

DO PRE-GRADUATE DENTAL STUDENTS HAVE ADEQUATE EDUCATIONAL BACKGROUND ON THE MANAGEMENT AND PREVENTION OF METHEMOGLOBINEMIA: A CROSS-SECTIONAL STUDY

Methemoglobinemi Yönetimi ve Önlenmesine Yönelik Mezuniyet Öncesi Diş Hekimliği Öğrencilerinin Eğitimsel Altyapısı: Kesitsel Araştırma

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ABSTRACT

Objective: Without prompt and correct intervention, methemoglobinemia can be fatal. Because of its rarity, it is often impossible to increase the permanence of knowledge about methemoglobinemia with actual patient practice. The study aimed to investigate the theoretical knowledge of pre-graduate dental students about methemoglobinemia.

Material and Methods: In the cross-sectional study, a 15-question survey was administered face-to-face to 172 pre-graduation students under the supervision of faculty members.

Results: It was clearly observed that the students performed the relevant interrogations in the pre-procedural evaluation stage; however, they did not possess the required level of knowledge in detecting high-risk patients with methemoglobinemia. Students had adequate knowledge about basic acute symptoms such as cyanosis, nausea, vomiting, dizziness, and brown coloration of bleeding. Regarding treatment, it was observed that only the level of knowledge about oxygen support and methylene blue was adequate. Although not in all parameters, women and 5th-grade students had higher levels of knowledge.

Conclusion: Although the basic knowledge of the students was adequate in terms of pre-procedural evaluation, symptoms, and treatment, it should be improved. It was clearly seen that students were unable to make accurate determinations about high-risk situations when faced with options in the form of patient and clinical situation simulations. Although rare, when methemoglobinemia develops, the dentist should intervene immediately. Increasing the knowledge level of dental students about methemoglobinemia is vital to increase patient safety during dental procedures. It was considered that trainings with realistic simulations with the help of professional medical acting would be beneficial.

ÖZ

Amaç: Methemoglobinemi, hızlı ve doğru müdahale edilmezse ölümcül olabilir. Nadir görülen bir durum olduğu için, methemoglobinemi ile ilgili bilgilerin kalıcılığını gerçek hasta pratiğiyle artırmak genellikle mümkün değildir. Bu çalışma, diş hekimliği öğrencilerinin methemoglobinemi ile ilgili teorik bilgilerini incelemeyi amaçlamıştır.

Gereç ve Yöntemler: Kesitsel çalışmada, 172 mezuniyet öncesi diş hekimliği öğrencisine, fakülte üyelerinin gözetiminde, 15 sorudan oluşan bir anket yüz yüze uygulanmıştır.

Bulgular: Öğrencilerin, işlem öncesi değerlendirme aşamasında ilgili sorgulamaları yaptıkları ancak methemoglobinemi açısından yüksek riskli hastaları tespit etme konusunda gerekli bilgi seviyelerine sahip olmadıkları açıkça gözlemlenmiştir. Öğrenciler, siyanoz, bulantı, kusma, baş dönmesi ve kanamanın kahverengileşmesi gibi temel akut semptomlar hakkında yeterli bilgiye sahipti. Tedaviye yönelik olarak, sadece oksijen desteği ve metilen mavisi hakkında bilgi seviyelerinin yeterli olduğu gözlemlenmiştir. Her parametrede olmasa da, kadınların ve 5. sınıf öğrencilerinin bilgi düzeylerinin daha yüksek olduğu görülmüştür.

Sonuç: Öğrencilerin, işlem öncesi değerlendirme, semptomlar ve tedavi konularında temel bilgileri yeterli olsa da, bu bilgilerin geliştirilmesi gerekmektedir. Öğrencilerin, hasta ve klinik durum simülasyonları şeklinde seçeneklerle karşılaştıklarında yüksek riskli durumları doğru şekilde belirleyemedikleri açıkça görülmüştür. Methemoglobinemi nadir olsa da, geliştiğinde diş hekimi hemen müdahale edebilmelidir. Diş hekimliği öğrencilerinin methemoglobinemi konusundaki bilgi seviyelerinin artırılması, dental prosedürler sırasında hasta güvenliğini artırmak için hayati öneme sahiptir. Profesyonel tıbbi oyunculuk yardımıyla gerçekleştirilen gerçekçi simülasyonlarla eğitimlerin faydalı olacağı düşünülmüştür.

Keywords: Methemoglobinemia, patient safety, dental students, local anesthetics, knowledge level

Anahtar Kelimeler: Methemoglobinemi, hasta güvenliği, diş hekimliği öğrencileri, lokal anestezikler, bilgi düzeyi



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Received / Geliş Tarihi: 30.12.2024

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Accepted / Kabul Tarihi: 06.04.2025

INTRODUCTION

Methemoglobinemia, which is one of the acute systemic complications related to local anesthetics (LAs), is rare, but without immediate and appropriate management, morbidity and mortality rates are high.¹ Acquired methemoglobinemia may develop with inhibition of the enzyme function by various chemicals or exposure to potent oxidant agents such as LAs.^{2,3} In literature, there are many reported cases of methemoglobinemia due to LAs.⁴⁻⁷ Although the risk of methemoglobinemia increases with high doses of lidocaine, benzocaine, prilocaine and tetracaine, which are at high risk for methemoglobinemia among LAs, methemoglobinemia has also been reported at therapeutic doses.⁸⁻¹⁰ Additionally, articaine, bupivacaine, mepivacaine and lidocaine are LAs with moderate risk for methemoglobinemia.¹¹ The risk of methemoglobinemia increases with cytochrome b5 reductase deficiency, the neonatal period, and the use of oxidant pharmacologic agents such as dapsone and nitroprusside.^{4,10,12} Therefore, pre-procedural detailed evaluation and subsequent selection of the appropriate LAs are critical for the prevention of methemoglobinemia.

Basically, the specific acute findings of methemoglobinemia include cyanosis and respiratory distress. The brown coloration of bleeding due to hypoxia during bleeding procedures is also an important indicator. In progressive methemoglobinemia, confusion, chest pain, headache, tachypnea, tachycardia and delirium may be observed. In severe cases, convulsions, coma and even death can occur.⁴ It is important to closely monitor vital signs after the detection of the clinical signs. Pulse oximetry using standard 2 wavelengths cannot distinguish between methemoglobin and oxyhemoglobin.⁴ Therefore, the presence of cyanosis and other clinical signs of hypoxia in the absence of a marked decrease in oxygen saturation measured by pulse oximetry is alerting.^{4,13} To increase patient safety, it is very important to educate dental students who frequently use local anesthetics about methemoglobinemia. When methemoglobinemia develops in the dental practice, accurate and effective management should be provided by the dentist until professional medical help arrives. In acute management, the dentist's provision of oxygen support and IV (intravenous) hydration is vital. In severe cases, IV administration of methylene blue is recommended as the first choice.¹

The etiology, symptoms and signs, diagnosis, treatment, and preventive measures of methemoglobinemia were theoretically lectured in detail by the faculty member anesthesiologist (GNE) within the scope of the 3rd year curriculum in the faculty of dentistry, where the study was conducted. It has been reported in different studies that the knowledge levels of surgical branch physicians

and dentists about LAST, allergy and anaphylaxis, which are the systemic complications related to LAs, were inadequate and should be improved.¹⁴⁻¹⁷ However, after the theoretical education on methemoglobinemia, the level of permanence of knowledge in pre-graduated dental students was unclear. To the best of our knowledge, there was no study investigating the knowledge level about methemoglobinemia.

The aim of this study was to investigate the theoretical knowledge and awareness levels of pre-graduated dental students about methemoglobinemia. It was also aimed to correlate the obtained data with gender and educational grade. The hypothesis of the study was that the knowledge level of students about methemoglobinemia in terms of early diagnosis, preventive measures, and pre-procedural evaluation may be inadequate after only theoretical education, and in addition to gender, there may be a difference in the knowledge level between educational grades.

MATERIALS AND METHODS

For this cross-sectional study, the ethics committee approval of Kırıkkale University Non-Interventional Research Ethics Committee, numbered 2022.03.32, was obtained on April 7, 2022. Written informed consent was obtained from all participants. A total of 172 volunteer students from the Faculty of Dentistry at Kırıkkale University, consisting of 74 from 4th grade and 98 from 5th grade, were included in the study. The lecture on methemoglobinemia was delivered by GNE to fourth-year students one year prior to the survey and to fifth-year students two years prior to the survey. The questionnaire form, including 14 multiple-choice and 1 open-ended question, was applied to the 4th and 5th grade students of our faculty under the supervision of faculty members. Students were ensured to sit at a distance during the survey. In order to increase the reliability of the survey data, all students were administered the survey at the same time and were not allowed to share information and ideas with each other. The data collection with the survey took place at the end of the academic year, on May 26, 2023. To assess participants' knowledge and awareness regarding methemoglobinemia, a survey was developed comprising questions on risk factors, diagnostic criteria, clinical manifestations, and treatment options associated with the condition. The question (Q8), which includes options in the form of patient and clinical situation simulations for high-risk situations in terms of methemoglobinemia, was designed to assess the awareness of detecting high-risk patients. All questions asked in the questionnaire and their options were given in Table 2. In addition, comparisons of the knowledge levels of the participants according to educational grade and gender were made.

Statistical analysis

Data were analyzed using the statistical package program IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, New York, USA). Descriptive statistics were given as number of units (n) and percentage (%). Pearson chi-square and Fisher exact test were used to compare the groups with categorical variables. If the chi-square test results were found to be significant, subgroup analyses were performed with Bonferroni corrected two ratio z test. $p < 0.05$ was considered statistically significant.

Participants who answered 50% of the survey questions correctly were considered to have adequate knowledge. There were 39 correct answers to the questions aimed at evaluating the level of knowledge (Questions 8-15). Therefore, the test value was determined as 20 points. The mean number of correct answers for all participants was 13.1 and the standard deviation was 6.9. For 172 participants, the one-way effect size was 1.007 and the statistical power was 99.9%.

RESULTS

Descriptive data of the participants were listed in Table 1. The questions and answers of the participants in the questionnaire were given in Table 2. All participating students inquired about patients' comorbidities prior to the procedure. Additionally, the majority of students assessed medication use (99.4%) and investigated any history of complications during previous dental procedures (96.5%). The rate of aspiration before LA injection was 95.9%. Students stated that they use articaine in their daily practice at the highest rate (91.3%).

Table 1: Descriptive data

Variables	Statistics n (%)
Gender (Q1)	
Male	77 (44.8)
Female	95 (55.2)
Educational Grade (Q2)	
5th Grade	74 (43.0)
4th Grade	98 (57.0)

When the answers of the questions about high-risk situations of methemoglobinemia were analyzed, the knowledge level of the students was detected inadequate in all options. Level of knowledge on acute symptoms including cyanosis, nausea, vomiting, dizziness and brown coloration of bleeding was adequate. In the question regarding treatment options, students demonstrated adequate knowledge only about oxygen support and methylene blue. For diagnostic support parameters, knowledge was sufficient concerning the recognition of brown-colored blood and reduced partial oxygen pressure in laboratory findings. Additionally, awareness of the first-line treatment for severe

methemoglobinemia was found to be adequate. Only 16.9% of the students knew that methylene blue was contraindicated in G6PD deficiency. None of the students knew the dose of methylene blue for a 70 kg adult patient that developed methemoglobinemia. (Table 2).

Table 2: Survey questions and response rates

QUESTIONS /ANSWERS	STATISTICS n (%)
Do you ask patients about their comorbidities before the procedure? (Q3)	
No	0 (0.0)
Yes	172 (100.0)
Do you ask patients about their medications before the procedure? (Q4)	
No	1 (0.6)
Yes	171 (99.4)
Do you ask patients if they have had any problems with previous dental procedures? (Q5)	
No	6 (3.5)
Yes	166 (96.5)
What are the LA(s) you use in your daily practice? (Q6)	
Lidocaine	105 (61.0)
Prilocaine	3 (1.7)
Articaine	157 (91.3)
Bupivacaine	3 (1.7)
Do you perform negative aspiration before injection of LA? (Q7)	
No	7 (4.1)
Yes	165 (95.9)
Which of the given patient(s) has a higher risk of methemoglobinemia? (Q8)[†]	
Patient using dapsone to treat acne	22 (12.8)
Patient using nitroprusside for cardiovascular disease	83 (48.3)
Premature newborn	66 (38.4)
Term newborn	31 (18.0)
Patient using phenazopyridine for UTI	38 (22.1)
Patient using nitrofurantoin for UTI	35 (20.3)
Patient with cytochrome b5 reductase (NADH reductase) deficiency	59 (34.3)
Patient using trimethoprim+sulfamethoxazole for toxoplasmosis prophylaxis	49 (28.5)
Which of the followings can be seen clinically due to methemoglobinemia? (Q9)[†]	
Cyanosis	105 (61.0)
Nausea, vomiting	94 (54.7)
Dizziness	99 (57.6)
Tachypnea, tachycardia	59 (34.3)
Brown coloration of bleeding	87 (50.6)
Delirium	33 (19.2)
Coma	39 (22.7)
Headache	62 (36.0)
Confusion	81 (47.1)
Respiratory distress	84 (48.8)
Chest pain	71 (41.3)
Fatigue	72 (41.9)
Convulsion	28 (16.3)
Death	36 (20.9)
Which medications are used to treat methemoglobinemia? (Q10)[†]	
IV Hydration	46 (26.7)
Methylene blue	86 (50.0)
Hyperbaric oxygen	39 (22.7)
Oxygen support	89 (51.7)

Ascorbic acid	23 (13.4)
Blood exchange	39 (22.7)
Which LA(s) are at high risk for methemoglobinemia? (Q11)[†]	
Lidocaine	38 (22.1)
Tetracaine	42 (24.4)
Prilocaine	55 (32.0)
Benzocaine	40 (23.3)
Which one(s) are supportive for the diagnosis of methemoglobinemia? (Q12)[†]	
Normal saturation levels on pulse oximetry in a cyanosed patient	16 (9.3)
Brown coloration of bleeding	102 (59.3)
Low partial O ₂ pressure in laboratory analysis	96 (55.8)
High methemoglobin level in laboratory analysis	84 (48.8)
Which is the first-line drug in the treatment of severe methemoglobinemia? (Q13)	
Incorrect answer (Adrenaline, dexamethasone, dextroline, ascorbic acid)	81 (47.1)
Correct answer (Methylene blue)	91 (52.9)
In which enzyme deficiency should methylene blue not be used? (Q14)	
Incorrect answer (Alpha-L-Iduronidase, Cytochrome b5 Reductase)	143 (83.1)
Correct answer (G6PD)	29 (16.9)
What is the dose of methylene blue that should be administered if methemoglobinemia develops in a 70 kg adult patient? (Q15)	
Incorrect answer	172 (100.0)
Correct answer (70 mg)	0 (0.0)

[†]Question in which all options are correct. G6PD, Glucose-6-phosphate dehydrogenase; UTI, Urinary tract infection.

In Table 3, a comparison of the answers according to gender was made. There was no significant difference

Table 3: Level of knowledge in terms of gender and educational year

	Gender			Educational Year		
	Male	Female	p value	4 th Grade	5 th Grade	p value
Which of the given patient(s) has a higher risk of methemoglobinemia? (Q8)[†]						
Patient using dapsone to treat acne	9 (11.7)	13 (13.7)	0.697	10 (10.2)	12 (16.2)	0.242
Patient using nitroprusside for cardiovascular disease	34 (44.2)	49 (51.6)	0.333	37 (37.8)	46 (62.2)	0.002*
Premature newborn	24 (31.2)	42 (44.4)	0.080	33 (33.7)	33 (44.6)	0.145
Term newborn	15 (19.5)	16 (16.8)	0.654	17 (17.3)	14 (18.9)	0.791
Patient using phenazopyridine for UTI	12 (15.6)	26 (27.4)	0.064	20 (20.4)	18 (24.3)	0.540
Patient using nitrofurantoin for UTI	15 (19.5)	20 (21.1)	0.799	18 (18.4)	17 (23.0)	0.458
Patient with cytochrome b5 reductase (NADH reductase) deficiency	29 (37.7)	30 (31.6)	0.403	28 (28.6)	31 (41.9)	0.068
Patient using trimethoprim+sulfamethoxazole for toxoplasmosis prophylaxis	18 (23.4)	31 (32.6)	0.181	20 (20.4)	29 (39.2)	0.007*
Which of the followings can be seen clinically due to methemoglobinemia? (Q9)						
Cyanosis	39 (50.6)	66 (69.5)	0.012*	50 (51.0)	55 (74.3)	0.002*
Nausea, vomiting	40 (51.9)	54 (56.8)	0.521	53 (54.1)	41 (55.4)	0.863
Dizziness	44 (57.1)	55 (57.9)	0.921	61 (62.2)	38 (51.4)	0.152
Tachypnea, tachycardia	23 (29.9)	36 (37.9)	0.270	33 (33.7)	26 (35.1)	0.842
Brown coloration of bleeding	39 (50.6)	48 (50.5)	>0.999	48 (49.0)	39 (52.7)	0.629
Delirium	15 (19.5)	18 (18.9)	0.930	21 (21.4)	12 (16.2)	0.390
Coma	21 (27.3)	18 (18.9)	0.195	21 (21.4)	18 (24.3)	0.653
Headache	32 (41.6)	30 (31.6)	0.175	35 (35.7)	27 (36.5)	0.917
Confusion	36 (46.8)	45 (47.4)	0.936	49 (50.0)	32 (43.2)	0.379
Respiratory distress	42 (54.5)	42 (44.2)	0.178	47 (48.0)	37 (50.0)	0.791
Chest pain	30 (39.0)	41 (43.2)	0.578	40 (40.8)	31 (41.9)	0.887

between genders regarding the identification of patients at high risk for methemoglobinemia and the diagnosis of methemoglobinemia. The knowledge level about cyanosis, which is one of the important symptoms of methemoglobinemia, is significantly higher in females ($p=0.012$). The level of knowledge about methylene blue, was significantly higher in females ($p=0.009$). Regarding the same topic, male participants demonstrated a significantly higher level of knowledge about hyperbaric oxygen therapy ($p=0.042$). Females had significantly higher knowledge about the high risk of prilocaine in terms of causing methemoglobinemia ($p=0.005$). Females' level of knowledge about methylene blue as a first-line drug was significantly higher ($p=0.017$). Females had significantly higher knowledge about the contraindication of methylene blue in G6PD deficiency ($p=0.004$). Table 3 presents a comparative analysis of responses based on the participants' educational grade level. The level of knowledge of 5th grade students about the high risk of methemoglobinemia in patients using nitroprusside for cardiovascular disease and in patients using trimethoprim + sulfamethoxazole for toxoplasmosis was significantly higher ($p=0.002$ and $p=0.007$, respectively). The level of knowledge of 5th grade students about cyanosis in symptoms, oxygen support in the treatment, and the high risk of benzocaine in the cause of methemoglobinemia were significantly higher ($p=0.002$, $p=0.018$, $p=0.035$, respectively).

Fatigue	33 (42.9)	39 (41.1)	0.811	41 (41.8)	31 (41.9)	>0.999
Convulsion	11 (14.3)	17 (17.9)	0.524	13 (13.3)	15 (20.3)	0.218
Death	17 (22.1)	19 (20.0)	0.739	22 (22.4)	14 (18.9)	0.573
Which medications are used to treat methemoglobinemia? (Q10)[†]						
IV Hydration	18 (23.4)	28 (29.5)	0.369	22 (22.4)	24 (32.4)	0.143
Methylene blue	30 (39.0)	56 (58.9)	0.009*	52 (53.1)	34 (45.9)	0.355
Hyperbaric oxygen	23 (29.9)	16 (16.8)	0.042*	21 (21.4)	18 (24.3)	0.653
Oxygen support	41 (53.2)	48 (50.5)	0.723	43 (43.9)	46 (62.2)	0.018*
Ascorbic acid	14 (18.2)	9 (9.5)	0.095	9 (9.2)	14 (18.9)	0.063
Blood exchange	18 (23.4)	21 (22.1)	0.843	21 (21.4)	18 (24.3)	0.653
Which LA(s) are at high risk for methemoglobinemia? (Q11)[†]						
Lidocaine	19 (24.7)	19 (20.0)	0.462	22 (22.4)	16 (21.6)	0.897
Tetracaine	17 (22.1)	25 (26.3)	0.520	22 (22.4)	20 (27.0)	0.489
Prilocaine	16 (20.8)	39 (41.1)	0.005*	29 (29.6)	26 (35.1)	0.440
Benzocaine	18 (23.4)	22 (23.2)	0.973	17 (17.3)	23 (31.1)	0.035*
Which ones are supportive for the diagnosis of methemoglobinemia? (Q12)[†]						
Normal saturation levels on pulse oximetry	6 (7.8)	10 (10.5)	0.539	8 (8.2)	8 (10.8)	0.554
in a cyanosed patient	47 (61.0)	55 (57.9)	0.676	52 (53.1)	50 (67.9)	0.055
Brown coloration of bleeding	49 (63.6)	47 (49.5)	0.063	51 (52.0)	45 (60.8)	0.252
Low partial O ₂ pressure in laboratory analysis	35 (45.5)	49 (51.6)	0.424	44 (44.9)	40 (54.1)	0.234
High methemoglobin level in laboratory analysis						
Which is the first-line drug in the treatment of severe methemoglobinemia? (Q13)						
Incorrect answer(Adrenaline, dexamethasone, dentrolene, ascorbic acid)	44 (57.1)	37 (38.9)	0.017*	48 (49.0)	33 (44.6)	0.568
Correct answer (Methylene blue)	33 (42.9)	58 (61.1)		50 (51.0)	41 (55.4)	
In which enzyme deficiency should methylene blue not be used? (Q14)						
Correct answer(G6PD)	8 (10.4)	21 (22.1)	0.004*	17 (17.3)	12 (16.2)	0.845
Incorrect answer(Alpha-L-Iduronidase, Cytochrome b5 Reductase)	69 (89.6)	74 (77.9)		81 (82.7)	62 (83.8)	

[†]Question in which all options are correct. G6PD, Glucose-6-phosphate dehydrogenase; UTI, Urinary tract infection. *p<0.05 was considered statistically significant.

DISCUSSION

In this study, it was aimed to evaluate the theoretical knowledge and awareness levels of pre-graduated dental students about methemoglobinemia. It was observed that almost all of the students interrogated the patients about methemoglobinemia in the pre-procedural evaluation and performed aspiration before local anesthetic injection. However, it was clearly seen that the students' knowledge level about high-risk patients and LAs in terms of methemoglobinemia was inadequate. In addition, none of the students had any idea about the dose of methylene blue that should be administered in patients with methemoglobinemia. In the literature, it was reported that almost all dentists questioned patients' allergy history and past local anesthesia applications regarding anaphylaxis.¹⁸ It was reported that 73% of emergency medicine physicians did not question risk factors in terms of LAST before the procedure.¹⁶ It was observed that the rates of pre-procedural evaluation were higher in dentists than in medical doctors. The rate of negative aspiration was only 10.8% in research assistants from different medical specialties, 59% in emergency medicine physicians, and 70% in multispecialty postgraduate residents.^{16,17,19} In the present study, it was shown that before the procedure, almost all of the students questioned patients about their comorbidities, the medications, and the

complications that occurred in previous dental procedures. In addition, almost all of the students stated that they performed negative aspiration before the LA injection. Analysis of responses to simulation-based questions revealed that pregraduate dental students possessed limited knowledge in identifying patients at elevated risk for methemoglobinemia. This finding underscores a critical gap in pre-procedural risk assessment and highlights the insufficient emphasis placed on comprehensive patient evaluation prior to treatment.

Articaine was used as a local anesthetic in the majority of dental procedures in our Faculty of Dentistry Hospital. Pre-graduated students had high knowledge and awareness about the local anesthetic agent mostly used. However, it was demonstrated that students' knowledge of LAs at high risk for methemoglobinemia was clearly inadequate.

Dental students need to know the signs of cyanosis and brown color of bleeding to be able to identify patients with methemoglobinemia in their professional careers. It was observed that students had adequate knowledge about cyanosis, brown coloration of bleeding, nausea-vomiting, and dizziness. The knowledge level of students about convulsions, coma and death, which are relatively late findings, was very low. This result may be due to the fact that the dentist has the responsibility of

acute management until professional medical help arrives, and therefore, students pay more attention to specific and acute signs. Similar to the present study, it has been reported in the literature that dentists had adequate knowledge about shortness of breath and skin rash, which are acute symptoms of anaphylaxis.¹⁵ On the other hand, it has been shown that dentists had inadequate knowledge about tinnitus and metallic taste on tongue, which are the initial symptoms of LAST.¹⁴ Dental students' knowledge about the acute symptoms of methemoglobinemia was adequate, but students were not aware that the process could progress with mortal symptoms. Students had adequate knowledge about brown coloration of bleeding and low partial O₂ pressure in laboratory analysis as supportive of the diagnosis of methemoglobinemia. When the students monitored the patient in clinical settings, they could easily detect normal pulse oximetry in a cyanosed patient. Unfortunately, less than 10% of the students were aware of this method. It was considered that it would be beneficial to increase the knowledge level of students about this finding, which can be easily detected noninvasively and rapidly in the acute period to support the diagnosis.

Regarding the treatment of methemoglobinemia, it was observed that although the knowledge level of the students about methylene blue and oxygen support was adequate, knowledge level about other treatment options and especially IV hydration was inadequate. In addition, students had adequate knowledge about methylene blue being the first-line drug of choice in the treatment of severe methemoglobinemia. In case of severe methemoglobinemia, IV infusion of 1mg/kg methylene blue is recommended.²⁰ The dose of methylene blue that should be administered in the treatment of methemoglobinemia was explained to our students. However, none of the students had any knowledge about the dose of methylene blue. In a study investigating the knowledge level of dentists about anaphylaxis, similar to our study, the knowledge level of dentists about adrenaline as the first-line drug of choice in anaphylaxis was found to be adequate.¹⁸ In contrast, in another study investigating the knowledge level of dentists about anaphylaxis, the level of knowledge about epinephrine as the first-line drug was insufficient and less than 10% of dentists knew the dose of epinephrine.¹⁵ In a study investigating the level of knowledge of dentists about LAST, 67.3% of dentists had no knowledge about lipid therapy and only 1.5% of the participants had accurate knowledge about lipid therapy dosage and administration.¹⁴ There are studies in the literature showing that the level of knowledge of medical doctors about LAST treatment is higher but inadequate.^{16,19,21} Methylene blue is contraindicated in patients with G6PD deficiency and ascorbic acid is recommended instead of

methylene blue.²² The knowledge level of students about this contraindication was very low. Patients with G6PD deficiency can be easily identified by evaluating their medical history. In case of methemoglobinemia in these patients, dentists might not administer methylene blue themselves. However, it is very important to inform the professional medical care team that the patient has G6PD deficiency. This would save lives by preventing the administration of methylene blue in the advanced stages of methemoglobinemia treatment.

In the comparisons made according to the gender, the level of knowledge about cyanosis as one of the clinical findings, about methylene blue being one of the treatment options in methemoglobinemia and methylene blue being a first-line treatment, and about prilocaine having a high risk for methemoglobinemia was significantly higher in women. In addition, the level of knowledge about the contraindication of methylene blue in G6PD deficiency was significantly higher in females. It has been reported that female dental students have a significantly higher level of knowledge about the correct position in syncope, management of choking in unresponsive adult or child and primary management of bleeding after dental extraction.²³ The higher knowledge level of female students in the study may be associated with studies in the literature showing that the knowledge and perception level of females was higher in different issues.²³⁻²⁵

In the comparisons made according to the grade of education, the knowledge level of 5th grade students about nitroprusside and trimethoprim-sulfamethoxazole increasing the risk of methemoglobinemia was significantly higher. It was considered that the fact that both drugs are commonly used drugs and that 5th grade students communicate with patients more frequently and take more roles in dental treatment processes could be effective in this result. It was considered that the use of nitroprusside, especially in elderly patients admitted to our hospital, might relatively increased the level of knowledge of 5th grade students on this subject. 5th grade students had a significantly higher level of knowledge about the effect of benzocaine increasing the risk of methemoglobinemia and the cyanosis symptom. In a study in the literature investigating the level of knowledge about medical emergencies in dental students, the knowledge level of 5th grade students was found to be high, similar to our study.^{23,26} The fact that 5th grade students' knowledge level was generally higher suggests that the permanence of theoretical knowledge can be increased by participation in actual patient treatments in the clinic.

The limitation of our study was that it was a single-center and single-national study. In the study, it was aimed to investigate the level of knowledge of pre-graduated dental students who went through the same

practical training phases after the same theoretical education given by the same faculty member anesthesiologist.

Dentists who frequently use LAs are likely to encounter methemoglobinemia, but the study clearly showed that the knowledge level of pre-graduated dental students was generally inadequate. It was expected that additional training and information on the methemoglobinemia in the pre-graduation period would contribute positively to the quality of health services and patient safety after graduation. In addition, in order to prevent methemoglobinemia and to provide effective and accurate intervention in case of methemoglobinemia, dental students should conduct more conscious pre-procedural evaluation. Methemoglobinemia appears to be quite rare and students are unlikely to experience a real methemoglobinemia clinic before the graduation. Therefore, it was considered that the knowledge level and permanence of knowledge can be increased by creating realistic patient simulations and acute management simulations as much as possible. In addition, it was believed that it would be very beneficial to organize courses, trainings, etc. that include simulations that allow active participation to be organized with professional medical acting in the pre- and post-graduation period.

Conflict of interest: The authors declare that they have no conflicts of interest.

Support and Acknowledgment: No financial support was received from any institution or person.

Researchers Contribution Rate Statement: Concept/Design: GNE, MEÖ; Analysis/Interpretation: GNE; Data Collection: GNE, MEÖ; Writer: GNE; Critical Review: MEÖ; Approver: GNE, MEÖ

Ethics Committee Approval: The study protocol was approved by the Kırıkkale University Clinical Research Ethics Committee (Date: April 7, 2022, Number: 2022.03.32)

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