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The Effect of Eustachian Tube Dimensions on the Success Rate of Cartilage Type 1 Tympanoplasty

Östaki Tüpü Boyutlarının Kartilaj Tip 1 Timpanoplasti Ameliyatının Başarı Oranına Etkileri

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ABSTRACT Objective: To clarify the influence of eustachian tube (ET) anatomical measurements on the success rate of Type 1 cartilage tympanoplasty. **Material and Methods:** The medical records of 99 patients, who underwent cartilage Type 1 tympanoplasty were reviewed retrospectively. The length of ET (ETl), tubotympanic angle (TTa), ET-Reid horizontal plane angle (ETa), and ET pretympanic diameter (ETd) were measured on temporal bone computed tomography using the multiplanar reconstruction technique. Two groups were created based on the anatomical success of the procedure. Group 1 consisted of ears with successful anatomic outcomes and Group 2 consisted of ears without successful anatomic outcomes a year postoperatively. The ET anatomical measurements of Groups 1 and 2 were compared. **Results:** A total of 108 ears (90 unilateral and 9 bilateral ears of 99 patients) were included in our study. The differences between the ETl, TTa, ETa, and ETd of Groups 1 and 2 were statistically insignificant. **Conclusion:** Our study showed that ETl, TTa, ETa and ETd do not have a significant role in the anatomic outcome of Type 1 cartilage tympanoplasty. Using cartilage grafts in Type 1 tympanoplasty might be preferred to rule out the anatomical disadvantages regarding the ET. Studies with greater sample sizes are required to assess both the anatomy and function of the ET in the success rate of Type 1 tympanoplasty with various graft types.

Keywords: Eustachian tube; myringoplasty; tympanoplasty; tympanic membrane perforation; diagnostic imaging

ÖZET Amaç: Bu çalışmanın amacı, östaki tüpü [eustachian tube (ET)] anatomik ölçümlerinin kartilaj Tip 1 timpanoplasti ameliyatının başarı oranı üzerindeki etkilerini açıklamaktır. **Gereç ve Yöntemler:** Kartilaj Tip 1 timpanoplasti ameliyatı uygulanan 99 hastanın tıbbi kayıtları retrospektif olarak incelendi. Temporal kemik bilgisayarlı tomografisinde multiplanar rekonstrüksiyon tekniği kullanılarak ET uzunluğu [length of ET (ETl)], tubotimpanik açı [tubotympanic angle (TTa)], ET-Reid yatay düzlem açısı [ET-Reid horizontal plane angle (ETa)] ve ET pretimpanik çapı [ET pretympanic diameter (ETd)] ölçüldü. İşlemin anatomik başarısına göre 2 grup oluşturuldu. Ameliyattan 1 yıl sonra anatomik sonuçları başarılı olan kulaklar Grup 1'e, başarısız olan kulaklar Grup 2'ye dâhil edildi. Grup 1 ve 2'nin ET anatomik ölçümleri karşılaştırıldı. **Bulgular:** Çalışmamıza toplam 108 kulak (90 hastanın 90 unilateral ve 9 bilateral kulağı) dâhil edildi. Grup 1 ve 2'nin ETl, TTa, ETa ve ETd değerleri arasında istatistiksel olarak anlamlı fark bulunmadı. **Sonuç:** Çalışmamız ETl, TTa, ETa ve ETd'nin kartilaj Tip 1 timpanoplastinin anatomik sonucunda anlamlı bir etkisi olmadığını göstermiştir. ET ile ilgili anatomik dezavantajları ortadan kaldırmak için Tip 1 timpanoplastide kartilaj greftlerin kullanılması tercih edilebilir. Tip 1 timpanoplastide ET'nin anatomisini ve işlevini değerlendirmek için çeşitli greft tipleri kullanılarak yapılmış daha büyük örneklemli çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Östaki tüpü; miringoplasti; timpanoplasti; timpanik membran perforasyonu; tanısal görüntüleme

Tympanic membrane (TM) perforations are usually seen due to chronic otitis media (COM), trauma or iatrogenic causes. The aim of tympanoplasty is to repair the perforated TM and restore the conductive hearing loss. Since in Type 1 tympanoplasty ossicular chain is usually intact, the primary criterion of success is the repair of TM perforation. Various materials such as skin, temporalis fascia, fat tissue, vein,

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perichondrium and cartilage are used for grafting.[1,2] Cartilage grafts being resistant to retraction and infections, are preferred in patients with eustachian tube (ET) dysfunction, retraction pockets, anteriorly located perforations and revision surgery.

ET has an important duty in sustaining the middle ear physiology. The major functions of the ET are equalizing the middle ear pressure, drainage of secretions and protection of middle ear from retrograde migration of microorganisms, reflux of nasopharyngeal secretions and excess noise.[3] The three dimensional orientation and shape of the ET are considered to be responsible for otitis media with effusion (OME), COM and cholesteatoma.[4,5] In addition syndromic patients with craniofacial anomalies do have a higher risk of otitis media as a consequence of shorter ET length and horizontal location.[6]

In the past years anatomy of ET was examined mostly by cadaver studies. Today, due to the remarkable advances in computed tomography, ET anatomy is evaluated more effectively with the use of multiplanar reconstruction (MPR) technique.[7]

The factors effecting the success rate of tympanoplasties were investigated in various studies.[8-10] However there is only one study in the literature investigating the relationship between the anatomic measurements of ET and the outcome of Type 1 tympanoplasty.[11] We measured the length of ET (ETl), tubotympanic angle (TTa), the ET-Reid horizontal plane angle (ETa), and ET pretympanic diameter (ETd) in Type 1 cartilage tympanoplasty patients, using the MPR technique on temporal bone computed tomography. To our knowledge there is no study exploring the effect of these four measurements on the anatomic outcome of cartilage Type 1 tympanoplasty. Our aim is to clarify the influence of ET anatomical measurements on the outcome of Type1 cartilage tympanoplasty.

MATERIAL AND METHODS

The Clinical Research Ethics Committee approved the study protocol (date: June 22, 2022; no: 129-2022) and the principles of Helsinki Declaration was applied. All patients granted an informed written consent for the study. The medical records of 99 patients (58 female and 41 male), who underwent cartilage Type 1 tympanoplasty between January 2016 and December 2021 were reviewed retrospectively.

Patients of age 11-63 with perforated TMs were recruited into the study. The diagnosis was confirmed preoperatively by otomicroscopy, pure tone audiometry and computered tomography (CT) of the temporal bone. Ears which were dry for 12 weeks before surgery and wet ears which failed to dry after a month of local antibiotherapy were selected. One hundred and eight ears of 99 patients (90 unilateral and 9 bilateral ears) were included. Age, gender, side of surgery, type of surgery (cartilage Type 1 tympanoplasty with or without mastoidectomy/antrostomy), size (<50%=small, >50%=subtotal, total) and type of perforation (central or marginal), condition of the contralateral ear (diseased vs. healthy), condition of the middle ear (cholesteatoma, adhesive otitis media, COM and tympanosclerosis), Middle Ear Risk Index (MERI) score, history of previous surgery, smoking habits, success rate and follow up period were noted.

Exclusion criteria were; ossicular chain defects, concomitant ossiculoplasty, previous ear surgery other than ventilation tubes and Type 1 tympanoplasty, craniofacial abnormalities eg. cleft palate, congenital ear deformities, Down syndrome, malignancies of the paranasal sinuses and nasopharynx. Patients with follow up of less than one year were also excluded.

Two groups were created according to the anatomical success of the procedure. Anatomical success was described as an intact TM graft after a year of follow up without lateralisation or retraction. Group 1 consisted of ears with successful anatomic outcome and group 2 consisted of ears with perforated, retracted or lateralized TM after a year postoperatively.

Temporal bone imaging was done by a multidedector CT system (Ingenuity PHILIPS 128 CT Scanner, Philips Medical Systems, Cleveland, Ohio, USA). The imaging parameters were as follows; a slice thickness and reconstruction interval of 0.5 mm, a 35x35 cm field of view and a pitch of 1. Contrast material was not used for imaging. The images were evaluated on an offline picture archiving and com-

munication system. Every image was measured by 2 different radiologists, the mean values were used for the data analysis. The reconstruction of 0.5 mm thick images were done by MPR technique. The images were standardized by modifying the inclination of reformatted image as far as the basal turns of each cochlea was viewed uniformly on axial and coronal planes. The anatomic sections of ET were described likewise the studies of Takasaki et al. and Sadler-Kimes et al.[7,12] The nasopharyngeal opening of ET was described as the closest spot to the nasopharynx where a circle shaped lumen occured, the tympanic opening of ET was described as the closest spot before the external ear canal appears on the cross-sectional image. ETl, TTa, ETa, and ETd were measured using the same technique with other studies.[7,13,14] The measurement of ETl was done by oblique MPR images. The distance between the tympanic and nasopharyngeal openings of ET in the same coronal section was measured as ETl (Figure 1). The angle between the line passing through the midst of the tympanic opening of ET and the line passing through the midst of the bony external ear canal was described as TTa (Figure 2). Reid plane is the horizontal plane crossing through the superior wall of external ear canal and inferior wall of orbita bilaterally. The angle between the longitudinal axis of ET and Reid horizontal plane was accepted as ETa (Figure 3). The cone shaped section of the ET next to the tympanic opening is the pretympanic segment. The tensor tympani muscle builds the roof of the pretympanic segment where it bulges into the ET lumen. The pretympanic segment was visualized efficiently on the axial images (Figure 4).

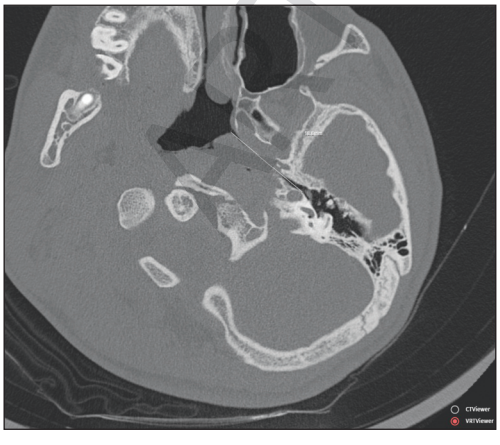

FIGURE 1: The distance between the tympanic and pharyngeal openings of eustachian tube in the same coronal section was measured as the eustachian tube length.

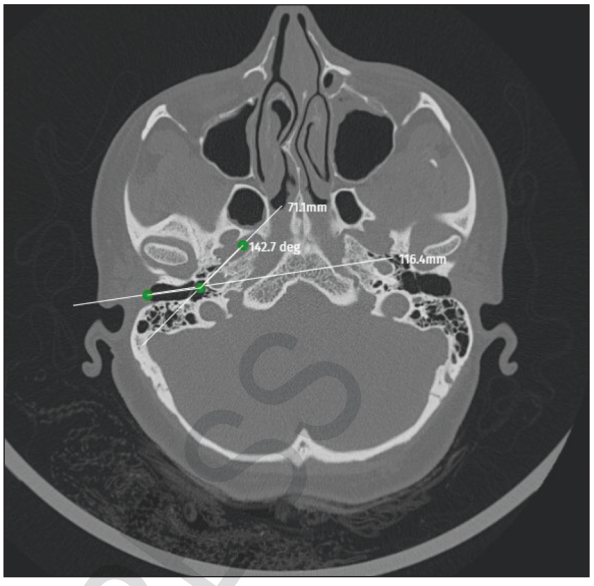

FIGURE 2: The angle between the line passing through the midst of the tympanic opening of eustachian tube and the line passing through the midst of the bony external ear canal was described as tubotympanic anglea.

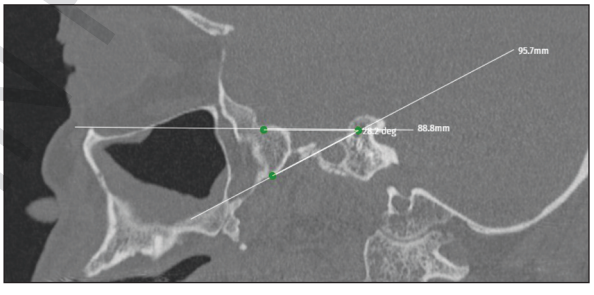

FIGURE 3: The angle between the longitudinal axis of eustachian tube and Reid horizontal plane was accepted as eustachian tubea.

The over-under tympanoplasty technique was performed in all cases. Cartilage graft was harvested from the tragus or cymba concha. Perforated edges were prepared and tympanomeatal flap was elevated routinely. TM was dissected from the manibrium mallei and the mobility of ossicles were controlled. The cartilage graft was thinned and reshaped by a no 11 blade. The graft was placed over the manibrium mallei and under the TM remnant. Middle ear was filled with Spongostan™ (Ferrosan, Copenhagen, Denmark) to uphold the cartilage graft. After the tympanomeatal flap was laid back, the external ear canal was also filled with Spongostan™.

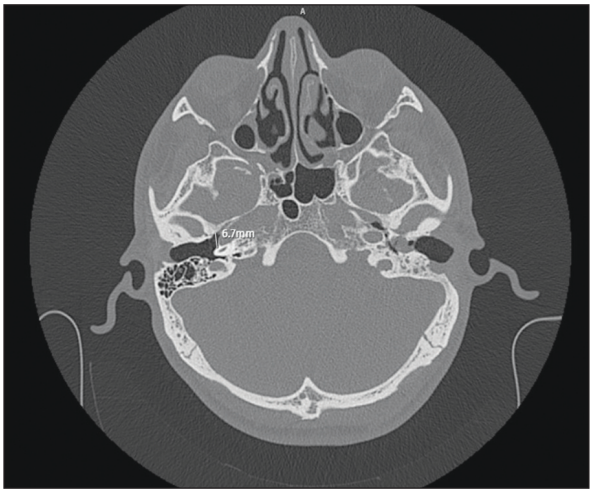

FIGURE 4: The cone shaped section of the eustachian tube next to the tympanic opening is the pretympanic segment, which can be visualized efficiently on the axial images.

Statistical analyses were performed by SPSS 15.0 for Windows (SPSS Inc, Chicago, IL). Descriptive statistics were mentioned as frequencies and percentages for caterogical variables, and as means (±standard deviation) or medians (minimum-maximum) for numeric variables. The comparison of groups was done by chi-square test. In independent groups, the numeric variables with and without normal distribution were compared by the Student's t-test and Mann-Whitney U test, respectively. The age of patients in Group 1 and 2 were compared by Mann-Whitney U test, sex and smoking habits of patients in Group 1 and 2 were compared by chi-square test. Middle ear status, type of surgery, type and size of perforation and status of the contralateral ear in Group 1 and 2 were compared by chi-square test, MERI was compared by Mann-Whitney U test. ET length of patients in Group 1 and 2 were compared by Mann-Whitney U test, TTa, ETa and ETd were compared by Student's t test. p values <0.05 were accepted as statistically significant.

RESULTS

A total of 108 ears (90 unilateral and 9 bilateral ears of 99 patients) were involved in our study. Of 99 patients; 58 (58.6%) were female and 41 (41.4%) were male. The mean age was 30.3±14.1 with a range of 11-63. The demographic data is documented in Table 1.

Two groups were formed due to the anatomical success of the procedure. Group 1 consisted of ears with successful anatomic outcomes and Group 2 consisted of ears with perforated, retracted or lateralized TM after 6 months postoperatively. No significant differences regarding the age, sex and smoking habits of patients in Group 1 and 2 were observed. In addition, middle ear condition, type of surgery, perforation type and size, condition of the contralateral ear and MERI of the 2 groups were similar. The group characteristics are documented in Table 2. We were unable to detect a significant difference between the ETl, TTa, ETa, and ETd of Group 1 and 2. The measurements of ET dimensions in Group 1 and 2 are documented in Table 3.

DISCUSSION

The benefits of a successful tympanoplasty are protection of middle ear, prevention of recurrent middle ear infections and improved hearing. There are numerous studies investigating the prognostic factors in tympanoplasty.[8-10,14,15] Identification of the prognostic factors would promote the successful outcome and cost-effectiveness of surgery.

TABLE 1: The demographic data of all patients.

		Total (n=99)	Group 1 (n=80)	Group 2 (n=28)	p value
Age ($\bar{X}$±SD) (years)		30.3±14.1	29.3±14.0	33.0±14.4	0.179[a]
Sex n (%)	Female	58 (58.6%)	47 (58.8%)	14 (50.0%)	0.422[b]
	Male	41 (41.4%)	33 (41.3%)	14 (50.0%)	
Smoking habits	Non-smoker	89 (89.9%)	72 (90.0%)	25 (89.3%)	1.000[b]
	Smoker	10 (10.1%)	8 (10.0%)	3 (10.7%)	

[a]Mann-Whitney U test; [b]Chi-square test; SD: Standard deviation.

TABLE 2: The group characteristics of all ears operated.

		Total (n=108)	Group 1 (n=80)	Group 2 (n=28)	p value
Middle ear condition	Cholesteatoma	3 (2.8%)	3 (2.8%)	0 (0.0%)	0.586[b]
	Adhesive otitis media	7 (6.5%)	5 (6.3%)	2 (7.1%)	
	Chronic otitis media	79 (73.1%)	56 (70.0%)	23 (82.1%)	
	Tympanosclerosis	19 (17.6%)	16 (20.0%)	3 (10.7%)	
Type of surgery	Type 1 tympanoplasty	98 (90.7%)	71 (88.8%)	27 (96.4%)	0.448[b]
	Type 1 tympanoplasty with mastoidectomy/antrostomy	10 (9.3%)	9 (11.3%)	1 (3.6%)	
Type of perforation	Central	102 (94.4%)	75 (93.8%)	27 (96.4%)	1.000[b]
	Marginal	6 (5.6%)	5 (6.3%)	1 (3.6%)	
Size of perforation	Small (=<50%)	52 (48.1%)	39 (48.8%)	13 (46.4%)	0.966[b]
	Subtotal (=>50%)	44 (40.7%)	32 (40.0%)	12 (42.9%)	
	Total	12 (11.1%)	9 (11.3%)	3 (10.7%)	
Condition of the contralateral ear	Healthy	71 (65.7%)	52 (65.0%)	19 (67.9%)	0.784b
	Diseased	37 (34.3%)	28 (35.0%)	9 (32.1%)	
Middle Ear Risk Index score ($\bar{X}$±SD)		2.49±1.73	2.46±1.74	2.57±1.71	0.736[a]

aMann-Whitney U test; bChi-square test; SD: Standard deviation.

TABLE 3: The measurements of ET dimensions in Group 1 and Group 2 ($\bar{X}$±SD).

	Total (n=108)	Group 1 (n=80)	Group 2 (n=28)	p value
ET length (mm)	23.7±6.3	23.2±6.2	25.0±6.3	0.178[a]
TT angle (°)	140.7±9.2	140.6±9.9	140.8±7.1	0.916[c]
ET angle (°)	22.0±3.8	22.0±3.8	22.0±3.7	0.993[c]
ET pretympanic diameter (mm)	4.15±0.71	4.09±0.62	4.34±0.90	0.115[c]

[a]Mann-Whitney U test; [c]Student t-test; ET: Eustachian tube; SD: Standard deviation; TT: Tubotympanic angle.

ET has a major role in maintaining a healthy middle ear cavity. Ventilation, clearance and protection of the middle ear cavity are the essential duties of ET. The dysfunction of ET is an underlying cause of OME, atelectasis and adhesive otitis media.[3,16]

A properly functioning ET is vitally important in the successful outcome of Type 1 tympanoplasty. Sato et al. detected that the positive pressure equalization and clearance test results of the ET were related with the success rate of tympanoplasty. Takahashi et al. examined the patency, pressure-regulation function and mucosal gas exchange function of ET in 74 ears undergoing Type 1 tympanoplasty and detected a significantly poor surgical outcome when those 3 parameters were impaired. They also confirmed that the mechanical obstruction of ET was a contraindication for tympanoplasty.[17,18]

There are several studies which confirm a relevance between the anatomical measurements of ET and etiology of COM.[13,14,19] Dinç et al. measured the ETl in 125 patients with COM, tympanosclerosis, cholesteatoma and retraction pockets. In healthy ears, COM, tympanosclerosis, retraction pockets and cholesteatoma the ETl were as; 39.3±2.5 mm, 37.9±2.1 mm, 38.5 mm (37.6-44.0), 41.5 mm (34.3-43.8) and 38.9±2.2 mm, respectively. ETl was lower in COM versus tympanosclerosis, COM versus healthy ears and cholesteatoma versus retraction pockets.[13] In the study of Gulustan et al. the length of the bony ET segment in patients with cholesteatoma was found significantly shorter than healthy ears.[19] Several authors detected a wider TTa in patients with COM.[14,20] Nemade et al. measured the TTa as 148.12±3.43° in diseased ears and 145.14±4.34° in normal ears.[14] Vivek et al. detected the TTa as 146.17±6.11° in case group and 143.17±6.01° in control group.[20] In addition, ETa was found to be narrower in COM vs. normal ears in multiple studies.[13,14,21] Dinç et al. found the ETa to be

23.6±2.4° in normal ears and 22.9±2.8° in diseased ears.[13] In the study of Nemade et al. the ETa was 27.56±3.62° in normal ears and 25.41±2.57° in diseased ears.[14] Aksoy et al. measured the ETa as 28.84±3.97° and 26.85±4.04° in healthy and diseased ears.[21] Vivek et al. detected that the pretympanic diameter of ET was narrower in ears with COM.[20] Nemade et al. assessed the ET patency in ears with COM and found that the pretympanic diameter was significantly narrow in patients with blocked ET.[14] In the study of Paltura et al., diameter of isthmus was found as 1.947±0.524 mm and 1.788±0.530 mm for normal and diseased ears.[22] Gulustan et al. measured the ET isthmus diameter as 1.43±0.37 mm in normal ears and 1.27±0.35 mm in diseased ears. In both studies ET isthmus diameter was found significantly narrow in ears with COM.[19,22]

We measured the ETl, TTa, ETa, and ETd in Type 1 cartilage tympanoplasty patients in order to clarify the influence of ET anatomical measurements on the outcome of Type1 cartilage tympanoplasty. No prior study has evaluated the influence of these 4 measurements on tympanoplasty success rate. The results of our study show that these ET measurements do not have a role in the anatomical outcome of Type 1 cartilage tympanoplasty.

Yegin et al. investigated the effect of ET length and ETa on the success rate of cartilage Type 1 tympanoplasty in 160 patients.[11] The ETa and ET length measurements of the groups with successful and unsucessful surgical outcomes were similar. They concluded that the ET length and ETa had no effect on the success rate of Type 1 cartilage tympanoplasty. Their findings are concordant with the present study.

The limitations of our study are;

1) The small sample size,

2) ET function was not assessed due to the retrospective study design,

3) Type 1 tympanoplasty procedures performed with temporalis muscle fascia grafts were not included in the present study due to the insufficient number of patients.

The anatomic measurements of ET might have had a greater effect on the outcome of Type 1 tympanoplasties with temporalis muscle fascia grafts. Prasad et al. assessed the ET function in patients with mucosal COM.[23] Eighty-six patients who underwent Type 1 tympanoplasty with temporalis fascia graft was evaluated. Those with normal ET function and partial dysfunction had a success rate of 93.75% and 68.42%, respectively. In patients with gross dysfunction; failure rate was 100 percent. Uzun et al. compared the ET patency and function in tympanoplasties with cartilage palisades and temporalis fascia grafts.[24]They stated that when cartilage palisade tympanoplasty was performed in ears with poor ET function, an intact TM graft was detected more often. Therefore cartilage grafting method used in this study may be the underlying reason why we were unable to demonstrate a significant correlation between the anatomical measurements of ET and outcome of Type1 tympanoplasty.

CONCLUSION

Our study shows that the ET length, TTa, ETa and ETd do not have a significant role on the outcome of Type 1 cartilage tympanoplasty. Using cartilage grafts in Type 1 tympanoplasty might be preferred to rule out the anatomical disadvantages regarding the ET. Studies with greater sample sizes are required to assess both the anatomy and function of the ET in Type 1 tympanoplasty with various graft types.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Işıl Taylan Cebi, Abdullah Karataş, Nurdan Göçgün, Behice Kaniye Yılmaz, Ali Taha Göçer;* ***Design:*** *Işıl Taylan Cebi, Abdullah Karataş, Nurdan Göçgün, Behice Kaniye Yılmaz, Ali Taha Göçer;* ***Control/Supervision:*** *Işıl Taylan Cebi,*

Abdullah Karataş, Behice Kaniye Yılmaz; ***Data Collection and/or Processing:*** *Işıl Taylan Cebi, Ali Taha Göçer, Nurdan Göçgün, Behice Kaniye Yılmaz;* ***Analysis and/or Interpretation:*** *Işıl Taylan Cebi, Abdullah Karataş, Nurdan Görgün, Behice Kaniye Yılmaz, Ali Taha Göçer;* ***Literature Review:*** *Işıl Taylan Cebi, Nurdan Göçgün, Behice Kaniye Yılmaz;* ***Writing the Article:*** *Işıl Taylan Cebi, Nurdan Göçgün, Behice Kaniye Yılmaz;* ***Critical Review:*** *Işıl Taylan Cebi, Nurdan Göçgün, Behice Kaniye Yılmaz, Abdullah Karataş;* ***Materials:*** *Ali Taha Göçer, Nurdan Göçgün, Behice Kaniye Yılmaz, Işıl Taylan Cebi.*

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