PARAMETERS	2-jaw surgery group (n=32)		T2-T1	p value
	T1	T2		
	X ± Sx	X ± Sx		
Skeletal Parameters				
SNA	77.72± 4.25	81.81±3.81	4.71	***
Nperp-A	-4.92± 3.12	-0.85±1.89	5.77	***
A-Ver	43.97± 4.27	47.84±4.00	3.87	***
Co-A	59.32±4.12	62.44±3.72	3.12	***
A-Hor	36.83±3.61	35.15±4.60	0.68	*
SNB	83.96±4.38	79.62±4.11	3.34	***
Nperp-B	1.66±4.99	-3.47±3.30	5.13	***
B-Ver	48.24±5.04	43.48±5.07	4.76	***
Pg-Ver	50.14±5.47	45.59±5.14	4.55	***
Me-Ver	44.65±5.58	39.88±5.02	4.77	***
Cd-Gn	89.54±5.38	86.27±5.50	3.27	***
Cd-Go	41.85±4.52	40.03±4.92	1.55	**
Go-Gn	57.51±3.66	54.80±3.71	2.71	***
ANB	49.89±4.43	45.78±3.99	7.36	***
SN-GoGn	79.12±7.48	79.43±5.43	1.56	***
OP-SN	52.36±4.29	50.02±4.73	1.53	*
N-Me	49.89±4.43	45.78±3.99	2.08	***
Dental Parameters				
U1i-Ver	47.31±4.65	51.34±5.52	4.03	***
U6t-Ver	29.53±3.51	33.18±4.46	3.65	***
U1i-Hor	51.70±4.02	50.36±4.91	1.34	*
U6t-Hor	48.23±3.70	47.47±4.63	0.76	*
L1i- Ver	49.89±4.43	45.78±3.99	4.11	***
IMPA	79.12±7.48	79.43±5.43	0.31	
L1i-Hor	52.36±4.29	50.02±4.73	2.34	***
Overjet	-2.83±2.05	2.39±0.64	5.22	***
Overbite	-0.19±1.77	1.01±0.34	1.40	***
Soft Tissue Parameters				
Pn-Ver	69.35±4.15	71.60±4.41	2.25	***
Nazolabial Angle	101.78±11.71	102.65±12.98	0.87	
ULA-Ver	57.35±4.20	59.90±4.27	2.55	**
LLA-Ver	59.64±4.63	55.92±3.81	3.72	***
B'-Ver	55.52±5.77	50.90±4.54	4.62	***
Pg'-Ver	57.95±6.11	53.21±4.82	2.34	***
Hyoid Bone Position				
H-Ver	13.10±4.54	10.73±4.54	2.34	***
H-Hor	76.36±4.06	74.23±3.64	2.13	***
Tongue Position				
D1	11.05±2.89	8.96±2.11	2.09	***
D2	21.10±3.70	18.74±3.67	2.36	***
Pharyngeal Airway Linear Parameters				
PNS-R	1.66±4.99	-3.47±3.30	1.84	***
PNS-R1	48.24±5.04	43.48±5.07	1.84	***
SPSS	50.14±5.47	45.59±5.14	0.78	***
MPS	44.65±5.58	39.88±5.02	1.38	***
IPS	89.54±5.38	86.27±5.50	1.17	***
EPS	41.85±4.52	40.03±4.92	1.27	***
Pharyngeal Airway Areal Parameters				
Nasopharynx, mm2	183.50±33.87	224.71±46.93	41.21	***
Oropharynx, mm2	212.59±34.51	191.81±32.83	20.78	***
Hypopharynx, mm2	178.87±48.35	155.00±42.12	23.87	***

Note: Data presented as mean±standard deviation, p<0.05*,p<0.01**, p<0.001*** Wilcoxon Signed Ranks Test; Abbreviations: Ver: Vertical Referance Plane, Hor: Horizontal Reference Plane, Nperp: Nasion perpendicular, Co; Condylion OP-SN: Occlusial Plane- Sella-Nasion, U1i: Upper 1. incisor, U6t: Upper 1. molar, L1i: Lower 1. incisor, ULA: Upper Lip Anterior, LLA: Lower Lip Anterior, H: Hyoidale, PNS: Posterior Nasal Spina, PPS: Palatal pharyngeal region, SPSS : Superior posterior pharyngeal region, MPS: Middle pharyngeal region, IPS: Inferior pharyngeal region, EPS: Epiglottic pharyngeal region, D1: The line drawn from the PNS point to the dorsum of the tongue parallel to the vertical reference plane (Ver). D2:It is the distance of the point where the dorsum of the tongue cuts the mandibular plane to the line perpendicular to the Frankfort horizontal plane and passing through the Porion.

1 value expressing the nasopharyngeal area post-treatment was 224.71 mm^2 in the double jaw group. This value was measured as 192.20 mm^2 in the control group, and the difference between them was statistically significant (p<0.05). While the AREA 2 value expressing the oropharyngeal area at post-treatment was 191.81 mm2 in the double jaw group,

Table 3. *Evaluation of Skeletal, Dental, Soft Tissue, Hyoid Bone, Tongue and Pharyngeal Airway Measurements in Double Jaw Surgery and Control Group.*

PARAMETERS	Non-Surgical (Control) Group (n=25)	2-jaw surgery group (n=32)			
		Pre-Treatment (T1) X±Sx	P value	Post-treatment(T2) X±Sx	P value
Skeletal Parameters					
SNA	81.88±1.98	77.72± 4.25	***	81.81±3.81	
Nperp-A	-0.82±1.19	-4.92± 3.12	***	-0.85±1.89	
A-Ver	49.80±3.93	43.97± 4.27	***	47.84±4.00	
Co-A	62.63±3.95	59.32±4.12	**	62.44±3.72	
A-Hor	35.93±3.95	36.83±3.61		35.15±4.60	
SNB	79.36±1.80	83.96±4.38	***	79.62±4.11	
Nperp-B	-4.79±1.01	1.66±4.99	***	-3.47±3.30	
B-Ver	46.41±4.25	48.24±5.04		43.48±5.07	
Pg-Ver	47.86±4.45	50.14±5.47		45.59±5.14	
Me-Ver	41.94±4.84	44.65±5.58		39.88±5.02	
Cd-Gn	84.19±4.55	89.54±5.38	***	86.27±5.50	
Cd-Go	40.75±3.94	41.85±4.52		40.03±4.92	
Go-Gn	56.74±3.22	57.51±3.66		54.80±3.71	
Dental Parameters					
U1i-Ver	52.48±3.77	47.31±4.65	***	51.34±5.52	
U6t-Ver	32.35±4.17	29.53±3.51	**	33.18±4.46	
U1i-Hor	51.64±4.32	51.70±4.02		50.36±4.91	
U6t-Hor	47.63±4.17	48.23±3.70		47.47±4.63	
L1i- Ver	50.04±3.86	49.89±4.43	***	45.78±3.99	***
IMPA	93.12±4.41	79.12±7.48	***	79.43±5.43	***
L1i-Hor	49.94±4.36	52.36±4.29	*	50.02±4.73	
Maxillo-Mandibular Skeletal Parameters					
ANB	2.44±1.00	-5.18±2.53	***	2.18±1.35	
SN-GoGn	33.12±2.35	37.90±8.30	**	36.34±6.66	*
OD-SN	13.72±4.03	15.83±6.57		17.34±6.51	*
N-Me	83.87±4.91	86.93±5.52		84.85±4.97	
Maxillo-Mandibular Dental Parameters					
Overjet	2.63±0.71	-2.83±2.05	***	2.39±0.64	
Overbite	1.51±0.45	-0.19±1.77	***	1.21±0.34	
Soft-Tissue Parameters					
Pn-Ver	73.43±4.60	69.35±4.15	***	71.60±4.41	
Nazolabial Angle	99.64±3.32	101.78±11.71		102.65±12.98	
ULA-Ver	61.68±4.47	57.35±4.20	***	59.90±4.27	
LLA-Ver	58.70±4.53	59.64±4.63		55.92±3.81	
B'-Ver	53.16±4.40	55.52±5.77		50.90±4.54	
Pg'-Ver	56.22±4.84	57.95±6.11		53.21±4.82	
Hyoid Bone Parameters					
Hi-Ver	11.67±6.06	13.10±4.54		10.73±4.54	
Hi-Hor	77.75±6.23	76.36±4.06		74.23±3.64	
Tongue Position Parameters					
D1	9.13± 2.22	11.05±2.89	**	8.96±2.11	
D2	17.60±3.88	21.10±3.70	**	18.74±3.67	
Pharyngeal Airway Linear Parameters					
PNS-R	17.73±1.69	17.91±1.66		19.74±1.92	***
PNS-R1	18.66±2.13	17.51±1.91	*	19.35±2.22	
SPSS	9.10±1.37	10.01±1.75	*	9.18±1.84	
MPS	9.40±2.03	11.39±2.18	***	10.01±2.32	
IPS	8.13±1.55	9.98±2.28	***	8.81±2.20	
EPS	8.11±1.70	9.80±2.25	***	8.53±2.11	
Pharyngeal Airway Areal Parameters					
Nasopharynx, mm2	192.20±40.67	183.50±33.87		224.71±46.93	*
Oropharynx, mm2	222.80±35.39	212.59±34.51		191.81±32.83	**
Hypopharynx, mm2	149.20±40.23	178.87±48.35	*	155.00±42.12	

Note: Data presented as mean±standard deviation, p<0.05*,p<0.01**, p<0.001*** Mann Whitney U Test; Abbreviations: Ver: Vertical Referance Plane, Hor: Horizontal Reference Plane, Nperp: Nasion perpendicular, Co; Condylion, OP-SN: Occlusial Plane- Sella-Nasion, U1i: Upper 1. incisor, U6t: Upper 1. molar, L1i: Lower 1. incisor, ULA: Upper Lip Anterior, LLA: Lower Lip Anterior, H: Hyoidale, PNS: Posterior Nasal Spina, PPS: Palatal pharyngeal region, SPSS : Superior posterior pharyngeal region, MPS: Middle pharyngeal region, IPS: Inferior pharyngeal region, EPS: Epiglottic pharyngeal region, D1: The line drawn from the PNS point to the dorsum of the tongue parallel to the vertical reference plane (Ver). D2: It is the distance of the point where the dorsum of the tongue cuts the mandibular plane to the line perpendicular to the Frankfort horizontal plane and passing through the Porion.

this value was measured as 222.80 mm^2 in the control group, and the difference between them was statistically significant (p<0.01) (Table 3). The questionnaire data we obtained from the same dpatients in the patient group with the skeletal Class III malocclusion who underwent double jaw orthognathic surgery are shown in Table 4.

Discussion

Skeletal Class III malocclusions are clinically defined as mandibular prognathia, maxillary retrognathia, or a combination of both. Orthognathic surgery aims to provide patients with a healthy occlusion and chewing function as well as a better aesthetic appearance (2).

Current literature shows that mandibular setback surgery narrows the upper airway by posterior positioning of associated structures such as the soft palate, tongue, and hyoid bone. The total pharyngeal volume decreased considerably between its preoperative level and one year postoperatively (7, 13). The decrease in airway volume after the operation may cause respiratory distress and decrease the patients' quality of life.

Ho *et al.* (14) reported that the hyoid bone moved upwards and backwards one week after the double jaw surgery in the

Table 4. *Evaluation Of Pre- and Post-Treatment Measurements with Intraclass Correlation Coefficient*

Parameters	Pre-Treatment (T1)		Post-Treatment (T2)	
	Intraclass Correlation Coefficient	P value	Intraclass Correlation Coefficient	P value
Maxillary Skeletal Measurements				
SNA	0.997	***	0.981	***
Nperp-A	0.998	***	0.947	***
A-Ver	0.998	***	0.958	***
Co-A	0.775	**	0.997	***
A-Hor	0,967	***	0.977	***
Maxillary Dental Measurements				
U1i-Ver	0.998	***	0.947	***
U6t-Ver	0.954	***	0.979	***
U1i-Hor	0.997	***	0.948	***
U6t-Hor	0.978	***	0.964	***
Mandibular Skeletal Measurements				
SNB	0.998	***	0.987	***
Nperp-Pg	0.964	***	0.979	***
B-Ver	0.997	***	0.986	***
Pg-Ver	0.967	***	0.977	***
Me-Ver	0.949	***	0.939	***
Cd-Gn	0.919	***	0.989	***
Cd-Go	0.889	***	0.964	***
Go-Gn	0.964	***	0.898	***
Mandibular Dental Measurements				
L1i-Ver	0.939	***	0.949	***
IMPA	0.944	***	0.979	***
L1i-Hor	0.889	***	0.974	***
Maxillo-Mandibular Skeletal Parameters				
ANB	0.919	***	0.989	***
SN-GoGn	0.934	***	0.979	***
OD-SN	0.889	***	0.934	***
N-Me	0.997	***	0.986	***
Maxillo-Mandibular Dental Parameters				
Overjet	0.888	***	0.937	***
Overbite	0.919	***	0.989	***
Soft-Tissue Parameters				
Pn-Ver	0.889	***	0.976	***
Nazolabial Angle	0.997	***	0.981	***
ULA-Ver	0.998	***	0.958	***
LLA-Ver	0.949	***	0.939	***
B'-Ver	0.934	***	0.979	***
Pg'-Ver	0.998	***	0.997	***
Hyoid Bone Parameters				
Hi-Ver	0.954	***	0.979	***
Hi-Hor	0.998	***	0.996	***
Tongue Position Parameters				
D1	0.947	***	0.981	***
D2	0.956	***	0.758	**
Pharyngeal Airway Linear Parameters				
PNS-R	0.939	***	0.949	***
PNS-R1	0.888	***	0.937	***
SPSS	0.889	***	0.776	**
MPS	0.949	***	0.739	***
IPS	0.862	**	0.973	***
EPS	0.788	**	0.937	***
Pharyngeal Airway Areal Parameters				
Nasopharynx, mm^2	0.913	***	0.916	***
Oropharynx, mm^2	0.785	**	0.978	***
Hypopharynx, mm^2	0.889	***	0.776	**

p<0.05*,p<0.01**, p<0.001*** Intraclass Correlation Coefficient (ICC)

maxillary impaction group. The computed tomography (CT) study of Park *et al*.(15) noted that the hyoid bone moved backward, but there was no significant change in its vertical position. However, these results we found in our study are similar to those of Marşan *et al*. (8).

Statistically significant decreases occurred in the tongue position (p<0.001). Kawakami et al. (3) evaluated the posterior airway, tongue position, and post-operative patient satisfaction in cases with skeletal Class III malocclusion, and reported that none of the existing patients had any OSA symptoms before or after orthognathic surgery, despite the tongue being positioned more posteriorly and superiorly after surgery. Their studies it was reported reported that the mean of the D2 parameter, which expresses the movement of the tongue in the sagittal direction, was more than 10.0 mm, which was larger than previously reported in OSA patients. Some of the changes seen in the oropharyngeal region after surgery are quite similar to the changes in OSA patients. The previously published studies show that OSA developed after mandibular retrieval surgery in two patients (5, 16). Both patients reported worsening of snoring and narrowing of the airway in the first 18 months after surgery. We could say that this result was equivalent to the movement of the mandible as a result of double jaw surgery.

Statistically significant changes were observed in all pharyngeal dimensional and areal parameters in the pre- and post-operative analyses of the group undergoing bimaxillary surgery (p<0.001) (16).

The PNS-R and PNS-R1 values, which express the dimensional measurement of the nasopharynx, increased and the value of AREA 1, which expresses the areal measurement,

Table 5: *Postoperative Patient Satisfaction Questionnaire Results*

Postoperative Patient Satisfaction Questionnaire	
Questions	**Average Scores**
1. How satisfied are you with your current loud snoring?	4.20
2. How satisfied are you with your fatigue complaint when you wake up in the current morning?	4.30
3. How satisfied are you with your current shortness of breath during sleep?	4.50
4. How satisfied are you with your complaint of shortness of breath during current physical activity?	4.50
5. How satisfied are you with your current breathing?	3.70
6. How satisfied are you with your current speech?	4.20
7. How satisfied are you with the side view of your current face?	4.45
8. How satisfied are you with the current closure and stance of your lips?	4.20
9. How aesthetically pleasing are you with the appearance of your current teeth?	4.70
10. How satisfied are you with your current chewing and biting function?	4.20
11. How satisfied are your family, relatives or friends about the outcome of your surgical operation?	4.60
12. Has your self-confidence increased after orthognathic surgery?	4.50
13 .If you were to decide again, would you want to have the same surgical operation again?	4.50
14. Would you recommend the same surgical operation to other people who have similar problems as you?	4.50

increased. The change in PNS-R measurement is associated with the prominence of the PNS point after maxillary advancement operation. Depending on the increase in PNS-R length, an increase in AREA 1 value is expected. The significant increase we obtained in our double jaw group coincides with Chen *et al.*'s findings. In this study, in which 31 cases with skeletal Class III malocclusion were evaluated, a significant increase was found in the nasopharynx three to six months after the double jaw group's operation (17). In our study, there was an increase in the nasopharynx with a change SNA and SNB. Likewise, Marşan *et al.* (8) observed a significant increase in the nasopharyngeal measurement after 1.3 years with SNA and SNB change in 53 female patients who underwent double jaw surgery.

If we talk about the changes in the oropharynx region, a decrease and expresses the dimensional measurement of the oropharynx, and a decrease in the AREA 2 value expresses the areal measurement. The literature states that the oropharynx is the region most affected and there is narrowing with the mandible's retraction (15, 18-20). However, our study reveals that the hypopharynx is also seriously affected by the narrowing. IPS and EPS values, which express the dimensional measurement of the hypopharynx, decreased and 1.27 mm and AREA 3, which expresses the areal measurement, decreased ($p<0.001$). If we support the results of our study with the literature, in the CT study of Değerliyurt *et al.*(21), 35% narrowing of the oropharynx and 29% narrowing occurred in the hypopharynx as a cross-sectional area in the mandibular retraction group, where the mandible was retracted 7 mm, while these values were observed in the double jaw group in which the 7.3 mm mandible was retracted, respectively. 15% and 8%.

When the pre-treatment values of the double jaw group and the maxillary skeletal values of the control group were compared, statistically significant differences were found in the SNA, Nperp-A, and A-Ver parameters, thereby giving information in the sagittal direction, and in the Co-A parameter (SNA: $p<0.001$, Nperp-A: $p<0.001$, A-Ver: $p<0.001$, Co-A: $p<0.01$). Mouakeh et al. (22) compared a total of 138 cases (69 Class I patients and 69 Class III patients) with Class I and Class III malocclusions, and found that there were statistically significant differences in SNA, Nperp-A, and Co-A parameters, similar to our findings. They emphasized that the maxillary length (Co-A) of Class III patients is shorter than that of normal individuals and that the maxilla is located further back. When the pre-treatment values of the double jaw group were compared with the data of the control group on the mandibular skeletal values, statistically significant differences were found in the SNB and Nperp-Pg parameters, which gave information in the sagittal direction, and in the Cd-Gn parameter (SNB: $p<0.001$, Nperp-Pg: $p<0.001$, A-Ver: $p<0.001$, Cd-Gn: $p<0.001$). Studies comparing Class I and Class III cases showed that there were significant differences in SNB and Nperp-Pg parameters, similar to the findings in our study (22, 23).

The D2 value, which shows the horizontal movement of the tongue position in the pre-treatment double jaw group, was 21.10 mm, while this value was 17.60 mm in the control group, and the difference between them was statistically significant ($p<0.01$). Cheng et al., in their study in which they examined the posterior airway and tongue position of Class I, Class II, and Class III patients, stated that the tongue was located more anteriorly in Class III patients (24).

Statistically significant differences were found in PNS-R1, SPSS, MPS, IPS, and EPS parameters when the pre-treatment values of the double jaw group were compared with the pharyngeal airway dimensional measurements of the control (PNS-R1: $p<0.05$; SPSS: $p<0.05$; MPS, IPS, and EPS: $p<0.001$). Statistically significant difference was observed in the AREA 3 value from the pharyngeal airway areal parameters (AREA 3: $p<0.05$). A study examining the posterior airway of the non-surgery group (Class I and Class II) and Class III patients stated that nasopharyngeal dimensional measurements of Class III patients were less and the difference was statistically significant at the $p<0.05$ level. In the same study, when the dimensional measurements of the hypopharynx were examined, it was found that this length was greater in the Class III patient group and was statistically significant at the $p<0.001$ level. Researchers stated that the anterior positioning of the mandible in Class III patients caused this difference (24). In our study, the results are similar to this study when evaluated in terms of dimensional measurements.

In most studies evaluating the posterior airway, the post-treatment measurements of Class III patients who underwent orthognathic surgery and those of the control group individuals with Class I malocclusion were not compared (25). Kitahara *et al*. (25) evaluated 46 female Japanese

patients with skeletal Class III malocclusion and control group patients with Class I malocclusion who had undergone different orthognathic surgical procedures.

When the post-treatment mandibular dental values of the double jaw group are compared to the mandibular dental values of the control group with skeletal Class I malocclusion in the L1i-Ver parameter—which gives information in the sagittal direction—and in the IMPA angle—which indicates the position of the lower incisor relative to the mandibular plane—there were statistically significant differences, respectively (L1i-Ver: $p<0.001$, IMPA: $p<0.001$). The L1i-Ver and IMPA values were lower in the double jaw surgery group than in the control group after treatment. If we support the findings of our study with the literature; Troy *et al*. evaluated two groups of patients with skeletal Class III malocclusion treated as orthognathic surgery and orthodontic camouflage, and stated that the mandibular incisors were retroclined after treatment in the orthognathic surgery group (26). Similar to our study, An et al. evaluated long-term patients with skeletal Class III malocclusion, whose treatment was carried out as orthognathic surgery (27).

The PNS-R1 value, one of the dimensional measurements of the nasopharynx, was higher in the double jaw group at the end of the treatment when compared to the control group. Likewise, when the AREA 1 parameter, which expresses the nasopharyngeal area, was evaluated, it was larger than the control group at the end of the treatment. Chen et al.(17), Marşan et al.(8), and Cakarne et al. (12) with the effect of maxillary advancement/impaction operation, an increase in nasopharyngeal dimensional and spatial measurements was a finding that we expected after surgery. Contrary to our study, Kitahara et al. (25) reported that posterior airway dimensional measurements were similar in their study comparing Class III patients who had undergone orthognathic surgery and Class I patients.

There are many studies in the literature evaluating patient satisfaction after surgery (28-30). The most frequently used questionnaires in these studies; Orthognathic Quality of Life Questionnaire (OQLQ), Rosenberg Self-esteem Scale, Oral Health Impact Profile-14 (OHIP-14), Short Form-36 (SF-36). When these questionnaires are examined, it is seen that the questionnaires mostly evaluate aesthetic awareness, social awareness, functional recovery and postoperative complications. There are no questions that evaluate respiratory problems in detail. Considering these shortcomings while creating our questionnaire, we included questions questioning possible respiratory problems. While the score given by the patients to the 9th question after surgery was the highest, the score they gave to the 5th question was the lowest. Considering these results, we can say that there is no noticeable change in respiration after the surgery compared to the preoperative period. At the same time, we observe that the highest post-operative satisfaction is the aesthetic change of the teeth. Similar to our study, in a study in which hard and soft tissue changes and postoperative patient satisfaction were evaluated in patients with skeletal Class III malocclusion who had undergone double jaw surgery, a high satisfaction score was observed in patients in the double jaw group in the question questioning respiratory problems (28). Kiyak *et al*. (30) and Asada *et al.(29)* interpreted the high satisfaction scores of even patients with multiple problems as the main determinant of post-operative satisfaction, whether or not there were aesthetic improvements. They reported that if the patient perceives aesthetic developments as high, independent of any functional problem, their satisfaction is also high.

Conclusion

It was observed that the majority of the patients were satisfied with their quality of life after orthognathic surgery and the aesthetic, functional and psychological results of the surgery.

Türkçe özet: *Sınıf III İskelet Anomalisi Olan Hastalarda Ortognatik Cerrahi Sonrası Faringeal Havayolu Değişiklikleri ile Hasta Memnuniyetinin Değerlendirilmesi. Amaç: Çalışmamızın amacı, çift çene cerrahisi ile tedavi edilen Sınıf III maloklüzyonlu hastaların cerrahi sonrası faringeal hava yolundaki değişikliklerini belirlemek, sert doku ve yumuşak doku parametrelerini ve hyoid kemik ve dil pozisyonlarını belirlemek, çift çene grubundaki hastaların tedavi öncesi ve tedavi sonrası ölçümlerini kontrol grubu hastalarının ölçümleriyle karşılaştırmak ve ameliyat sonrası hasta memnuniyetindeki değişiklikleri değerlendirmektir. Gereç ve Yöntem: Çalışmaya çift çene cerrahisi geçirmiş 32 Sınıf III yetişkin hasta ve yirmi beş Sınıf I hasta dahil edildi. Tedavi öncesi (T1) ve tedavi sonrası (T2) sefalometrik kayıtlar alındı. Bulgular: Çift çene ortognatik cerrahi sonrası tüm faringeal hava yolu lineer ve alan parametrelerinde istatistiksel olarak anlamlı değişiklikler izlendi ($p<0,001$). Ameliyat sonrası dil ve hyoid kemiğinde belirgin superior ve posterior yönde yer değiştirme görüldü. Çift çene cerrahisi grubu ve kontrol grubunun tedavi sonrası analizi, çift çene cerrahisi grubundaki hastalarda mandibular dental parametreleri ve faringeal hava yolu ölçümlerinde istatistiksel olarak anlamlı farklılıklar ile karşılaştırıldı. Sonuç: Hasta memnuniyet anketinde tespit edilen daralmalara rağmen yüksek memnuniyet skorları gözlendi ve hastalarda solunum sıkıntısı yaşanmadığı görüldü. Anahtar Kelimeler: Ortognatik Cerrahi, Sınıf III Maloklüzyon, Faringeal Havayolu, Hasta Memnuniyeti, Sefalometri.*

Ethics Committee Approval: The study protocol has been approved by the Karadeniz Technical University Institutional Review Board for Scientific Research Ethics Committee (2020/330).

Informed Consent: Participants provided informed constent.

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Author contributions: NK participated in designing the study. SK, NK participated in generating the data for the study. SK, NK participated in gathering the data for the study. SK, NK participated in the analysis of the data. SK, NK wrote the majority of the original draft of the paper. SK, NK, SK participated in writing the paper. SK, NK have had access to all of the raw data of the study. SK, NK have reviewed the pertinent raw data on which the results and conclusions of this study are based. SK, NK, MBO, YTK, SK have approved the final version of this paper. NK guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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Original research

The effects of different cavity disinfectants on fracture resistance of tooth fragment reattachments

Purpose
This study was conducted to investigate the fracture strength of reattached tooth fragments after different cavity disinfection protocols.

Materials and Methods
Incisal edges of 144 bovine incisors were sectioned and then randomly divided into 4 different groups as follows: Group C: no disinfectant; Group NaOCl: 2.5% sodium hypochlorite solution; Group NaOCl+Asc: 2.5% sodium hypochlorite followed by 10% ascorbic acid solution; Group CHX: 2% chlorhexidine solution. Teeth were further divided into 3 subgroups according to universal adhesive (G-Premio Bond, Scotchbond Universal, Prime and Bond Universal). Fracture resistance was evaluated using a universal testing machine. Data was analyzed using 2-way ANOVA with Bonferroni tests.

Results
Cavity disinfectant had a statistically significant effect on bond strength ($p<0.05$), with the highest bond strength detected in the NaOCl+Asc Group (148.22 ± 51.64) and the lowest in the NaOCl Group (112.84 ± 43.12). Scotchbond Universal exhibited the highest bond strength values (163.59 ± 49.94); however, there were no significant differences between the other adhesive systems ($p> 0.05$). .

Conclusion
Application of ascorbic acid following sodium hypochlorite treatment can improve dentin bond strength.

Keywords: *Cavity disinfectants, crown fracture, reattachment, universal adhesives*

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Introduction

Crown fracture is a relatively common event that affects mainly children and adolescents (1). Reattachment of the original tooth fragment, if available, appears to be the most conservative approach to restorative treatment, providing conditions are feasible (2). Reattachment of a fractured fragment not only represents a simple and low-cost alternative to other restorative techniques such as composite restorations and laminate veneers, the preservation of the natural tooth also provides better esthetics and wear-resistance (3).

An uncomplicated crown fracture results in the exposure of a considerable number of dentin tubules in the oral cavity. Depending on the location of the fracture line, this number varies from 15,000-45000 per mm^2 (4). Long-term exposure of dentin tubules and inadequate cleaning of fractured surfaces can create a potential pathway of invasion for bacteria that can lead to pulpal disease (5). In order to minimize bacterial invasion and ensure pulpal healing, prompt treatment of dentin is essential; however, this cannot be achieved in all cases (6). According to Diaz et al. (7),

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whereas 45.7% of patients apply for dental treatment within 2-24 h after traumatic injury, 32.6% of them do not present until after 24h.

Disinfection of fractured surfaces could help to alleviate the problems associated with delayed treatment. Various chemical solutions, including chlorhexidine digluconate (CHX), sodium hypochlorite (NaOCl), and iodine have been tested and proven to be effective as cavity disinfectants. However, the use of a disinfectant could be problematic if it inhibits the wettability and micromechanical bonding of resin to dentin (8).

Various up-to-date techniques and materials have been tested to improve the clinical success of reattached teeth (2). However, to the best of our knowledge, no studies have investigated how their resistance to fracture is affected by the use of cavity disinfectants on the exposed tooth surfaces. Therefore, this study was conducted to compare the effects of 3 different disinfection protocols on the shear bond strength of 3 different universal adhesives to reattached bovine incisor fragments. The null hypothesis was that differences in cavity disinfectants and adhesive systems would have no effect on the fracture resistance of reattached teeth.

Material and Methods

Study materials

This study was conducted with 3 different cavity-disinfection protocols (2.5% NaOCl solution, 2.5% NaOCl+10% ascorbic acid solution, 2% chlorhexidine solution) and 3 different universal adhesives (G-Premio Bond, Prime & Bond Universal, Scotchbond Universal) (Table 1).

Sample size estimation

Power analysis was performed according to Poubel et al. (9) using the G-power computer program and indicated that a minimum of 12 observations per group were required for a 95% confidence level (1-α), 85% test power (1-β) and effect size of f=0.413.

Specimen preparation

In the present study, bovine incisor teeth were used so there is no need ethical approval. A total of 144 freshly extracted bovine permanent incisors were used in this study. In order to ensure standardization of specimens, teeth were selected according to crown dimensions (26±1 mm inciso-cervical length, 15±1 mm mesio-distal width) and visually examined under x3 loope magnification for any cracks, defects or caries. After cleaning and removal of tissue remnants, teeth were stored in a 0.01% thymol solution until the experiment.

Standardized fragment areas were created by tracing a line perpendicular to the long axis of the root at a distance of one-third away from the anatomical crown and parallel to the incisal edge, and then slicing the tooth along the marked line using a low-speed diamond saw (Isomet, Buehler Ltd, IL, USA) under water-cooling. The separated tooth structures and fragments were submitted to ultrasonic bathing for 2 h to remove the smear layer and then stored individually in distilled water.

Specimens (teeth+fragments) were randomly divided into 4 groups (n=35) according to surface-disinfectant treatment, as follows: Group C: No disinfectant (control group). Group NaOCl: Teeth and fragments were rinsed with 2.5% NaOCl for 20 s, rinsed with distilled water for 10 s, and dried with oil-free air. Group NaOCl+Asc: Teeth and fragments were dis-

Table 1: *The compositions and manufacturer details of the materials used in this study.*

	Composition	Manufacturer	Mode of Application
G-Premio Bond	MDP, 4-MET, MEPS, Methacrylate monomer, Acetone, Water, Initiators, Silica	GC Corp, Tokyo, Japan	Apply to both enamel and dentin surfaces for 20 s and leave undisturbed for 10 s. Then dry for 5 s with oil free air under maximum pressure to allow solvent evaporation and light cure.
Prime&Bond Universal	Mono-, di- and trimethacrylate resins, PENTA, diketone, organic phosphine oxide, stabilizers, cetylamine hydrofluoride, isopropanol, water	Dentsply Caulk, Milford, DE, USA	Apply to both enamel and dentin surfaces and slightly agitate for 20 s. Then dry gently for 5 s with oil free air to allow solvent evaporation and light cure.
Scotchbond Universal	MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond Copolymer, Filler, Ethanol, Water, Initiators, Silane	3M ESPE, St Paul, MN, USA	Apply to both enamel and dentin surfaces and rub for 20 s. Then dry gently for 5 s with oil free air to allow solvent evaporation and light cure.
Aeliteflo flowable composite resin	Ethoxylated BİS-GMA triethyleneglycol dimethacrylate, barium glass filler, 72 % (w) filler load	Bisco Inc, Schaumburg IL, USA	Place the flowable composite to the cavity max 1.5 mm depth and light cure for 20 s.
Consepsis	2% chlorhexidine	Ultradent products, South Jordan, UT, USA	Rinse with chlorhexidine solution for 20 s, rinsed with distilled water for 10 s, and dried with oil-free air.
Werax	2.5% NaOCl	Werax, Istanbul, Turkiye	Rinse with NaOCl solution for 20 s, rinsed with distilled water for 10 s, and dried with oil-free air.
Ascorbic acid	10%	Prepared manually in the laboratory	17.61g L ascorbic acid was taken in a 100ml volumetric flask and discolved in 100ml distilled water

infected as above for Group NaOCl, after which they were immersed in a freshly prepared solution of 10% ascorbic acid for 10 minutes and then rinsed with distilled water for 10 s and dried with oil-free air. Group CHX: Teeth and fragments were rinsed with 2% chlorhexidine solution for 20 s, rinsed with distilled water for 10 s, and dried with oil-free air.

Reattachment procedures

Following surface treatment, the fractured surfaces of the fragments and the remaining tooth structures were selectively etched (enamel only) with 35% phosphoric acid for 15 s, rinsed for 10 s, and dried with oil-free air. Each group of specimens was then randomly divided into 3 subgroups (n=12) according to adhesive system (Table 1). Adhesives were light-cured for 20 s on each surface (10 s on the mesial portion and 10 s on the distal portion) using a LED light-curing unit (Elipar S10, 3M ESPE, St Paul, MN, USA) at 1,000 mw/cm^2. For each specimen, flowable microhybrid composite (Table 1) was applied to the fractured tooth surface, the fragment was positioned in place, and the specimen was light-cured along the fracture line for 40 s (20 s on the buccal surface and 20 s on the lingual surface).

Teeth were stored at 37°C in distilled water for 24 h and then finished and polished using Sof-Lex aluminum oxide discs (3M ESPE, St Paul, MN, USA) for 15 s per disc (coarse, medium, fine, and superfine). Specimens were then subjected to electronic thermocycling (DTS B1, Dentester, Salubris Technica, Istanbul, Turkey) between 5°C and 55°C (1000 cycles, 10 s dwell time, 30 s transfer time between baths).

The root portions of the specimens were embedded in self-curing acrylic resin cylinders 1 mm from the cemento-enamel junction. Fracture resistance was measured by tightly fixing each specimen to a universal testing machine (AGS-X, Schimadzu Corp, Kyoto, Japan) (Figure 1) and applying a 5kN load to the labial surface perpendicular to the long axis of the tooth and incisal to the reattachment line using a stainless-steel tip at a cross-head speed of 1 mm/min. Fracture loads were recorded in *N* and then analyzed under a stereomicroscope (Nikon SMZ 1500, Tokyo, Japan) at x16 magnification. Fracture modes were classified as either cohesive within dentin, adhesive, or mixed, according to the following criteria:

Adhesive failure: less than 25% of the resin composite remaining at the tooth-resin bonding interface; Cohesive failure: more than 75% of the resin composite remaining at the tooth-resin bonding interface; Mixed failure: 25% to 75% of the resin composite remaining at the tooth-resin bonding interface.

Statistical analysis

Statistical analysis was performed using the software program SPSS 23 (SPSS Inc., Chicago, IL, USA). Normality of distribution was verified with a Shapiro Wilk test. Differences among experimental groups were compared using two-way ANOVA followed by Bonferroni correction, with the significance level set at 0.05.

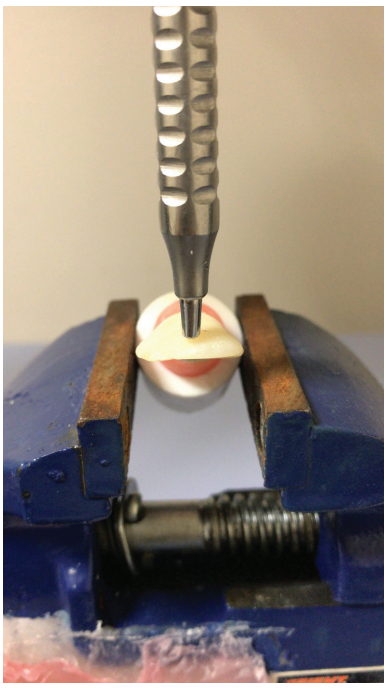

Figure 1. *The view of the test specimen in universal test machine.*

Results

Results of two-way ANOVA are presented in Table 2. As the table shows, mean reattachment strengths were significantly affected by both disinfectant (p=0.003) and adhesive (<0.001); however, the interaction between the two variables was not statistically significant (p=0.927).

Fracture strengths of the reattached teeth (means and standard deviations) are given in Table 3. When the effect of cav-

Table 2: *Analysis of variance.† Df: Degree of freedom*

	Type III Sum of Squares	df	Mean Square	F	p
Disinfectants	23868,4	3	7956,1	4,9	0,003
Adhesives	91490,3	2	45745,1	28,0	<0,001
Interaction disinfectants * adhesives	3108,1	6	518,0	0,3	0,927

Table 3: *Mean values and standard deviations of fracture strength (kgf)*

Groups	Control	NaOCl	CHX	NaOCl+Asc	Total
G-Premio Bond	107,45 ± 29,51	90,93 ± 28,82	103,57 ± 24,35	125,28 ± 46,59	106,81 ± 34,63^{A}
Scotchbond Universal	160,54 ± 57,98	148,5 ± 48,77	169,89 ± 33,83	175,41 ± 57,59	163,59 ± 49,94^{B}
Prime&Bond Universal	105,15 ± 41,74	99,08 ± 24,30	108,59 ± 32,3	143,95 ± 39,97	114,19 ± 38,44^{A}
Total	123,09 ± 50,12^{ab}	112,84 ± 43,12^{a}	128,64± 42,86^{ab}	148,22 ±51,64^{b}	128,20 ± 48,37

‡Different letters, lowercase in rows and uppercase in columns, indicate statistically significant differences * p < 0.05

Table 4: *The classification of the failure modes.*

Experimental groups	Prime&Bond Universal			Scotchbond Universal			G Premio Bond		
	adhesive	mixed	cohesive	adhesive	mixed	cohesive	adhesive	mixed	cohesive
Control	11	1	0	9	2	1	12	0	0
NaOCl	11	1	0	10	2	0	11	1	0
NaOCl+Asc	11	1	0	9	2	1	11	0	1
Chx	10	2	0	11	1	0	12	0	0

ity disinfectant was examined, Group NaOCl+Asc was found to have the highest bond-strength value (148.22±51.64), and Group NaOCl was found to have the lowest bond-strength value (112.84±43.12), with the difference between the two groups statistically significant ($p<0.05$). No other statistically significant differences were observed among disinfectant protocols ($p>0.05$). When the effect of adhesive system was examined, the mean bond-strength value of the Scotchbond Universal subgroups (163.59±49.94) was significantly higher than that of the other adhesive systems ($p<0.05$). No statistically significant difference was observed between the mean bond strengths of Prime&Bond Universal (114.19±38.44) and G Premio Bond (106.81±34.63).

Failure modes are presented in Table 4. Regardless of adhesive system or cavity disinfectant, the majority of failures were adhesive failures.

Discussion

The simplicity and versality of universal adhesives, which can be used in etch-and-rinse, self-etch, or selective-etch modes, has led to a rapid increase in their use in clinical practice, and further research into these materials is warranted. This study found that a sodium hypochlorite solution decreased the bond strength between tooth fragments reattached using 3 universal adhesives in selective-etch mode. Moreover, an ethanol/water-based universal adhesive exhibited significantly higher bond-strength values than 2 acetone/water-based universal adhesives. Therefore, the null hypothesis that different cavity disinfectants and adhesive systems would have no effect on the fracture resistance of reattached teeth was rejected.

Bovine incisors are considered a valid alternative to human incisors in adhesion tests because their morphology, ultrastructural architecture, microhardness and mineral content are similar to those of human teeth. Moreover, they are more easily available and can be selected and standardized for size and age (9,10). For these reasons, in the present study, bovine incisors were selected and screened for optimum tooth standardization.

In adhesion tests, it is important to standardize the samples before bonding procedures by preparing equivalent enamel and dentin bonding surfaces (10,11). In the present study, in order to obtain exposed areas of equal size, all teeth were cut at a similar distance from the incisal margin. However, the process of creating the standardized fragments that are required to ensure repeatability of this *in vitro* study resulted in the production of a smear layer that does not exist with a naturally occurring fracture (10). In order to better simulate traumatic fracture, after sectioning teeth with a diamond saw, specimens were sonically cleaned to remove the smear layer.

Uncomplicated crown fractures should never be left untreated. Given the excellent quality of currently available adhesive materials, reattachment of a fractured fragment is the recommended technique when a fragment has been saved following trauma (2,9). A systematic review study concluded that the reattachment of a tooth fragment using an adhesive system with an intermediate composite and with no additional preparation allows fractured teeth to recover an adequate amount of lost strength (12). According to Pamir et al. (13), the use of a material with a low modulus of elasticity at the tooth-composite interface can reduce the effects of compressive and tensile stresses that can cause debonding during functional mobility. Therefore, in the present study, a flowable composite with a low elastic modulus was selected as an intermediate agent for the reattachment procedure.

The proposed technique for fragment reattachment is selective etching of enamel, followed by application of a universal adhesive for self-etching of dentin. Many clinicians prefer to use 30%-40% phosphoric acid for enamel etching because it increases wettability, surface energy, and surface porosity, thereby improving adhesive penetration and enabling the formation of a uniform hybrid layer (9). In contrast, self-etching systems are preferred in dentin because they generate better hybridization, as their resinous monomers are capable of simultaneously demineralizing and infiltrating dentin (9,14). Moreover, because trauma-induced fractures usually involve deep dentin, the use of a self-etching adhesive system has been recommended in such cases in order to avoid any pulpal damage (9,15). For these reasons, the present study examined the use of 3 different universal adhesives in selective-etch mode for the reattachment of tooth fragments.

The findings showed the bond strength of reattached teeth to be material-dependent. The fact that the Scotchbond Universal specimens exhibited the highest bond strength regardless of disinfectant protocol can be attributed to the material composition of this adhesive, which differs from the other tested adhesives in several ways. First, unlike the other adhesives, Scotchbond Universal contains a polyalkenoic acid copolymer (Vitrebond copolymer, 3M Oral Care) derived from resin-modified glass ionomer technology that has been reported to prevent surface wetness from negatively affecting the durability of the adhesive bond to ensure long-term bond strength (16). Moreover, the water content by volume of Scotchbond Universal, G-Premio Bond, and Prime & Bond Universal are 10%, 25%, and 5%-24.5%, respectively, and, according to Choi et al. (17), the ideal range for universal adhesives is 10%-15%, where-

as adhesives containing more than 25% water by volume are reported to undergo phase separation, resulting in less chemical interaction with the substrate. Finally, Scotchbond Universal is water/ethanol-based, whereas both G-Premio Bond and Prime & Bond Universal are water/acetone-based, and studies have reported that the faster evaporation of acetone-based adhesives results in a relatively thin layer of adhesive that is subject to oxygen inhibition and may eventually lead to bond failure (18).

According to the literature, the prognosis of uncomplicated crown fractures may differ due to a variety of concurrent problems, such as bacterial contamination of dentin and pulp (13). Compounds such as chlorhexidine gluconate-based solutions, sodium hypochlorite, hydrogen peroxide, sodiumethylene tetraacidic acid, and iodine have been reported to possess antibacterial properties that make them suitable for use as cavity disinfectants; however, some authors have expressed concern that their application to dentin might have negative effects on the sealing capacity of adhesive bonding resins (19,20,21). Several mechanisms have been put forward to explain NaOCl's adverse effect on dentin bond strength, including removal of the organic matrix from treated dentin, which leaves a less receptive bonding surface, and dissolution of collagen fibrils, which leads to a breakdown of the bonds between carbon atoms and disorganization of the primary collagen structure, thereby preventing the formation of a consistent hybrid layer (22-24). Another problem that has been reported is associated with NaOCl's oxidizing activity, which prematurely terminates chain formation, resulting in incomplete polymerization of the adhesive resin (25). The significant reduction in bond strength values of all the tested adhesive systems found in this study following NaOCl treatment is in line with these earlier findings.

A number of natural antioxidants – e.g. ascorbic acid, sodium ascorbate, rosmarinic acid, green tea extracts, and proanthocyanidin – have been reported to reverse the negative effects of NaOCl on dentin bond strength (22). According to Prasansuttiporn et al. (26), these antioxidants remove the remnants of NaOCl through oxidation-reduction, thereby stabilizing the resin-dentin interface and improving bond strength to NaOCl-treated dentin. Vongphan et al. (27) reported that application of 10% sodium ascorbate to NaOCl-treated dentin for 10 min enhanced the bond strength of a total-etch system, and Morris et al. (28) reported a reversal in the decrease in bonding of resin cements with the application of 10% ascorbic acid. Similarly, the present study found 10% ascorbic acid application to NaOCl-treated dentin for 10 min increased the bond strength values in all the groups tested.

Chlorhexidine digluconate (CHX) is the most popular antimicrobial solution and matrix metalloproteinase (MMP) inhibitor. The high bactericidal effect of 2% CHX has been attributed to its ability to precipitate cytoplasmic contents, which leads to cell death. Numerous studies have reported on the effects of CHX application on dentin bond strength (19,29,30). For example, de Castro (29) reported that CHX treatment prior to dentin acid-etching did not adversely affect the μTBS of composite resin to dentin. Mohammed Hassan (30) similarly reported that the CHX application prior to etching did not affect dentin bond strength; however, dentin bond strength was significantly reduced when CHX was applied after etching. These findings are consistent with the results of the present study, which found CHX application had no negative effect on the dentin bond strength of the reattached tooth fragments.

Conclusion

The findings of this *in-vitro* study showed sodium hypochlorite followed by 10 min ascorbic acid application resulted in the highest bond strengths of the different adhesive protocols tested. However, this may not be the preferred choice in clinical practice because it requires longer chair time. Chlorhexidine application, which was found to have no negative effect on the bond strength of reattached teeth, may be a more practical, time-saving solution, especially for anxious trauma patients. In addition, this study found that the ethanol/water-based universal adhesive Scotchbond Universal performed better than the acetone/water-based adhesives tested in terms of bond strength.

Türkçe özet: *Diş fragmanlarının reataşmanlarının kırılma direnci üzerine farklı kavite dezenfektanlarının etkileri. Amaç: Bu çalışma, farklı kavite dezenfeksiyon protokollerinden sonra diş fragmanlarının reataşmanının kırılma dayanımını araştırmak amacıyla yapılmıştır. Gereç ve Yöntemler: 144 dana kesici dişinin kesici kenarları kesilerek rastgele 4 farklı gruba ayrıldı: Grup C: dezenfektan yok; Grup NaOCl: %2,5 sodyum hipoklorit solüsyonu; Grup NaOCl+Asc: %2,5 sodyum hipoklorit ve ardından %10 askorbik asit solüsyonu; Grup CHX: %2 klorheksidin solüsyonu. Dişler ayrıca uygulanan üniversal adezive göre (G-Premio Bond, Scotchbond Universal, Prime ve Bond Universal) 3 alt gruba ayrıldı. Kırılma dayanımı Universal test cihazı kullanılarak değerlendirildi. Veriler, Bonferroni ve 2-way ANOVA testleri kullanılarak analiz edildi. Bulgular: Kavite dezenfektanının bağlanma dayanımı üzerine istatistiksel olarak anlamlı bir etkiye sahip olduğu bulundu($p<0.05$). En yüksek bağlanma dayanımı NaOCl+Asc Grubunda (148.22 ± 51.64) ve en düşük ise NaOCl Grubunda (112.84 ± 43.12) tespit edildi. Scotchbond Universal, en yüksek bağlanma dayanımı değerlerini gösterirken (163,59 ± 49,94); diğer adeziv sistemler arasında anlamlı bir fark yoktu. Sonuç: Sodyum hipoklorit tedavisini takiben askorbik asit uygulaması dentin bağlanma dayanımını arttırabilir. Anahtar kelimeler: askorbik asit, kavite dezenfektanları, kron fraktürü, reataşman, universal adeziv*

Ethics Committee Approval: All procedures performed in studies were in accordance with the ethical standards of the institutional and/or national research committee and based on welfare of animals.

Informed Consent: Not required.

Peer-review: Externally peer-reviewed.

Author contributions: NG, EST, EK participated in designing the study. NG, EST, EK, SO, HG participated in generating the data for the study. NG, EST, EK, SO, HG participated in gathering the data for the study. NG, EST, EK participated in the analysis of the data. NG, EST wrote the majority of the original draft of the paper. NG, EST participated in writing the paper. EST, HG have had access to all of the raw data of the study. NG, EST have reviewed the pertinent raw data on which the results and conclusions of this study are based. NG, EST, EK, SO, HG have approved the final version of this paper. EK guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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Original research

Release of mercury from amalgam filling and its relationship with metallothionein and superoxide dismutase

Purpose
This study aims at determining the amount of mercury released over time from amalgam after treatment in healthy subjects and to examine the relation of mercury with serum MT-1 and SOD-1 levels.

Materials and Methods
Amalgam filling was applied to the 15 subjects aged 19-22 years and blood samples were collected before treatment and 1 day, 7 days, 21 days and 35 days after treatment. Mercury analysis of serum samples was performed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). In addition, MT-1 and SOD-1 levels in serum samples were measured using commercial enzyme-linked immunosorbent assay (ELISA). Friedman test and Spearman's correlation analysis was performed to analyse the data. p value was interpreted in significance level of 0.05.

Results
As a result of the analysis for MT-1, it was found that the values decreased over time and this decrease was statistically significant after 21 days ($p<0.05$). In addition, it was found that SOD-1 decreased over time, but this decrease was not statistically significant . In terms of released mercury, there was no statistically significant difference among the values of mercury released over time . According to the results of correlation analysis, no statistically significant relationship was found among the variables.

Conclusion
The results of the present study indicated that the amount of mercury released from the tested amalgam were found to be tolerable and no significant relationship was found between MT-1 and SOD-1.

Keywords: *Amalgam, antioxidants, mercury, metallothionein, superoxide dismutase*

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Introduction

Dental amalgam is a restorative material that has been used in dentistry for many years. The main ingredients of amalgam alloy are silver (Ag), tin (Sn), copper (Cu) and mercury (Hg), but it also contains small amounts of zinc (Zn) and palladium. Although amalgam is an easy to handle, durable and cheap material, its use has become questionable due to its inability to meet aesthetic criteria, low dimensional stability and also Hg in its content (1). Since amalgam fillings are exposed to chemical, biological, mechanical and thermal effects in the mouth, they are in constant interaction with the oral environment and the most important part of this interaction is the corrosion of amalgam (2). Also, excessive chewing of gum increases the wear of amalgam fillings and the Hg release rate (3).

Metallothionein (MT) is a low molecular weight protein rich in intracellular cysteine and has the capacity to bind heavy metal ions such as cadmium (Cd), Zn, Hg and Cu. MT binds metal ions via the thiol (-SH) group of cysteine resi-

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dues. MT shows a high affinity for both basic metals such as Cu and Zn and non-essential (or toxic) metals such as Hg and Cd (4). MTs found in humans are four classes (MT1-MT4) with multiple isoforms of MT-1 and MT-2, and MT-1 and MT-2, in particular, play a very crucial role in the distribution and storage of elements such as Hg in the body (5). Metallothioneins have many crucial functions in the regulation of Zn and Cu homeostasis, removal of heavy metals (6). Cell proliferation and differentiation and scavenging of free radicals (4,7). Previous study reported that MT can act as a free radical scavenger and metallothionein scavenges hydroxyl radicals in vitro (8).

Thornalley and Vasak (8), reported in their study that rabbit liver MT-1 can scavenge free hydroxyl (•OH) and superoxide (O2−•) radicals produced by xanthine/xanthine oxidase. Superoxide Dismutase (SOD) is an antioxidant enzyme with metal itons in its active center. There are three types of SOD, two of which are cytoplasmic (Cu/Zn SOD) bound to Zn and Cu, and the other extracellular SOD (Ec SOD) (9).

Humans are exposed to Hg released from amalgam as a result of swallowed saliva and direct absorption to blood via oral mucosa (1). It has been reported in the literature that Hg forms reactive oxygen species (ROS) by interacting with protein-bound -SH groups and can cause oxidative damage in tissues by affecting mechanisms such as lipid peroxidation (10). It has been reported that cells can remove ROS by producing proteins such as glutathione and metallothione that have the ability to bind to ROS (11). In addition, Cu and Zn including superoxide dismutase (Cu/Zn-cytoplasmic enzyme (SOD-1) protects the cell against ROS toxicity by metabolizing superoxide radicals to molecular oxygen and hydrogen peroxide (12).

This study aims at determining the amount of Hg released over time from amalgam after treatment in healthy subjects and to investigate the relationship of Hg with serum MT-1 and SOD-1 levels. The main null hypothesis of the study is that Hg released from amalgam do not affect serum MT-1 and SOD-1 levels of subjects.

Material and Methods

Ethical statement

This study was approved by Atatürk University Faculty of Dentistry Ethics Committee (20.11.2014/031) and was conducted in accordance with the Declaration of Helsinki. All subjects included in the study were informed about the study and written consent was obtained from the subjects that they were informed about the study. The study was conducted with 15 subjects aged between 19-22 (21.11±1.32).

Sample size determination

The sample size was determined by G*Power 3.1.9.4 software (Heinrich-Heine Dusseldorf University, Dusseldorf, Germany) using the following parameters: 95% power, 0.38 effect size, and α error at 0.05. It was determined that the appropriate sample size should be a minimum of 15 persons.

Study design

Subjects who did not have systemic disease, did not take any medication at least 3 months ago, did not smoke or consume alcohol, did not have bruxism or chewing gum habit, did not have periodontal disease and did not have fillings in their mouths were included in this study.

The amalgam filling material (Cavex Avalloy, Cavex Co., Holland, lot no:130523) was applied to the subjects according to the manufacturer's instructions. According to the information given by the manufacturer, the content of amalgam used in the present study was Cu 24.0%, Zn 0.5%, Sn 30.5%, Ag 45.0%. The mixing ratio is: 10 parts of alloy to 10.3 parts of Hg. Subjects were asked not to eat on the day of the test and fillings were made between 9-12 in the morning. Maximum 3 occlusal restorations were applied to subjects. One day after the treatment, the filling surfaces were polished. Rubber dam was used during polishing. The masses of the amalgam fillings were weighed and recorded in milligrams. (10, 13). Blood samples were collected baseline and 1 day, 7 days, 21 days and 35 days after treatment. Blood samples were obtained by collecting venous blood into test tubes as in routine procedure. After centrifugation (1000 rpm/20 min), the serum samples were kept at –80 °C until analysis.

MT-1 and SOD-1 analysis

MT-1 levels in serum samples were measured using commercial enzyme-linked immunosorbent assay (ELISA) (human MT-1, Cloud-Clone Corp., Houston, TX, USA, Lot No: L150626819), and SOD-1 levels were determined by ELISA kits (human SOD-1, Cloud-Clone Corp., Houston, TX, USA, Lot No: L160203202) according to the manufacturer's recommendations.

Testing protocols

MT-1 and SOD-1 analysis was performed by a similar method. These kits include a microtiter plate which is pre-coated with an antibody specific for MT-1 or SOD-1. Then, standards or samples is added to the wells of the suitable microtiter plate with MT-1 or SOD-1 specific biotin-conjugated antibody. Later, Horseradish Peroxidase conjugated Avidin is incubated after adding it to the entire microplate well. TMB substrate solution is then added. After this procedure, only wells containing MT-1 or SOD-1, biotin-conjugated antibody, and enzyme-conjugated Avidin will show a change in color. By adding sulfuric acid solution, the enzyme-substrate reaction is terminated and a color change occurs. This change is measured spectrophotometrically at a wavelength of 450 nm ± 10 nm.

The concentration of MT-1 or SOD-1 in the samples is determined by comparing the Optical Density of the samples to the standard curve. For MT-1, the standard curve concentrations used for the ELISA's were 2,000 pg/mL, 1,000 pg/mL, 500 pg/mL, 250 pg/mL, 125 pg/mL, 62.5 pg/mL, 31.2 pg/mL. Detection range of MT-1 is 31.2-2,000 pg/mL. For SOD-1, the standard curve concentrations used for the ELISA's were 4,000 pg/mL, 2,000 pg/mL, 1,000 pg/mL, 500 pg/mL, 250 pg/mL, 125 pg/mL, 62.5 pg/mL. Detection range of SOD1 is 62.5-4,000 pg/mL.

Analysis process

Assay procedure was firstly started by preparing all reagents, samples and standards. Wells for sample, diluted

standard and blank were determined. 100 µL standard or sample to each of wells was added and incubated 2 hours at 37°C. Later, aspirated and added 100 µL prepared Detection Reagent A and incubated 1 hour at 37 °C. In addition, aspirated and washed 3 times and 100 µL prepared Detection Reagent B was added and incubated 30 minutes at 37 °C. Then, aspirated and washed 5 times and 90 µL Substrate Solution was added, incubated 15-25 minutes at 37 °C and 50 µL Stop Solution was added. Then, run the microplate reader and conduct measurement at 450 nm immediately.

Sample preparation for mercury analysis

0.5 mL of serum samples were taken and transferred into teflon containers. 9 mL of HNO_3 and 1 mL of H_2O_2 solution were added on them, and the vessels and segments that make up the system were closed and placed in the microwave. Digestion of the samples was subsequently performed using an Milestone connect ETHOS UP microwave digestion system (Milestone, Sorisole, Italy) which employ a microwave program reaching 190 °C within 15 min and then held at 190°C for 15 min. 5 mL of ultrapure water was added to 10 ml samples as a result of decomposition and diluted. The samples were filtered using a 0.45 µm syringe filter and read by giving to the device without a second dilution. Each reading was the average of 3 parallel readings.

Analysis process

Hg analysis of serum samples was performed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), (Agilent 7800 series, Agilent Technologies, Japan). The ICP-MS device contains a glass MikroMist nebulizer (U-series, Australia) and a quartz spray chamber (double pass, USA) used to load samples into the system. The plasma part consists of an inert sample entry kit containing quartz torch (2.5 mm, Japan) and sample cone and skinner cone (for x-lens, USA) parts consisting of nickel material.

Before starting the analysis, the device was purged with helium gas for 45 minutes. The device was activated after parameters such as Plasma gas: 15 L/min, auxiliary gas: 1 L/min, carrier gas: 1 L/min, makeup/dilution gas: 1 L/min and carrier gas pressure 1.45 kPa were adjusted. After the device was activated, torch axis, resolution axis, EM, standard lenses tune, plasma corection, full spectrum and performance report tests were performed, respectively. Then, the calibration process of the device was carried out with tuning solution (1µg / L Ce, Co, Li, Mg, Tl, Y). The values obtained as a result of the tune operation were checked and it was determined whether there was any deviation in the device. Standard solutions prepared by using stock solutions were read and calibration curves were checked (standard reference range, for Hg element: 0, 2.5, 5, 7.5, 10 ppb). After checking the calibration curves, the samples were loaded into the device by the autosampler and analyzed. The autosampler and tubing was washed with 2% HNO_3 and ultrapure water, and the probe part was washed with a 1% HCl solution and made ready for the next injection. Measurements were made at 1200 W RF power, 1 L/min carrier gas flow and 0.30 rps nebulizer pump speed. Argon gas was used as carrier gas. Limit of detection (LOD) for Hg was 0,078 ppb and limit of quantification (LOQ) for Hg was 0.259 ppb.

Statistical analysis

Data were analysed using SPSS 20 (IBM, Chicago, IL, USA) statistical package software. Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to determine the distribution of the data. Friedman test was used to compare the levels of Hg released from amalgam fillings over time and also to compare changes in serum MT-1 and SOD-1 levels over these time periods. The relationship among MT-1, SOD-1 and Hg was examined with correlation analysis (Spearman's Correlation Analysis). In addition, Spearman's Correlation Analysis was used to determine between amalgam filling masses and released Hg. p value was interpreted in significance level of 0.05.

Results

Serum MT-1, SOD-1 and Hg values obtained from subjects and statistical analysis results are shown in Figure 1 and 2. As a result of the analysis for MT-1, it was found that the values decreased over time and this decrease was statistically significant after 21 days (180.35±64.74 pg/mL) according to baseline (349.87±36.34 pg/mL) ($p<0.05$) (Figure 1).

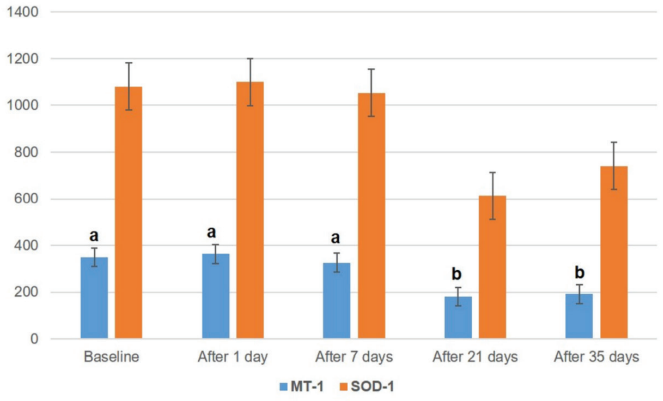

Figure 1. *Mean and standard deviation for values (pg/mL) of serum MT-1 and SOD-1 and statistical analysis results (Different lowercase letters indicate a significant difference).*

In addition, it was found that SOD-1 decreased over time, but this decrease was not statistically significant (Figure 1). According to the analysis results in terms of released Hg, no statistically significant difference was determined among the values of Hg released over time (Figure 2). Although the

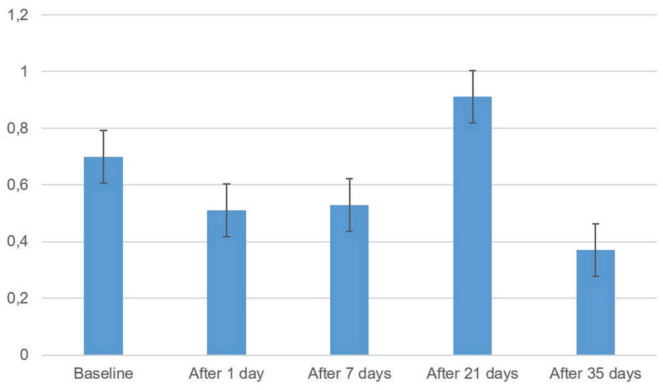

Figure 2. *Mean and standard deviation for values (ng/mL) of serum Hg and statistical analysis results.*

Hg values were not statistically significant, it was found to increase a little after 21 days.

According to the results of correlation analysis performed to determine the relationship between Hg released from amalgam and MT-1 and SOD-1 levels, no statistically significant relationship was found between the variables . Amalgam masses used in this study were found as 0.09 ± 0.08 g. No correlation was found between amalgam filling masses and released Hg .

Discussion

It has been known since ancient times that Hg in composition of amalgam, enters the body in ionic or elemental form. Exposure to the patient or dentist may occur in cases of wear or abrasion from mouth fillings (ionic form), direct evaporation of metallic mercury contained in amalgam, preparation, placement and removal of fillings (elemental mercury) (14). It is generally accepted that the short-term sudden rise in Hg concentrations during the placement, polishing or removal of amalgam fillings does not pose a significant health problem or life-threatening risk to patients (15).

The surface area of the amalgam filling and the time after treatment are the two most important variables that affect Hg release from amalgam fillings (16). Mackert and Berglund (3) stated that the Hg release rate from amalgam was on average 0.4 µg per day per amalgam surface. Al-Salehi *et al.* (16) determined that that approximately 1.0 µg/cm2 of Hg was released from four bleached amalgam surfaces within 24 hours. In this case, assuming a surface area of 1 cm^2 is equivalent to four Hg amalgam surfaces *in vivo*, it means that only 1.0 µg of Hg will be released per day into the oral cavity.

It has been reported that blood Hg levels can be used as an index to determine recent Hg^0 exposure, especially in situations of acute accidental or occupational exposure (18). In addition, measuring Hg levels in whole blood and urine is reported to be a reliable method for detecting inorganic and elemental mercury exposure (Hg) (12, 18).

It has been reported that the tolerable maximum level of Hg in the blood is 3 ng/mL (19). Skoner et al. (20) reported toxic mercury doses in the blood as 200 ng/mL and lethal mercury doses as 600 ng/mL. The results of the studies on blood Hg concentrations show differences. Melchart et al. (21) reported the amount of inorganic Hg in erythrocyte and plasma as 0.37 ng/mL and 0.38 ng/mL, respectively, and the total plasma Hg level as 0.49 ng/mL. Özdabak et al. (22) stated that the Hg measured in plasma was mainly due to amalgam fillings. Kronce et al. (23) and Ott et al. (24) reported in their study that there was no significant difference between the blood Hg concentrations of individuals with amalgam fillings and those without fillings. On the contrary, Abraham *et al.* (25) reported that the blood Hg levels of individuals with amalgam fillings were higher than those without amalgam fillings. Yildiz *et al.* (10) reported the plasma Hg levels of subjects as 5.21 ng/mL measured 24 hours after treatment. The different results from the studies might be attributed to the use of different methods to assess Hg concentrations as well as the effect of other sources of Hg, such as exposure to mercury from diet, inhaled air and drinking water. Since Hg is not taken into the body in a single way, it is difficult to blame amalgam fillings directly for the increase in Hg in the blood (19). In this respect, subjects who did not have fillings in their mouths were included in the present study in order to prevent extra Hg release that may arise from old fillings.

Hg is found in the blood like other body fluids, but its levels in the blood are quite low compared to others. Even in industrial workers exposed to high levels of Hg, measured Hg concentrations have been reported to be in the parts per billion (ppb) range (17). In the present study, serum Hg concentrations reached the highest level 21 days after treatment (0.91 ng/mL), but no statistically significant difference was found among time periods ($p=0.072$). It was found that the amounts of Hg released were low and below the maximum medically acceptable level. In present study, a maximum of three single-surface fillings (occlusal) were applied to each individual on average, and the low amount of Hg released may also be due to this situation. In order to eliminate Hg release from old fillings, participants without old fillings were included in the study. In the present study, no significant correlation was found between the released Hg and the filler masses. These results are consistent with previous studies (10, 26).

There are many studies in the literature investigating the effects of Hg on antioxidant activity systems in various tissues and fluids such as saliva and plasma (26, 27). While some of these studies found a significant relationship between Hg and antioxidants, some found no significant relationship (17, 26). Because Hg can produce reactive oxygen species, it can affect antioxidant enzymes such as SOD-1 and catalase (28). Actually, Hg produces ROS (12, 29). In this respect, enhanced SOD-1 activity helps maintain the oxidative balance in the organism, otherwise this balance could be disturbed by Hg released by dental fillings (28).

A number of mechanisms can be explained by the protective effect of MTs against Hg cytotoxicity. The most important of these is that Hg has a strong affinity for MTs due to its high -SH contents. In this respect, MT has been proposed as a biomarker of both environmental and biological monitoring reflecting metal exposure, due to its high metal binding capacity (30). However, a study examining the relationship between MT and Hg released from amalgam in human serum was no found in literature.

Metallothionein plays an effective role in controlling the intracellular metabolism of Zn and can serve as a supplier of Zn when needed (4, 6). In addition, MT has an important role in regulating the activity of Cu/Zn SOD. It is known that both MT and Cu/Zn SOD play an important role in the removal of free radicals that occur in the extracellular and intracellular environment (9). Bizon *et al.*(9) investigated the Cu/Zn SOD activity and MT concentration in the blood of non-smokers and smokers and found a negative relationship between these two variables. According to the authors, the reduction in Cu/Zn SOD activity may be due to the inactivation of the reduction reaction of $O_2\bullet\text{--}\text{--}H_2O_2$ (31). Depending on aging, an increase in MT concentration and a reduction in Cu/Zn SOD occur. This makes us think that these antioxidants may be complementary to each other.

In the present study, the MT-1 and SOD-1 levels measured in the serum of the subjects decreased after 21 days, but this decrease was found to be statistically significant for MT-1 ($p<0.05$). In addition, as a result of the correlation analysis, no significant relationship was found between the Hg released

from amalgam and MT-1 and SOD-1 levels, as well as between MT-1 and SOD-1 . As a result, the null hypothesis of the study was accepted. According to the findings of the study, we think that the antioxidant system may not have been activated due to the low amount of Hg released from amalgam.

The limitation of this study is that it was conducted with a limited number of subjects. Studies that can be carried out with more subjects will provide clearer information on the subject.

Conclusion

According to the results of the present study, the amount of Hg released from the tested amalgam were found to be tolerable and no significant relationship was found between MT-1 and SOD-1. However, more studies are needed on this subject.

Türkçe özet: *Amalgam dolgudan civa salımı ve civanın metallotionein ve süperoksit dismutaz ile ilişkisi. Amaç: Bu çalışmada, sağlıklı bireylerde tedavi sonrası amalgamdan zamanla salınan civa miktarının belirlenmesi ve civanın serum MT-1 ve SOD-1 düzeyleri ile ilişkisinin incelenmesi amaçlanmıştır. Gereç ve Yöntem: Yaşları 19-22 arasında değişen 15 deneğe amalgam dolgu uygulandı ve tedavi öncesi ve tedaviden 1 gün, 7 gün, 21 gün ve 35 gün sonra kan örnekleri alındı. Serum numunelerinin civa analizi, İndüktif Olarak Eşleştirilmiş Plazma Kütle Spektrometresi (ICP-MS) kullanılarak yapıldı. Ek olarak, serum numunelerindeki MT-1 ve SOD-1 seviyeleri ticari ELISA kitleri kullanılarak ölçüldü. Elde edilen verilerin analizi Friedman testi ve Spearman korelasyon analizi kullanılarak yapıldı. p<0,05 değeri istatistiksel olarak anlamlılık düzeyinde yorumlanmıştır. Bulgular: MT-1 için yapılan analiz sonucunda değerlerin zamanla azaldığı ve bu düşüşün 21 gün sonra istatistiksel olarak anlamlı olduğu bulundu. Ayrıca SOD-1'in zamanla azaldığı ancak bu düşüşün istatistiksel olarak anlamlı olmadığı bulundu (p>0,05). Salınan civa miktarı açısından zamanla salınan civa değerleri arasında istatistiksel olarak anlamlı bir fark bulunmadı. Korelasyon analizi sonuçlarına göre değişkenler arasında istatistiksel olarak anlamlı bir ilişki bulunmadı. Sonuç: Bu çalışmanın sonuçları, test edilen amalgamdan salınan civa miktarının tolere edilebilir olduğunu ve MT-1 ile SOD-1 arasında anlamlı bir ilişki bulunmadığını göstermiştir. Anahtar kelimeler: Amalgam, antioksidanlar, civa, metallotionein, süperoksit dismutaz*

Ethics Committee Approval: This research has been approved by the Bioethics Committee of the Faculty of Dentistry, Ataturk University (approval number: 20.11.2014/031).

Informed Consent: All subjects included in the study were informed about the study and written informed consent was obtained from the subjects. This study has followed the guidelines stated in the Helsinki Declaration for clinical investigations.

Peer-review: Externally peer-reviewed.

Author contributions: PG, AK participated in designing the study. OK, OS, SA, OT participated in generating the data for the study. OK, OS, SA, OT participated in gathering the data for the study. PG participated in the analysis of the data. PG wrote the majority of the original draft of the paper. PG, OK, OS participated in writing the paper. PG, OK, OS, SA, OT have had access to all of the raw data of the study. PG, AK have reviewed the pertinent raw data on which the results and conclusions of this study are based. PG, OK, OS, SA, OT, AK have approved the final version of this paper. PG guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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

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Original research

A comparative study to evaluate the heat generated during osteotomy with conventional drill, trephine and alveolar expander

Shubhanshi Omar[1], **Honey Jaiswal**[1], **Sunil Kumar Mishra**[1], **Darpan Bhargava**[2], **Prince Kumar**[1]

Purpose
Excessively produced heat could lead to clinical failure of osseointegration. This study was done to compare the heat generated during osteotomy with the conventional drill, trephine, and alveolar expander .

Materials and Methods
This in vitro study was performed on ten bovine femoral bones. In each femoral bone, three osteotomy sites were prepared at a distance of 1.5cm using the conventional drill, trephine, and alveolar expander. During osteotomy, the site was irrigated with a copius amount of normal saline. Osteotomy sites of 3.6 mm in diameter and 11.5 mm in length were prepared using the conventional drill and bone trephines. The alveolar expander used for preparing the osteotomy site was 3.5mm, the nearest dimensions available. The temperature rise was measured using a thermocouple thermometer. Repeated measures ANOVA and Fisher's least significant difference pairwise comparison test was done for statistical analysis.

Results
Repeated measures ANOVA revealed a significant difference in the heat generation with the conventional drill, trephine, and alveolar expander ($p<0.001$). The mean heat generated was maximum with the trephine (28.26±0.246 ºC) followed by the conventional drill (27.27±0.297 ºC) and least with alveolar expander (25.64±0.142 ºC). Pairwise comparison showed a significant difference in heat generated during osteotomy with conventional drill compared to trephine ($P=0.023$), conventional drill compared to alveolar expander ($P=0.014$), and trephine compared to alveolar expander ($P< 0.001$).

Conclusion
The heat generated with trephine was maximum compared to the alveolar expander and conventional drills. If in case trephine is to be used, both internal and external irrigation must be used. Less heat generation during osteotomy by alveolar expander seems very promising and advantageous for better osseointegration.

Keywords: *Alveolar expander, dental implant, heat generation, osteotomy, trephine*

Introduction

Implant dentistry has become extremely popularized and emerged as a viable option in the present era. Most clinicians recommend it as the first choice for replacing missing teeth. Literature has well stated that implant success principally depends on the extent of osseointegration. Successful osseointegration is primarily dependent on design, chemical composition, surface texture and shape of implant, medicaments, heat produced during osteotomy, and initial healing response at the implant site (1,2).

A considerable number of research studies have been performed on dental implant design but less has been attempted on implant site-relat-

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ed factors (3). The heat produced during site preparation is one of the vital factors for the lack of osseointegration. The temperature rise is mostly due to friction between the cutting surface of drills and bone. However, the ideal geometric design for a drill to diminish heat generation is still unclear (4,5). Excessively produced heat could lead to clinical failure of osseointegration. Additionally, this frictional heat could lead to a certain degree of necrosis of cells. The temperature threshold for tissue survival during osteotomy is 47 ºC when drilling is done for more than 1 min (6).

While preparing the implant sites with drills, it is essential to keep an eye on heat injury since osseous tissues are highly prone to thermal insult (7). To preserve the bone from rising temperature during drilling, different irrigation systems are utilized. Predominantly, sterile saline solutions are the material of choice for clinicians. Modifications in drill designs are also introduced and experimented with to control heat. Drill systems with internal irrigation are very popular and efficient in this regard (8). The study by Gupta *et al*. (9) evaluated heat generation during osteotomy with the conventional drill and trephine and a study by Bhargava *et al.* (10) evaluated bone loss during osteotomy using the standard drill, bone trephine, and alveolar expanders. Studies evaluating heat generation by alveolar expander seem to be not attempted yet.

Therefore, considering all these imperative factors, this study was conducted to compare the heat generated during osteotomy with the conventional drill, trephine, and alveolar expander in bovine femoral bone. The null hypothesis undertaken was that there was no difference in heat generation during osteotomy with conventional drill, trephine and alveolar expander.

Material and Methods

Study design

This in vitro study was conducted on the fresh bovine femoral bone obtained from the slaughtered goats for human consumption at the local butcher's shop to simulate the clinical conditions. The femoral bones were obtained from healthy male goats, with a mean age of 17.9±0.7 months (range 17.5-19 months) and mean weight of 34.8±0.7 Kg (range 34-36 Kg).

The study was performed on ten bovine femoral bones, slaughtered within 1h of starting the osteotomy. In each femoral bone, 1.5cm was kept as a safe distance between osteotomy sites to standardize the different drilling procedures and to check any possible effects of adjacent osteotomy sites.

Drilling procedures and heat generation

In each femoral bone, three osteotomy sites were prepared at a distance of 1.5cm using an implant drill, trephine, and alveolar expander (Figure 1a-c). Osteotomy sites of 3.6 mm in diameter and 11.5 mm in length was prepared using the conventional implant drill and bone trephines. The alveolar expander used for preparing the osteotomy site was 3.5mm, as it was the nearest dimension available. The temperature rise was measured using a thermocouple thermometer (Figure 2). A horizontal hole at 90-degree angle to the midpoint of the osteotomy site (at a depth of 5.75mm) was made in all the femoral bones for placement of the thermocouple. The thermocouple was placed such that the distance between the sensor tip and the implant site was 0.5mm to record the temperature.

The osteotomy site preparation with implant drills (Surgical Kit, DR0010, DR0020, DRN028-DRN036, ARDS Implants, Tefen,

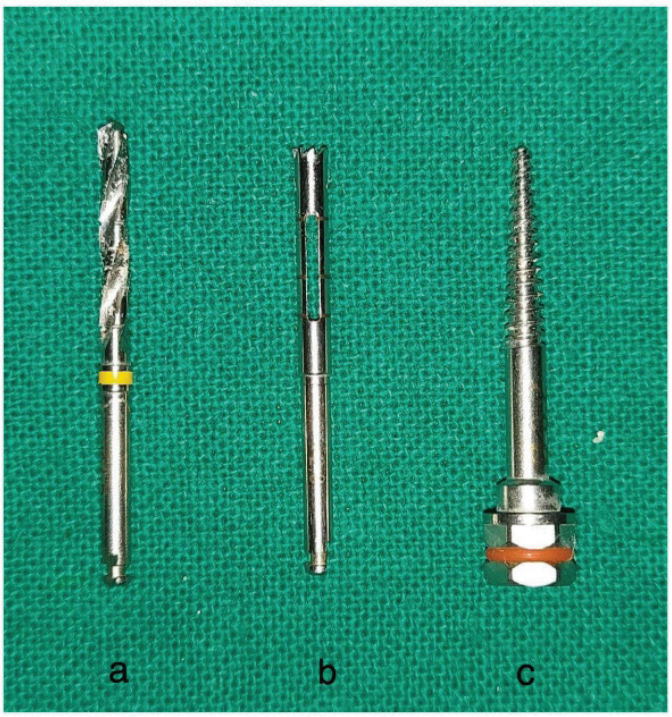

Figure 1. *a) Conventional drill. b) Trephine. c) Alveolar expander.*

Figure 2. *Temperature measurement with thermocouple thermometer.*

Italy) was done in the recommended pattern at 800 rpm with a reduction gear dental implant handpiece (SII 20:1, Daegu, Korea), driven by a surgical motor (MPi 2.0, Madrid, Spain) with profuse irrigation using normal saline. At the first site, a marking was made on the femoral bone with the implant marking drill. The osteotomy was completed in sequence using a 2.0 mm pilot drill, followed by 2.8 mm, 3.2 mm, and 3.5 mm drills to achieve a site of 3.6mm diameter and a depth of 11.5mm. After using the last drill of 3.6 mm, the temperature was measured with the thermocouple thermometer (Divinext -50 ^{0}C to 1300 ^{0}C, Type K, Vani International, Vadodara, India) (Figure 3a). The temperature was measured three times in all the ten femoral bones and the mean temperature was recorded.

The osteotomy site preparation with trephines (PGD Kit, DR0010-DR0036, ARDS Implants, Tefen, Italy) was also done in the recommended pattern at 800 rpm with a reduction gear dental implant handpiece (20:1), driven by a surgical motor with profuse irrigation using normal saline. At the second site also, firstly a marking was made on the femoral bone with the implant marking drill. The osteotomy was done in sequence using a 2.0mm pilot drill, followed by 2.8mm, 3.2mm, and 3.6mm drills to achieve a site of 3.6mm diameter and a depth of 11.5mm. After using the last trephine drill of 3.6mm, the temperature was measured with the thermocouple thermometer (Figure 3b). The temperature was measured three times in all the ten femoral bones and the mean temperature was recorded.

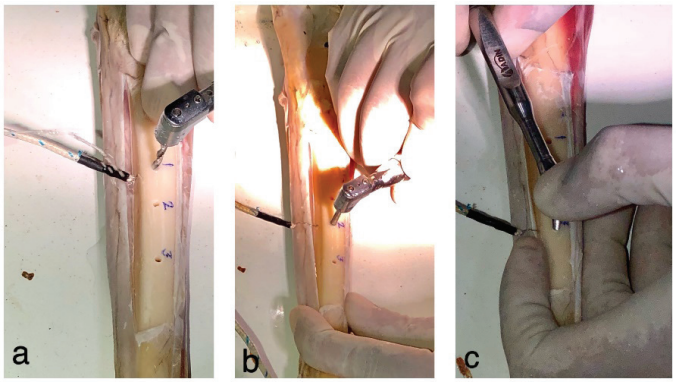

Figure 3. *Osteotomy site preparation in bovine femoral bone. a) with conventional drill. b) with trephine. c) with alveolar expander*

At the third site, the osteotomy was done with the alveolar expander (SBE01-04, IDEA implant system, Chennai, India). During osteotomy, profuse irrigation was ensured with normal saline at this site too. The osteotomy was started with a marking on the femoral bone with flame-shaped dental implant marking bur followed by pilot drilling with a 2.0mm pilot drill. The site was further expanded using a tapered screw-type alveolar expander in the sequence of 3.2mm, 3.4mm and 3.5mm to achieve a site of 3.6mm diameter and a depth of 11.5mm. While using the different diameters of alveolar expander, a break of 10 sec was taken to allow adequate expansion of the bone. After using the last alveolar expander of 3.5mm, the temperature was measured with the thermocouple thermometer (Figure 3c). The temperature was measured three times in all the ten femoral bones and the mean temperature was recorded.

Statistical analysis

The temperature rise was tabulated in an excel sheet. The temperature was measured three times with the drill, trephine and alveolar expander in all the ten femoral bones, and the mean temperature was calculated. The data were analyzed using the Statistical Package for the Social Sciences (version 20.0 version, IBM, Chicago, IL, USA). Repeated measures ANOVA was done to find whether there was a significant difference exist in heat generated during osteotomy with the conventional drill, trephine, and alveolar expander. Fisher's least significant difference pairwise comparison was done to find the significant difference in heat generated during osteotomy between different drilling techniques. *P*-value <0.05 was considered statistically significant.

Results

The descriptive statistics of heat generated during osteotomy with the conventional drill, trephine, and alveolar expander were presented in Table 1. Repeated measures ANOVA for comparison of heat generated during osteotomy with conventional drill, trephine and alveolar expander was presented in Table 2. The mean heat generated was maximum with a trephine (28.26±0.246 ºC) followed by the

Table 1: *Descriptive statistics of heat generated during osteotomy with conventional drill, trephine and alveolar expander*

Group	n	Reading	Mean (^{0}C)	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Conventional drill	10	1	27.03	0.327	26.25	27.81
		2	27.38	0.303	26.60	28.17
		3	27.40	0.316	26.62	28.18
Trephine	10	1	28.18	0.275	28.18	28.18
		2	28.15	0.262	28.15	28.15
		3	28.45	0.275	27.83	29.07
Alveolar expander	10	1	25.54	0.171	25.54	25.54
		2	25.66	0.172	25.66	25.66
		3	25.72	0.193	25.72	25.72

n=number of femoral bones

conventional drill (27.27±0.297 ºC) and least with alveolar expander (25.64±0.142 ºC). When the heat generated with a conventional drill during osteotomy was evaluated, the maximum heat generated value obtained was 28.8 ºC and the minimum was 25.5 ºC. In the case of heat generated with a trephine, the maximum value obtained was 29.2 ºC and the minimum was 27.4 ºC. In the case of heat generated with alveolar expander, the maximum value obtained was 26.0 ºC and the minimum was 25.3 ºC.

The Fisher's least significant difference pairwise comparison was done to find the difference in heat generated during osteotomy with the conventional drill, trephine, and alveolar expander (Table 3). Pairwise comparison showed a significant difference in heat generated during osteotomy with conventional drill compared to trephine (*P*=0.023), conventional drill compared to alveolar expander (*P*=0.014), and trephine compared to alveolar expander (*P<0.001*).

Discussion

The null hypothesis undertaken in this study was rejected, as differences exists in heat generation during osteotomy with the conventional drill, trephine, and alveolar expander. The heat generated was minimum with a alveolar expander (25.64±0.142 ºC) and maximum with trephine (28.26±0.246 ºC).

The implant-supported prostheses should be given following proper guidelines with minimal surgical intervention (11). One of the important requisites during implant placement is proper preparation of the osteotomy site. During osteotomy, care should be taken to avoid excessive temperature rise at the site due to implant drills, so that damage to the surrounding tissues can be prevented. Excess heat generated by implant drills while osteotomy causes necrosis of bone. The increase in temperature and the period of thermal exposure causes an exponential increase in injury to the bone (12,13). During osteotomy, external irrigation with low-temperature saline seems to be quite effective in cooling the bone, so continuous irrigation of the osteotomy site in between the drilling should be done (14). In the present study, also external irrigation with low-temperature saline was done with all the three drilling techniques.

Researchers had proposed incremental preparation of the implant site with a sequence of implant drills in increasing diameter to reduce the heat generation and damage to the bone damage during osteotomy. A graded series of the drill was found to be better than a single large drill for osteotomy site preparation (15-17). A similar concept was followed in the present study also and incremental site preparation with all the three drilling techniques was followed. Gupta *et al.* (9) had done the infrared thermographic evaluation of rise in temperature with conventional drill and trephine and found that temperature rise was significantly higher for trephine (52.98±1.67 °C) than for conventional drills (48.20±0.67 °C) at the tip. In the present study also the heat generated was higher with the trephine (28.26±0.246 °C) compared to conventional drill (27.27±0.297 ºC) and the difference was statistically significant (*P*=0.023). The heat generated with the trephine was maximum due to the fact that trephine has the closely arranged cutting blades at the tip, which generates much friction and localized heat production with uneven distribution of heat. In the case of conventional drills, the blades were present throughout the drill, which does the efficient cutting, with less heat generation and uniform the heat distribution.

To the best of the author's knowledge, this would be the first study comparing the heat generated during osteotomy with the conventional drill, trephine, and alveolar expander. The mean heat generated was maximum with the trephine (28.26±0.246 ºC) followed by the conventional drill (27.27±0.297 ºC) and least with alveolar expander (25.64±0.142 ºC). The heat generated with the alveolar expander was minimum and it may be because there was lateral condensation of bone rather than removal of the marrow, which generates less heat (10). The researchers have indicated that an alveolar expander is an advantageous modality for implant osteotomy since the procedure is less inva-

Table 2: *Repeated measures ANOVA for comparison of heat generated during osteotomy with conventional drill, trephine and alveolar expander*

Group	n	Min (ºC)	Max (ºC)	Baseline (ºC)	Mean (ºC)	Std. Error	95% Confidence Interval		F value	P value
							Lower Bound	Upper Bound		
Conventional drill	10	25.5	28.8	24.9	27.27	0.297	26.48	28.06	38.310	<0.001*
Trephine	10	27.4	29.2	24.8	28.26	0.246	27.78	28.74		
Alveolar expander	10	25.3	26.0	25.1	25.64	0.142	25.64	25.64		

n=number of femoral bones; *statistically significant (*P* < .05)

Table 3: *Fisher's least significant difference pairwise comparisons to find the difference in heat generated during osteotomy with conventional drill, trephine and alveolar expander*

Group (I)	Group (J)	Mean Difference (I-J)	Std. Error	*P*-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Conventional drill	Trephine	-0.990	0.389	0.023*	-1.820	-0.160
	Alveolar expander	1.630	0.386	0.014*	0.555	2.705
Trephine	Alveolar expander	2.620	0.302	<0.001*	2.028	3.212

*statistically significant (*P* < .05)

sive and easy to attempt. Alveolar expander causes minimal bone trauma with better initial healing at the bone-implant interface (18-20). Implant drills relatively produce more heat as found in the present study, and it may lead to necrosis of bone, with excess bone loss during the healing phase of implants (19).

In the study by Bhargava *et al*.(10) where they evaluate the bone loss during osteotomy using the standard drill, bone trephine, and alveolar expanders for implant placement using cone-beam computed tomography. They found that osteotomy with an alveolar expander shows the minimum bone loss as seen on cone-beam computed tomography. Expanders produce undersized implant osteotomies. More bone conservation with less heat generation during osteotomy by alveolar expander will definitely be advantageous for better primary stability and osseointegration of implants.

The present study has certain limitations, such as this is an *in vitro* animal model study and does not exactly simulate the human oral environment. In order to standardize the procedure with alveolar expanders, the internal irrigation drill and trephines were not used in the study. Further human studies should be done on osteotomy using an alveolar expander to find heat generation and its effect on osseointegration of dental implants.

Conclusion

Within its limitations, the findings of the present study indicated that the heat generated with trephine was greater compared to the alveolar expander and conventional drills. If the trephine drill is to be used, using both internal and external irrigation should be considered. Less heat generation during osteotomy by alveolar expander seems very promising and could be advantageous for the osteointegration of dental implants.

Türkçe özet: *İmplant frezi, trefan frez ve alveolar genişletici ile osteotomi sırasında üretilen ısının deneysel olarak değerlendirilmesi. Amaç: Aşırı üretilen ısı, osseointegrasyonun klinik olarak başarısız olmasına neden olabilir. Bu çalışma, osteotomi sırasında geleneksel frez, trefan frez ve alveolar genişletici ile yapılan osteotomi sırasında ortaya çıkan ısının karşılaştırılmasını amaçlamaktadır. Gereç ve yöntem: Bu in vitro çalışma, on adet sığır femur kemiği üzerinde yapıldı. Her bir femur kemiğinde, geleneksel frez, trefan frez ve alveolar genişletici kullanılarak 1.5 cm mesafede üç osteotomi bölgesi hazırlandı. Osteotomi sırasında bölge bol miktarda normal salin ile yıkandı. 3,6 mm çapında ve 11,5 mm uzunluğunda osteotomi alanları, geleneksel frez ve kemik trefanları kullanılarak hazırlandı. Osteotomi bölgesini hazırlamak için kullanılan alveolar genişletici, mevcut en yakın boyut olan 3.5 mm idi. Sıcaklık artışı bir termokupl termometresi kullanılarak ölçüldü. İstatistiksel analiz için tekrarlanan ölçümlerde ANOVA ve Fisher testi kullanıldı. Bulgular: Tekrarlanan ölçümlerde ANOVA bulguları, geleneksel frez, trefan ve alveolar genişletici ile ısı üretiminde anlamlı bir fark ortaya çıkardı (P< 0.001). Üretilen ortalama ısı en fazla trepan (28,26±0,246) ve ardından geleneksel frez (27,27±0,297) ve en az alveolar genişletici (25,64±0,142) ile elde edildi. İkili karşılaştırmalar, trefan ile karşılaştırıldığında standard frez ile osteotomi sırasında üretilen ısıda (P=0.023), alveolar genişletici ile karşılaştırıldığında geleneksel frezle (P=0.014) ve alveolar genişletici ile karşılaştırıldığında trefanda (P< 0.001) anlamlı bir fark olduğunu ortaya koymuştur. Sonuç: Alveolar genişletici ve konvansiyonel frezlere kıyasla trefan ile üretilen ısı en yüksek değerdedir. Trepan kullanılacak ise hem iç hem de dış sulama yapılmalıdır. Alveolar genişletici ile osteotomi sırasında daha az ısı üretimi, daha iyi osseointegrasyon için çok umut verici ve avantajlı görünmektedir.Anahtar kelimeler: alveolar genişletici, diş implantı, ısı üretimi, osteotomi, trefan frez*

Ethics Committee Approval: The proposal of the study was presented to Institutional Ethics Committee for ethical approval. Following approval, the study was initiated with convenience sampling.

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: SO, SKM, DB participated in designing the study. SO, HJ, SKM, DB, PK participated in generating the data for the study. SO, SKM, DB participated in gathering the data for the study. SO, HJ, SKM, DB, PK participated in the analysis of the data. SO, HJ, SKM, DB, PK wrote the majority of the original draft of the paper. SO, HJ, SKM, DB, PK participated in writing the paper. SO, SKM, DB have had access to all of the raw data of the study. SO, HJ, SKM, DB, PK have reviewed the pertinent raw data on which the results and conclusions of this study are based. SO, HJ, SKM, DB, PK have approved the final version of this paper. SKM guarantee that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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Original research

Does the face mask increase the impact of rapid maxillary expansion on sagittal airway dimensions?

Muhsin Cifter[1], **Ozge Ekmen**[2], **Asuman Deniz Gumru Celikel**[1], **Beyza Tagrikulu**[1], **Elif Erbay**[2]

Purpose

Airway dimensions associated with the transversal and sagittal position of the maxilla are affected by orthodontic treatment. The objective of this study was to compare the effects of rapid maxillary expansion (RME) and RME followed by face mask (FM) therapies on the airway space and investigate whether application of the FM increases the short-term and long- term impact of RME on sagittal airway dimensions.

Materials and Methods

A total of 26 patients were divided into two groups. Group I included 14 adolescents treated with RME (3 males, 11 females; mean age: 12.2 11 ± 2.1 years), and Group II included 12 adolescents treated with RME followed by FM therapy (7 males, 5 females; mean age: 11.6 ± 1.3 years). Sagittal and vertical skeletal measurements, as well as ten linear cross-sectional airway measurements, were calculated from pretreatment, posttreatment, and postretention cephalometric radiographs.

Results

RME followed by FM resulted in a significant increase in the SNA angle, ANB angle, and Wits parameter by the forward movement of the maxillary bone. A significant increase in the vertical dimensions was also observed. Regarding the airway measurements in both groups, significant oropharyngeal increases were revealed, and these were maintained in the follow-up period. However, there were no other significant differences in the short-term and long-term results obtained for Groups I and II.

Conclusion

The dimensions of the airway were significantly affected by both therapies. However, no additional effect of FM was observed.

Keywords: *Airway, expansion, bonded RME, face mask, long term*

Introduction

Orthodontic procedures that have an impact on facial growth patterns and skeletal structures are likely to affect airway dimensions as well (1). In particular, mandibular advancement, maxillary expansion, and maxillary protraction represent principle interventions that affect the pharyngeal airway (2, 3, 4).

Rapid maxillary expansion (RME) is commonly used for the correction of maxillary constriction and posterior cross-bite. Expansion of the maxilla with RME has been associated with positive effects on the airway and septal deformity, thereby reducing the risk of recurrent ear or nasal infections (5-7). Orthopedic maxillary expansion has also been shown to improve respiratory functions (5, 7, 8-11), while RME is an effective treatment modality for pediatric obstructive sleep apnea (12).

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Face mask (FM), an extraoral maxillary protraction device, has been used since 1960 to stimulate maxillary growth in the forward direction in growing children (13). The combination of RME and FM therapy can augment the protraction effect of FM therapy on the nasomaxillary complex.

The pharyngeal airway is closely related to the nasomaxillary complex, and the dimensions of the airway space can vary with FM therapy as a result of forward displacement of the maxilla, clockwise rotation of the mandible, and counterclockwise rotation of the palatal plane (14-20). However, while Kılınç *et al* (16) and Oktay and Ulukaya (17) have reported significant dimensional changes after extraoral maxillary protraction, Sayınsu *et al*. (15) and Kaygısız *et al*. (18) have observed significant changes only in the nasopharynx. In contrast, Baccetti *et al*. (21) and Mucedaro *et al*. (19) have reported no significant correlation between skeletal changes and airway changes.

A variety of imaging methods can be used to evaluate airway changes that are associated with these procedures. The most commonly used methods include cephalometric radiographs, traditional computed tomography, and cone-beam computed tomography. In addition to radiographic imaging techniques, medical techniques such as nasal endoscopy and acoustic rhinometry have also been used for this purpose. Each of these methods has their own advantages and limitations (10).

The specific effects of RME therapy with or without FM on airway dimensions has been the subject of considerable discussion in the literature. However, a comparison of these methods with regard to airway dimensions has not been reported. Thus, the purpose of this study was to compare the effect of RME with and without FM on airway dimensions and to investigate the hypothesis that a FM appliance increases both the short-term and long-term impact of RME on sagittal airway dimensions.

Material and Methods

Subjects

Lateral cephalograms were obtained from the records of 26 adolescents (16 girls, 10 boys) that were treated at the Department of Orthodontics, Faculty of Dentistry, Istanbul University, Turkey. The patients were subsequently allocated into two groups: Group 1 (RME) included 14 adolescents (3 boys, 11 girls) with a mean age of 12.2 ± 2.1 years. These patients presented with maxillary constriction and a bilateral or unilateral cross bite. This group received RME therapy with a bonded-type Hyrax appliance (Fig. 1). The activation protocol was two times a day for two weeks until the palatal cusps of the upper posterior teeth achieved an edge-to-edge position with the buccal cusps of the lower posterior teeth. Group 2 (RME + FM) included 12 adolescents (7 boys, 5 girls) with a mean age of 11.6 ± 1.3 years. These patients presented with skeletal Cl III deficiency with maxillary constriction. Treatment included a bonded-type Hyrax appliance in combination with a Petit-type FM appliance (Fig. 2). The FM appliance applied 6–7 N of force bilaterally for at least 16 h a day, with a direction of 40 degrees below the occlusal plane. This treatment was applied until a dental Angle Cl I canine and molar relationship was achieved.

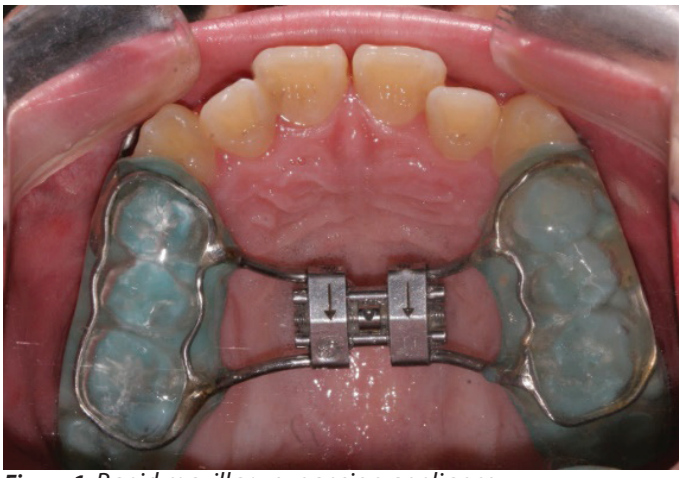

Figure 1. *Rapid maxillary expansion appliance.*

Figure 2. *Face mask appliance.*

Cephalometric analyses

Lateral cephalograms were obtained at three different time-points: before treatment (T1), after treatment (T2), and during the observation period after treatment (T3). For Group I, the total duration of the T1-T2 treatment period performed in two stages was 37.66 ± 14.29 months and the duration of the T3 period was 32.72 ± 14.98 months. For Group II, the total duration of the T1-T2 treatment period performed in two stages was 41.87 ± 11.93 months and the duration of the T3 period was 39.25 ± 20.22 months.

Skeletal measurements

Skeletal changes were evaluated by using sagittal and vertical measurements (Fig. 3).

Airway measurements

The reference lines and points used for the cephalometric tracings are shown in Figure 4. Two reference lines were constructed for the measurements as follows: S0 line passing through the anterior nasal spine and the posterior nasal spine; and N line, perpendicular to the S0 line and passing through the nasion. The airway was then divided into eleven cross-sections of equal thickness through lines parallel to S0 (S1-S10) from the superior level of the velopharynx to the level of the base of the epiglottis. To evaluate alterations in the airway space, linear distances from eleven different points on the N line to the posterior and anterior walls of the airway were measured and the differences between the posterior and anterior walls were assessed relative to the airway (22, 23).

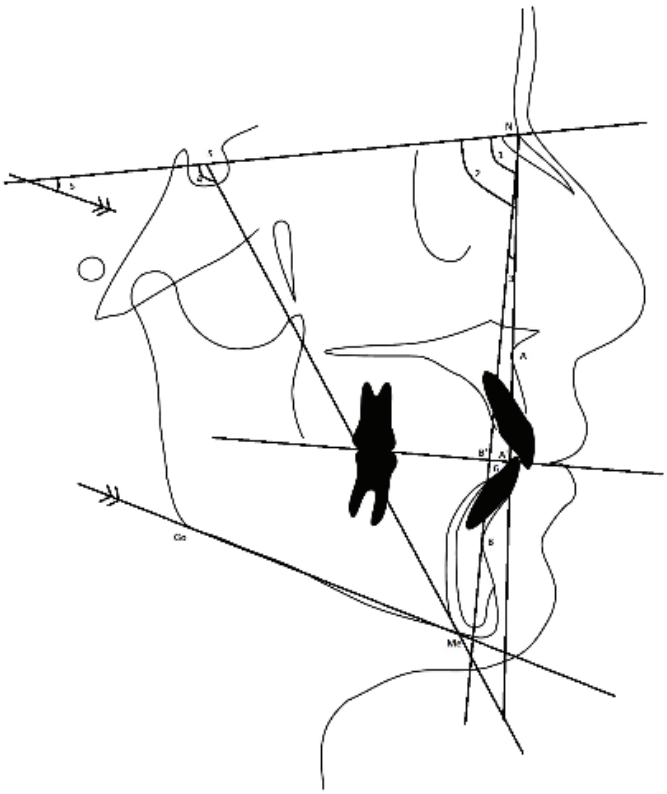

Figure 3. *Skeletal measurements: 1. SNB angle, 2. SNA angle, 3. ANB angle, 4. NSMe (Y) angle, 5. SN-GoMe angle, 6. Wits appraisal.*

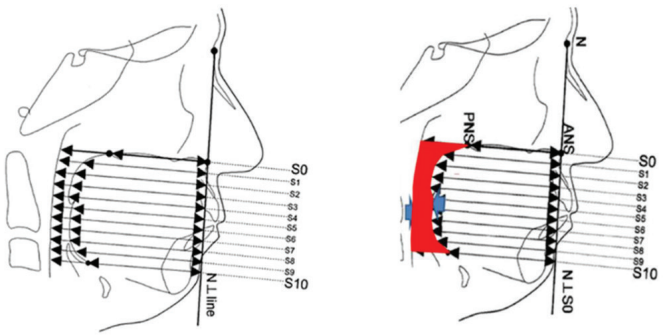

Figure 4. Airway measurements.

This study was approved by the Clinical Research Ethical Committee of Istanbul University, Faculty of Dentistry (19.10.2021/560).

Statistical analysis

For the statistical assessment of the study data, SPSS (Statistical Package for Social Sciences) 15.0 (SPSS Inc., Chicago, IL, USA) for Windows for Windows software was used. Conformity of the parameters to the normal distribution was assessed by the Kolmogorov–Smirnov test. In addition to descriptive statistical methods (mean, standard deviation), within-group and between-group comparisons of quantitative data were done. Analysis of variance for repeated measurements was used for within-group comparisons of parameters with normal distribution and Bonferroni test was used for the determination of the group responsible for the observed difference. For parameters without normal distribution, Friedman test was used for within-group comparisons and Wilcoxon sign test was used for the determination of the group causing the difference. Student t test and Mann-Whitney U tests were used for between-group comparisons of parameters with or without normal distribution, respectively. Significance was evaluated at a level of $p<0.05$.

Results

For Groups I and II, the mean skeletal and airway measurements for each group are listed in Tables 1–4. Comparisons of the treatment changes for both groups are listed in Table 5 and Table 6.

In Group 1, there were no significant changes in the skeletal measurements before and after treatment. However, the airway measurements significantly differed after treatment at levels S0, S2, S3, S4, S7, and S10. In Group 2, significant changes were observed in all of the skeletal measurements after treatment, except for the SNB angle. In addition, the airway measurements significantly differed at levels S0, S1, and S2 after treatment.

A comparison of the two groups identified significant changes in the skeletal measurements obtained. For Group I, only a statistically significant decrease in the SNA angle was observed during the retention period (T2-T3). However, for Group II, a statistically significant increase in the SNA angle was observed after treatment (T1-T2), while a statistically significant decrease in the SNA angle was observed during the retention period (T2-T3). The ANB angle and WITS parameter for Group II also exhibited statistically significant increases after treatment (T1-T2).

For the airway measurements, the only significant change observed after treatment (T1-T2) was at level S7. For Groups I and II, an increase versus a decrease at level S7 were observed, respectively.

Discussion

It is hypothesized that orthodontic treatments that enlarge the oral cavity and change the position of the

tongue affect pharyngeal airway dimensions. For the therapeutic management of snoring and obstructive sleep apnea by orthodontists (12, 24, 25), the oropharyngeal airway is thought to be the most affected region. In the present study, cephalometric parameters were evaluated to examine skeletal and oropharyngeal airway changes in adolescents treated with RME or RME followed by FM therapy. Comparisons between these groups were also made to determine whether a FM induces any additional effects on airway dimensions.

RME is a commonly used method for maxillary constriction and is also a recommended procedure for

Table 1: *Skeletal measurements in RME group.*

	Skeletal						
RME	**T1**	**T2**	**T3**	**⁺p**	***T1-T2 ++p***	***T1-T3 ++p***	***T2-T3 ++p***
	Mean±SD	**Mean±SD**	**Mean±SD**				
SNA	79,10±3,36	79,89±3,92	80,43±2,90	***0,416***	*1,000*	*0,534*	*1,000*
SNB	77,57±4,75	77,46±4,36	78,46±3,80	***0,254***	*1,000*	*1,000*	*0,272*
ANB	1,82±3,59	2,42±1,94	2,10±2,43	**0,621**	*1,000*	*1,000*	*1,000*
Wits	0,46±2,76 (1)	0,82±1,96 (1,5)	0,71±2,12 (1)	**•0,850**	*••0,929*	*••0,964*	*••0,564*
SN/GoMe	39,14±6,43	40,28±7,47	39,21±7,24	**0,177**	*0,885*	*1,000*	*0,178*
Y	71,03±5,26	72,14±5,05	72,07±5,03	**0,386**	*0,562*	*0,565*	*1,000*

*⁺ Repeated measures analysis of variance; ⁺⁺ Bonferroni test; ˙Friedman Test; •• Wilcoxon sign test; * p<0.05; ** p<0.01*

Table 2: *Airway measurements in RME group.*

	Airway						
RME	**T1**	**T2**	**T3**	**⁺p**	***T1-T2 ++p***	***T1-T3 ++p***	***T2-T3 ++p***
	Mean±SD	**Mean±SD**	**Mean±SD**				
S0	18,00±4,09	20,60±4,26	20,71±4,35	**0,009****	*0,007***	*0,022**	*1,000*
S1	11,96±2,85	13,89±3,28	13,39±3,96	**0,082**	*0,071*	*0,451*	*1,000*
S2	9,14±2,66	10,35±2,69	10,03±2,89	**0,047***	*0,044**	*0,469*	*1,000*
S3	7,82±3,06	9,25±3,12	8,67±2,71	**0,025***	*0,018**	*0,328*	*0,864*
S4	8,28±4,27	9,71±4,65	9,10±5,03	**0,043***	*0,033**	*0,470*	*0,605*
S5	10,64±4,42	11,32±4,39	10,28±4,47	**0,058**	*0,056*	*1,000*	*0,415*
S6	9,71±4,25	11,00±4,42	9,92±4,25	**0,224**	*0,237*	*1,000*	*0,416*
S7	9,07±4,14	10,32±4,01	9,42±4,29	**0,023***	*0,015**	*1,000*	*0,588*
S8	9,75±3,61	10,35±3,88	9,25±3,98	**0,125**	*0,596*	*1,000*	*0,203*
S9	10,82±4,18	11,35±4,21	10,78±3,70	**0,646**	*1,000*	*1,000*	*1,000*
S10	14,35±4,93	15,67±4,77	15,82±5,00	**0,003****	*0,004***	*0,006***	*1,000*

*⁺ Repeated measures analysis of variance; ⁺⁺ Bonferroni test; * p<0.05; ** p<0.01*

Table 3: *Skeletal measurements in RME&FM group.*

	Skeletal						
RME&FM	**T1**	**T2**	**T3**	**⁺p**	***T1-T2 ++p***	***T1-T3 ++p***	***T2-T3 ++p***
	Mean±SD	**Mean±SD**	**Mean±SD**				
SNA	75,29±3,04	77,75±3,58	76,58±3,98	***0,001*****	*0,001***	*0,313*	*0,151*
SNB	77,87±3,54	77,37±3,69	77,66±4,31	***0,451***	*0,939*	*1,000*	*1,000*
ANB	-2,58±2,97	0,37±1,49	-1,08±2,39	**0,001****	*0,001***	*0,461*	*0,067*
Wits	-4,25±2,92 (-3,5)	-1,25±2,59 (-0,5)	-2,25±2,70 (-1)	**•0,001****	*••0,002***	*••0,058*	*••0,136*
SN-GoMe	39,91±5,57	41,87±5,44	41,25±6,09	**0,015***	*0,012**	*0,468*	*1,000*
Y	70,33±3,17	72,75±3,96	72,16±4,40	**0,006****	*0,009***	*0,096*	*1,000*

*⁺ Repeated measures analysis of variance; ⁺⁺ Bonferroni test; ˙Friedman Test; •• Wilcoxon sign test; * p<0.05; ** p<0.01*

Table 4: *Airway measurements in RME&FM group.*

RME&FM	Airway			+p	*T1-T2 ++p*	*T1-T3 ++p*	*T2-T3 ++p*
	T1	T2	T3				
	Mean±SD	Mean±SD	Mean±SD				
S0	15,29±4,20	19,54±4,37	20,50±3,63	**0,003****	*0,001***	*0,006***	*0,674*
S1	12,12±2,94	14,20±2,27	14,20±2,57	**0,018***	*0,013**	*0,030**	*1,000*
S2	10,33±2,37	12,29±2,22	11,83±1,980	**0,024***	*0,020**	*0,028**	*0,879*
S3	10,25±2,90	11,83±3,06	10,75±1,99	**0,059**	*0,056*	*0,890*	*0,336*
S4	10,20±2,78	12,95±3,45	12,25±2,93	**0,087**	*0,072*	*0,221*	*0,872*
S5	12,33±4,45	12,91±4,75	11,54±3,92	**0,379**	*1,000*	*1,000*	*0,465*
S6	11,75±3,95	11,25±4,45	10,41±4,56	**0,324**	*1,000*	*0,443*	*0,802*
S7	10,66±4,00	9,79±3,85	10,16±5,14	**0,365**	*0,897*	*1,000*	*1,000*
S8	10,83±5,05	10,29±3,74	10,16±4,97	**0,894**	*1,000*	*1,000*	*1,000*
S9	10,91±5,12	11,54±4,95	10,83±5,00	**0,558**	*1,000*	*1,000*	*0,852*
S10	15,29±6,13	15,83±6,93	16,33±7,64	**0,567**	*1,000*	*0,863*	*1,000*

*+ Repeated measures analysis of variance; ++ Bonferroni test; * p<0.05; ** p<0.01*

Table 5: *Comparision of the groups by skeletal measuraments.*

		RME	RME&FM	+p
		Mean±SD	Mean±SD	
SNA	**T1-T2**	0,78±2,94 (0,75)	2,46±1,48 (2,75)	**0,046***
	T2-T3	0,53±2,25 (0)	-1,16±1,83 (-1)	**0,045***
	T1-T3	1,32±3,47 (0,5)	1,29±2,52 (0,75)	**0,917**
SNB	**T1-T2**	-0,10±3,02 (0,5)	-0,50±1,63 (-0,5)	**0,351**
	T2-T3	1,00±2,04 (0,5)	0,29±1,91 (0,75)	**0,714**
	T1-T3	0,89±3,53 (0,5)	-0,21±2,86 (0,25)	**0,437**
ANB	**T1-T2**	0,60±2,78 (0)	2,95±1,99 (2,5)	**0,011***
	T2-T3	-0,32±1,38 (0)	-1,45±1,90 (-2)	**0,064**
	T1-T3	0,28±2,68 (0)	1,50±3,39 (0,5)	**0,437**
Wits	**T1-T2**	0,35±2,70 (0)	3,00±1,75 (2)	**0,001****
	T2-T3	-0,10±0,65 (0)	-1,00±2,04 (-1)	**0,062**
	T1-T3	0,25±2,44 (0)	2,00±3,13 (1,5)	**0,091**
SN-GoMe	**T1-T2**	1,14±3,91 (1)	1,95±1,87 (2)	**0,380**
	T2-T3	-1,07±1,94 (-1)	-0,62±2,28 (-0,5)	**0,814**
	T1-T3	0,07±3,60 (1)	1,33±3,03 (0,5)	**0,587**
Y	**T1-T2**	1,10±2,97 (0)	2,41±2,20 (2)	**0,103**
	T2-T3	-0,07±2,12 (0)	-0,58±3,35 (-0,25)	**0,775**
	T1-T3	1,03±2,79 (0,75)	1,83±2,58 (2)	**0,621**

*+ Mann Whitney U test ; * p<0.05; ** p<0.01*

airway volume augmentation in the nasopharyngeal area (26). In a study by Cistulli *et al*. (27), RME improved obstructive sleep apnea due to maxillary constriction in 9/10 patients. Correspondingly, the apnea-hipopnea index value for these patients decreased from 19 to 7 per hour, and the total expansion achieved was 12.1 mm (27). In another study of 38 children that underwent maxillary expansion, Felippe *et al*. (8) observed an increase in both the palatal and nasal area and volume, concomitant with a decrease in nasal resistance. Similarly, Iwasaki *et al.* found a decrease in pharyngeal airway pressure during inspiration with the reduction of nasal resistance by the RME (28).

Measurements of the nasopharyngeal region have been reported. However, there are few studies that have investigated the effects of RME on the oropharyngeal region. Using three-dimensional measurements with computed tomography, Smith *et al*. (4) observed an increase in the volume of nasal cavity and nasopharynx, and a decrease in the volume of the oropharynx, following rapid maxillary expansion. In the present study, the dimensions of the superior oropharyngeal region increased at levels S0, S2, S3, and S4, and also increased in the inferior oropharyngeal region at levels S7 and S10, with RME. Moreover, these changes maintained in the long-term. The factors that may have contributed to the observed increase in the oropharyngeal dimensions include repositioning of the tongue and mandible due to expansion of the maxilla. Ribeiro *et al*. (11) also noted a significant change in the oropharynx after RME. However, there were inconsistencies in the acquisition of the measurements reported due to tongue posture, head inclination, and breathing and swallowing movements that were not standardized between patients (11).

Forward displacement of the maxilla and clockwise rotation of the mandible have been commonly reported after FM treatments (21, 29, 30). Examinations of pharyngeal airway changes after FM treatments have reported similar skeletal changes (16-18). The present results are consistent with both sets of findings, as statistically significant increases were observed in all of the skeletal parameters examined, except the SNB angle. Moreover, although long-term relapse was observed, it was not statistically significant.

Concerning the relationship between application of a FM and pharyngeal airway dimensions, varying results have been published. For example, Kaygısız *et al*. (18) reported an improvement in nasopharyngeal airway dimensions that was maintained over an extended period of time following

Table 6: *Comparision of the groups by airway measuraments.*

		RME	RME&FM	+p
		Mean±SD	Mean±SD	
S0	T1-T2	2,60±2,57 (1,75)	4,25±2,98 (4)	**0,147**
	T2-T3	0,10±1,33 (0)	0,95±2,58 (0)	**0,671**
	T1-T3	2,71±3,19 (1)	5,20±4,50 (4,5)	**0,097**
S1	T1-T2	1,92±2,82 (1)	2,08±2,00 (1,5)	**0,479**
	T2-T3	-0,50±2,48 (0)	0,00±1,70 (0)	**0,979**
	T1-T3	1,43±3,49 (1,5)	2,08±2,32 (2)	**0,586**
S2	T1-T2	1,21±1,61 (1)	1,95±2,03 (1,5)	**0,358**
	T2-T3	-0,32±1,99 (0)	-0,45±1,43 (-1)	**0,479**
	T1-T3	0,89±2,22 (1)	1,50±1,65 (1,75)	**0,421**
S3	T1-T2	1,43±1,62 (1,5)	1,58±1,91 (0,5)	**0,693**
	T2-T3	-0,57±1,93 (0)	-1,08±2,17 (0,75)	**0,466**
	T1-T3	0,86±1,86 (1)	0,50±1,58 (0)	**0,418**
S4	T1-T2	1,43±1,80 (1)	2,75±3,64 (2)	**0,272**
	T2-T3	-0,61±1,68 (0)	-0,70±2,21 (-1)	**0,450**
	T1-T3	0,82±2,04 (1)	2,04±3,57 (1)	**0,550**
S5	T1-T2	0,68±0,91 (0)	0,58±3,13 (0,25)	**0,654**
	T2-T3	-1,03±2,45 (0)	-1,37±3,12 (-1)	**0,716**
	T1-T3	-0,36±2,19 (0)	-0,79±3,10 (0)	**0,735**
S6	T1-T2	1,28±2,52 (0,25)	-0,50±3,00 (0)	**0,208**
	T2-T3	-1,07±2,54 (-0,5)	-0,83±2,47 (-0,5)	**0,917**
	T1-T3	0,21±1,23 (0)	-1,33±2,96 (0)	**0,244**
S7	T1-T2	1,25±1,38 (1,25)	-0,87±2,78 (0)	**0,047***
	T2-T3	-0,89±2,45 (0)	0,37±1,74 (0)	**0,250**
	T1-T3	0,35±2,29 (0,25)	-0,50±3,70 (0)	**0,660**
S8	T1-T2	0,60±1,68 (0,25)	-0,54±3,89 (0,25)	**0,659**
	T2-T3	-1,11±2,07 (0,25)	-0,12±2,24 (0)	**0,260**
	T1-T3	-0,50±2,55 (0)	-0,67±4,73 (-0,5)	**0,917**
S9	T1-T2	0,53±2,13 (0)	0,62±3,39 (0)	**0,936**
	T2-T3	-0,57±2,52 (0)	-0,71±2,17 (0)	**1,000**
	T1-T3	-0,03±2,00 (0)	-0,08±3,42 (0,5)	**0,677**
S10	T1-T2	1,32±1,23 (1)	0,54±2,82 (1)	**0,635**
	T2-T3	0,14±1,36 (0)	0,50±2,16 (0,25)	**0,715**
	T1-T3	1,46±1,42 (1,5)	1,04±3,22 (1,75)	**1,000**

*+ Mann Whitney U test; * p<0.05*

FM therapy. An increase in the oropharyngeal airway area was also observed, although the increase was not statistically significant at the end of treatment, yet a significant increase occurred during the follow-up period (18). Sayınsu *et al*. (15) and Cakırer *et al*. (31) also observed an increase in nasopharyngeal airway dimensions, yet an increase in the oropharyngeal dimensions were not observed. In the present study, only an increase in the superior oropharyngeal airway was observed at the level of S0, S1, and S2 in the RME + FM group, similar to the short-term findings reported by Kaygısız *et al*. (18) However, in contrast with the findings of Kaygısız *et al*. (18), the oropharyngeal measurements in the present study were maintained over the long-term interval monitored.

Between-group comparisons of skeletal measurements revealed statistically significant differences in the SNA angle, the ANB angle, and Wits appraisal. The vertical measurements also increased for the RME + FM group, yet the increase was not statistically significant. In terms of airway dimensions, the only statistically significant difference between the two groups was associated with level S7. However, while an increase was observed at level S7 for the RME group, a decrease after treatment was observed for the RME + FM group. It is possible that the latter observation is due to clockwise rotation of the mandible. For example, Akcam *et al*. (32) observed a decrease in airway space in patients with clockwise rotation of the mandible. Furthermore, according to Ceylan and Oktay (33), pharyngeal airway size may be influenced by changes in the ANB angle, and oropharyngeal dimensions may be diminished in subjects with an increased ANB angle.

The present results suggest that treatments of RME and RME followed by FM therapy have similar effects, and the FM appliance has no additional effect on oropharyngeal airway dimensions. Previously, no relationship between changes in craniofacial morphology and upper-airway dimensions after maxillary protraction were observed in a study by Hiyama *et al*. (14). These results were attributed to an increase in the superior-airway dimension relative to the anterior position of the tongue, and to the increased volume of the oral cavity and head posture (14). Mucedero *et al*. (19) also analyzed changes in oropharyngeal and nasopharyngeal airway dimensions in the sagittal plane following orthopedic therapy of Cl III malocclusion with FM or FM plus RME. Compared to subjects with untreated Cl III malocclusion, there were no significant changes observed in the treatment groups. Changes in the sagittal airway dimensions induced by orthopedic therapy or physiological growth also exhibited greater inter-individual variability in subjects with Cl III malocclusion (19). Similarly, Baccetti *et al*. (21) found no significant short-term or long-term changes in sagittal oropharyngeal and nasopharyngeal airway dimensions induced by maxillary protraction in subjects with Cl III malocclusion compared with an untreated control group. The authors also emphasized the importance of considering age-related 266 physiological changes of the posterior pharyngeal lymphoid tissue (21).

Due to the difficulty in finding untreated children with the type of malocclusion treated in the present study, no control group was included for ethical reasons. Changes that occur in the dimensions of the upper-airway during natural growth are also important to consider in order to determine whether the observed increase in upper-airway dimensions following treatment were directly related to maxillary expansion. Özbek *et al*. (2), previously reported that 15 untreated patients (mean age: 11.3 years) exhibited only negligible changes in the upper-airway dimensions over a 1.8-year observation period. These results support the observation of the present study that maxillary expansion is responsible for the increase in oropharyngeal airway dimensions that was achieved.

In the present study, two-dimensional measurements of airway dimensions were obtained from cephalometric radiographs. Despite the reported use of a variety of methods for the measurement of nasal airway dimensions, cephalometric radiography continues to represent a widely available and cost-effective method for obtaining quantitative information on changes in the nasopharyngeal

area (34,35). Nevertheless, it is important to remember that soft tissue components of the airway are susceptible to atrophy or hypertrophy, and this can have a marked impact on measured airway dimensions. An assessment of airway changes induced by orthodontic therapy also requires a multidisciplinary approach. Thus, future prospective studies should incorporate different measurement modalities in order to obtain a more comprehensive evaluation of the airway changes that may occur. Moreover, considering the significant variability observed between patients in the present study, the unpredictability of the present results, and the controversial results from previous studies, RME or RME combined with FM should not be considered as a treatment option for improving airway space without an orthodontic indication (36).

Conclusion

In conclusion, RME and RME followed by FM therapy resulted in an increase in sagittal airway dimensions, particularly in the superior oropharyngeal region. However, there were no statistically significant differences observed at the sagittal plane following these two treatment approaches in terms of pharyngeal airway dimensions. In addition, no additional effect of FM therapy was observed.

Türkçe özet: *Yüz Maskesi Hizli Üst Çene Genişletmesinin Sagital Havayolu Boyutlari Üzerine Etkisini Arttirir Mi? Giriş ve Amaç: Üst çenenin transversal ve sagittal konumundan etkilenen havayolu boyutları ortodontik tedavilerden etkilenmektedir. Bu çalışmanın amacı; sadece üst çene hızlı genişletme prosedürü uygulanmış olgular ile hızlı genişletme sonrası yüz maskesi uygulanmış olguların havayolu boyutlarında meydana gelen değişimlerin karşılaştırılması ve yüz maskesi 40 apareyinin kısa ve uzun dönemde genişletme ile meydana gelen değişimleri etkileyip 41 etkilemediğinin araştırılmasıdır. Gereç ve Yöntem: Çalışmada toplam 78 sefalometrik film incelenmiştir. Olgular iki gruba ayrılmıştır. I. grupta hızlı üst çene genişletmesi uygulanan 14 olgu (3 erkek, 11 kız; ortalama 44 yaş: 12.2 ± 2.1 yıl), II. grupta hızlı üst çene genişletmesi sonrası yüz maskesi uygulanan 12 olgu (7 erkek, 5 kız; ortalama yaş: 11.6 ± 1.3 yıl) yer almaktadır. Tedavi öncesi, tedavi sonrası ve pekiştirme sonrası üç dönemde alınan sefalometrik filmler üzerinde sagittal ve vertikal ölçümlerle birlikte 10 kesitsel havayolu ölçümü yapılmıştır. Bulgular: Genişletme sonrası yüz maskesi uygulanan grupta üst çenenin öne gelmesiyle birlikte SNA, SNB açıları ve Wits ölçümünde anlamlı artış meydana gelmiştir. Vertikal yönde de anlamlı artış gözlemlenmiştir. Havayolu ölçümleri incelendiğinde hem kısa hem de uzun dönemde orofarengeal bölgede anlamlı artış meydana gelmiştir. Gruplar arasında her iki 53 dönemde anlamlı bir farklılık meydana gelmemiştir. Sonuç: Her iki tedavi yöntemi ile havayolu boyutlarında önemli değişiklikler meydana gelmiş olmakla birlikte yüz maskesi apareyinin havayolu boyutlarına ilave bir etkisi olduğu tespit edilememiştir. Anahtar Kelimeler: havayolu, genişletme, bonded RPE, yüz maskesi, uzun dönem.*

Ethics Committee Approval: This study was approved by the Clinical Research Ethical Committee of Istanbul University, Faculty of Dentistry (19.10.2021/560).

Informed Consent: The participants provided informed consent.

Peer-review: Externally peer-reviewed.

Author contributions: MC, OE, ADGC, BT, EE participated in designing the study. MC, OE, ADGC, BT, EE participated in generating the data for the study. MC, OE, ADGC, BT participated in gathering the data for the study. OE participated in the analysis of the data. MC, OE wrote the majority of the original draft of the paper. MC, OE, ADGC, BT participated in writing the paper. MC, OE, ADGC, BT, EE have had access to all of the raw data of the study. MC, EE have reviewed the pertinent raw data on which the results and conclusions of this study are based. MC, OE, ADGC, BT, EE have approved the final version of this paper. ADGC guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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Original research

The effects of metal nanoparticles incorporation on the mechanical properties of denture base acrylic resin

Purpose
The aim of this study was to examine the flexural strength of acrylic resin base material incorporated with iron, copper, and titanium nanoparticles.

Materials and Methods
Seventy bars of samples (65x10x2.5 mm^3) were divided into seven groups. Acrylic samples were prepared according to the manufacturer's instructions. Fe_2O_3, CuO and TiO_2 nanoparticles were manually added in a proportion of 1wt% and 3wt% to the heat-polymerized acrylic resin. The Universal Testing Machine was used for 3-point flexural test of 5 mm/min force. ANOVA and Weibull analyses were used for the statistical analyses.

Results
A statistical difference was found between the nanoparticle-added group and the control group. The highest mean value was observed for the 1wt% TiO_2 added group, (84.99 MPa) and the lowest value was for the 3wt% CuO added group (71.32 MPa) ($p<0,001$). The 3wt% Fe_2O_3 and CuO added groups showed lower values than the control group.

Conclusion
The incorporation of TiO_2 nanoparticles into acrylic resin in a proportion of 1wt% increased the flexural strength values of the resins. Within the limitations, the nanoparticle addition to acrylic resins could improve the mechanical properties; however, when the percentage of nanoparticle addition increases, the flexural strength values of the acrylic resins decrease.

Keywords: *Acrylic resin, nanoparticle, flexural strength, prosthodontics, weibull analysis*

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Introduction

Acrylic resins are commonly used denture base materials. It is preferred especially due to its easy laboratory processes, low weight, reasonable price as well as convenient aesthetic and color matching properties (1,2). However, high thermal expansion coefficient, low thermal conductivity and denture fractions are among the disadvantages of this material (1,3). Especially denture fractions that occur by mistakenly dropping, or fatigue due to recurring stretches caused by chewing activities, are still serious problems (4,5). There are studies focusing on the methods to prevent acrylic resin fractures and improve its mechanical features by reinforcing with different amounts of metal, metal oxide particles, carbon and fibers such as glass aramid (6,7).

Recently, the use of nanoparticles has become increasingly common because of their anti-corrosion features, biocompatibility and resistance to fatigue and rupture. There are some studies in the literature examining the mechanical effects of denture base acrylic resins incorporated

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with nanoparticles such as copper oxide (CuO), iron oxide (Fe_2O_3), zinc oxide (ZnO), titanium dioxide (TiO_2), aluminum oxide (Al_2O_3) and silicon oxide (SiO_2) (7,8,9). According to these studies, the concentration, size, and shape of nanoparticles might affect the endurance and the fracture resistance of materials (8). It was reported that adding nanoparticles in a proper concentration might improve the mechanical properties of a material (9).

Based on the literature review, few studies examined iron and copper nanoparticle incorporation into heat-polymerized acrylic resins. Therefore, the aim of this study was to examine the flexural strength of heat-cure acrylic resins incorporated with 1wt% and 3wt% CuO, Fe_2O_3 and TiO_2 nanoparticles. The null hypothesis was that the nanoparticle added groups would not have higher flexural strength values.

Material and Methods

Sample preparation

Materials used in this study were listed in Table 1. For sample preparation, stainless steel molds were used according to the ISO 1567 standards (2.5 mm thick, 10 mm wide and 65 mm long) (10). Pink Wax (Cavex Set Up wax; Cavex, Holland) was put into the molds, after 70 wax samples were prepared, they invested in dental stone (Fujirock EP; GC) by using a metal denture mold. Wax was eliminated by conventional methods.

The heat-cure acrylic resin samples (Panacryl, Arma Dental, İstanbul, Turkey) were prepared by mixing powder and liquid at a 25 gr/10 ml ratio according to the manufacturer's recommendation. As for the groups with nanoparticle incorporation in a proportion of 1wt% and 3wt%, Fe_2O_3 nanoparticles (99.9 % purity 50 nm particle size), CuO nanoparticles (99.9 % purity 20 nm particle size) and TiO_2 nanoparticles (99.9 % purity 30 nm particle size) were added to acrylic resin using a digital precision scale (Nanografi Nanotechnology, Ankara, Turkey). The acrylic resin powder with nanoparticles (1 wt% and 3 wt%) were thoroughly homogenized in a mixer (President Dental, Germany) in a 2900 rpm cycle for 30 seconds.

For polymerization, the resins were put into the mold, were kept for 8 h at 74±1 ºC in water, after 8 h, and they were boiled for 2 h. After the resin samples were retrieved from the molds, they were polished with 200, 400 and 600 grits respectively to obtain a standard surface (Waterproof silicon carbide paper, English Abrasives Ltd., London, England) for 5 minutes under the water-cooling (Figure 1). The sizes of the samples were measured to ensure standardization for the test processes. The samples were kept in distilled water for one week.

Flexural strength test

Universal Testing Machine (Lloyd-LRX, Lloyd Instruments, Fareham, UK) was used to determine the flexural resistance. A load was applied in the center of the samples at the crosshead speed of 5 mm/min until a fracture occurs. The maximum force (N) and the flexural strength values (mm) of each sample were automatically recorded in the processing unit of the machine.

Statistical analysis

Statistical package software (SPSS Version 24.0; SPSS Inc., Chicago, IL, USA) was used for data analysis. The data obtained in the study displayed a statistically normal distribution. Since the data had normal distribution within the groups, the means and the variations among the groups were examined by using the One-Way Variance Analysis (ANOVA) and the post-hoc Tukey test. The confidence interval was set to 95% and $p < 0.05$ was considered statistically significant. Variations within groups were examined by calculating the Weibull module (m). The fracture values were classified from minimum to maximum, and line graphics were obtained by using the median regression method.

Results

The values obtained from the flexural strength tests were compared by using ANOVA and Tukey test. The means, stan-

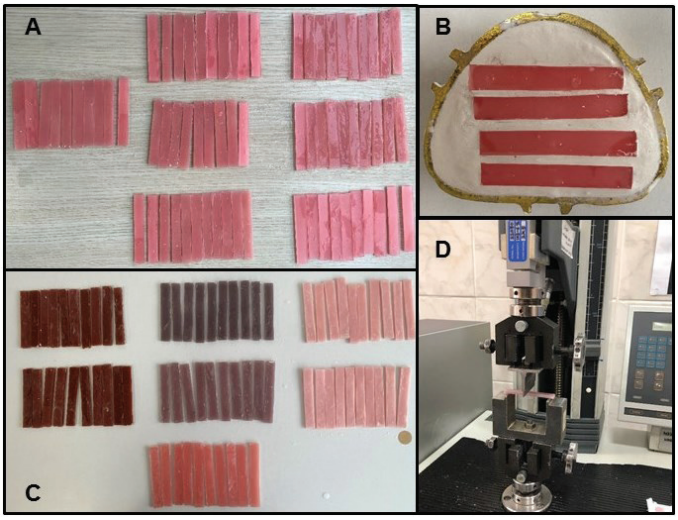

Figure 1. *Experimental design of the study (A: 70 waxes, B: Waxes placed in muffles, C: Control and modified heat-cure acrylic resins, D: Flexural strength test).*

Table 1: *Experimental materials used in this study.*

Material Name	Manufacturer	Composition
Panacryl Heat-cure acrylic resin	Arma Dental, İstanbul, Turkey	95% Methyl Methacrylate (MMA), 5% Ethilenglicoldimethilacrylate (EGDMA)
Fe_2O_3 nanoparticles	Nanografi Nanotechnology, Ankara, Turkey	99.9 % purity 50 nm particle size
CuO nanoparticles	Nanografi Nanotechnology, Ankara, Turkey	99.9 % purity 20 nm particle size
TiO_2 nanoparticles	Nanografi Nanotechnology, Ankara, Turkey	99.9 % purity 30 nm particle size

dard deviation values, minimum -maximum and Weibull analysis results are shown in Table 2. Boxplot graph and Weibull graph are shown in Figures 2 and 3. According to the flexural strength test results in this study, the significantly highest flexural strength value was found for 1wt% TiO_2 added acrylic resin. 3wt% CuO added acrylic resin had lower flexural strength values than those of the control group. Similarly, flexural resistance values, Weibull modulus and Weibull characteristics of 3wt% Fe_2O_3, CuO and TiO_2 added acrylic resins were lowest than those of the other groups.

Discussion

In the present study, 1wt% TiO_2 added group had significantly higher flexural strength value than all other groups, while 3wt% Fe_2O_3, CuO and TiO_2 added groups had lower flexural strength value than the other groups. Thus, the null hypothesis of the study was rejected.

Some recent studies in the literature examined the effects of adding nanoparticles in different concentrations to enhance the resistance of denture base material against fractures and improve its mechanical properties. According to these studies, the addition of nanoparticles in various amounts ranging between 1wt% and 5wt% strengthens the mechanical properties of materials; however, these properties weaken when the amount exceeds 5wt% (11, 12). Therefore, 1wt% and 3wt% nanoparticle incorporation were examined in the present study. The flexural strength values obtained in this study also showed a significant decrease in flexural strength values for 3wt% concentration added groups when compared to other groups. Compared to monomers and polymers, nanoparticles might negatively affect the properties of a material by clustering in large sizes (13, 14). When nanoparticles are inappropriately distributed in an acrylic resin matrix, monomer reaction decreases, and the amount of non-reactive monomers increases (15). It is also possible that the stress concentrations caused by filler particles alter the elasticity module and crack the growth mode of resin (14). Therefore, if the nanoparticle can be uniformly distributed in the resin, the stress concentration can be avoided, and the mechanical properties of the resin can be improved (16). Therefore, in this study, the nanoparticles were incorporated into resin with a mixing machine for 30 minutes to ensure homogenization.

Toodehzaeim *et al.* (17) added 0.01wt, 0.5wt and 1wt% CuO nanoparticles to nanocomposites It was reported that the shear bond strength values did not reveal a significant difference between the control group and CuO particle added groups. The results of the present study showed a decrease in strength values when compared to the control group in the case of CuO particle addition. Poosti *et al.* (18) examined the mechanical properties of TiO_2 added resins by using the shear bond test and did not find a difference between TiO_2 added group and the control group. The difference in our study might be explained by using different material and mechanical tests as well as different nanoparticle proportions.

The 3-point bending test is a commonly used and well-recognized method to measure the bending resistance of denture base polymers in conformity with international ISO 1567 standards (10). The samples were applied 5 mm/min force as suggested in Barbosa's study (19). According to ISO 1567, the bending resistance of an acrylic resin polymerized by using any known methods should not be lower than 65 MPa (10). The

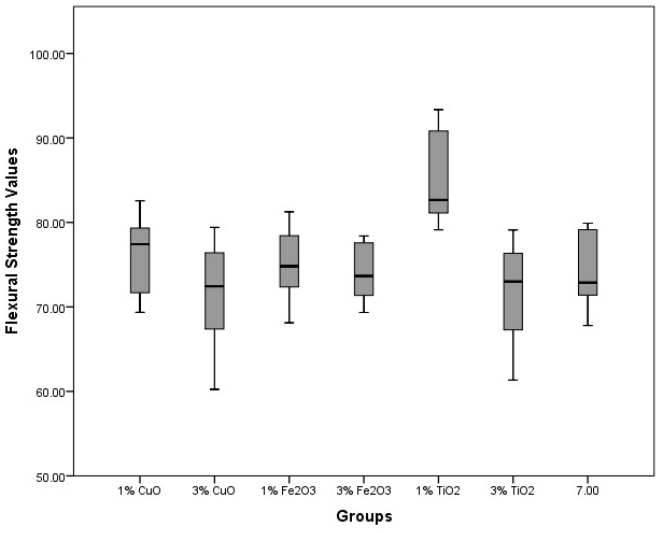

Figure 2. *Boxplot graph of flexural stress values and statistical significant differences.*

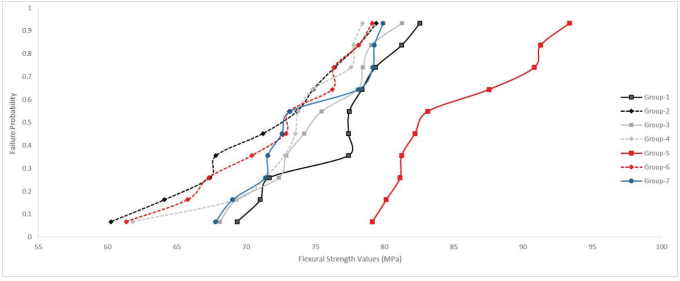

Figure 3. *Weibull plot of failure probability against stress to failure (MPa) for each group.*

Table 2: *The mean flexural strength values, SDs, min and max values of each group.*

Groups	Mean ± SD	Min	Max	Weibull Modulus	Weibull Characteristics
1% CuO	76.58±1.40	69.35	82.56	18.31	78.68
3% CuO	71.32±1.99	60.24	79.41	12.26	74.16
1% Fe_2O_3	74.91±1.37	68.11	81.26	18.88	76.90
3% Fe_2O_3	73.12±1.56	61.81	78.40	15.38	73.99
1% TiO_2	84.99±1.66	79.12	93.35	16.53	87.52
3% TiO_2	72.07±1.84	61.34	79.11	13.38	74.72
Control	74.20±1.43	67.79	79.90	17.33	76.35

group with the lowest bending resistance in our study was the 3% CuO added group (71.32 Mpa), which might be explained by the fact that acrylic resin failed to complete the chain reaction and the full polymerization due to metal nanoparticles. Similarly, the literature review showed that the effect of incorporating nanoparticles such as Fe_2O_3, TiO_2 and SiO_2 on the mechanical properties of acrylic resins is directly related to the nature of "concentration". The strength of a material decreases as nanoparticle concentration increases (7, 11). In contrast, a study found that the addition of 1wt% TiO_2 decreases the micro hardness of an acrylic resin while adding 5wt% TiO_2 causes an increase in this type of hardness. Since such an increase causes higher fatigue resistance in acrylic resin, it can be used in certain equipment restorations such as occlusal splints (20, 21). On the other hand, since higher concentrations (5wt% TiO_2) are likely to deteriorate the impact resistance of a resin, any attempt to add nanoparticles after reaching saturation during polymerization might lead to interruptions in the sustainability of resin chains (22). In addition, it was observed that nanometals added in high concentrations might cause great changes in the color of the acrylic resin.

Weibull analysis was included in the present study because it provides information about the variations in the results as well as the reliability and endurance of the material used and makes a more accurate clustering of fracture tension values and indicates. The highest Weibull characteristic value in this study was found in 1wt% TiO_2 added group. A high Weibull characteristic value means that the material is durable and displays better mechanical properties. On the other hand, the lowest Weibull characteristic values were calculated for the groups in which 3wt% nanoparticles were added. These findings imply that acrylic resins might get weaker and have lower fracture resistance in time. The Weibull results in our study are consistent with the flexural resistance test results. Thus, Weibull distribution can be considered an alternative method in evaluating the fracture possibility of materials (23).

This invitro study is limited, as it does not accurately simulate real conditions of the oral cavity. When it is considered the fact that the acrylic resin might be affected by factors such as temperature and Ph changes in the oral cavity, it might be difficult to predict the material's original clinical reactions by interpreting the in vitro reactions. Obtaining microscopic views of fractured surfaces might provide more detailed information about fatigue resistance by allowing an effective examination of surface structure and some possible voids inside the resin interface. Due to the mentioned limitations, it is necessary to conduct more advanced clinical and in vitro studies examining the effects of incorporating various nanoparticles into acrylic resin.

Conclusion

It can be concluded that adding 1wt%TiO_2 nanoparticles to acrylic resin improved the mechanical properties of acrylic resins. Despite some limitations, nanoparticle addition to acrylic resins might improve its mechanical features; however, flexural resistance values of acrylic resin decreases as the percentage of incorporated nanoparticles increases.

Türkçe özet: *Akrilik Rezinlerin Metal Nanopartikülleri İlavesi Sonrası Eğilme Mukavemetinin Değerlendirilmesi. Amaç: Bu çalışmanın amacı, demir, bakır, titanyum nanopartikülleri eklenmiş ısı ile polimerize olan akrilik rezinin eğilme mukavemetini incelemektir. Gereç ve Yöntem: Üreticinin talimatlarına göre hazırlanmış yetmiş adet örnek (65x10x2.5 mm³) yedi gruba ayrıldı. Isı ile polimerize edilmiş akrilik rezine ağırlıkça %1 ve %3 oranında Fe_2O_3, CuO ve TiO_2 nanopartikülleri manuel olarak eklendi. 3 noktalı eğilme testi için 5 mm/dk süreye ayarlanan Universal Test Cihazı kullanıldı. İstatistiksel analizler için ANOVA ve Weibull analizleri kullanıldı. Bulgular: Nanopartikül eklenen grup ile kontrol grubu arasında istatistiksel olarak fark bulundu. En yüksek ortalama değer ağırlıkça %1 TiO2 eklenen grup için (84.99 MPa) ve en düşük değer ağırlıkça %3 CuO eklenen grup için gözlendi (71.32MPa) ($p<0.001$). Ağırlıkça %3 Fe_2O_3 ve CuO ilaveli gruplar kontrol grubuna göre daha düşük değerler gösterdi. Sonuç: Akrilik rezine TiO_2 nanopartiküllerinin ağırlıkça %1 oranında katılması rezinlerin eğilme mukavemeti değerlerini arttırmıştır. Limitasyonlar dahilinde, akrilik rezinlere nanopartikül ilavesi mekanik özellikleri iyileştirebilir; ancak nanopartikül ilave yüzdesi arttığında akrilik rezinlerin eğilme mukavemeti değerleri düşmektedir. Anahtar Kelimeler: Akrilik rezin, nanopartikül, eğilme mukavemeti, protetik diş tedavisi, weibull analizi*

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Original research

Evaluation of shade matching in the repair of indirect restorative materials with universal shade composites

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Purpose
To evaluate color differences in repair of indirect ceramic and resin nanoceramic CAD/CAM blocks with two universal shade composites after different surface preparations.

Materials and Methods
120 samples were prepared from IPS Empress and GC Cerasmart270 CAD/CAM blocks and thermocycled (5000 cycles, 5°C–55°C). Initial colors of sample surfaces were measured using a spectrophotometer. Rectangular prism-shaped cavities were prepared and repaired with Tokuyama Universal Bond/Omnichroma and G-Multiprimer/G-Premio/Essentia Universal following surface preparation with aluminum oxide, Cojet, and bioactive glass (Sylc). Repaired samples were thermocycled (5000 cycles) and color measurement was performed. Color coordinates L*a*b* were recorded, and color differences were calculated using the CIELab formula. Color differences between pre-and post-repair (ΔE_1) and between post-repair and post-aging (ΔE_2) were determined. Data were analyzed using Three-way ANOVA with a significance level set at $p<0.05$.

Results
ΔE_1 values in all subgroups exceeded the threshold of 3.3. No significant difference was found between the surface preparation processes regarding ΔE_1 values. There was no significant difference between the composites and bonding agents in ΔE_1 values, except for Cerasmart/Sylc and Empress/Sylc groups. No statistically significant difference was detected in ΔE_2 values between the surface preparation treatments in all groups. ($p>0.05$).

Conclusion
Color match of the universal shade composites, which are preferred to increase the esthetic satisfaction and to simplify repair procedures, were found above the acceptable threshold. Post-aging color stability of universal shade composites was below the acceptable threshold.

Keywords: *Dental restoration repair, Color, Composite resin, CAD/CAM, Surface preparation*

Introduction

The use of CAD/CAM systems in dentistry is increasing due to the advantages such as time saving, easy and fast production, maximum compatibility of the restoration with the tooth tissue, as well as their decreasing costs. The diversity of biocompatible material options that provide high esthetics allows the production of restorations that appear similar to natural teeth in terms of color and shape (1-3). Advances in computerized systems has led to an improvement and increase in the restorative material options for performing successful treatments. CAD/CAM composite resin blocks can be processed and repaired more easily than ceramic blocks. In addition, they combine the advantages of ceramic and composite materi-

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als such as high loading capacity, fatigue resistance, superior elastic modulus, and fragility (4-8).

Each restoration has a limited lifespan, regardless of the type of the restorative material. The most common restoration-related complications in clinical diagnosis are secondary caries, marginal defects and staining, wear, discoloration and fracture, color mismatch between restoration and tooth, and fractures of the adjacent tooth structures (9, 10). Restoration fractures occur due to chewing forces and defects in the material structure (11). Repairing restoration failures is a simple and fast alternative treatment that provides satisfactory clinical performance (12, 13). In the statement of FDI about Restoration Repair in 2019 (14), the repair was defined as a minimally invasive approach that turns a clinically unacceptable restoration into a clinically acceptable one, with the application of restorative material.

In restoration repair, air abrasion methods are preferred, which are suitable for minimally invasive approach, are conservative, and provide high bonding values to the restoration surface with the repair composite without reducing the resistance of the existing restoration or tissue. Air abrasion methods are recommended for the repair of many restorative materials, as they facilitate the micromechanical connection between the restoration and repair composite (15).

Current advances in composite resin technology have made these materials indispensable in both anterior and posterior restorations (16,17). Composite resins are the first choice when repairing restoration failures (18). It is important to ensure both functional and esthetic integrity while repairing a restoration. If the restoration repair is considered esthetically successful by the patient and the dentist, it will make it an acceptable and frequently preferred treatment option. In addition, it is an environmentally friendly approach in clinical practice, where sustainable living habits are gaining importance day by day.

Composite resins are produced in forms that can mimic various optical properties to imitate the natural tooth. In composite systems with different layering options, it is possible to encounter conditions that require technical sensitivity, such as selection of the wrong combinations or incorrect thickness in the layers, and different final colors (19-21). To avoid these issues, universal shade composite resins with maximum shade matching ability are produced, which will reduce the chair time and require minimum technical sensitivity. Single shade universal composites are available on the market to match all Vita colors from A1 to D4. While producing universal shade composites, manufacturers aimed to reveal a material with translucency that could best mimic the optical properties of dentin and enamel (22-24). Contrary to Essentia U with higher chameleon effect, Omnichroma presents Smart Chromatic Technology, does not contain dyes or pigments, has structural color. The manufacturer (Tokuyama Dental) reported that the structural color of Omnichroma combines with reflected color of the restoration/tooth and creates perfect match. Smart Chromatic Technology is obtained with supra nano spherical filler particles (25).

The color difference (ΔE) method, which evaluates the perceptibility and acceptability of color in clinical and social life, is the most commonly used method in the literature in the analysis of color match (26). *CIE Lab* system is generally used in color measurement devices. The magnitude of color difference or change is represented by the ΔE value in the *CIE Lab* system and is determined using the following formula (27):

$$\Delta E = [(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2]^{1/2}$$

The aim of this study is to evaluate the shade matching ability of two universal shade composites in repair of indirect ceramic and resin nanoceramic CAD/CAM blocks following different surface preparations. The clinical acceptability of the difference obtained by baseline and post-repair color measurements of the samples was evaluated. The null hypotheses in the study are as follows; 1: Universal shade composites used in restoration repair do not show any color difference with the repair surface, 2: There is no color difference on the surface repaired with universal shade composite before and after aging, 3: There is no color difference between the surface preparation methods in terms of ΔE values.

Materials and Methods

Sample size determination and preparation

Composition of the materials used int this study are listed in Table 1. Power analysis was performed and the sample size was calculated as n=10 for color measurement in each group (Power= 100, α= 0.05). A total of 120 samples with the dimensions of 10×10×4 mm from IPS Empress LT (Ivoclar Vivadent, Schaan, Liechtenstein) (n=60) and Cerasmart 270 LT (GC Corp., Tokyo, Japan) (n=60) CAD blocks in shade A2 were cut under water cooling using a low speed diamond saw (Isomet 1000 – Buehler, IL, USA). Both surfaces of the prepared samples were polished with 600-grit silicon carbide paper under running water for 20 seconds and rinsed

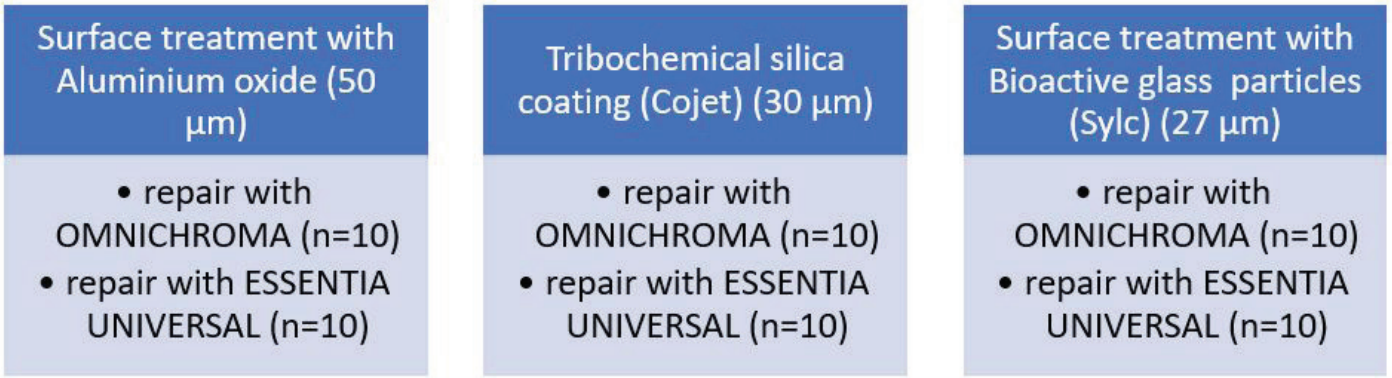

Figure 1. *Subgroups according to the surface preparation process and repair composite of ceramic and resin nanoceramic samples.*

with distilled water. Aging was performed to prepare the samples for the repair procedure. All samples were thermocycled to correspond 6 months of clinical use (5ºC-55ºC; ±2ºC water bath, 5000x, 10 s transfer time and 30 s dwell time)(28). Following aging, the ceramic and resin nanoceramic samples were randomly divided into 12 subgroups. The groups according to the surface preparation methods and the repair composites are shown in Figure 1.

Initial color measurement was performed from the selected surface of the samples with a spectrophotometer (Easy Shade V; VITA Zahnfabrik, Bad Säckingen, Germany). The manufacturer states that Easyshade V is not affected by ambient conditions. While the visual color evaluation can be affected by ambient light, the digital systems which have their own light sources make the ambient light insignificant. Therefore measurements were performed in daylight conditions, using a grey background. Three consecutive measurements were made from each sample surface (4 mm distance between the tip of the spectrophotometer and the sample borders) and the average of these values was recorded. In all color measurement steps the spectrophotometer was positioned perpendicular to the sample surfaces. Calibration of the device was performed by placing the device on the charging unit as recommended. The L*, a*, and b* values obtained were recorded as L_1*, a_1*, and b_1*.

After initial color measurement, a rectangular prism-shaped cavity of 8 × 8 × 2 mm was prepared on the surface of the samples obtained from Empress/Cerasmart blocks. The cavities were prepared under copious water cooling using a handpiece with fine-grit cylindrical burs (Figure 2).

Figure 2. *Cavity preparation with fine-grit cylindrical burs.*

Three different surface preparation procedures were performed on the prepared cavities (Figure 1). The surfaces of each group were sandblasted from a distance of 15-mm, under 2.5-bar pressure for 10 seconds, with 30-µm Cojet particles (3M Dental Productions, St Paul, USA), 27-µm Sylc (Velopex, London, UK) particles, and 50-µm aluminum oxide particles.

Following the surface preparation procedures, for the samples to be restored with Omnichroma (Tokuyama Dental Corp, Tokyo, Japan), the components A and B of the Tokuyama Universal Bond (Tokuyama Dental Corp., Tokyo, Japan) were mixed and applied to the cavity surfaces according to manufacturer's instructions (Figure 3). Omnichroma composite was placed into the cavities at a single step. A smooth surface was obtained by placing a mylar strip on the composite and pressing it with a glass slab, and the composite was polymerized for 20 seconds using Valo Cordless (Ultradent, USA) light curing device (1200 mW/cm^2).

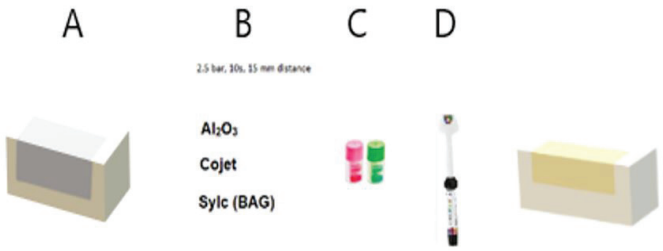

Figure 3. *Preparation of the subgroups repaired with Omnichroma A) Cavity with dimensions of 8 ×8 × 2 mm, B) 2.5 bar; 10 s; surface preparation at a distance of 15 mm, C) Tokuyama Universal Bond application, D) Omnichroma composite application.*

For the Essentia Universal group, Multiprimer (GC Corp., Tokyo, Japan) and G-Premio Bond (GC Corp., Tokyo, Japan) were applied into the cavities in accordance with the manufacturer's instructions, and Essentia Universal (GC Corp., Tokyo, Japan) was placed and polymerized as previously described for the Omnichroma group (Figure 4).

Figure 4. *Preparation of the subgroups repaired with Essentia Universal A) Cavity with dimensions of 8 × 8 × 2 mm, B) 2.5 bar; 10 s; surface preparation at a distance of 15 mm, C) Multiprimer application D) G-Premio Bond application E) Essentia Universal composite application.*

Subsequently, the samples were polished with Soflex (3M Dental Production, St Paul, USA) discs from coarse to fine grit, each for 10 s without water cooling. The samples were stored in distilled water for 24 hours before color measurements.

Color measurement

Color measurement was performed from the center of the cavity surfaces (2 mm distance between the tip of the spectrophotometer and the cavity borders) where the composites were placed as described in the initial color measurement and the values were recorded as L_2*, a_2*, b_2*.

After the samples were aged again in 5000 cycles (5°C-55°C; ±2°C), final color measurement was performed, and the values of L_3* a_3* b_3* were obtained. The resulting color changes were calculated using the ΔE formula.

The color difference between the initial and post repair values (L_1*, a_1*, b_1*. and L_2*, a_2*, b_2* values difference) was calculated as ΔE_1. To compare the color changes of the repaired composites following aging, the ΔE_2 value was obtained by using the difference between L_2*, a_2*, b_2* and L_3*, a_3*, b_3* values.

Statistical analysis

Data were analyzed using SPSS version 22 (IBM SPSS, IBM, Armonk, USA). The normality of the data was checked with

the Kolmogorov-Smirnov and Shapiro Wilks tests. The effects of the material, surface preparation, and repair composite factors on color change were tested with three-way analysis of variance (ANOVA) and the Tukey HSD test was used for pairwise comparasions. Significance level was set at $p<0.05$.

Table 1: *Composition of the materials used in the study*.*

Material	Manufacturer	Composition
Omnichroma	Tokuyama Dental Corp, Tokyo, Japan	Filler: w 79% uniform size supra-nano spheric filler (SiO_2-ZrO_2 260 nm), v 68% Base monomer: UDMA, TEGDMA
Essentia Universal	GC Corp., Tokyo, Japan	Filler: w 81%, v 65% Base monomer: BisEMA
Tokuyama Universal Bond A-B	Tokuyama Dental Corp, Tokyo, Japan	A: Phosphoric acid monomer (new 3D SR monomer), MTU-6, BisGMA, TEGDMA, aceton B: γ-MPTES, borate, peroxide, acetone, isopropyl alcohol, water
G Premio Bond	GC Corp., Tokyo, Japan	MDTP, 4-MET, MDP, aceton, initiator, water, dimethacrylate monomers, silicon dioxide
G Multi Primer	GC Corp., Tokyo, Japan	Phosphoric ester monomer, ethanol, methacrylate monomer, γ-methacryloxy propyl trimethoxylan
Aquacare Sylc Powder	Velopex, London, UK	Bioactive glass (SiO_2 46.1%, Na_2O 24.4%, CaO 26.9%, P_2O_5 2.6%) (in mol)
Cojet Powder	3M Dental Productions, St Paul, USA	Tribochemical silica coating with 30 µm alumina particles modified by silica
Cerasmart 270 LT A2	GC Corp., Tokyo, Japan	SiO_2, Al_2O_3, K_2O Monomer: BisMEPP, UDMA Filler: SiO_2, Ba glass Filler weight: 78%
IPS Empress LT A2	Ivoclar Vivadent, Schaan, Liechtenstein	SiO_2 60.0 – 65.0 Al_2O_3 16.0 – 20.0 K_2O 10.0 – 14.0 Na_2O 3.5 – 6.5 Other oxides 0.5 – 7.0 Pigments 0.2 – 1.0

*The content information is in line with the manufacturer's declaration.

Results

The ΔE_1 values obtained immediately after the repair of the resin nano-ceramic and ceramic samples with three different surface preparation processes and two different composites are shown in Table 2.

The ΔE_1 values for all subgroups were above the clinically acceptable threshold of $\Delta E \leq 3.3$. There was no statistically significant difference between the surface preparation processes in terms of ΔE_1 values. In the repair of Cerasmart blocks, Essentia Universal composite after surface preparation with Sylc showed significantly higher color difference values than Omnichroma. Empress blocks repaired with Omnichroma showed significantly higher color difference than Essentia Universal in surface preparation with Sylc ($p=0.03$), (Table 2, 3), (Figure 5). There was no statistically significant difference between the amount of color change in terms of composite in other groups.

Table 3: *Significance levels for ΔE_1 and ΔE_2 (Sign + denotes the category of comparison).*

Material	Composite	Surface preparation process	P values	
			ΔE_1	ΔE_2
Cerasmart	Omnichroma	+	0.056	0.434
	Essentia	+	0.485	0.640
	+	Al_2O_3	0.247	**0.002***
	+	Cojet	0.795	**0.000***
	+	Sylc	**0.041***	**0.005***
Empress	Omnichroma	+	0.095	0.620
	Essentia	+	0.436	0.435
	+	Al_2O_3	0.470	0.180
	+	Cojet	0.590	**0.000***
	+	Sylc	**0.030***	0.106
+	Omnichroma	Al_2O_3	0.275	0.260
+	Omnichroma	Cojet	0.964	0.240
+	Omnichroma	Sylc	**0.004***	0.455
+	Essentia	Al_2O_3	0.494	0.327
+	Essentia	Cojet	0.657	0.266
+	Essentia	Sylc	0.159	0.715

Table 2: *Comparison of ΔE_1 and ΔE_2 values regarding the repair composite, surface preparation process, and blocks.*

		Surface preparation process					
		Al_2O_3		Cojet		Sylc	
Material	Composite	ΔE_1	ΔE_2	ΔE_1	ΔE_2	ΔE_1	ΔE_2
Cerasmart	Omnichroma	4.88 ± 0.87 **a**	3.29 ± 0.98 **A**	4.33 ± 0.75 **b**	3.05 ± 0.71 **B**	3.65 ± 1.49 **c**	3.67 ± 1.40 **C**
	Essentia Universal	4.39 ± 0.95 **d**	1.87 ± 0.74 **A**	4.44 ± 1.11 **e**	1.45 ± 0.81 **B**	4.88 ± 0.90 **c**	1.73 ± 1.33 **C**
Empress	Omnichroma	4.33 ± 1.27 **f**	2.89 ± 0.51 **D**	4.3 ± 1.8 **g**	3.45 ± 0.78 **E**	5.55 ± 1.03 **h**	3.07 ± 2.07 **F**
	Essentia Universal	4.83 ± 1.71 **j**	2.32 ± 1.19 **G**	4.74 ± 1.76 **k**	1.84 ± 0.71 **E**	3.87 ± 1.94 **h**	1.93 ± 0.64 **H**

The ΔE_2 values showing the color difference after thermalcycling following repair are shown in Table 2. There was no statistically significant difference between the surface preparation processes in terms of ΔE_2 values in any of the groups ($p>0.05$). When comparing the ΔE_2 values for the composites used in the repair process; in Cerasmart blocks, the color difference obtained with Omnichroma in all three surface preparation procedures was found to be statistically significantly higher than Essentia Universal ($p=0.002$, $p=0.001$, $p=0.005$) (Table 2, 3) (Figure 6). While there was no statistically significant difference between the composites in terms of ΔE_2 values when Al_2O_3 and Sylc were applied to Empress blocks ($p>0.05$), it was determined that in Cojet application the mean ΔE_2 values obtained with Omnichroma were statistically significantly higher than the values obtained with Essentia Universal ($p=0.000$; $p<0.05$) (Table 2, 3) (Figure 6).

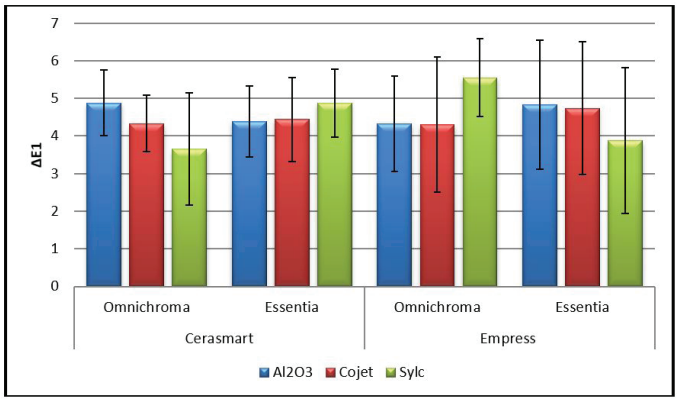

Figure 5. *ΔE_1 values obtained with 3 different surface preparation methods, 2 different CAD/CAM blocks and 2 different composites.*

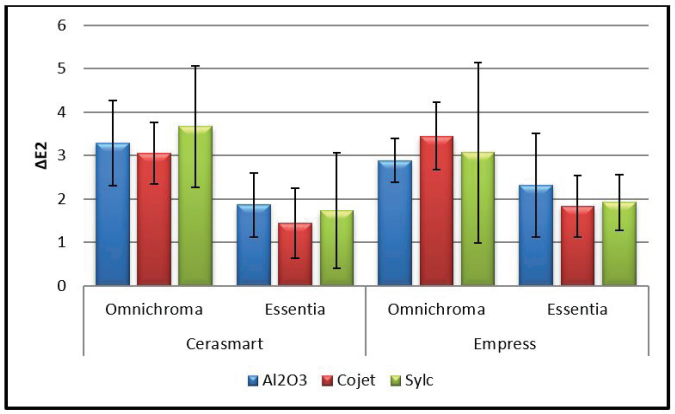

Figure 6. *ΔE_2 values obtained with 3 different surface preparation methods, 2 different CAD/CAM blocks and 2 different composites*

Discussion

The esthetics of restoration depends on the characteristics of color, shape, surface form, opalescence, and translucency. Ceramic and composite based dental materials should mimic natural tooth color as much as possible to be esthetically acceptable (29). The successful shade match of the restoration depends on the appropriate shade selection and the imitability of the color. The acceptance of the selected shade by the patient and the dentist is the most important criteria for successful shade determination (30).

One of the goals of this study was to ensure the success of restoration by utilizing the high shade matching ability that single shade composites will provide on the repair surface, as well as to eliminate the complexity of shade determination and layered composite applications. In addition, many dentists have to pay for rarely used colors when buying composite sets. However, if shade matching ability of the universal shade composites is satisfactory, such material loss and expenses could be avoided. The economic burden caused by increased restoration cycles with restoration replacement can also be avoided. In addition, if the universal shade composites enhance shade matching, it would be possible to satisfy the esthetic expectation of patients and dentists and eliminate the problem of shade determination.

In dentistry, two parameters, acceptability and perceptibility, define the magnitude of the color difference. Acceptability thresholds are higher than perceptibility thresholds. For practical interpretation of color differences, the following thresholds are used: $\Delta E>1$ can be detected by observers; $\Delta E<3.3$ is clinically acceptable (31). Acceptability thresholds are also evaluated in the literature with different values such as $\Delta E <2.72$ or $\Delta E <3.7$ (32, 33). To reduce or eliminate the inconsistencies of traditional shade matching, spectrophotometers are preferred, which are useful, reliable, and provide mobility in shade matching (34). It is possible to evaluate the clinical color performance of restorative materials using intraoral spectrophotometers which are used in clinical and laboratory settings in many studies (30, 33). Spectrophotometers with an internal light source used in contact mode have been reported to be unaffected by ambient light (35). In this study, the Vita EasyShade V spectrophotometer was used in daylight conditions without using any extra light sources.

While producing universal shade composites, manufacturers aimed to create a material with translucency and opacity that could best mimic the optical properties of dentin and enamel. High filler content affects the translucency of the composite (22). Suh *et al*. (36) found that an increase in filler content improved the opacity and blending effect of the resin. It is known that color mismatches or differences between teeth/restoration are minimized with a high blending effect. Previous studies have reported that the blending effect of the composite depends on the material and shade. The decrease in restoration volume and increase in translucency is enhancing blending effect (23, 37). The filler amount of Essentia Universal is 81% by weight and 65% by volume, while Omnichoma's is 79% by weight and 68% by volume.

In this study, the shade matching of two universal shade composites in repair of ceramic and resin nanoceramic CAD/CAM blocks was evaluated and it was observed that the color difference values were above the clinically acceptable threshold. The first null hypothesis of the study was rejected.

In the study of de Abreu *et al*. (22), the shade matching of Omnichroma and several brand composites in the incisor teeth was evaluated and similarly, the ΔE values of Omnichroma were found to be high. In this study, it can be thought that the size of the cavity volume was not sufficiently tolerated by the composite, causing high ΔE values to be obtained in

universal shade composites. Lucena *et al.* (38) evaluated the optical properties of universal shade composites and Omnichroma showed higher opalescence at 2mm thickness compared to other thicknesses. Arimoto *et al.* (39) emphasized that the opalescence of composite samples increased above 1 mm material thickness. The effect of the depth and volume of the cavity on the performance of universal shade composites should be evaluated with further studies.

Iyer *et al*. (19) evaluated the shade matching instrumentally and visually, and Omnichroma showed lower ΔE values with lighter colors in terms of shade matching. It also showed a better match with lighter colors in visual evaluation (19). Pereira Sanchez *et al*. (23) emphasized that the potential for shade matching is an optical illusion, and visual evaluation is important in the evaluation of color differences as well as instrumental evaluations.

In this study, no superiority was observed between Omnichroma and Essentia Universal composites in terms of shade matching, except for the use of Sylc for surface preparation on Cerasmart and Empress samples. While Essentia Universal showed higher color difference in Sylc treated Cerasmart270 CAD block, Omnichroma revealed higher color difference in Sylc treated Empress block. This may be caused by the effect of the Sylc particles adhering on the surfaces of Cerasmart270 and Empress blocks on the optical properties of Omnichroma and Essentia Universal, which have different chromatic technologies. The lack of studies examining the effect of surface preparation methods on the color performance of the repair material shows that there is a need for new studies on this subject. In this study, there was no statistically significant difference between the surface preparation processes in terms of ΔE_1 values. Considering the ΔE_1 values, the third hypothesis of the study was accepted.

The color difference of the resin nanoceramic and ceramic samples repaired with Omnichroma and Essentia Universal following aging (ΔE_2) were found to be below the clinically acceptable threshold in most of the samples ($\Delta E<3.3$). The 2nd hypothesis of this study was partially accepted. However, the color difference in the groups with Tokuyama Universal Bond was found to be higher than the groups with G-Premio Bond. This may be caused by the prevention of hydrolysis-induced discoloration that occurs with aging due to the HEMA-free structure of G-Premio Bond. On the other hand, it has been observed that Tokuyama Universal Bond contains HEMA. The effect of HEMA in self-adhesive systems on the color difference in restoration repair may be a different research topic.

The microstructural properties of resin composites and the degradation resistance of the composite are effective on its performance. The monomer conversion, water absorption, solubility and color stability of the co-polymer BisEMA/TEGDMA offered physicochemical properties suitable for further development as a base monomer in dental composites. It has been shown that water sorption in composite resins containing BisGMA and UDMA is higher than composites containing TEGDMA (40, 41). Fonseca *et al*. (41) showed that color stability is directly related to water sorption and solubility, which are associated with the basic monomer formulation.

It has been reported by the manufacturers that Essentia Universal contains BisEMA and Omnichroma contains UDMA and TEGDMA. In this study, Omnichroma showed higher color difference in four groups following the aging procedures. This may be due to the fact that BisEMA content has lower hydrophilicity than other monomers and thus causes less water sorption (42, 43).

High degree of conversion is important in color stability. In a study by Fonseca *et al*. (41), the BisEMA composite with a high conversion degree showed the best color stability. It can be considered that, in addition to the above-mentioned factors, the BisEMA content of Essentia Universal affects the color stability of the composite favorably, causing it to show a lower ΔE_2 value. In addition, the TEGDMA content in Omnichroma, may have result in inferior performance in color matching following aging.

It was observed that the color difference was not affected by surface preparation processes. When the effect of surface preparations on ΔE_2 was evaluated, the third hypothesis of the study was accepted regarding the effect of surface preparations on ΔE_2.

Based on this study with different components, further studies should evaluate whether shade matching and color stability are affected by adhesive systems in addition to composites.

Conclusion

Within the limitations of this study, the use of universal single shade composites in the repair of ceramic and resin nanoceramic indirect restorations was found to be close to acceptable limits in terms of shade matching. In addition, the post-aging color performance of the universal single shade composites was within acceptable limits. However, in order to obtain values below the acceptable threshold, further studies that also evaluate the effect of the restoration size and surface preparation methods on the color difference and the performances of the newly released universal shade composites would be beneficial.

Türkçe özet: *İndirekt Restoratif Materyallerin Üniversal Renk Kompozitlerle Tamirinde Renk Uyumunun Değerlendirilmesi. Amaç: Bu çalışmanın amacı farklı yüzey hazırlık işlemleri uygulanmış seramik ve rezin nano seramik CAD/CAM bloklardan elde edilen restorasyonların iki farklı üniversal renk kompozit ile tamirinde renk uyumunun değerlendirilmesidir. Gereç ve Yöntem: IPS Empress ve GC Cerasmart 270 CAD/CAM bloklardan 10x10x4 mm boyutlarında 120 adet numune hazırlanarak 5000 devir termal döngüde yaşlandırılmıştır. Numune yüzeylerinden spektrofotometre ile renk ölçümü yapılmasının ardından bu yüzeylerde 8*8*2 mm boyutlarında dikdörtgen prizma şeklinde kavite açılmıştır. Kaviteler Al_2O_3, Cojet ve Sylc (Aquacare) sistemleri ile yüzey hazırlığına tabi tutulduktan sonra Tokuyama Universal Bond/ Omnichroma (Tokuyama) ve G-Multiprimer/G-Premio/Essentia Universal (GC) materyalleri ile tamir edilmiştir. Tamir yüzeylerinden renk ölçümü yapılıp 5000 devir termal döngüye maruz kaldıktan sonra tekrar spektrofotometre (Easyshade V, VITA) ile renk ölçümü yapılmıştır. L*, a*, b* koordinatları kaydedilip CIELab formülüne göre renk farkı hesaplanmıştır. Tamir öncesi ile tamir sonrası (ΔE_1) ve tamir sonrası ile yaşlandırma sonrası (ΔE_2) renk farkları Three-way ANOVA testi ile $p<0,05$ anlamlılık düzeyinde değerlendirilmiştir. Bulgular: Tüm alt gruplarda elde edilen ΔE_1 değerleri 3,3 eşik değerin üzerindedir. Yüzey hazırlık işlemleri arasında ΔE_1 değerleri açısından istatistiksel olarak anlamlı bir farklılık tespit edilmemiştir ($p>0,05$). Kompozit ve bonding ajanlar açısından Cerasmart/Sylc ve Empress/Sylc grupları dışında ΔE_1 değerleri arasında istatistiksel olarak anlamlı bir fark bulunmamıştır. Tüm gruplarda yüzey hazırlık işlemleri arasında ΔE_2 değerleri açısından istatistiksel olarak anlamlı bir farklılık saptanmamıştır. Sonuç: Restorasyon tamirinde estetik tatmini yükseltmek ve uygulama kolaylığını artırmak amacıyla tercih*

edilen üniversal renk kompozitlerin tamir renk uyumu değerleri kabul edilebilir eşiğin üzerinde bulunmuştur. Üniversal renk kompozitlerin yaşlanma sonrası renk stabilitesi kabul edilebilir eşiğin altında bulunmuştur. Anahtar kelimeler: dental restorasyon tamiri, renk, kompozit rezin, CAD/CAM, yüzey hazırlığı

Ethics Committee Approval: Not required.

Informed Consent: Not required.

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Author contributions: BKG, BT participated in designing the study. BKG, EA, BT participated in generating the data for the study. BKG, EA, BT participated in gathering the data for the study. BKG, EA, BT participated in the analysis of the data. BKG wrote the majority of the original draft of the paper. BKG, EA, BT participated in writing the paper. BKG, BT have had access to all of the raw data of the study. BKG, EA, BT have reviewed the pertinent raw data on which the results and conclusions of this study are based. BKG, EA, BT have approved the final version of this paper. BKG guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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Original research

Evaluation of Turkish emergency medicine physicians' knowledge on emergency management of tooth avulsion

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Purpose
Tooth avulsion is a type of trauma that requires emergency intervention, and a significant number of patients apply to the emergency. The aim of this study is to evaluate the level of knowledge and the awareness about tooth avulsion among emergency medicine physicians throughout Turkiye.

Materials and Methods
The study was conducted with 545 physicians, working in emergency departments. An online questionnaire about tooth avulsion was applied to the participants. The questionnaire consisted of 3-section which evaluated personal information, the level of knowledge of avulsion cases in primary and permanent dentition, and the level of training on this subject.

Results
Of the physicians, 61.3% had not previously received education on dentoalveolar traumas, 58.7% would replant an avulsed permanent tooth, 28.3% would prefer replantation to be performed "immediately", and 28% would prefer milk as the ideal storage medium. The mean±SD and median(min-max) values of the correct answer scores on a scale of 0 to 35 were 16.42±7.08 and 17(0-32), respectively. 45.6% of the physicians' level of knowledge was below the median score.

Conclusion
The level of knowledge about tooth avulsion among Turkish emergency medicine physicians is not sufficient and there is a need to improve the knowledge level of physicians with comprehensive educational programs. This study indicates that the training of the physicians about the subject will reflect positively on the treatment of dental trauma patients.

Keywords: *Dentofacial trauma, tooth avulsion, emergency medicine physicians, knowledge, Turkiye*

Introduction

Although the oral region constitutes 1% of the body in total, 5% of traumatic injuries occur in this region (1). Dentoalveolar trauma is considered to be the most important oral health problem in children and young adults due to its functional, aesthetic, psychological, and economic consequences (2, 3).

Avulsion, one of the dental traumas, occurs when a tooth comes out of its alveolar socket completely due to trauma (4-6). The most common avulsed teeth in both primary and permanent dentition are maxillary central incisors (4, 6). The incidence of avulsion in primary teeth is 7-21%, whereas it is 0.5-3% in permanent teeth (7, 8). Furthermore, this trauma is most commonly seen between the ages of 7 to 9 years (9). While it has been stated that the immediate replantation of an avulsed permanent tooth has a 85-90% success rate, its exposure to the dry environment for long periods affects the prognosis negatively (10-12).

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It has been reported that the most common dentoalveolar trauma is avulsion in children under the age of 15 who received treatment in the emergency room (13). In a study conducted in 2010, it was reported that the percentage of dentoalveolar trauma patients who went to a children's hospital within 6 months were 36% for primary tooth avulsion and 22% for permanent tooth avulsion (14). However, there are no full-time dentists in emergency departments. In a study conducted in Turkey, it was reported that 68.1% of emergency medicine physicians witnessed emergency dentoalveolar trauma cases at least once in their professional careers, but 40.6% felt inadequate in the emergency management of dentoalveolar traumas observed in children (6). Since the possible delays in the treatment affect the prognosis negatively, the training and awareness of the physician performing the intervention in the emergency department are critical (15).

In many countries and in certain parts of our country, studies have been conducted on the knowledge and awareness of emergency medicine employees of dentoalveolar traumas (4-6, 16-22). However, it has not been found any studies focusing on tooth avulsion and involving emergency physicians from each region in Turkey. Therefore, the findings of the previous studies cannot be attributed to Turkish emergency medicine physicians (6, 21, 22).

In this study, it was aimed to evaluate the level of knowledge and the awareness of emergency medicine physicians throughout Turkey and to compare the physicians' level of knowledge according to their demographic status and experiences on the subject. The null hypothesis (H_0) of this study was that the physicians' personal data and their experiences on the subject do not affect their level of knowledge about emergency management of tooth avulsion.

Materials and Methods

Ethical approval

This cross-sectional study was conducted from April, 2018 to February, 2019. Before starting the study, approval was obtained from Inönü University Health Sciences Non-Interventional Clinical Research Ethics Committee (ethics approval number: 2018/18-12).

Creating the questionnaire

An online questionnaire was created. The questions in the questionnaire were divided into 3 sections. The first section was about personal information, the second section was on measuring the physicians' level of knowledge about the management of tooth avulsion in primary and permanent dentition, and the last section was about the personal opinions of physicians on their level of knowledge and on the awareness of receiving dentoalveolar trauma training. In addition, a picture of an avulsed anterior central tooth was placed on the first page of the questionnaire and a description of the avulsed tooth was made under the picture.

For content validity, the questionnaire was sent to experts (four pediatric dentists, three endodontists, two maxillofacial surgeons, one general dentist, and one biostatistician). The necessary changes were made in the questionnaire according to the experts' comments, and language correction was made by a linguist for clarity of the language of the questionnaire.

A pilot study involving 50 physicians (20 emergency medicine physicians, 10 general practitioners, 10 physicians in emergency medicine rotation, and 10 medical students) who did not participate in the main study was conducted to test the suitability of the methodology, which revealed no need to change the proposed methods. For section 2, the reliability assessment of the questionnaire was done with internal consistency using Cronbach's alpha coefficient and test-retest reliability using Cohen's Kappa. For test-retest reliability, 50 physicians completed the final format of the questionnaire twice in a 1-week interval.

The final online questionnaire, which consisted of three parts, contained 23 questions- 49 items: first section- 6 questions; second section- 9 questions (35 items); the third section- 8 questions.

Sample size determination

The number of the emergency medicine physicians in Turkey were calculated separately for each city and totally from the data of the ministry of health, and then their numbers were calculated for seven geographical regions in Turkey. The number of the emergency medicine specialists and the residents working in the public sector in Turkey is 3297, and it was calculated that a minimum of 345 (10.5%) emergency medicine physicians have to be reached from Turkey with 95% confidence and 5% tolerance. In this study, 393 (11.9%) of emergency medicine physicians were reached throughout the country.

Based on the stratified random sampling method, the minimum number of emergency medicine physicians needed for each region in Turkey was determined by considering the targeted-sample size. While the minimum numbers needed to be reached in each region are 31 in Black Sea, 98 in Marmara, 52 in Aegean, 28 in Mediterranean, 74 in Central Anatolia, 40 in Eastern Anatolia, and 23 in Southeastern Anatolia, the numbers of Turkish emergency medicine physicians reached in each of these 7 regions were 32, 100, 88, 31, 75, 42, and 25, respectively.

In addition, 152 physicians working in the emergency department (115 general practitioners, 37 physicians in the emergency medicine rotation) participated in the questionnaire. A total of 545 physicians serving in emergency departments in different regions of Turkey participated in this study.

Data collection

The final online questionnaire was sent to all the physicians working in emergency departments whose contact information had been provided by email, WhatsApp, and social networking platforms, such as Facebook, Instagram, etc. In addition, the questionnaire was distributed to some forums on Facebook groups that are actively used by Turkish physicians working in emergency departments. A total of 545 Turkish physicians working in emergency departments, all volunteers, answered the questionnaire. The map of the provinces where the questionnaire was applied is shown in Figure 1.

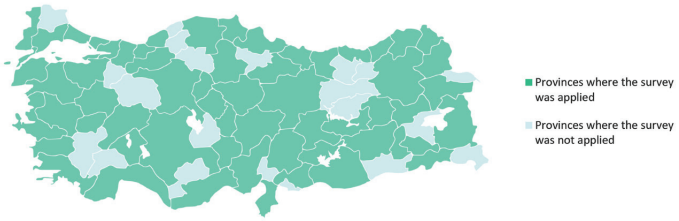

Figure 1. *The map of the Turkish provinces where the questionnaire was applied.*

Inclusion / Exclusion criteria

The study included emergency medicine specialists, residents, general physicians working in emergency departments, and practitioners in emergency medicine rotation.

Calculation of correct answer scores

The physicians' level of knowledge on emergency management of tooth avulsion was calculated according to the section 2. The correct answers to the questions in Section 2 were determined with the reference to the 2012 avulsion guideline of the International Association of Dental Traumatology (IADT) (7). Each item in Section 2 was scored as "zero" for incorrect answers and "one" for correct answers, and thus, the total correct answer scores of the physicians were determined. The theoretical range was from 0 "no knowledge" to 35 "excellent knowledge" on a scale of 0 to 35 (23).

Statistical analysis

The data obtained were analyzed using IBM SPSS V22 (SPSS Inc., Chicago, IL, USA). Internal consistency and test-retest reliability to measure the reliability of the questionnaire were used with the Cronbach's alpha and Cohen's Kappa, respectively. The data were first analyzed for the normal distribution with Kolmogorov-Smirnov test, and as a result, the data were analyzed using non-parametric tests to determine statistical differences. The Mann-Whitney *U* and Kruskal-Wallis tests were used to compare the correct answer scores according to the physicians' personal data and experiences on the subject. Multiple linear regression analysis was used to estimate the relative parameters of the knowledge score of emergency management. The significance level was accepted as $p<0.05$.

Results

In section 2 of the questionnaire, the results of the reliability tests showed that Cronbach's alpha was 0.92 ($\alpha > 0.90$ indicates excellent internal consistency) and Cohen's Kappa was 0.93 ($\kappa > 0.80$ is evaluated as very good agreement). The physicians' personal data are presented in Table 1. A total of 545 physicians working in emergency departments, consisting of 366 (67.2%) males and 179 (32.8%) females, participated in the study (mean age: 33.12 ± 6.7 years). Of the physicians, who participated in the questionnaire, 40.2% were residents, 31.9% were emergency medicine specialists, and 21.1% were general practitioners. More than half of the physicians (58%) had been working in the emergency department for 0-5 years.

The percentage of the participants who stated that they had reached information about tooth avulsion was 31.4%, and 52.3% of those reported that they had obtained the necessary information from their faculties. Furthermore, 61.3% of the physicians stated that the training they received did not include oral and dentoalveolar traumas. The percentage of the physicians who stated that they had encountered 1-5 avulsion cases where they worked in the last six months because of tooth avulsion was 39.4%, and the percentage of the physicians who did not encounter a tooth avulsion case within the 6 months was 51.6% (Table 1).

While 45.7% of the physicians stated that they could differentiate between primary and permanent teeth in avulsion cases, 63.7% stated that they would not replant the primary teeth.

The percentages of the physicians' answers to the questions about emergency management of avulsed permanent teeth are presented in Table 2.

The mean correct knowledge score (based on section 2) was 16.42±7.08 and median score (min-max) was 17 (0-32) (range 0 to 35). The physicians' level of knowledge was determined as low (45.6%), moderate (6.1%), and upper (48.3%) according to the median value of the correct answer scores (Figure 2).

The mean±SD and median (min-max) values of the level of knowledge on emergency management of avulsed teeth, and statistical comparisons of these values according to the questions in section 1 and section 3 are presented in Table 3. The knowledge level of the emergency medicine specialists was found to be higher compared to the general practitioners ($p<0.01$). The physicians' experience in emergency department was also statistically significant on the level of knowledge ($p<0.05$). Furthermore, the level of knowledge of the physicians who received training on tooth avulsion was higher than those who did not receive training ($p<0.001$). The physicians who reported their level of knowledge as "sufficient" had the highest level of knowledge ($p<0.001$).

When examining whether the physicians have received training on oral and dentoalveolar trauma according to their position, 51.7% of the emergency medicine specialists stated that they received training, while it was limited to 22.6% among the general practitioners. Of the physicians who received training on the subject (n=211), 42.7% were emergency medicine specialists, 39.3% were residents, and 12.3% were general practitioners.

Of the physicians, 93.4% stated that it is important to receive training on dentoalveolar traumas and 88.6% stated that they wanted to participate in a training program related to dentoalveolar traumas. Moreover, 84% of the physicians thought that their level of knowledge on dental traumas is inadequate.

According to the nine variables included in the regression model, 15.4% of the variances can be estimated in the correct answer scores on emergency management of dental avulsion among the physicians ($p<0.001$). The variable "whether to reach the information about tooth avulsion" had the most estimation power, which was significant ($p<0.001$) and positively related ($\beta=0.310$) to the higher knowledge scores (Table 4).

Table 1: *I- Personal data of the physicians, III- Knowledge and/or experience of the physicians about tooth avulsion.*

Section I. Personal Data of The Physicians		
Q1. Age	**mean±SD**	**min-max**
	33.12±6.7	24-76
	n	**%**
Q2. Gender		
Male	366	67.2
Female	179	32.8
Q3. Geographic regions where physicians working		
Black Sea	47	8.6
Marmara	122	22.4
Aegean	126	23.1
Mediterranean	40	7.3
Central Anatolia	90	16.5
Eastern Anatolia	82	15.0
Southeastern Anatolia	38	7.0
Q4. Position of physicians		
Emergency medicine resident	219	40.2
Emergency medicine specialist	174	31.9
General practitioner	115	21.1
Practitioner in emergecy medicine rotation	37	6.8
Q5. Academic title of the emergency medicine specialist (n=174)		
Professor	3	1.7
Associate professor	11	6.3
Academic specialist	18	10.3
Specialist	142	81.6
Q6. Years of experience in emergency department		
0-5	316	58.0
5-10	158	29.0
10-15	49	9.0
15-20	14	2.6
> 20	8	1.5
Section III. Knowledge and/or Experience of The Physicians About Tooth Avulsion		
Q1. Have you ever had access to any information about tooth avulsion?		
Yes	171	31.4
No	374	68.6
Q2. Where did you receive the information about tooth avulsion?		
Faculty of medicine	90	52.3
Medical journals	25	14.5
Dentist	35	20.3
Internet/ social media	34	19.8
Conferences, panels, seminars	60	34.9
Others	18	10.6
Q3. Does your education cover dentoalveolar traumas?		
Yes	211	38.7
No	334	61.3
Q4. Have you ever face with a tooth avulsion case in your family/ patients or yourself?		
Yes	215	39.4

Table 1: *Continue.*		
Section III. Knowledge and/or Experience of The Physicians About Tooth Avulsion		
Q4. Have you ever face with a tooth avulsion case in your family/ patients or yourself?	**mean±SD**	**min-max**
No	330	60.6
Q5. How many patients with tooth avulsion have you seen in the last 6 months?		
0	281	51.6
1-5	215	39.4
5-10	10	1.8
>10	39	7.2
Q6. Do you think it is important to get training on dental trauma?		
Yes	509	93.4
No	36	6.6
Q7. Would you like to attend a training program on dental trauma?		
Yes	483	88.6
No	62	11.4
Q8. Self-evaluation		
No idea	40	7.3
Insufficient	458	84
Sufficient	43	7.9
Comprehensive	4	0.7

SD: Standard Deviation

Table 2: *The percentage distribution of the physicians' opinion about the emergency management of tooth avulsion.*

Section II. The Physicians' Knowledge Levels About Emergency Management of Tooth Avulsion				
Q1. If a child who doesn't have any general health problem has refer to the hospital where you work with an avulsed tooth: (3 items)	**Yes n (%)**	**No n (%)**	**Do not know n (%)**	
Can you differentiate that is the primary or permanent tooth?	**249 (45.7)**	174 (31.9)	122 (22.4)	
If you think it's a primary tooth, would you replace it?	93 (17.1)	**347 (63.7)**	105 (19.3)	
Does replantation of the primary tooth damage the underlying permanent tooth?	**77 (14.1)**	134 (24.6)	334 (61.3)	
Q2. What do you think of the following statements about a patient whose permanent tooth has avulsed by trauma and who doesn't have any general health problem? (7 items)	**Yes n (%)**	**No n (%)**	**Do not know n (%)**	
The permanent avulsed tooth can be replaced.	**320 (58.7)**	34 (6.2)	191 (35.1)	
Replantation is not preferred due to the risk of inflammation.	58 (10.6)	**244 (44.8)**	243 (44.6)	
If the avulsed tooth is not brought by the patient, the physician should recommend that the tooth be searched at scene of the accident.	**208 (38.2)**	125 (22.9)	212 (38.9)	
Extraoral period of the avulsed tooth is vital for replantation.	**327 (60)**	36 (6.6)	182 (33.4)	
The avulsed tooth that stayed more than 1 hour in extraoral area, should be replace by the dentist.	**183 (33.6)**	66 (12.1)	296 (54.3)	
If the tooth has been replaced. Antibiotics should be prescribed.	**423 (77.6)**	13 (2.4)	109 (20)	
If the tooth has been replaced. The tetanus vaccine of the patient should be checked.	**438 (80.4)**	9 (1.7)	98 (18)	
Q3. If the avulsed tooth thought to be replaced, when should it be done?	**Immediately n (%)**	**In a few hours n (%)**	**In a few days n (%)**	**Do not know n (%)**
	154 (28.3)	162 (29.7)	37 (6.8)	192 (35.2)

Table 2: *Continue.*

Section II. The Physicians' Knowledge Levels About Emergency Management of Tooth Avulsion				
Q4. Which part of the avulsed tooth would you hold from?	**Crown of the tooth n (%)**	**Root of the tooth n (%)**	**Anywhere of the tooth n (%)**	**Do not know n (%)**
	273 (50.1)	47 (8.6)	13 (2.4)	212 (38.9)
Q5. If the avulsed tooth is dirty, which one(s) can be preferred to clean it? (6 items)	**Preferable n (%)**	**Not preferable n (%)**	**Do not know n (%)**	
Washing with tap water	**261 (47.9)**	165 (30.3)	119 (21.8)	
Washing with alcohol	51 (9.4)	**349 (64)**	145 (26.6)	
Washing with normal saline	**487 (89.3)**	4 (0.7)	54 (9.9)	
Scrubing the tooth with clean gauze or brush and washing with tap water	112 (20.5)	**292 (53.6)**	141 (25.9)	
Cleaning with wet gauze	307 (56.3)	**114 (20.9)**	124 (22.8)	
Doing nothing	71 (13)	**308 (56.5)**	166 (30.5)	
Q6. While replacing the avulsed tooth; (3 items)	**Yes n (%)**	**No n (%)**	**Do not know (%)**	
I align the avulsed tooth with the symmetrical tooth.	**395 (72.7)**	7 (1.3)	141 (26)	
If I face with obstacles, I can strech the alveolar socket slightly.	**146 (26.9)**	102 (18.8)	295 (54.3)	
If I can't replace, I direct the patient to the dentist immediately.	**447 (82.5)**	6 (1.1)	89 (16.4)	
Q7. How do you fix the replaced tooth in alveolar socket while you're directing the patient to the dentist? (4 items)	**Yes n (%)**	**No n (%)**	**Do not know n (%)**	
I tell the patient to bite a gauze.	**361 (66.2)**	23 (4.2)	161 (29.5)	
I advice the patient to avoid contacting his/her upper teeth with his/her lower teeth.	**170 (31.2)**	121 (22.2)	254 (46.6)	
I can fix the avulsed tooth with suturing it to the adjacent gingiva.	**98 (18)**	157 (28.8)	290 (53.2)	
I do nothing.	31 (5.7)	**240 (44)**		274 (50.3)
Q8. When should the dentist be consulted after replacing the avulsed tooth?	**Immediately n (%)**	**In a few hours n (%)**	**Within a week n (%)**	**Do not know n (%)**
	164 (30.1)	162 (29.7)	89 (16.3)	130 (23.9)
Q9. Which storage media are appropriate for the avulsed tooth? (9 items)	**Preferable n (%)**	**Not preferable n (%)**	**Do not know n (%)**	
Clean sponge, cotton or napkin	366 (67.1)	**72 (13.2)**	107 (19.6)	
Ice	159 (29.2)	**189 (34.7)**	197 (36.1)	
Normal saline	**394 (72.3)**	45 (8.3)	106 (19.4)	
Patient's mouth	**190 (34.9)**	194 (35.6)	161 (29.5)	
Patient's saliva	**208 (38.1)**	162 (29.7)	175 (32.1)	
Tap water	**106 (19.4)**	280 (51,4)	159 (29.2)	
Cold milk	**153 (28)**	215 (39.4)	177 (32.5)	
Alcohol	34 (6.3)	**353 (64.8)**	158 (29)	
Any aseptic solution	127 (23.2)	**209 (38.4)**	209 (38.4)	

The percentages written in bold type indicate the correct answers.

Discussion

Since traumatic dental injuries can occur during off-hours or during holidays, the emergency department is usually the first place to apply in these cases (18). Because there is rarely a dentist in emergency departments of public hospitals or university hospitals in Turkey, the first intervention has to be performed by a medical doctor (21). Therefore, the knowledge of emergency physicians about emergency management of tooth avulsion is very important. In this study, the level of knowledge about tooth avulsion among emergency physicians in Turkey was evaluated. Although there are the studies conducted in Turkey, neither the sample size nor the regional distribution of the participants can reflect the population of Turkish emergency medicine physician (6, 21, 22). In addition, none of these studies focused on tooth avulsion which is one of the most serious dental traumas and requires emergency intervention. In this study, every stage that should be followed according to IADT in the emergency management of avulsed teeth was questioned.

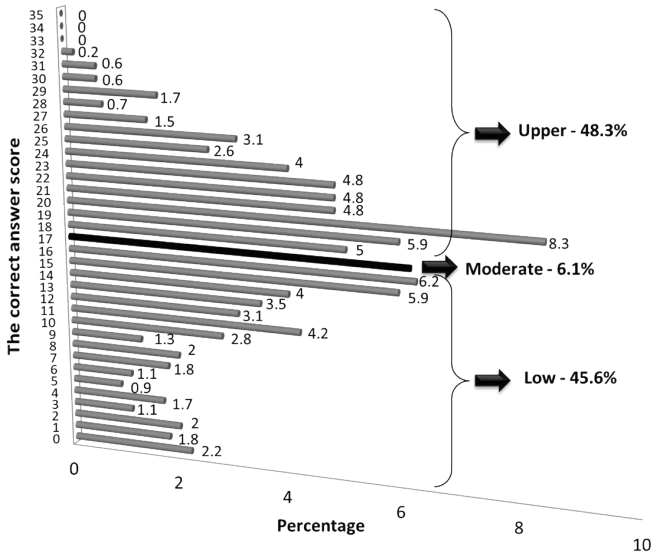

Figure 2. *The percentage column chart of the physicians' low, moderate, and upper levels of the knowledge according to the median value of the correct answer score (range 0 to 35).*

Bahammam (24) asked the physicians about the definition of tooth avulsion. In our study, the definition of tooth avulsion was given with pictures at the beginning of the questionnaire. Thus, a participant could integrate the avulsion case he/she encountered in the clinic with the questionnaire questions without being stuck in terminology.

In the 2012 guideline of IADT, it was recommended that an avulsed permanent tooth should be held from the crown, washed under running tap water, replanted into the alveolar socket and taken to the dentist, if it cannot be replanted, it should be delivered to the dentist in the first 60 minutes in a suitable transport medium (7).

In this study, 58.7% of the physicians stated that an avulsed permanent tooth could be replanted, while 10.6% stated that they would not prefer it due to the possibility of developing inflammation after replantation. In the study conducted by Diaz et al.(17), 43.9% of physicians stated that they would replant an avulsed tooth despite the risk of tetanus. In another study, some physicians stated that they would avoid replantation only when multiple avulsions occurred and when the patient is unconscious (16).

Table 3: *The mean (SD) and median (min-max) values of the correct scores on the emergency management of avulsed teeth according to the physicians' characteristics and experiences on the subject, and the statisctical comparisions.*

	Mean (SD)	Median (min-max)	Test statistic	*p*-values
Gender				
Male	16.32 (7.31)	17 (0–32)	*U*= 33.182	0.806
Female	16.63 (6.60)	17 (0–31)		
Geographic regions where the physicians working				
Black Sea	17.34 (6.66)	19 (0–30)	= 3.496	0.744
Marmara	15.67 (7.43)	16 (0–31)		
Aegean	16.40 (7.07)	17 (0–32)		
Mediterranean	16.50 (6.91)	17 (0–30)		
Cantral Anatolia	15.87 (6.75)	17.5 (0–26)		
Eastern Anatolia	17.46 (7.21)	17 (0–31)		
Southeastern Anatolia	16.71 (7.24)	19 (0–29)		
Position of the physicians				
Emergency medicine resident	15.94 (7.47)	17 (0 – 31)[ab]	= 11.251	**0.010**
Emergency medicine specialist	17.77 (6.72)	19 (0 – 30)[a]		
General practitioner	15.58 (6.70)	16 (0 – 32)[b]		
Practitioner in emergecy medicine rotation	15.51 (6.85)	17 (0 – 26)[ab]		
Years of experience in emergency department				
0-5	15.85 (7.03)	17 (0 – 31)	= 10.195	**0.037**
5-10	16.65 (7.32)	18 (0 – 32)		
10-15	17.65 (6.94)	20 (2 – 30)		
15-20	20.79 (5.10)	20 (15 – 30)		
> 20	19.38 (4.31)	19.5 (12 – 25)		
Accessing information about tooth avulsion				
Yes	20.32 (6.08)	21 (0 - 32)	*U*= 16.636	**<0.001**
No	14.64 (6.79)	16 (0 - 28)		
Whether the education covers dentoalveolar traumas				
Yes	18.50 (6.71)	20 (0 - 32)	*U*= 25.416	**<0.001**
No	15.10 (7.00)	16 (0 - 31)		

Table 3: *The mean (SD) and median (min-max) values of the correct scores on the emergency management of avulsed teeth according to the physicians' characteristics and experiences on the subject, and the statisctical comparisions.*

	Mean (SD)	Median (min-max)	Test statistic	*p*-values
Encountering with tooth avulsion before				
Yes	17.24 (6.83)	18 (0 - 31)	*U*= 32.002	**0.053**
No	15.89 (7.20)	17 (0 - 32)		
Number of tooth avulsion cases encountered in the last 6 months				
0	15.69 (7.32)	17 (0-31)	= 4.150	0.246
1-5	17.28 (6.84)	18 (0-32)		
5-10	17.10 (4.73)	17.5 (10-24)		
>10	16.77 (6.78)	19 (2-29)		
Self-evaluation of the physicians				
No idea	13.03 (8.50)	14 (0-27)[a]	= 40.928	**<0.001**
Insufficient	16.19 (6.69)	17 (0-30)[a]		
Sufficient	22.51 (6.08)	23 (4-32)[b]		
Comprehensive	11.25 (9.71)	11.5 (0-22)[a]		
Total	16.42 (7.08)	17 (0-32)		

SD: StandardDeviation, *U*: Mann-Whitney *U*, $\chi 2$: Kruskal-Wallis, a-b: There is no difference between the positions with the same letter.

Table 4: *The estimation power on the correct answer score of the independent variables in the multiple regression model.*

	Estimate (β)	95% CI	**p*-values
(Constant)		-1.914-5.984	.312
Gender	.037	-.639-1.751	.361
Geographic regions where physicians working	.027	-.205-.418	.502
Position of physicians	-.001	-.304-.295	.977
Years of experience in emergency department	.015	-.263-.382	.716
Accessing information about tooth avulsion (1:No. 2:Yes)	**.310**	3.404-6.059	**<.001**
Whether the education covers dentoalveolar traumas	.067	-.301-2.242	.134
Encountering with avulsion before	.015	-.985-1.416	.724
Number of dental avulsion cases encountered in the last 6 months	.041	-.397-1.224	.317
Self-evaluation (1:No idea…. 4: Comprehensive)	**.135**	.913-3.579	**.001**
R^2 (Adjusted)	.154		<.001

*Multiple linear regression analysis, Dependent variable: Correct answer score

Of the physicians, 50.1% stated that they would hold an avulsed tooth from its crown. This result was close to the results found by Aren et al. (48.4%) (21) and Bahammam (51.6%) (24).

Of the physicians, 47.9% preferred tap water to clean an avulsed tooth, while 89.3% of them preferred normal saline. Both of them are acceptable choices. However, since normal saline is widely used for many purposes in hospitals, it is expected that the physicians will mostly prefer saline for cleaning avulsed teeth. Furthermore, more than half of the physicians (56.3%) stated that avulsed teeth can be wiped with a wet sponge, which indicates that they were unaware that this practice would damage the periodontal ligaments. Bahammam(24) reported that 50.8% of the physicians preferred tap water to clean an avulsed tooth. After this study was carried out, the new guideline of IADT was published in the second half of 2020 (25). According to the new guideline, if an avulsed tooth is dirty, it is recommended to gently wash it with milk, serum or patient's saliva rather than washing it under tap water. Since this study was conducted before the publication of the new guideline, washing an avulsed dirty tooth under tap water was considered correct according to the previous guideline (7, 25). The authors of this study wanted to emphasize this important information which was included in the new guideline.

Clinical studies have shown that prognosis is the best for avulsed teeth replanted within 5 minutes (26). The correct treatment provided within the first 15 minutes after avulsion is critical for the long-term prognosis of the avulsed tooth (10, 27). In this study, the percentage of the phsicians who think that the tooth should be replanted "immediately" was 28.3%. In a study involving dentists, medical doctors and a portion of the population in Pakistan, the percentage of those who recommended immediate replantation was

10.1%, while the percentage obtained after the exclusion of dentists drops to 4.6% (20).

If the avulsed tooth cannot be replanted immediately, it should be delivered to the dentist in a suitable transport medium, such as HBSS, cold milk, salin, patient's saliva or tap water if necessary. It is not preferred to leave it inside the mouth because there is a risk for young children to swallow it (25, 28, 29). The first choices should be HBSS and milk which is more accessible. Since normal saline does not contain nutrients, unlike milk and HBSS, it can preserve the viability of fibroblasts for only 2 hours and is suitable for short-term storage of avulsed teeth (30). Periodontal ligament cells can not survive when the tooth remains in a dry environment for 60 minutes or more (7, 29). However, in this study, more than half of the physicians (67%) preferred dry environment. In other studies, the percentages of them were 33.3%, 25%, 8.7%, and 5.8% (5, 6, 18, 21). In this study, the most preferred option by the participants was normal saline (72%). The closest result to our study was observed in the study by Aren et al. (21) (62.7%), and the percentages of the physicians who prefer normal saline were lower in other studies (35.5%, 42.4%, respectively) (18, 19). Of the physicians, 28% reported that an avulsed tooth can be carried in cold milk. In other studies, the percentages of the physicians who preferred milk were 40%, 31.9%, 31.1%, 16.7%, and below 10% (6, 17-19, 21, 24, 31). It can be concluded that milk was not the most preferred media to consider as the ideal solution in many studies.

IADT recommends the tetanus vaccine and antibiotic prophylaxis after replantation of the avulsed teeth (7, 25). The proportion of Turkish physicians who were aware of the necessity of the tetanus vaccine and antibiotic prophylaxis was over ¾.

Replantation of avulsed primary teeth is not recommended because of the potential risk of damaging the underlying permanent teeth germs (7, 25). Unfortunately, 17.1% of the physicians thought that an avulsed primary tooth can be replanted. In another study conducted in Turkey, the percentage of physicians who stated that avulsed primary teeth can be replanted was reported as 24.1% (6).

While 39.4% of the physicians who participated in this study stated that they encountered at least one avulsion case during their professional lives, in the previous study conducted in Turkey, this percentage was reported as 68.1% (6). The percentages of the physicians who came across avulsion cases were 28% in Hashim et al.'s study (19) and 59% in Bahammam's study (24). In this study, the level of knowledge on emergency management of avulsed teeth among the physicians who had encountered tooth avulsion cases before was higher than those who had not ($p=0.053$), and this result was similar to Bahammam's study (24). Probably, the incidents experienced and/or witnessed by a physician have increased the physician's interest in the subject.

In this study, it was observed that the amount of experience that physicians had in the emergency department and their encounters with avulsion cases affected their level of knowledge about tooth avulsion ($p=0.037$). The level of knowledge among the physicians who worked in the emergency for long years was higher than among those who did not. In the study by Ulusoy et al., the length of emergency department experience did not affect the level of knowledge, whereas in another study conducted in Turkey in 2019, it was stated that the emergency department experience increased the level of knowledge of dentofacial trauma (6, 22).

In many studies, it was observed that the level of physicians' knowledge related to oral and dentoalveolar traumas was not high (5, 6, 17, 19-21, 24). In addition, a recent meta-analysis of fourteen studies concluded that the level of knowledge of non-dental healthcare professionals about dental trauma was inadequate (32). In this study, the median score of the knowledge level was 17 and the maximum score was 32 on the scale ranging from 0 to 35, in which the knowledge levels of Turkish physicians working in emergency departments were determined. The level of knowledge among the 45.6% of the physicians was below the median score (<17). These results are associated with the lack of comprehensive training in medical schools and/or during the residency. In our study, 61.3% of the physicians stated that the training they received did not include oral and dentoalveolar traumas. The percentages of the physicians who did not receive any training on dentoalveolar traumas were higher in the studies conducted in Kuwait (83.3%), Chile (90.2%), and England (76.5%), but it was lower in Saudi Arabia (47.5%) (5, 17, 24, 33).

In this study, the correct answer score of the physicians who received training on tooth avulsion was found to be higher than the score of the physicians who did not ($p<0.001$). In addition, the physicians who received training on the subject were mostly among the emergency medicine specialists. Therefore, the emergency medicine specialists had the highest level of knowledge ($p=0.010$).

Of the physicians, 84% were aware that the level of their knowledge was inadequate and 7.3% had no idea about dental trauma, and therefore, 93% thought that it was important to receive training on dentoalveolar traumas. In similar studies, 97% and 100% of physicians think that it is important to receive training on the subject (18, 19). Of the participants, 88.6% stated that they would be interested in attending a training program on the subject. In other studies, the percentages of the physicians interested in receiving information about the subject were 97.6% and 95.1% (19, 24).

According to the self- assessment, the knowledge level of the physicians who stated that the level of their knowledge was "sufficient" was found to be the highest, which is in accordance with the literature (23). The number of physicians self-reported having "comprehensive" knowledge about the management of tooth avulsion was only four. It would not be proper to comment on the data released by few physicians because it can not be statistically accurate. Similar results were obtained in a previous study, on the knowledge level of dentists on avulsion management (23). The self-assessments of the participants reflected the expected-level of knowledge.

Looking at the regression analysis results, it was significant to access the information about the management of tooth avulsion ($p<0.001$) and it was positively related ($\beta=0.310$) to higher knowledge scores, followed by the self- assessment of the physicians ($p=0.001$; $\beta=0.135$). The result of the regression analysis is a concrete indicator of the effect of training about the subject on the level of knowledge.

Although the number of general practitioners participating in the study is limited, the strength of the study is the number of the participants. The number of the volunteer

emergency medicine physicians participating in the questionnaire was larger than the required-sample size calculated for this study. The results of the study can be attributed to Turkish emergency medicine physician population.

Avulsion cases, which are mostly seen in anterior teeth,[16,31] cause some functional, psychological, and aesthetic problems if the tooth is not replanted (5). In some western countries, the cost of traumas (treatment costs and additional costs such as transport, rehabilitation, labor loss, etc) is estimated to be about 4-5% of the gross national product (1, 2). Therefore, it has been reported that dentoalveolar traumas and their consequences may exceed the cost of dental caries and periodontal diseases in the young population (2). As it can be seen from the results of this study, the negative effects of trauma on individuals and society can be prevented by simple interventions performed by physicians working in emergency departments, which are one of the critical occupational groups that determine the prognosis of an avulsed tooth. The training of physicians on the subject is of great importance for the victim, dentist, and national economy at the same time. Therefore, the training on oral and dentoalveolar traumas should be added to the curriculum as a course before graduating from a medical faculty, the course of oral and dentoalveolar traumas should be given to all emergency medicine residents as part of the residency training, and panels, symposiums, and seminars should be organized on the subject. In emergency departments, a subunit that treats dentoalveolar traumas can be established and physicians educated on the subject can be employed in these subunits.

Conclusion

The findings from this study clearly suggest that the level of knowledge among Turkish physicians working in emergency departments on emergency management of tooth avulsion is not satisfactory. It is significant to design educational programs on this subject and train this critical occupational group in order to achieve more successful results in tooth avulsion. It is obvious that the emergency management of avulsed teeth will help physical and psychological growth and development, especially in children.

Türkçe özet: *Türkiye'deki Acil Tıp Doktorlarının Diş Avülsiyonunun Acil Müdahalesine İlişkin Bilgi Düzeylerinin Değerlendirilmesi. Öz: Amaç: Diş avülsiyonu acil müdahale gerektiren bir travma türüdür ve önemli sayıda hasta acile başvurmaktadır. Bu çalışmanın amacı, Türkiye genelinde acil tıp hekimlerinin diş avülsiyonu konusunda bilgi düzeylerini ve farkındalıklarını değerlendirmektir. Gereç ve Yöntem: Çalışma acil servislerde çalışan 545 hekim ile gerçekleştirildi. Katılımcılara diş avülsiyonu ile ilgili online anket uygulandı. Anket, kişisel bilgileri, süt ve daimi dişlenme dönemindeki avülsiyon olgularına ilişkin bilgi düzeyini ve bu konudaki eğitim düzeyini değerlendiren 3 bölümden oluşmaktadır. Bulgular: Hekimlerin %61,3'ü dentoalveolar travmalar konusunda daha önce eğitim almamış, %58,7'si avülse olmuş bir daimi dişin replantasyonunu, %28,3'ü replantasyonun "hemen" yapılmasını ve %28'i ideal saklama ortamı olarak sütü tercih etmiştir. 0'dan 35'e kadar olan bir ölçekte doğru cevap puanlarının ortalama±SS ve ortanca (min-maks) değerleri sırasıyla 16,42±7,08 ve 17(0-32) idi. Hekimlerin %45,6'sının bilgi düzeyi ortanca puanın altındaydı. Sonuç: Türkiye'deki acil tıp hekimlerinin diş avülsiyonu ile ilgili bilgi düzeyi yeterli olmayıp, kapsamlı eğitim programları ile hekimlerin bilgi düzeylerinin yükseltilmesine ihtiyaç vardır. Bu çalışma, konu ile ilgili hekimlerin eğitilmesinin travma hastalarının tedavisine olumlu yansıyacağını göstermektedir. Anahtar kelimeler: Dentofasiyal travma, diş avulsiyonu, acil tıp doktorları, Türkiye*

Ethics Committee Approval: The ethics approval has been obtained from the Health Sciences Non-Interventional Clinical Research Ethics Committee (ethics approval number: 2018/18-12).

Informed Consent: Participants provided informed consent.

Peer-review: Externally peer-reviewed.

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