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Collum Angle Of Maxillary Central Incisors In Class III Malocclusions: A Cross-Sectional Study

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ABSTRACT

Background: The purpose of this study was to compare the angle of the maxillary central incisors in Class I and Class III malocclusions, with cephalometric radiography.

Methods: This study analyzed 120 lateral cephalometric radiographs classified into study and control groups based on Angle's classification, ANB angles, and Wits appraisal. The study group with skeletal Class III malocclusion, while the control group included individuals with skeletal Class I malocclusion. The study group comprised 33 female and 27 male patients with a mean age of 13.59± 3.53, while the control group included 32 female and 28 male patients with a mean age of 14.26±2.60. The collum angle was defined as the angle between the long axes of the root and crown. Various cephalometric parameters were assessed, and descriptive statistics were calculated.

Results: The study group exhibited significantly greater proclination of the maxillary incisors than the control group, as evidenced by higher 1/NA° and 1-NA (mm) values ($p < 0.001$). The mean collum angle was significantly higher in Class III individuals (4.05° ± 3.98) than in Class I individuals (−0.44° ± 5.24) ($p<0.001$), indicating a more pronounced labial root positioning. These morphological features are consistent with true skeletal Class III malocclusion.

Conclusion: The increased collum angle observed in Class III individuals results in a more labial root position, which may heighten the risk of dehiscence and fenestration during orthodontic treatment. Therefore, clinicians should consider this factor when planning treatment strategies.

Sınıf III Maloklüzyonlarda Maksiller Santral Kesici Dişlerin Kollum Açısı: Kesitsel Çalışma

Makale Bilgisi

Makale Geçmişi

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Kollum açısı,
Kron-kök açısı.

ÖZET

Amaç: Bu çalışmada, lateral sefalometrik radyografiler kullanılarak iskeletsel Sınıf I ve Sınıf III maloklüzyona sahip bireylerin maksiller santral kesici dişlerindeki kollum açılarının karşılaştırılması amaçlanmıştır.

Gereç ve Yöntemler: Bu çalışmada, Angle sınıflandırması, ANB açıları ve Wits değerlendirmesine göre çalışma ve kontrol gruplarına ayrılan 120 lateral sefalometrik radyografi analiz edilmiştir. Çalışma grubunda iskeletsel Sınıf III maloklüzyonu olan bireyler, kontrol grubunda ise iskeletsel Sınıf I maloklüzyonu olan bireyler yer almıştır. Çalışma grubunda ortalama yaşı 13,59± 3,53 olan 33 kız ve 27 erkek hasta, kontrol grubunda ise ortalama yaşı 14,26±2,60 olan 32 kız ve 28 erkek hasta bulunmaktadır. Kollum açısı, kök ve kronun uzun eksenleri arasındaki açı olarak tanımlanmıştır. Çeşitli sefalometrik parametreler değerlendirilmiş ve tanımlayıcı istatistikler hesaplanmıştır.

Bulgular: Çalışma grubunda, kontrol grubuna kıyasla üst kesici dişlerin öne eğimi anlamlı düzeyde daha fazlaydı; bu durum, artmış 1/NA° ve 1-NA (mm) değerleriyle desteklenmiştir ($p<0,001$). Ortalama kollum açısı, Sınıf III bireylerde anlamlı olarak daha yüksek bulunmuştur (4,05° ± 3,98). Sınıf I bireylerde ise bu değer −0,44° ± 5,24 ($p<0,001$) olarak hesaplanmıştır. Bu morfolojik özellikler, gerçek iskeletsel Sınıf III maloklüzyonu ile uyumludur. Gözlemciler arası ve gözlemci içi güvenilirlik yüksek düzeyde bulunmuş olup, ICC değerleri 0,89 ile 0,99 arasında değişmiştir.

Sonuç: Sınıf III bireylerde artan kollum açısı, köklerin labial pozisyonda yerleşmesine neden olabilir ve bu durum ortodontik tedavi sırasında dehisens ve fenestrasyon riskini artırabilir. Bu nedenle, klinisyenlerin tedavi sürecinde bu durumu göz önünde bulundurmaları önerilmektedir.

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INTRODUCTION

The primary concern of patients seeking orthodontic treatment is to enhance the aesthetic appearance of their dental and facial structures. The position and shape of upper central teeth are critical to achieving an aesthetic appearance, as they are located in the facial midline and first visible during daily facial activities.[1] Due to their primary influence on the position of the lips, they are crucial for the creation of the ideal facial profile.[2]

The labiolingual inclination of the upper central teeth is of pivotal importance in achieving optimal occlusal guidance and lower face aesthetics. The collum angle of anterior teeth is a critical factor that plays an important role in all areas of dentistry, especially in orthodontics and aesthetic dentistry. In restorative dentistry, the presence of a large collum angle in anterior teeth presents several clinical challenges. During post-core applications, it may be necessary to reduce the length of the post to achieve proper crown angulation, which can compromise retention and overall structural stability.[3] The collum angle of anterior teeth is a critical anatomical parameter that significantly influences clinical outcomes across various dental disciplines, particularly orthodontics and aesthetic dentistry. In implantology, when replacing anterior teeth with a pronounced collum angle, angled abutments are often required to align the prosthetic crown correctly within the alveolar bone.[4] From a periodontal perspective, increased stress between the buccal aspect of the implant fixture and the abutment may contribute to gingival recession. Additionally, root prominence, alveolar dehiscence, and compromised soft tissue aesthetics are potential complications associated with increased collum angles.

In the field of orthodontics, Andrews' six-key model is widely accepted as the definitive approach to achieving optimal occlusal harmony.[5] Evaluation of the labiolingual inclination is based on the longitudinal axis passing through the crown.[6] The term "crown-root angulation" refers to the angle which is formed at the point at which the longitudinal axes of the crown and the root intersect. As posited by Andrews, a collum angle measuring 0° for the normal incisor is regarded as a critical element in the establishment of optimal occlusion.[7] Any deviation from this angle can explain variations in crown-root angulation. The morphological variations of maxillary central incisors have an impact on both the biomechanics of the active stage and the practices in the retention stage of orthodontic treatment in various ways. Bryant [8] analysed the variations in permanent central incisors and demonstrated the presence of morphological variation. It was hypothesised that the angle of the collum might constrain the extent of lingual torque of the incisor roots, which is a contributing factor to the observed variation. In order to optimise smile aesthetics and ensure post-treatment stability, incisor root torques must be executed in the ideal position. According to Gomaa et al., the collum angle affects the torque of the teeth.[9] Deviations in crown-root angulation and axial inclination magnitudes can also affect the force vector by changing the location of the rotation center during orthodontic movement in the vertical plane, such as intrusion and extrusion.[10] Furthermore, orthodontic treatment involving teeth with different root angles may result in deviations from the expected axial loads during intrusion and extrusion mechanics. [8]

Previous research has indicated that genetic and environmental factors contribute to variations in the collum angle.[11,12] Arvind and Felicita explored the relationship between the collum angle and lip position in individuals with Class II malocclusions, reporting that the collum angle increased when the lower lip contacted the middle third of the central incisor and decreased when it contacted the incisal third.[11] Another study investigated the correlation between the inclination of mandibular anterior teeth and the curve of Spee, revealing that a 0.5 mm increase in the curve of Spee corresponded to a 3.78° increase in the collum angle of the lower central incisor.[12] Assessing the collum angle is essential in orthodontic treatment planning, as it helps clinicians determine the appropriate bracket torque prescription and achieve optimal occlusion and tooth inclinations. While most studies on the collum angle have focused on patients with Class I and Class II Division 1 and Division 2 malocclusions, research on Class III malocclusion remains insufficient.[13,14]

In Class III malocclusions, increased collum angle during orthodontic treatment may lead to complications such as dehiscence and fenestration, as the roots become labially positioned. Identifying individual differences in collum angle in Class III individuals will help to ensure that bracket selection and torque values are adjusted individually, thus achieving safer and more effective treatment results. In this context, the present study aimed to conduct a thorough comparison of the crown-root angles of maxillary incisors in individuals with skeletal Class I or Class III malocclusions, using lateral cephalometric radiographs. The null hypothesis (H_0) posits that there is no significant difference in the collum angle of the maxillary central incisors between individuals with skeletal class I and class III malocclusions. The alternative hypothesis (H_1) assumes that individuals with skeletal Class III malocclusion have a significantly greater collum angle of the maxillary central incisors than those with skeletal Class I malocclusion.

MATERIAL AND METHODS

Ethical Considerations and Sample Size Determination

Ethics committee approval (decision number 2021/354) was obtained before the study by Gülhane Scientific Research Ethics Committee. The study was designed retrospectively, with the effect size determined by Delivanis and Kuftinec (d=1.1043153).[15] G*Power software (version 3.1, University of Kiel, Germany) was used for power analysis with an effect size of d= 0.8876863, 95% power, and Mann-Whitney U analysis in paired groups with 5% α error and 1/1 distribution rate, the minimum required sample size was calculated as 60, with 30 patients for each group. In this study, 120 samples were used to obtain more reliable test results and maximum test power, given the amount of data available.

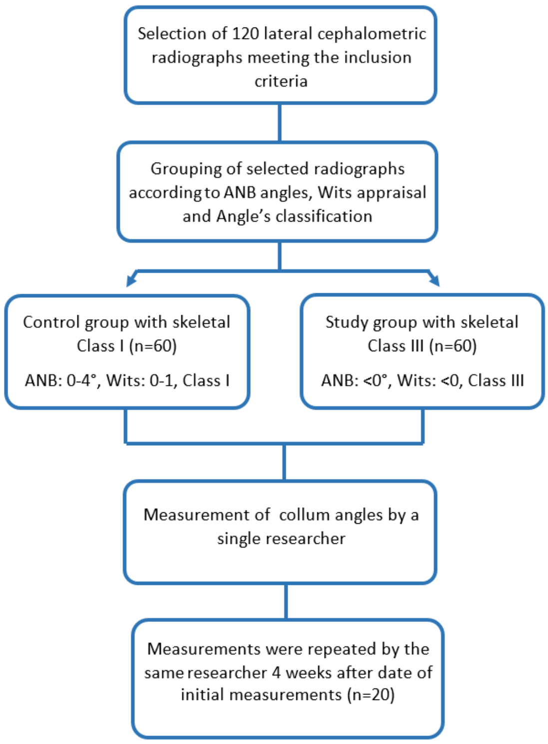
Determination of Study and Control Groups

Lateral cephalometric radiographs taken in the native head position were used to diagnose malocclusion in patients who presented for treatment at the orthodontic clinic of our faculty between 2010 and 2020. The study focused on the analysis of lateral cephalometric radiographs of patients with intact maxillary central teeth and no history of missing teeth, structural defects, significant morphological changes or trauma. Patients with craniofacial disorders, cleft lip and/or palate, severe facial asymmetry, or a history of previous orthodontic treatment were excluded from the study. Additionally, radiographs with poor image quality or those in which the central maxillary root or crown was not visible due to impaction, supernumerary teeth, or the presence of deciduous teeth were omitted. Two researchers with different levels of experience independently selected lateral cephalometric radiographs that met the inclusion criteria. The samples were categorized into study and control groups based on Angle's classification, ANB angles, and Wits appraisal. The ANB angle is formed by the intersection of the nasion-A and nasion-B lines. As a parameter of the Steiner analysis, the ANB angle shows the position of the maxillary and mandibular apical bases relative to each other.[16,17] The study group consisted of 60 patients with skeletal Class III malocclusion, characterized by ANB angles and Wits appraisal values below 0, along with Class III molar and incisor relationships. The control group included 60 patients with skeletal Class I malocclusion, defined by ANB angles between 0° and 4°, Wits appraisal values of 0–1, and Class I molar and incisor relationships (Figure 1). In total, the study analyzed 120 lateral cephalometric radiographs of Caucasian individuals. Table 1 shows the cephalometric parameters used in the study.

Table 1. The definitions of the orthodontic cephalometric parameters.

Parameters	Definitions
SNA (°)	The angle is formed by the interception of sella-nasion and nasion-A lines.
SNB (°)	The angle is formed by the interception of sella-nasion and nasion-B lines.
ANB (°)	The angle is formed by the interception of the nasion-A and nasion-B lines.
Witts (mm)	The distance between the points AO and BO formed by the intersections of the lines perpendicular to the occlusal plane from points A and B
1/NA (°)	The angle of the long axis of the upper centre incisor with the NA line
1-NA (mm)	It is the distance measured from the incisal between the long axis of the upper central incisor and the NA line.
SN-GoGn (°)	The angle is defined as the measure of the angular relationship between the SN line and the GoGn line.
Y-Axis (°)	It is the angle between the Y axis and the Frankfurt Horizontal plane.
SN-Occ (°)	The angle between the SN line and the occlusal plane
Collum Angle (°)	The angle between the long axes of the root and crown of the tooth

Figure 1: Flow chart of the study

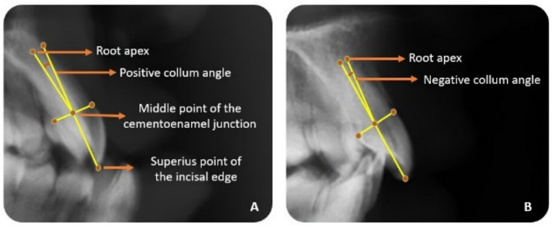


Definition and Measurement of the Collum Angle

The collum angle was assessed using the Collum Angle Measurement Method developed by Delivanis and Kuftinec.[12] This method involved marking three key points on the maxillary central incisors in 120 lateral cephalograms: the midpoint of the cementoenamel junction between the labial and palatal surfaces, the radiographic apex, and the incisal edge of the crown. Two researchers with different levels of experience performed the markings.

The root's longitudinal axis was defined as the line passing through the radiographic apex and the midpoint of the cementoenamel junction, while the crown's longitudinal axis was determined as the line passing through the superior point of the incisal edge and the midpoint of the cementoenamel junction. The collum angle was then measured as the angle between these two longitudinal axes. The collum angle was defined as positive when the longitudinal axis of the root was located palatal to the longitudinal axis of the crown, indicating a palatal inclination of the root relative to the crown. Conversely, a negative collum angle was recorded when the root axis was positioned labial to the crown axis, reflecting a labial deviation. A neutral collum angle was defined when both axes overlapped, indicating no angular discrepancy between the crown and root alignment (Figure 2). The measurements were performed by a single researcher who utilised Digimizer Image Analysis Software, version 4.6.1 (MedCalc Software, Belgium), for the identification of anatomical landmarks and the calculation of angle measurements.

Figure 2: Determination of the collum angle of maxillary incisor.
A. Positive collum angle in the maxillary incisor of a Class III individual
B. Negative collum angle in the maxillary incisor of a Class I individual



Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA), with the level of statistical significance set at $p < 0.05$. The Kolmogorov-Smirnov test was employed to assess the normality of the data distribution. According to the Kolmogorov-Smirnov normality test results, the data did not show a normal distribution. Given that the data did not follow a normal distribution, intergroup comparisons were conducted using the Mann-Whitney U test. Descriptive statistics for the examined parameters were reported as minimum, maximum, mean, and standard deviation values. Inter-observer consistency was evaluated using the intraclass correlation coefficient (ICC). To assess measurement reliability, the same researcher repeated the measurements in both the control and study groups on 20 randomly selected samples from each group four weeks after the initial assessments.

RESULTS

Table 2 presents the age and gender characteristics, while Table 3 shows the descriptive statistics of the analysed cephalometric parameters. The mean age of the 33 female and 27 male patients in the study group was 13.59 ± 3.53, while the mean age of the 32 female and 28 male patients in the control group was 14.26 ± 2.60 (Table 2). As illustrated in Table 3, the mean and standard deviation of SNA, SNB, ANB, 1/NA°, SN-GoGn, Y-axis, collum angles of the samples with 1-NA (mm), and Wits appraisal are presented. The investigation into maxillary central inclination in the study groups, based on 1/NA° and 1-NA (mm), demonstrated that the maxillary central teeth of the study group exhibited a greater proclination compared to those of the control group. Additionally, they exhibited some characteristics of true class III malocclusion, as indicated by other cephalometric indicators.[18,19]

Table 2: Age and gender distribution of the samples

Characteristics		Study Group (n=60) Mean (±SD)	Control Group (n=60) Mean (±SD)
Age (Months)		13.59 (±3.53)	14.26 (±2.60)
		Study Group %(n)	**Control Group %(n)**
Gender	Female	55.0 (33)	53.3 (32)
	Male	45.0 (27)	46.7 (28)

Table 3: Descriptive statistics of the cephalometric analyses parameters.

	Study Group (n=60)				Control Group (n=60)				
	Mean±SD	**Median**	**Min**	**Max**	**Mean±SD**	**Median**	**Min**	**Max**	***P***
SNA (°)	79±3.34	80	71	87	79.6±3.18	80	73	86	0.311
SNB (°)	81.6±3.75	81.5	75	96	77.3±3.12	77	70	83	0.003*
ANB (°)	-2.68±2.26	-2	-10	0	2.37±1.1	2	0	4	<.001*
Wits (mm)	-6.72±3.44	-6	-17	-1	0.05±0.87	0	-1	1	<.001*
1/NA (°)	27.4±6.03	27	16	47	22.3±6.18	22	8	40	<.001*
1-NA (mm)	5.27±2.29	5	1	11	4.35±2.51	4	0	12	0.024*
SN-GoGn (°)	32.6±5.52	32.5	23	43	33±5.15	32.5	20	42	0.657
Y-Axis (°)	57.6±4.04	58	48	64	59.5±6.87	60	14	68	0.002*
SN- Occ (°)	15.2±4.87	15.5	0	26	16.9±6.3	16	8	56	0.256
Collum Angle (°)	4.05±3.98	4.64	-	9.61	-0.44±5.24	0.645	-9.7	9.65	<.001*

SD: standard deviation; Min: minimum; Max: maximum. *There is a statistically significant difference at P<0.05.

Table 4: Comparison of the collum angle between study and control groups.

	Study Group (n=60)		Control Group (n=60)		
Measurement	**Mean±SD**	**Median**	**Mean±SD**	**Median**	**p***
Collum Angle (°)	4.05±3.98	4.64	-0.44±5.24	0.645	**<0.001**

SD: standard deviation; *$p < 0.05$.*

As demonstrated by the results of the Mann-Whitney U-test, the mean value of collum angles in the study group (4.05±3.98) was found to be significantly higher in comparison to the control group (-0.44±5.24), with a resultant statistical significance of p <0.001, as illustrated in Table 4. Inter-observer consistency was assessed using the intraclass correlation coefficient (ICC), yielding values of 0.89 and 0.99 for the study and control groups, respectively. Additionally, intraobserver reliability was evaluated using ICC analysis, which demonstrated a strong positive correlation.

DISCUSSION

This study aimed to assess differences in the collum angle of the maxillary central incisors in individuals with skeletal Class I and Class III malocclusions, with the objective of improving orthodontic treatment planning and bracket selection. The results indicated a significantly greater collum angle in individuals with Class III malocclusion, leading to the rejection of the null hypothesis. This finding is particularly relevant for clinical orthodontics, where small anatomical deviations can influence both treatment planning and the biological response of dental and periodontal tissues during orthodontic movement.

Lateral cephalometric radiographs remain essential in orthodontic diagnostics due to their accessibility, cost-effectiveness, and proven value in the evaluation of skeletal and dental relationships. Although cone beam computed tomography (CBCT) offers advanced three-dimensional analysis capabilities, its routine use is restricted by concerns regarding radiation exposure, especially in growing patients.[20,21] CBCT also requires additional processing to isolate and measure specific anatomical angles such as the collum angle, which further justifies the use of standardised lateral cephalograms in studies like ours.[22,23] These imaging modalities, while two-dimensional, provide sufficient accuracy for evaluating sagittal and angular tooth positions when interpreted with appropriate landmarks.[24]

Bracket prescriptions must be tailored to tooth morphology. Systems like Roth and MBT integrate specific torque and angulation values to optimise treatment outcomes and minimise the need for wire adjustments.[25-28] In patients with skeletal Class III malocclusion, the increased proclination of upper central incisors and the associated rise in collum angle may challenge standard bracket prescriptions. For example, the MBT system incorporates enhanced palatal root torque in upper anterior brackets, which can help counteract the labial crown angulation that naturally occurs with a higher collum angle.[29,30] Understanding these anatomical deviations is vital for selecting or modifying bracket systems to ensure appropriate root positioning and force distribution. Tooth morphology and incisor inclination influence both esthetics and treatment mechanics. The increased collum angle in Class III patients may restrict the amount of lingual root torque achievable during orthodontic movement, potentially resulting in compromised axial inclination or increased risk of labial root dehiscence. This anatomical feature should therefore be evaluated when making decisions regarding extraction, incisor retraction, or the application of torque. Without accounting for these variations, orthodontic forces may become concentrated in areas of reduced alveolar bone support, potentially leading to undesirable outcomes such as root resorption or soft tissue recession.[8,31,32]

Several factors contribute to the development of collum angle, including lip pressure, muscular activity, genetic influences, and the timing of tooth eruption. In Class II Division 2 malocclusions, for example, hyperactivity of the lower lip during the eruption of maxillary incisors has been shown to increase the palatal inclination of crowns, leading to a higher collum angle.[11,33-36] Similarly, genetic predispositions and functional pressures from surrounding soft tissues may account for the variation in collum angle observed across different malocclusion types and ethnic groups. The morphological adaptations of maxillary central incisors in response to environmental or hereditary factors should not be overlooked when formulating treatment mechanics.

Our findings align with those of Harris et al., who observed lower collum angles in Class I cases.[37] They suggested that eruption timing and spatial constraints may cause root-crown axis discrepancies in Class III individuals, supporting the idea that malocclusion type can influence anatomical development. However, their inclusion of post-treatment cases and classification based on molar relationships differs from the methodology of the present study, which exclusively used untreated patients and skeletal criteria. On the other hand, Ma reported no significant difference between Class I and Class III groups, potentially due to differences in malocclusion severity, sample characteristics, or compensatory dental movements.[3] Ethnic background may influence collum angle variations, although its role is intertwined with multiple factors. Shen et al. observed higher collum angles in an East Asian population, possibly related to regional morphological traits.[4] In our sample of untreated Caucasian individuals, increased collum angles were particularly associated with Class III malocclusion. While population-based differences can provide insights, it is important to interpret them cautiously and consider the broader context of skeletal patterns and eruption dynamics rather than attributing variations solely to ethnicity or genetics.

In camouflage treatment for Class III malocclusion, upper incisor proclination is often employed to mask skeletal discrepancies. However, increased collum angle and reduced labial bone thickness can elevate the risk of dehiscence and fenestration, especially when aggressive torque or bodily movement is applied. Biomechanical considerations should therefore include three-dimensional assessments of alveolar bone volume and anatomical axis alignment. The MBT system, with its enhanced torque prescriptions, can facilitate controlled root movement in such cases, reducing the likelihood of iatrogenic outcomes. Nevertheless, clinicians must remain vigilant and incorporate individualised torque and force systems based on each patient's root morphology.

This study has certain limitations. The exclusion of Class II patients restricts our ability to generalise findings across the full spectrum of sagittal malocclusions. Additionally, the sample was limited to untreated Caucasian individuals from a single institution, which may reduce the external validity of the results. Including subjects from diverse ethnic backgrounds, malocclusion classes, and age groups could provide further insight into the developmental and morphological influences on collum angle. Future studies may also consider three-dimensional analysis to validate and expand upon the two-dimensional findings presented here.

In summary, this study highlights the clinical importance of evaluating the collum angle in orthodontic diagnostics and treatment planning, particularly for individuals with Class III malocclusion. Recognising anatomical differences in crown-root angulation can aid in developing personalised and biologically appropriate strategies, ultimately improving treatment safety, esthetics, and long-term stability. The integration of morphological assessment into routine orthodontic protocols represents an important step toward achieving more predictable and individualised outcomes.

CONCLUSION

This study demonstrated that individuals with skeletal Class III malocclusion exhibit a significantly greater collum angle in the maxillary central incisors compared to those with Class I malocclusion. An increased collum angle may result in a relatively more palatinal root and a more labial crown position. This situation is especially important in Class III cases in terms of considering the buccal bone thickness in the creation of the mechanics applied in preparation for camouflage or orthognathic surgery. Clinicians are advised to consider customized bracket prescriptions and biomechanical strategies that accommodate anatomical root-crown discrepancies to improve treatment safety and outcomes.

Ethical Approval

All the procedures of this research protocol adhered to the Declaration of Helsinki and were approved by University of Health Sciences Gülhane Scientific Research Ethics Committee. (2021/16-354)

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Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: ŞG, EY, KGT, Data collection and processing: ŞG,EY,KGT,SG, Analysis and interpretation: KGT, GSD, Literature review: ŞG,EY, GSD, Writing: ŞG,EY.

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