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Comparing the Shaping Efficiency of Original and Replica-Like Endodontic Instruments: *in vitro* Study

Orijinal ve Replika Endodontik Aletlerin Şekillendirme Etkinliğinin Karşılaştırılması: *in vitro* Çalışma

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This study was presented as an oral presentation at 10th International Endodontis Symposium, May 19-22, 2024, Antalya, Türkiye.

ABSTRACT Objective: Since research on the effectiveness of replica-like files in shaping root canals is limited, this study compared the shaping effectiveness of the original WaveOne Gold (WOG) file system with the replica Scope RS Gold (SC) file system in J-shaped simulated resin blocks. **Material and Methods:** Root canal preparations were performed in 24 simulated J-shaped root canals using WOG (#25.07) and SC (#25.07) files (n=12). The pre- and post-operative images of the prepared root canals were superimposed. The root canals in the images were divided into 9 segments of 1 millimeter each, and a total of 18 measurements were obtained from both canal surfaces. The inner and outer root canal walls were named B and A, respectively. The total resin removal amount (TRR) (A+B), the transportation value and direction (TV) (lB-Al), and the centering ability (CA) (A/B or B/A) were calculated. One-way analysis of variance and post-hoc Tukey tests were used for statistical analysis ($p<0.05$). **Results:** When TRR was evaluated, the SC instruments removed more resin in the apical, middle, and coronal thirds ($p<0.05$). When TV was evaluated, no difference was observed between the groups in the coronal third ($p>0.05$), while the SC instruments caused more transportation in the apical and middle thirds ($p<0.05$). Moreover, no statistically significant difference was found in terms of the instruments' CA in the apical, middle, and coronal thirds ($p>0.05$). **Conclusion:** The replica-like system exhibited significantly higher values in terms of resin removal and canal transportation.

Keywords: Endodontics; root canal preparation; root canal therapy

ÖZET Amaç: Kök kanallarının şekillendirilmesinde replika eğelerin etkinliği ile ilgili bilimsel veriler yetersizdir, bu nedenle çalışmanın amacı, orijinal WaveOne Gold (WOG) eğe sistemi ile replika Scope RS Gold (SC) eğe sisteminin J-şekilli simüle rezin bloklardaki şekillendirme etkinliğini karşılaştırmaktır. **Gereç ve Yöntemler:** Yirmi dört adet simüle J-şekilli kök kanalında, WOG (#25,07) ve SC (#25,07) eğeleri kullanılarak kök kanal preparasyonları gerçekleştirilmiştir (n=12). Preparasyonu tamamlanan kök kanalların preoperatif ve postoperatif görüntüleri bilgisayar ortamında çakıştırılmıştır. Görüntülerde kök kanalları 9 adet 1 mm'lik segmentlere ayrılarak her iki kök kanalı yüzeyinden toplamda 18 ölçüm elde edilmiştir. İç ve dış kök kanal duvarları sırasıyla B ve A olarak adlandırılmıştır. Toplam rezin uzaklaştırma miktarı (TRR) (A+B), transportasyon değeri ve yönü (TV) (lB-Al) ve merkezleme yeteneği (CA) (A/B veya B/A) görüntü işleme programı kullanılarak hesaplanmıştır. İstatistiksel analizler için tek yönlü varyans analizi ve "post hoc" Tukey testleri kullanılmıştır ($p<0,05$). **Bulgular:** TRR değerlendirildiğinde, SC apikal, orta ve koronal üçlüde daha fazla rezin uzaklaştırmıştır ($p<0,05$). TV değerlendirildiğinde, koronal üçlüde gruplar arasında fark gözlenmezken ($p>0,05$), apikal ve orta üçlüde SC daha fazla transportasyona sebep olmuştur ($p<0,05$). CA değerlendirildiğinde ise SC ve WOG grupları arasında merkezde kalma oranı açısından apikal, orta ve koronal üçlüde istatistiksel olarak anlamlı farklılık bulunamamıştır ($p>0,05$). **Sonuç:** Replika sistemi rezin uzaklaştırma ve kanal transportasyonu açısından daha büyük değerler göstermiştir.

Anahtar Kelimeler: Endodonti; kök kanalını hazırlama; kök kanal tedavisi

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Root canal preparation, one of the critical steps of endodontic treatment, involves creating a continuously tapered canal that expands from the apical foramen to the coronal third while preserving the original canal curvature.[1] However, due to the limited flexibility of conventional stainless-steel instruments in endodontics, maintaining the original canal morphology presents a significant challenge. Nickel-titanium (Ni-Ti) instruments, introduced in 1988, address this challenge by offering superior elasticity and shape memory properties.[2] Consequently, even in highly curved canals, Ni-Ti instruments facilitate safe shaping and offer significant advantages-for instance, they preserve the original root canal anatomy and reduce the incidence of procedural complications, such as zipping, ledge formation, and perforations.[3]

The Ni-Ti instruments have undergone continuous development in terms of design, metallurgical properties, mechanical behavior, shaping capabilities, and kinematics.[4] However, in 2008, to enhance time efficiency, prevent cross-contamination between patients, reduce the likelihood of complications, and offer cost-effectiveness, reciprocal single-file systems were introduced.[5-7]

Recent years have witnessed the emergence of numerous novel single-file systems that employ reciprocal motion. WaveOne Gold (WOG; Dentsply Sirona, Ballaigues, Switzerland), developed as a modification of WaveOne (Dentsply Sirona), features a parallel-sided cross-section with two cutting edges, which ensures that the contact between the file and dentin is limited to one or two points, thereby reducing the screw-in effect of the file in the root canal.[8] Gold heat treatment, unlike the pre-manufacturing heat treatment used for M-wire technology, involves heating the instrument followed by controlled cooling. This novel heat treatment, according to the manufacturer, enhances the file's flexibility and cyclic fatigue resistance.[9] The WOG system comprises four files: "small" (#20.07), "primary" (#25.07), "medium" (#35.06), and "large" (#45.05).[10]

Recently, replica-like files offering lower-cost alternatives to original brands have been introduced to the market. Though these replica-like systems replicate the original systems in terms of file quantity, usage parameters, and color-coding schemes, they are marketed under distinct brand identities.[11] SCOPE Endo W Gold RS (SC; ScopeEndo, Yozgat, Türkiye) is a Ni-Ti file system that works with reciprocal motion and follows the "Gold-wire" heat treatment. It has a parallelogram cross-section and, owing to the applied heat treatment, exhibits enhanced flexibility. The SC file system, similar to the WOG file system, comprises four files with apical diameters and taper angles of #20.07, #25.07, #35.06, and #45.05.[12]

In recent years, the increased use of Ni-Ti systems has resulted in the increased use of replica files, which have grown more visible in the market due to their cost reduction. However, unlike well-known brands, research on the impact of replica-like files on root canal preparation and the risk of complications remains limited. Since researching this topic holds clinical significance, this study compared the shaping ability of the replica-like SC file system on J-shaped simulated resin blocks with that of the original WOG file system.[11] The null hypothesis was the following: there would be no significant difference in the shaping efficiency of both systems.

MATERIAL AND METHODS

EXPERIMENTAL GROUPS AND ROOT CANAL SHAPING PROCEDURES

This study was performed in line with the principles of the Declaration of Helsinki. The sample size was calculated at the effect size of 0.8, Type 1 error of 0.05, and power of 0.80 using G* Power (ver.3.1.9.7). The experiment utilized 24 resin blocks containing J-shaped canals (0.02 taper, 10 mm radius, 70° angle, 16 mm working length). Following apical patency confirmation with a #15 K-file, black ink staining was performed. Pre-instrumentation images were captured with a fixed camera (Canon EOS 700 D, Canon Incorporated, Tokyo, Japan) positioned parallel to the floor (60 cm distance) from the resin blocks, which were perpendicularly positioned on a table. The samples were then randomly divided into two groups.

WOG group (n=12): Root canal preparation was performed using the WOG Primary #25.07 Ni-Ti file by following the manufacturer's instructions (150° counterclockwise followed by 30° clockwise movement) and a torque-controlled endodontic motor (AI-motor, Woodpecker, Guilin, China) with the "WaveOne" mode activated. The file was used with gentle apical pressure and a brushing motion against the lateral walls, which involved 3 mm back-and-forth strokes that were performed thrice at the most.

SC group (n=12): Root canal preparation was performed using the SC #25.07 file. Just as in the WOG group, following the manufacturer's instructions, a 3 mm brushing motion was conducted, and a reciprocal motion of 150° counterclockwise was followed by a 30° clockwise motion. A torque-controlled electric motor was used (AI-motor, Woodpecker).

After every three back-and-forth movements, the file was removed from the root canal, the debris on the file was cleaned with wet gauze, and recapitulation was performed using a #15 K-file. After each back-and-forth movement, using a 30-gauge side-vented irrigation needle (Fanta Dental, İstanbul, Türkiye), the root canals were irrigated with 2 mL of distilled water. The final irrigation was performed using 5 mL of distilled water. After root canal preparation, the simulated canals were stained with red ink (Pelikan, Hannover, Germany) and photographed again.

QUANTIFYING SHAPING ABILITY USING IMAGE EVALUATION

Blinded observer superimposed pre- and post-operative images using image analysis software (Adobe Photoshop 25.5.0, Adobe Systems, Inc., San Jose, CA). A measurement scale was then created on these images, marking nine points at 1mm intervals on both the outer (A side) and inner (B side) walls of the root canal curvature.

The measured points were divided into 3 based on their location within the root canal; points 1-3 showed the apical third, points 4-6 the middle third, and points 7-9 the coronal third (Figure 1). Using the data from the measurements, the total amount of resin removal (TRR), transportation value and direction (TV and TD), and centering ability (CA) were calculated using the following criteria.[13]

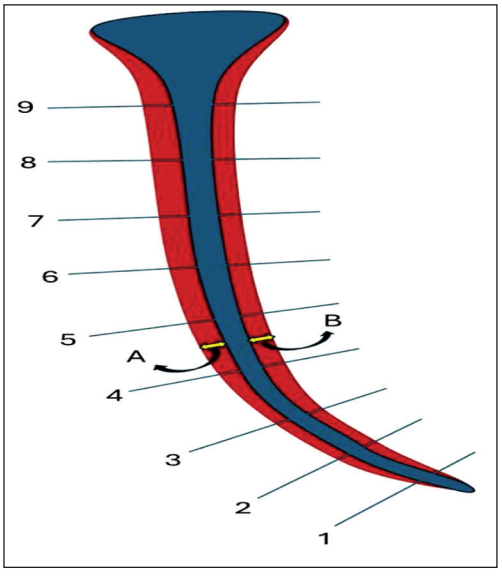

FIGURE 1: Drawing representing lines drawn at 1 mm intervals perpendicular to the center of the canal in which the measurements were done. The "A" side of the drawing shows the outer direction of the root canal curvature and the "B" side shows the inner direction.

1. TRR: Represents the total amount of resin removed from both the inner (A) and outer (B) walls of the canal (A+B).

2. TV and TD: Reflects the difference in resin removed between the outer (B) and inner (A) walls, expressed as the absolute value |B-A|. If the value is greater than zero, the transportation occurs inward; if it is less than zero, the transportation occurs outward; and if the value is zero, no transportation occurs.

3. CA: The ratio of resin removed between the two sides of the canal is determined by dividing the smaller value (A or B) by the larger value (B or A). If the value is close to or equal to 1, the file's CA is good or excellent; if the value is close to zero, it is poor.

STATISTICAL ANALYSIS

One-way analysis of variance and post-hoc Tukey tests were used for statistical analysis. The significance level was set at $p<0.05$.

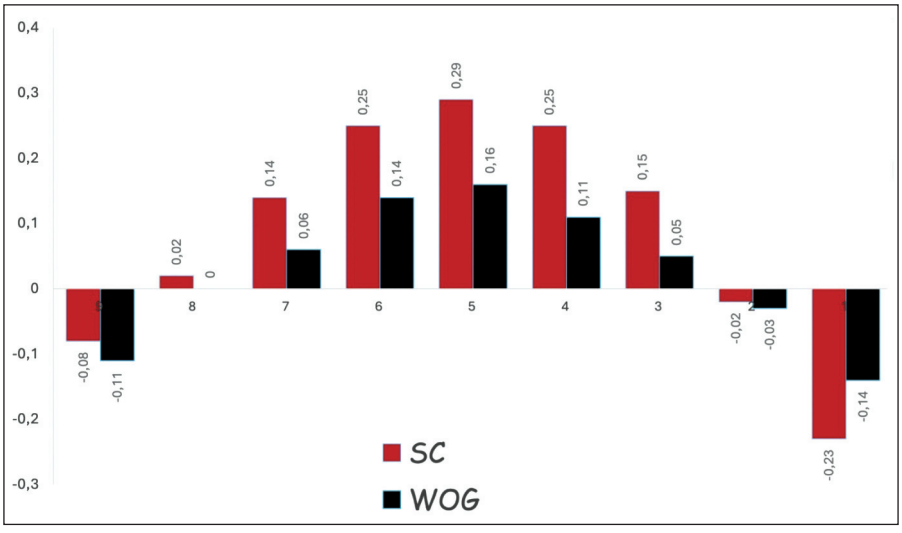

FIGURE 2: The value and direction of canal transportation (mm) at the different 9 points. The values greater than zero indicate that transport is inner side, and the values less than zero indicate that transport is outer side.
SC: Scope RS Gold; WOG: WaveOne Gold.

RESULTS

FILE SEPARATION AND ROOT CANAL ABERRATIONS

Shaping the simulated canals did not generate any Ni-Ti file fractures, though canal irregularities were observed in both groups. Apical transportation occurred in four samples in the SC group, while it occurred in one sample in the WOG group (Figure 3A and Figure 3B).

EVALUATION OF THE TOTAL AMOUNT OF MATERIAL REMOVAL

Table 1 summarizes the average TRR and TV values with their variation (standard deviation) for each group. Regarding the mean amount of TRR by the files, a statistically significant difference was observed between the groups. The SC group removed a statistically significantly higher amount of resin from all the canal regions (apical, middle, and coronal thirds) when compared with the WOG group ($p<0.05$).

EVALUATION OF TV AND TD

The mean values and standard deviations of TV are presented in Table 1. Figure 2 presents the amount of transportation in mm corresponding to the original

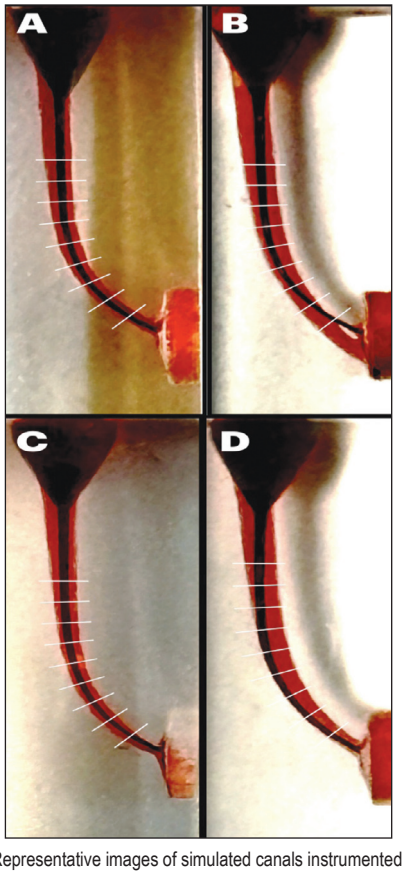

FIGURE 3: Representative images of simulated canals instrumented using WOG (A and C), and SC (B and D) file systems. No apical transportation was observed with the WOG file system (A). Apical transportation was observed with the SC file system (B). Images C and D show the CA of the WOG and SC file systems, respectively.
SC: Scope RS Gold; WOG: WaveOne Gold.

TABLE 1: The average canal widths (mm) with SDs at coronal, middle, and apical thirds after preparation with original and replica instruments.

		TRR		TV	
	Group	X̄±SD (mm)	p value	X̄±SD (mm)	p value
Coronal third	SC	0.692±0.092[a]	0.001	0.293±0.168[a]	0.017
	WOG	0.542±0.098[b]		0.177±0.1[a]	
Middle third	SC	0.602±0.119[x]	0.021	0.376±0.183[b]	0.015
	WOG	0.491±0.098[y]		0.195±0.154[b]	
Apical third	SC	0.528±0.139[α]	0.021	0.338±0.168[c]	0.057
	WOG	0.399±0.112[β]		0.186±0.114[d]	

Values with the different superscript letters were statistically different (p<0.05). The values are X̄±SD. TRR: Total resin removal; TV: Transportation value; SD: Standard deviation; SC: Scope RS Gold; WOG: WaveOne Gold.

TABLE 2: Means and SDs at the different measurement points of the canal (coronal, middle, and apical third) centering ratio values for original and replica-like files.

	Group	X̄±SD	p value
Coronal third	SC	0.473±0.242	0.38
	WOG	0.553±0.188	
Middle third	SC	0.269±0.240	0.054
	WOG	0.490±0.287	
Apical third	SC	0.265±0.188	0.143
	WOG	0.395±0.227	

Values with the different superscript letters were statistically different (p<0.05). The values are X±SD. CA: Centering ability; SD: Standard deviation; SC: Scope RS Gold; WOG: WaveOne Gold.

and replica-like file systems. When evaluating TV, no difference between the groups was observed in the coronal third (p>0.05). However, in the apical and middle thirds, SC instruments generated more transportation (p<0.05).

CA

Table 2 presents the mean values and standard deviations of the instruments' CA. No statistically significant difference was found between the instruments in terms of their CA in the apical, middle, and coronal thirds (p>0.05) (Figure 3C and Figure 3D).

DISCUSSION

Commercially available replica-like instruments have been introduced as lower-cost alternatives to established brands. However, scientific data on the shaping efficacy of these replica-like instruments remains limited. Consequently, this study aimed to fill a significant research gap by comparing the shaping efficiency of the original WOG file system with a replica-like SC system in J-shaped simulated resin blocks. Significant differences were found between the two groups for TRR and TV. Though the SC system demonstrated greater resin removal and transport, both groups had similar CA. The null hypothesis was thus partially rejected.

Despite advancements in Ni-Ti instruments and various preparation techniques, iatrogenic errors remain during endodontic treatment, particularly when dealing with curved root canals. J-shaped canals pose a frequent difficulty in clinical practice, with a high prevalence. They are found in up to 27% of maxillary canines and 24% of mandibular central incisors.[14] Due to the canals' curved and narrow anatomy, preparing them can generate procedural errors, such as transportation, ledge formation, deviations from the original anatomy, and perforations.[6]

Numerous studies that investigated the shaping abilities of various Ni-Ti rotary file systems used extracted human teeth and simulated resin blocks.[9,15] Nevertheless, the studies that utilized extracted human teeth indicated that standardization is challenging to achieve due to the natural anatomical variations of the teeth, which significantly impact the outcomes of the study.[16] Investigating J-shaped canals in natural teeth is challenging due to the inherent variability in their anatomy, including length, curvature degree, and diameter. Simulated canals offer a valuable alternative, allowing researchers to control these parameters for consistent study. In addition, in studies that used J-shaped simulated canals,

the shaping abilities of Ni-Ti files were easily compared by comparing the roots' pre- and post-shaping images using various computer programs.[17,18] Therefore, to ensure the standardization of experimental conditions, this study employed simulated canals and compared the shaping abilities of two distinct Ni-Ti rotary file systems. Simulated canals, however, have some disadvantages-for instance, their hardness, surface texture, and cross-section are different from the extracted teeth. In light of this, the results of the present study must be carefully adapted to clinical conditions.[19]

Enlarging the apical preparation can enhance cleaning and irrigation of the apical thirds of root canals but also raises the risk of canal transportation due to reduced flexibility of root canal instruments.[20] Studies suggests that an apical size of 0.25 mm may be as effective in bacterial reduction as larger sizes.[21] Similar to previous studies, Ni-Ti files with an apical diameter of 0.25 mm were used in this study to shape the J-shaped simulated canals.[17] Furthermore, similar to a previous study, since the initial apical diameter of the J-shaped canals was 0.15 mm, a glide path file was not used before instrumentation.[15]

Compared with the WOG group, the SC group removed statistically significantly more resin from all the canal regions ($p<0.05$). An extensive literature review identified no prior investigations that directly compared the shaping efficacy of WOG and SC files, thus limiting a direct comparison with existing data. In one study that compared replica files and original files, scanning electron microscopy (SEM)/Energy-Dispersive X-Ray Spectroscopy (EDS) analysis reported that the replica files were similar to the original files in terms of their geometrical design and atomic ratios of nickel and titanium elements. Moreover, it was suggested that the differences between the files' performance may be mostly related to the quality of the manufacturing process and differences in the martensitic-austenitic transformation stages at certain temperatures.[22]

The SC files were also found to cause more transportation in the apical and middle thirds. The files' taper, their cross-section and their tips' design, and the alloy's properties influence the quantity of transportation.[23,24] However, the present study compared the original and replica files with the same taper and cross-sectional designs; these variables were thus kept constant. The studies that compared the original and replica files reported that the amount of Ni-Ti in the alloy of replica files may differ and that the tip geometries and angles of transition to the blade may differ between instruments.[25] Therefore, similar to these studies, the reason for the higher apical transport in the replica file in the present study may be due to the difference in the amount of Ni-Ti in the alloy and the tip design. Moreover, it has been reported that obturation and prognosis will be negatively affected if the amount of apical transport exceeds 0.3 mm, but none of the measured transport values exceeded this limit.[26]

No statistically significant difference was found between the two instruments' CA in all the canal regions ($p>0.05$). CA depends on gold heat treatment, kinematics, and the file/sample contact surface.[17] WOG and OneCurve files, Ates and Arıcan reported, have similar CA, possibly due to the amount of contact between the file/sample surface.[17] The file's design, featuring a 120-degree reciprocating cutting motion and a full 360-degree rotation every three cycles due to its unequal bi-directional movement, helps it maintain a centered position within the canal by maximizing contact.[6] Both systems were thus found to have similar CA, as they have similar heat treatments, kinematics, and contact surfaces. Falakaloğlu and İriboz compared the shaping ability and canal straightening of T-Endo MUST and WaveOne Gold reciprocal file systems with glide path files in resin J-shaped canals and reported no statistically significant difference between the T-Endo MUST and WOG reciprocal file systems.[27] However, in our study, TRR and TV values were found to be statistically different between SC and WOG files. This difference may be attributed to the different taper and different alloy of the T-Endo MUST file system and the use of glide path files of rotary file systems before root canal preparation in their study.

Endodontic procedures can remove significant dentin in the danger zone, the thinnest and weakest

area of the root canal.[28] Excessive dentin removal during preparation in this area increases the risk of strip perforation. This complication creates significant challenges, potentially leading to vertical root fractures, lateral lesion, bone loss, and extruded filling materials.[29] In curved canals, only selective amounts of dentin must be removed, especially in the danger zone, located in the middle third of the root canal and generally associated with the areas where the curvature begins.[30] Since the SC group was found to remove more resin and cause more transport in the middle and apical regions, it may not be safe for root canal preparation, especially in teeth with curves and thin dentin canals.

A limitation of this study is that experiments were conducted at room temperature. However, several studies indicate that Ni-Ti files' mechanical properties are sensitive to temperature. Therefore, evaluating these files at body temperature is recommended for a more clinically relevant assessment.[31] Future studies may thus simulate different temperatures in their shaping ability test. Moreover, only a single file from the file systems was evaluated, and a multi-method examination was not conducted. Future studies should thus evaluate the shaping efficiency of all files with different tip diameters of replica-like file systems, examine their metallurgical properties, and conduct mechanical tests.

CONCLUSION

The replica-like system exhibited significantly higher values in terms of TRR and canal transportation. Clinicians should thus be cautious when using replica instruments during root canal preparation, especially in teeth with curved and thin dentin walls.

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: *Arzu Kaya Mumcu, Gülsen Kiraz;* ***Design:*** *Arzu Kaya Mumcu;* ***Control/Supervision:*** *Arzu Kaya Mumcu, Gülsen Kiraz;* ***Data Collection and/or Processing:*** *Salihanur Sarı, Zeynep Yağmur Özdemir;* ***Analysis and/or Interpretation:*** *Arzu Kaya Mumcu, Gülsen Kiraz, Safa Kurnaz;* ***Literature Review:*** *Arzu Kaya Mumcu, Gülsen Kiraz, Safa Kurnaz;* ***Writing the Article:*** *Arzu Kaya Mumcu;* ***Critical Review:*** *Gülsen Kiraz, Safa Kurnaz;* ***References and Fundings:*** *Arzu Kaya Mumcu, Gülsen Kiraz, Safa Kurnaz;* ***Materials:*** *Salihanur Sarı, Zeynep Yağmur Özdemir.*

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