ORIGINAL ARTICLE

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The Effect of 3D Models Created with Augmented Reality on Diagnosis and Orthopedic Resident Education of Tibial Plateau Fractures

Artırılmış Gerçeklik ile Oluşturulan 3D Modellerin Tibia Plato Kırıklarının Tanı ve Ortopedi Asistan Eğitimi Üzerindeki Etkisi

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ABSTRACT

Aim: Computed tomography (CT) is the gold standard imaging for the diagnosis of intra-articular fractures such as tibial plateau fractures that may show different fracture patterns. The aim of the study was to compare the diagnostic accuracy (DA) and response time (RT) between new technologies such as augmented reality (AR), CT and 3-dimensional CT (3D-CT): in the classification of tibial plateau fractures in orthopedic assistant education and daily practice.

Materials and Methods: The orthopedic residents receiving training in our clinic were divided into 2 groups according to their training period: 2.5 years and below and above 2.5 years. Nine separate tibial plateau fractures were selected according to the Schatzker and Luo classification. DA, RT and method confidence of each resident were measured with a double-blind questionnaire.

Results: DA averages of the participants were examined, and it was seen that DA for CT was 67.8%, for 3D-CT, it was 52.9% and for AR, it was 64%. When the correct RT were examined, the average RT-AR was 49.9 (±11.8) sec, RT-3D 58 (±16.7) sec and RT-CT 80 (±23.8) sec. When the RT values of the AR models were examined, the average RT-AR was 41.6 (±8.49) sec in the SEN group and 58.2 (±8.42) sec in the JUN RT-AR.

Conclusion: In this study, it was shown that the DA of AR in the diagnosis and treatment planning of tibial plateau fractures was similar to conventional CT and superior to 3D-CT. The DA rate of novice assistants was lower and the correct diagnosis time was longer, and similar results were obtained in all 3 groups.

Keywords: Tibia fracture, augmented reality, orthopaedic residents, computed tomography

ÖZ

Amaç: Bilgisayarlı tomografi (BT), tibial plato kırıkları gibi intraartiküler kırıkların tanısında altın standart görüntüleme yöntemidir ve farklı kırık paternleri gösterebilir. Çalışmanın amacı, ortopedi asistan eğitimi ve günlük uygulamada tibial plato kırıklarının sınıflandırılmasında artırılmış gerçeklik (AR), BT ve 3 boyutlu BT (3D-BT) gibi yeni teknolojilerin tanısal doğruluk (DA) ve yanıt süresi (RT) açısından karşılaştırılmasıdır.

Gereç ve Yöntem: Kliniğimizde eğitim gören ortopedi asistanları, eğitim sürelerine göre 2,5 yıl ve altı ile 2,5 yıl ve üstü olmak üzere 2 gruba ayrılmıştır. Schatzker ve Luo sınıflandırmasına göre 9 ayrı tibial plato kırığı seçilmiştir. Her asistanın DA, RT ve yöntem güvenilirliği çift kör bir anket ile ölçülmüştür.

Bulgular: Katılımcıların DA ortalamaları incelendi ve BT için %67,8, 3D-BT için %52,9 ve AR için %64 olduğu görüldü. Doğru yanıt süreleri incelendiğinde; ortalama RT-AR 49,9 (±11,8) saniye, RT-3D 58 (±16,7) saniye ve RT-BT 80 (±23,8) saniye olarak bulunmuştur. AR modellerinin RT değerleri incelendiğinde; ortalama RT-AR, SEN grubunda 41,6 (±8,49) saniye ve JUN RT-AR'da 58,2 (±8,42) saniye olmuştur.

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Sonuç: Bu çalışmada, tibial plato kırıklarının tanı ve tedavi planlamasında AR'nin DA konvansiyonel BT ile benzer ve 3D-BT'den üstün olduğu gösterilmiştir. Acemi asistanların DA oranı daha düşük ve doğru tanı süresi daha uzundu ve 3 grubun tümünde benzer bulgular elde edilmiştir.

Anahtar Kelimeler: Tibia kırığı, artırılmış gerçeklik, ortopedi asistanları, bilgisayarlı tomografi

INTRODUCTION

Tibial plateau fractures constitute 1-2% of the fractures seen in the extremities. These fractures occur in patients aged under 65 with high-energy trauma and in those over 65 with low-energy trauma[1]. Schatzker and Luo classifications are widely used today for the diagnosis and treatment of these fractures, which can be treated with surgical or conservative methods[2,3].

Anteroposterior (AP) and lateral radiographs alone are not sufficient to confirm the diagnosis and to plan surgery in tibial plateau fractures that are intra-articular and can show different fracture types. Computed tomography (CT) is the gold standard imaging for the diagnosis of intra-articular fractures that can show different fracture patterns, such as tibial plateau fractures[4]. Today, 3-dimensional CT (3D-CT) images that combine 2-D images in axial, sagittal and coronal planes are frequently used. With this imaging, which provides visual integrity, diagnosis and treatment planning in multi-part and complicated fractures can be made much more accurately and quickly.

In the last few years, virtual reality applications, which started with virtual reality glasses, have begun to be used in surgical planning and diagnosis with 3D imaging[5,6]. Augmented reality (AR) allows viewing images in a real-world environment[7,8]. Thanks to these developments, more understandable and easily accessible AR images can be utilized in student education. Thus, students can receive education with 3D images instead of the monotonous 2D images they only see in books, and they can learn faster and with more fun by keeping their excitement fresh[9].

Trauma is unpredictable by nature, and diagnosis and treatment may vary depending on the trauma energy and type of trauma for many different fracture types. When resident physicians see a fracture, ways are sought to facilitate planning its diagnosis and treatment and the ways to obtain the necessary information.

The aim of our study was to compare the diagnostic accuracy (DA) (and correct diagnosis speed between new technologies, AR, and the gold standard conventional CT and 3D-CT in the classification of tibial plateau fractures in orthopedic assistant training and daily practice. In addition, the relationship between the duration of orthopedics and traumatology training and the level of trust in these new technologies was also investigated.

MATERIALS AND METHODS

Ethics committee approval was received from the University of Health Sciences Türkiye, Ümraniye Training and Research Hospital with (decision no: E-54132726-000-271399262, date: 13.03.2025). The study was conducted in accordance with the principles of the Declaration of Helsinki.

In our hospital, 20 resident physicians who continue their postgraduate education in orthopedics and traumatology were divided into 2 groups as 2.5 years and below junior (JUN) and 2.5 years and above senior (SEN).

Patients between the ages of 18-65 who applied to our hospital in 2024 and were diagnosed with tibial plateau fractures were included in the study. Patients with pathological fractures, multiple traumas, pseudoarthrosis cases and patients without 3D-CT imaging were excluded from the study. Informed consent was obtained from the participants included in the study.

The tibial plateau fractures used in the study were selected and classified by 2 SEN surgeons with over 5 years of experience in the field of Orthopedics and Traumatology. Based on the Schatzker and Luo classifications, 9 different fracture models were numbered in 3 groups as conventional CT, 3D-CT and AR images. The final evaluation of the fracture type was completed in open surgery.

In conventional CT images, axial, coronal and sagittal images in the bone window were selected. DICOM format images were uploaded to the AR method "Object viewer'' application via the website. The images were uploaded to the cube as "format. stl'' files via the ''object viewer'' application downloaded from the application website (MergeEDU©, MergeLabsInc., SanAntonio, TX, USA). The cube was shown to the camera of a tablet. Thus, a 3D image that can be rotated in every axis was achieved on the tablet screen (Figure 1).

In addition to the two SEN surgeons who selected the fracture types, a third surgeon who was blind to the fracture types was shown the fracture patterns in a mixed order and only numbered to 20 orthopedic residents. The third surgeon had no previous involvement in the fracture selections and was the only one present during the survey, reducing the possibility of bias. They were asked to mark their answers using the prepared survey form and multiple-choice answers. Each candidate filled out the survey individually, and one of the study directors was with them during this time. The time it took them to reach the answer was recorded in seconds by the directors using a stopwatch.

They were asked to mark the method that came first when they ranked the three methods from the most reliable to the least reliable in terms of helping with diagnosis. Seven questions were asked as a survey about whether this method alone was sufficient for diagnosis, whether they would continue to use it in daily practice, and their views on the contribution of the AR method to resident education. The options given to the question of which method they felt most reliable were "Conventional CT", "AR", and "3D-CT". The answers to the other 6 questions were; "Absolutely yes", "Yes", "Undecided", and "No" (Figure 2).

The fractures were selected according to the Schatzker and Luo classifications, which are the two most commonly used classifications in the diagnosis and treatment of tibial plateau fractures. Nine different fracture patterns were selected, including Schatzker type "1,2,3,4,5 and 6" and Luo "medial, lateral and posterior column" types. The resident physicians who participated in the test were shown how to use the AR application. None of the participants had ever encountered AR technology before. Data: DA was recorded as "percentage", response time (RT) as "seconds" and survey responses were evaluated by groups and overall.

Statistical Analysis

Statistical analysis of the study was performed using SPSS program, version 29.0 (SPSS, Inc, an IBM Company, Chicago, IL). The conformity of the values to normal distribution was assessed using the Shapiro-Wilk test. Variables without normal distribution were analyzed using the Mann-Whitney U test. Independent Student's t-tests were used to compare variables with normal distribution. Categorical data were statistically analyzed using the chi-square test or Fisher's exact test. The statistical significance level (p) was determined as 0.05.

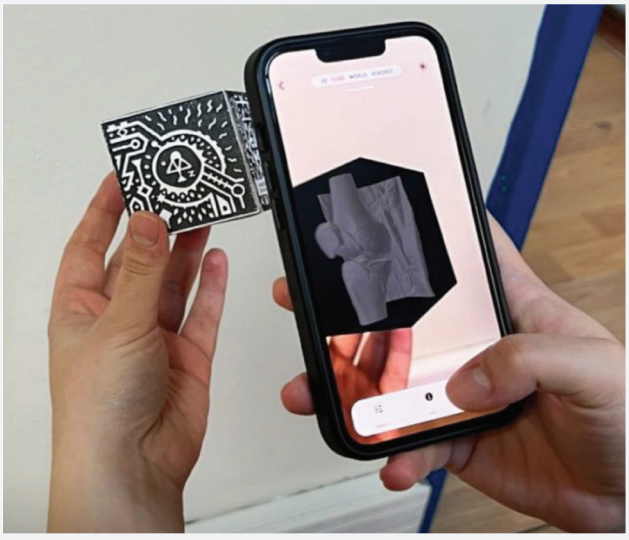

Figure 1. Screenshot of the AR model in the "Object Viewer" app

AR: Augmented reality

RESULTS

In our institution, 20 resident physicians who continue their postgraduate Orthopedics and Traumatology education were divided into two groups according to their education period as 2.5 years and below JUN (n: 10) and above 2.5 years SEN (n: 10). Conventional CT, 3D-CT and AR images of 9 different fractures that fit the Schatzker and Luo classification were given to the resident physicians separately in accordance with the double-blind study model and they were asked to answer.

When DA means were examined, it was seen that it was 67.8% for conventional CT, 52.9% for 3D-CT and 64% for AR. When the relationship between DA rates was examined, no statistically significant difference was observed between conventional CT and AR (p: 0.243). P<0.05 was observed between conventional CT and 3D-CT and between AR and 3D-CT. Accordingly, AR and conventional CT were found to be statistically superior to 3D-CT in terms of DA. However, no statistically significant difference was observed between conventional CT and AR.

When DA values were examined according to SEN and JUN groups; while the average DA-AR in the SEN group was 79%, it was found to be 49% in JUN DA-AR (Figure 3). In the SEN group, the average DA-3D was 66%, JUN DA-3D was 40%, and the average DA-CT in the SEN group was 83%, while it was found to be 52% in JUN DA-CT. Between the SEN and JUN groups, the p value for DA-CT, DA-3D and DA-AR was below 0.05, and it was seen that the correct response rate of the SEN group was higher than the JUN group.

When the correct RT were examined; mean RT-AR was 49.9 (±11.8) sec, RT-3D was 58 (±16.7) sec, and RT-CT was 80 (±23.8) sec. When the relationship between the correct RT of the groups was examined, the conventional CT group had the longest RT, and this difference was statistically significant (Table 1).

When the RT values were examined according to the SEN and JUN groups; in the SEN group, mean RT-AR was 41.6 (±8.49) sec, and in the JUN RT-AR, it was 58.2(±8.42) sec (Figure 4). In the SEN group, mean RT-3D was 46.2 (±11.0) sec, in the JUN RT-3D, it was 69.9 (±12.3) sec, and in the SEN group, mean RT-CT was 62.7 (±11.8) sec, and in the JUN RT-CT, it was 97.2 (±19.9) sec. The p-value was less than 0.05 in all 3 groups, and the mean correct RT of the SEN group had significantly faster RT than the JUN group. According to the answers given by the resident physicians participating in the study to the question of which method they find more reliable (Figure 5); according to the diagnostic method confidence ranking prepared according to the Likert scale, the JUN group chose AR first and found it more reliable, while the SEN group found conventional CT more reliable.

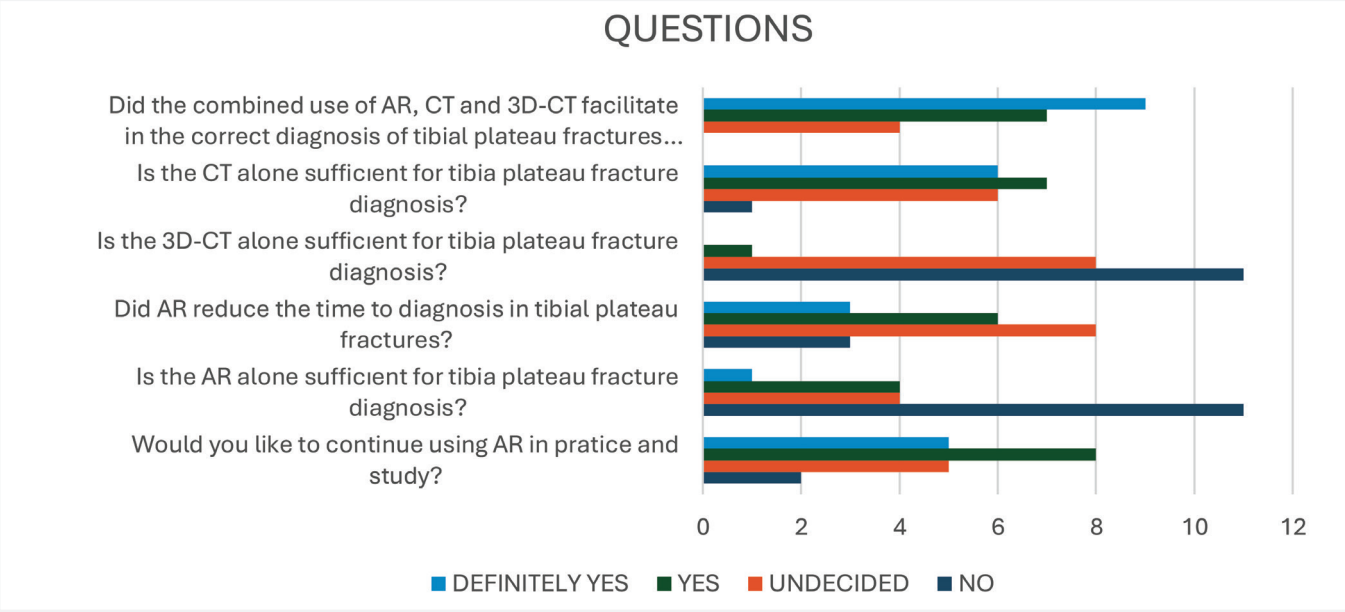

Figure 2. Questions asked to the participants

3D-CT: 3-dimensional computed tomography, AR: Augmented reality, CT: Computed tomography

Table 1. Summarization of DA and RT results for AR, 3D-CT and conventional CT between the JUN and SEN groups

	SEN	JUN
DA-AR	79%	49%
DA-3D-CT	66%	40%
DA-CT	83%	52%
RT-AR (sec)	41.6	58.2
RT-3D-CT (sec)	46.2	69.9
RT-CT (sec)	62.7	83.5

3D-CT: 3-dimensional computed tomography, AR: Augmented reality, DA: Diagnosis accuracy, JUN: Junior residents, Sec: Second, SEN: Senior residents, RT: Reponse time

DISCUSSION

Conventional CT imaging is superior to AP and lateral bidirectional radiography in the diagnosis and treatment of complex intra-articular fractures with 3 different image planes in axial, coronal and sagittal planes[10]. With the development of technology, 3D images have been developed from conventional CT images, and it has been proven that diagnosis and treatment planning in complex fractures can be made much faster and more accurately[11].

Tibial plateau fractures are also fractures where different fracture patterns and surgical planning change according to the fracture pattern[11,12]. Therefore, speed and accuracy in diagnosis are necessary for successful surgical results.

In recent years, the emergence of new technologies, 3D imaging and AR, has become increasingly important in student learning and practice[13]. Plates and cutting guides produced with 3D printers and imaging have been described in various studies, and articles showing technological developments not only in diagnosis but also in treatment are available in the literature[14,15].

Colcuc et al.[16] compared AR and conventional CT in surgical planning of tibial plateau fractures and although the planning time was longer in the AR group, the planned operation time was lower. In our study, we investigated the effect of AR on diagnosis and education. As a result, similar results were obtained with the literature.

Shen et al.[17] divided the patients into 2 groups in 42 complex tibial plateau fracture cases and performed the diagnosis in one group with conventional CT and in the other group with 3D-CT. As a result, the operation time, bleeding amount and fluoroscopy time were found to be significantly lower in the 3D-CT group. In our study, in accordance with the literature, the correct diagnosis time was found to be significantly lower in the 3D-CT group together with the AR group, but in terms of DA, conventional CT was found to be higher.

Montemagno et al.[18] compared AR, 3D printed models and conventional CT in the diagnosis and resident training of acetabular fractures. They divided 20 residents into 2 groups according to their education period and compared their correct diagnosis rate, diagnosis time and confidence in the methods of 5 different acetabular fractures. When the DA

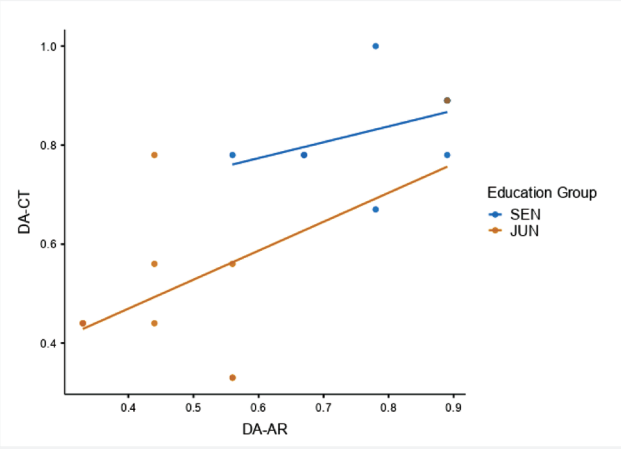

Figure 3. Scatter plot comparing diagnostic accuracy between JUN and SEN groups for conventional CT, 3D-CT, and AR

3D-CT: 3-dimensional computed tomography, JUN: Junior residents, SEN: Senior residents, AR: Augmented reality, DA: Diagnosis accuracy

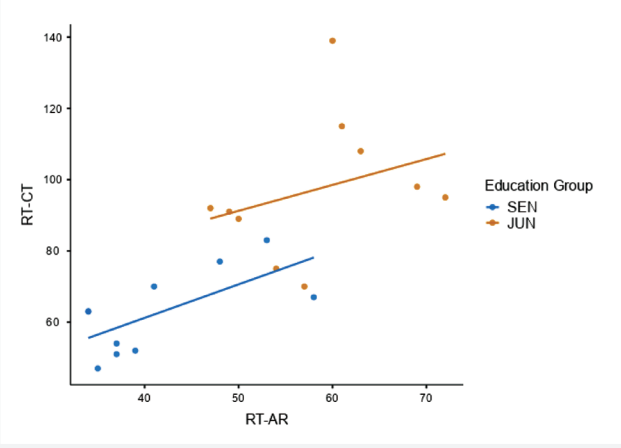

Figure 4. Scatter plot of education groups' response time between JUN and SEN groups for conventional CT, 3D-CT, and AR

3D-CT: 3-dimensional computed tomography, JUN: Junior residents, SEN: Senior residents, AR: Augmented reality, RT: Response time

rates were examined, AR and conventional CT were found to be better than 3D printed models. In our study, in accordance with the literature, the highest DA was observed in AR, which was close to conventional CT, and no statistically significant difference was observed between them. When the seniority period was examined, no difference was observed between the SEN and JUN groups in the AR group, and when the other groups and the SEN group were examined in general, the correct response rate was statistically higher[18]. In our study,

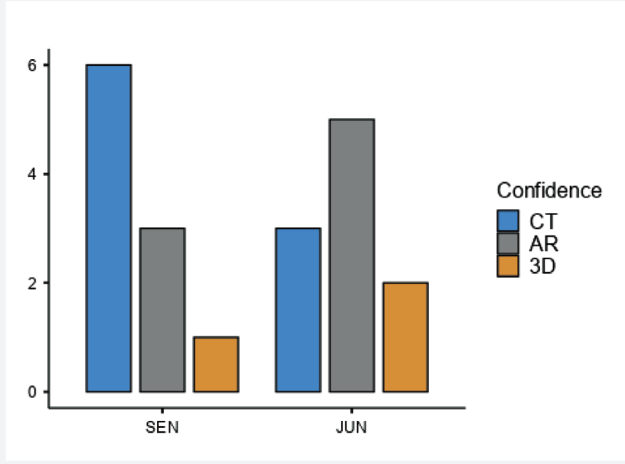

Figure 5. Confidence in diagnostic methods between JUN and SEN groups for conventional CT, 3D-CT, and AR

3D-CT: 3-dimensional computed tomography, JUN: Junior residents, SEN: Senior residents, AR: Augmented reality

all groups and the SEN group in general had a higher correct response rate, and these results were found to be consistent with the literature.

When the correct diagnosis time was examined, Montemagno et al.[18] found the diagnosis time to be shorter in the AR group compared to conventional CT. In their study, the diagnosis time of conventional CT was found to be higher in the SEN group. In our study, when conventional CT was used, the correct diagnosis time was generally found to be longer than in the AR and 3D-CT groups, and the SEN group made a statistically faster diagnosis than the JUN group.

In the Montemagno et al.[18] study, the JUN group found AR safer and the most reliable compared to the SEN group, and both groups placed AR ahead of conventional CT in terms of reliability. In our study, the JUN group found AR more reliable, but the SEN group found conventional CT more reliable than AR. We think that this difference is due to the SEN group's conventional CT usage habits for more than 2.5 years.

Montgomery et al.[19] investigated the role of 3D printed models in the diagnosis and treatment of calcaneus complex fractures with 16 residents and 5 specialist orthopedists and found that the correct diagnosis rate and time of residents were lower than those of specialists. However, this difference was observed to be closer in 3D printed models. In our study, the diagnosis time was faster and correct diagnosis rate of the SEN group was higher than the novice group. However, in our study, the novice group positioned AR ahead of 3D models. We assume that this difference is due to the use of 3D-CT images instead of 3D printed models in our study.

When the survey results of the study are examined, 60% of the participants stated that they could use AR again in their

daily practices. However, 55% of the participants stated that AR alone was not sufficient and 20% were undecided. When asked about the contribution of combining 3D imaging with AR to resident education, 80% of the participants answered "Definitely yes and yes". The JUN group has positioned AR ahead of conventional CT in terms of trust.

Study Limitations

In our study, 20 resident physicians working in our clinic were included in the study. However, the small sample size can be considered a limitation of the study. The lack of previous AR experience among the participants may have affected the results. More research and larger scale studies are needed to introduce AR technology to daily joint traumas.

CONCLUSION

In this study, AR's DA was comparable to conventional CT and superior to 3D-CT. When the correct diagnosis time was examined, AR and 3D-CT were found to be lower than conventional CT. The DA rate of novice residents was lower, and the correct diagnosis time was longer, and similar results were obtained in all 3 groups. However, although the difference was closer in AR, the SEN group was found to be statistically superior. Although 50% of JUN participants supporting AR in education, AR is not capable of replacing conventional CT, which is considered the gold standard in the diagnosis of complex tibial plateau fractures, but the existence of developing technology in orthopedics and traumatology resident education is encouraging in diagnosis and learning.

Ethics

Ethics Committee Approval: Ethics committee approval was received from the University of Health Sciences Türkiye, Ümraniye Training and Research Hospital with (decision no: E-54132726-000-271399262, date: 13.03.2025).

Informed Consent: Informed consent was obtained from the participants included in the study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.D., Ö.P., Concept: A.D., Design: A.D., M.G., Data Collection or Processing: A.D., Analysis or Interpretation: A.D., Ö.P., Literature Search: A.D., Ö.P., Writing: A.D., Ö.P.

Conflict of Interest: No conflict of interest was declared by the authors.

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