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ORIGINAL RESEARCH

Reliability, validity and minimal detectable change of the quadriceps angle assessment in patients with knee osteoarthritis

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Abstract

Knee osteoarthritis (OA) is a multifaceted degenerative disease characterized by knee alignment alterations that impact the amplitude of the quadriceps angle (Q-angle). Q-angle is a diagnostic measure of knee alignment, and an indicator of the load distribution of patellofemoral and tibiofemoral joints. However, accurate assessment of this parameter necessitates the implementation of standardized and reliable measures to ensure methodological reproducibility. Thus, this study aimed to examine the concurrent validity, reliability, and minimal detectable change (MDC) of the Q-angle in patients with knee osteoarthritis (OA). The intra-rater and inter-rater reliabilities of each goniometric measurement were determined with the use of intraclass correlations (ICCs). The correlations between goniometric (clinical) and radiography (gold standard) measurements of Q-angle were assessed for concurrent validity. The intra-rater reliabilities of goniometric assessments in the supine and standing positions of the Q-angle were 0.90 and 0.96, respectively. The standard error of measurement (SEM) and minimal detectable change (MDC95) were 1.18 and 3.27 degrees for supine assessment and 0.87 and 2.40 degrees for standing assessment, respectively. The inter-rater reliabilities of goniometric assessments of the supine and standing position of the Q-angle were 0.86 and 0.92, respectively. SEM and MDC95 values were 1.59 and 4.39 degrees for supine assessment and 1.19 and 3.28 degrees for standing assessment, respectively. The radiographic measure showed a strong correlation with supine goniometric assessment ($p<0.05$, r: 0.777) and a significantly excellent correlation with standing goniometric assessment ($p<0.05$, r: 0.878). According to the findings of the current study, the goniometric measurement for the Q-angle is a valid and reliable method in patients with knee OA. Also, our results suggest that the goniometric measurement, as an inexpensive and radiation-free alternative, can be used to assess the Q-angle as accurately as radiography, in clinical practice.

Introduction

Knee osteoarthritis (OA) is a common joint disorder, particularly among elderly people. The disease leads to increased pain, limited range of motion, muscle weakness, degenerative changes of joint structure, and eventually functional disability (Sharma, 2021). Many different risk factors that contribute to knee OA have been suggested. Although aging, obesity, previous knee injury, and repetitive kneeling activities are all associated with knee OA; however, lower extremity malalignment is a key predisposing factor for the initiation and progression of OA (Driban et al., 2020; Lim et al., 2008). Thus, routine and objective monitoring of knee alignment in this population allows clinicians to determine biomechanical changes and to design rehabilitative and preventative interventions for knee OA.

The quadriceps angle (Q-angle), which is formed by the intersection of the lines of the pull of the quadriceps muscle and the patellar tendon, is one of the few measures of knee alignment, and is routinely

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assessed by physiotherapists and orthopedists in clinical settings (Örtqvist et al., 2011; Smith et al., 2008). The malalignment of the knee joint, including genu varus and valgus, namely alteration in Q-angle, directly alters the load distribution and disrupts the quadriceps muscle functioning (Hunter et al., 2009; Lim et al., 2008). Therefore, changes in the Q-angle have been linked to disorders such as knee joint cartilage erosion, femoral internal rotation, and internal tibial torsion. Furthermore, abnormality in the Q-angle leads to the weakening of the quadriceps muscle, which is the primary determinant of knee functions and overall functional level. The aforementioned conditions predispose the knee joint structures to degenerative changes and, eventually, progression of the knee OA (Almeida et al., 2016; Devan et al., 2004). Thus, clinically, determining the Q-angle, which is a significant component of physical examination, assists clinicians in more accurately selecting therapeutic interventions for patients with knee OA (Hunter et al., 2009).

Some techniques are available for measuring the Q-angle, such as radiography, computed tomography, and goniometric measure (Chevidikunnan et al., 2015; Smith et al., 2008). The goniometric measure is a simple, portable, and non-invasive technique to assess Q-angle, not requiring sophisticated radiographic equipment (Chevidikunnan et al., 2015; Merchant et al., 2020; Rahimi et al., 2012). The validity and reliability of the goniometric measure of Q-angle are reported in individuals with various conditions, such as healthy subjects and patients with acute knee pain (Chevidikunnan et al., 2015; Draper et al., 2011; Shultz et al., 2006; Weiss et al., 2013). Nonetheless, according to our best knowledge, no study investigated the validity and reliability of goniometric measure of Q-angle in patients with knee OA in the existing literature, even though it is previously used in numerous studies conducted on knee OA to determine knee alignment (Ekim et al., 2017; Vassão et al., 2020). Therefore, this study aimed to assess the goniometric measure of the Q-angle in patients with knee OA in terms of the intra- and inter-rater reliabilities, and minimal detectable change (MDC), and concurrent validity with the radiographic measure.

Methods

Participants

Fifty-two patients with the diagnosis of knee OA were enrolled in this study. Inclusion criteria were that patients had a diagnosis of knee OA according to the classification criteria of Kellgren and Lawrence, and able to understand the measure instructions, and were 30 years or above. Patients were excluded if they had a history of knee surgery, trauma, and rheumatic disease that may cause secondary knee OA, had a history of an orthopedic or neurological disorder that limited standing and walking ability, had a body-mass index (BMI) of ≥40 kg/m^2 to avoid any problem associated with the identifying of anatomical landmarks. An a priori power analysis indicated that a sample size of 48 subjects was sufficient in the reliability analysis to achieve 0.90 statistical power of intraclass correlations (ICCs) with a lower confidence interval (CI) of ICC=0.70 (Walter et al., 1998).

This study received ethical approval from the Dokuz Eylül University of Medical Ethics Committee (approval number: 2401-GOA). In the current study, informed consent was obtained prior to enrollment from all participants, according to the Declaration of Helsinki.

Procedure

Demographic characteristics of the patients with knee OA were obtained. The clinical assessment of the Q-angle was conducted by two examiners (one physiotherapist and one orthopedist) using a standard long-arm goniometer with one-degree accuracy. They had more than eight years of clinical experience in clinical assessment of patients and in orthopedic rehabilitation. Examiners were blinded to the assessment values that were obtained by the previous examiner. The anatomical landmarks identified before the assessment were erased by the examiner immediately following the assessment to avoid any influence on reliability measurement. The subjects were repositioned in between each assessment.

Goniometric Measure of Q-Angle

The goniometric measures of the Q-angle were performed in two different positions (supine and standing) for all subjects, according to a standardized protocol (Örtqvist et al., 2011). The two assessment methods of the Q-angle were performed in a random order. For the supine position assessment of the Q-angle, patients were placed in the supine position at the examination table with quadriceps relaxed, hip and knee extended, and lower extremity in a neutral position. After the testing position was aligned, the examiner identified the three anatomical landmarks (tibial tuberosity, the center of the patella and anterior superior iliac spine (ASIS)) by using inspection and palpation, and then labeled these landmarks. The goniometer axis was placed over the center of the patella with one arm in the ASIS direction, and the other arm in the tibial tuberosity center direction. For the standing position assessment of the Q-angle, the subjects were then instructed to stand in a comfortable and relaxed position with no obvious contraction of their quadriceps, and with their weight evenly distributed on both lower extremities aligned in a neutral position. The anatomical landmarks were redefined and labeled for this position. Then, the goniometer was repositioned as previously described for the supine position assessment, and the Q-angle was measured.

Patients were assessed twice by two independent investigators (physiotherapist and orthopedist) with an interval of 10 minutes to assess the inter-rater reliability. For intra-rater reliability, patients were measured for the two assessment methods of the Q-angle by the same investigator on two occasions at one-hour intervals. To avoid examiner bias and any possible confounding effect, the examiner was blinded to the other's measurements, the anatomical landmarks were erased immediately following assessments, and distinct forms were used. All assessments were performed in the same clinical setting to eliminate any confounding effect.

Radiographic Measure of Q-Angle

The Q-angle was measured using the full-limb anteroposterior radiograph of the lower extremities, which was taken in a weight-bearing position with full extension knee, relaxed quadriceps muscle, and bare feet aligned in a parallel position (Abdullah & Rajasekaran, 2022). The anatomic landmarks (the tibial tubercle, the midpoint of the patella and the ASIS) were identified on the radiographic image by an independent, experienced and blinded investigator. The intersection of the line connecting the center of the patella and the ASIS with the line connecting the tibial tuberosity and the center of the patella was recorded as the Q-angle.

Statistical Analysis

The data was analyzed using the IBM® SPSS® (ver. 26.0; IBM Corp., Armonk, NY, USA) package program for Windows software. The Kolmogorov-Smirnov normality test was used to determine the distribution of the data. The intra- and inter-rater reliabilities were calculated by ICCs, which determine the internal consistency between two measures. A coefficient value was defined as (<0.5) poor, (0.51 to 0.75) moderate, and (>0.75) excellent (Shrout & Fleiss, 1979). The accuracy of the measurement method was determined by calculating the standard error of measurement (SEM). The minimal detectable changes at the 95% confidence level (MDC_{95}) were calculated using the formula $MDC_{95}=SEM\times1.95\times\sqrt{2}$.

The correlation coefficient between the radiographic and the goniometric assessments was calculated using the Pearson's correlation to determine the concurrent validity of the goniometric Q-angle measurement. The correlation coefficient level was considered unacceptable if the coefficient was less than 0 and 0.49, moderate if it was between 0.50 and 0.69, strong if it was between 0.70–0.79, and excellent if it was between 0.80–1.00 (Lee Rodgers & Nicewander, 1988). A value of $p<0.05$ was set as statistically significant.

Results

No adverse events or complications were developed in participants during tests. Fifty-two patients [female: 46 (%88.5), male: 6 (%11.5)] with knee OA were included in this study. Patients' demographic and clinical characteristics are presented in Table 1.

Table 1
The demographics and characteristics (n=52).

Variables	Mean ± SD
Age	67.63 ± 8.35
Height (cm)	157.36 ± 7.01
Weight (kg)	80.78 ± 13.33
Body mass index (kg/m^2)	32.63 ± 4.90
Radiographic level of OA	**n (%)**
Stage-1	-
Stage-2	-
Stage-3	15 (28.8)
Stage-4	37 (71.2)

SD: Standard deviation; cm: centimeter; kg: kilogram; OA: Osteoarthritis.

Goniometric measures (supine and standing) of the Q-angle showed excellent intra-rater and inter-rater reliabilities. The intra-rater reliabilities of the goniometric Q-angle measurements in supine and standing were 0.90 and 0.96, respectively. The inter-rater reliabilities of the goniometric Q-angle measurements in supine and standing were 0.86 and 0.92, respectively. SEM and MDC_{95} of goniometric measure for both in supine and standing positions ranged from 0.87 to 4.39 degrees (see Table 2).

Table 2
The inter- and intra-examiner reliabilities of Q-angle in patients with knee OA.

Inter-Examiner	Rater 1 (PT)	Rater 2 (OS)	ICC (95% CI)	SEM	MDC_{95}
StQA (deg)	12.40 ± 4.41	12.96 ± 4.21	0.92 (0.86 to 0.95)	1.19	3.28
SuQA (deg)	14.03 ± 4.89	15.13 ± 4.26	0.86 (0.74 to 0.92)	1.59	4.39
Intra-Examiner	First Trial	Second Trial	ICC (95% CI)	SEM	MDC_{95}
StQA (deg)	12.40 ± 4.41	12.34 ± 4.36	0.96 (0.94 to 0.98)	0.87	2.40
SuQA (deg)	14.03 ± 4.89	12.65 ± 3.75	0.90 (0.74 to 0.95)	1.18	3.27

Q-angle: Quadriceps angle; OA: Osteoarthritis; ICC: Intra-class correlation coefficient, CI: confidence interval, SEM: standard error of measurement with a 95% confidence interval, MDC_{95}: Minimal Detectable Change at the 95% confidence level. StQA: Standing Q-Angle measure; SuQA: Supine Q-Angle measure; deg.: degrees, PT: Physiotherapist, OS: Orthopedic surgeon.

Table 3
Correlation between goniometric and radiographic measurement of the Q-angle.

Variables	Radiographic (r)	SuQA (r)
StQA	0.878***	0.895***
SuQA	0.777***	1

**0.01 < p ≤ 0.0;, **0.001 < p ≤ 0.01; ***p ≤ 0.001; r: Pearson's correlation coefficient for results; StQA: Standing Q-Angle measure; SuQA: Supine Q-Angle measure.*

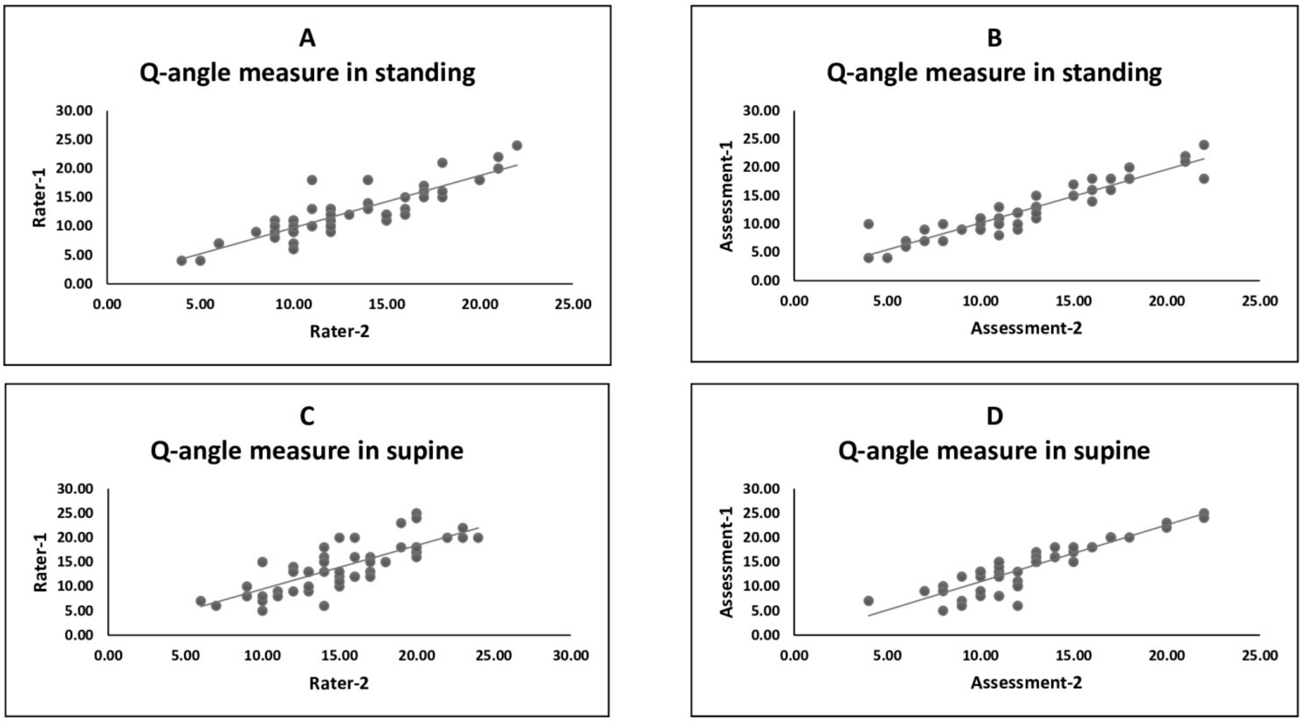

Figure 1: Plots showing the distributions of Q-angle of patients. A, Inter-examiner of Q-angle measure in standing. B, Intra-examiner of Q-angle measure in standing. C, Inter-examiner of Q-angle measure in supine. D, Intra-examiner of Q-angle measure in supine.

The goniometric measure in the supine position showed a strong correlation with the radiographic measure ($p<0.05$; r: 0.777), and the goniometric measure in the standing position showed an excellent correlation with the radiographic measure ($p<0.05$; r: 0.878). The validity and reliability findings of the Q-angle measurement are presented in Table 2 and Table 3. The distribution plot of Q-angle degrees between patients is shown in Figure 1.

Discussion

To the best of our knowledge, this is the first study to determine the intra- and inter-rater reliabilities, concurrent validity, SEM and MDC_{95} for the Q-angle assessment using a goniometer in patients with knee osteoarthritis. Our results showed goniometric measure of the Q-angle is a reliable and valid method in patients with knee OA. Our findings corroborate those of the previous studies that found the ICCs between 0.78 and 0.98 for goniometer-based Q-angle measures in different populations, such as asymptomatic subjects (Draper et al., 2011; Shultz et al., 2006; Weiss et al., 2013). However, these previous studies investigated the reliability of the goniometric measure of Q-angle using different methods (i.e., with a contracted or relaxed quadriceps) and equipment (i.e., short or long arm goniometer). Nevertheless, similar-level ICCs suggest that the goniometric measure is considerably reliable for assessing Q-angle, regardless of these differences.

Some alternative methods, such as radiography, computed tomography, and goniometric measures, are used for measuring Q-angle in the clinical setting (Chevidikunnan et al., 2015; Smith et al., 2008). Radiographic assessment is shown as a "gold standard" in the Q-angle assessment, and a slight angular change in the Q-angle can be detected by this method (Smith et al., 2008). Nonetheless, it is clinically impractical due to its non-portable, expensive, radiation-exposure, and sophisticated nature. Conversely, the goniometric measure is relatively simple, easily accessible, portable, and economical, and it eliminates radiation exposure to subjects in the assessment of Q-angle compared to the x-ray measure (Chevidikunnan et al., 2015; Merchant et al., 2020; Rahimi et al., 2012).

An increased or decreased Q-angle can be predisposing factors for quadriceps dysfunction, knee pain, and the occurrence of patellofemoral or tibiofemoral joint pathology, leading to early knee OA (Ekim et al., 2017; Otsuki et al., 2016; Vassão et al., 2020). The normal range of Q angle is between 10 and 14 degrees in men and 14.5 to 17 degrees in women, while its mean normal value has been reported as 13° in men and 18° in women (Wilson & Kitsell, 2002; Belchior et al., 2006). However, its values of 15° are generally considered normal (Ekim et al., 2017). The lower Q-angle values lead to increased pressure in the medial tibiofemoral compartment, while excessive Q-angles encourage the lateral force on the lateral patellofemoral as well as tibiofemoral compartments (Otsuki et al., 2016). In this context, a possible association between the presence of OA in the affected compartment and the magnitude of the Q-angle can be considered. Namely, varus alignment and medial compartment involvement are expected in patients with low Q-angle, while patients with excessive Q-angle have valgus alignment and lateral compartment involvement. However, in the present study, the Q-angles of a considerable number of patients were close to the normal value. Biomechanical and anthropometric factors, such as quadriceps muscle weakness, articular cartilage thickness, and overweight, could influence knee OA beyond the lower or excessive Q-angle (Kocak et al., 2009; Özgül et al., 2013). This could be a possible explanation of our results. Nonetheless, the malalignments in the lower extremities can be characterized by Q-angle measurement, which could have implications for diagnostic consideration and rehabilitation planning (Ekim et al., 2017). Showing a strong to excellent correlation with the radiographic method, our results verified assessing Q-angle using goniometric measure and its relation with knee disorders in the routine clinical setting.

Some methodological factors could affect the reliability of the goniometric measure of Q-angle, such as using a long-arm or short-arm goniometer in testing (Draper et al., 2011). Correctly identifications of the anatomical landmarks (ASIS, center of patella, tuberoses tibia) are important for accurately assessing the Q-angle. Long-arm goniometers allow the easy identification of these landmarks and the precise overlapping of goniometer arms with lines between the landmarks. On the other hand, a short-arm goniometer, not reaching the ASIS, may affect the accuracy of the Q-angle measure, and its accuracy mostly relies on the assessors' clinical experience and ability to correctly overlap the goniometer arms with the lines between landmarks. Correspondingly, a previous study showed higher ICCs of a long-arm goniometer (ICCs from 0.88 to 0.92) than a short-arm goniometer (ICCs from 0.56 to 0.78) (Draper et al., 2011). These suggest that the long-arm goniometer assessment is more repeatable than the short-arm goniometer assessment. The current study, using a long-arm goniometer in assessment, showed higher ICCs than those of a short-arm goniometer used in the previous study (Draper et al., 2011). Thus, our findings confirm the aforementioned suggestions. Nevertheless, the existing literature showed that the short-arm goniometric assessment of the Q-angle is still acceptable in a clinical setting, and can achieve an excellent reliability level (Draper et al., 2011).

Relative reliability is not enough to determine whether a change is clinically meaningful in a clinical setting. Therefore, absolute (SEM and MDC_{95}) reliability should be defined to interpret a minimal change in the score that is clinically meaningful for patients (de Vet et al., 2006). MDC scores are defined as the small amounts of change that are not due to measurement error. A change exceeding the MDC score represents a clinically meaningful change in the patient's score rather than a measurement error (de

Vet et al., 2006; Eymir et al., 2024). The current study assessed the relative and absolute reliabilities of the goniometric-based Q-angle measure. In the current study, low SEM and MDC_{95} values were found. This may result from the slight variations in the Q-angle degrees from patient to patient in the current study, as shown in Figure 1 (distribution plot). According to our results, the Q-angle measure using a goniometer can be performed with a small measurement error in a clinical setting. A difference greater than MDC values determined in this study can be regarded as a true difference in patients with knee OA. These values are consistent with those of previous studies conducted in different populations (Chevidikunnan et al., 2015; Rahimi et al., 2012).

The Q-angle measure is mostly used by orthopedic teams (i.e., physiotherapists and orthopedists) in pre-intervention diagnosis, treatment planning, and patients' prognosis (Örtqvist et al., 2011; Smith et al., 2008). In such a case, the inter-rater reliability of any measurement method (i.e., Q-angle measure) should be investigated among different healthcare professionals to ascertain its appropriateness if it is used among different clinicians, including physiotherapists and orthopedists. Measurement agreement was reported between a physiotherapist and an orthopedist in previous studies investigating the inter-rater reliability of different assessment methods in other populations (Springer et al., 2000; Springer et al., 2009). Nonetheless, according to our best knowledge, this is the first study that showed the inter-rater reliability of the Q-angle measure using a goniometer among physiotherapists and orthopedists in patients with knee OA. The experience of an examiner may limit the inter-rater agreement of an assessment method (Eymir et al., 2021). In our study, both examiners, physiotherapist and orthopedist, have a broad experience (> 8 years) in orthopedic assessments. This may have aided in identifying the anatomic landmarks for measuring Q-angle and thus provided excellent inter-rater reliability. On the other hand, Q-angle measurement with a goniometer is a more repeatable method as it is simple and easily applicable, requiring any sophisticated equipment (Chevidikunnan et al., 2015; Merchant et al., 2020; Rahimi et al., 2012). These may be possible reasons for the obtained results regarding inter-rater reliability in the current study.

The current study has some limitations. Firstly, the generalizability of our findings to all stages of knee OA is limited, as this study was conducted exclusively on participants with stage 3 and stage 4 knee OA. Secondly, reliability assessments were performed using an along-arm goniometer for the positions adopted during the measures in the current study; therefore, the ICCs obtained cannot be generalized to other assessment positions or imaging techniques. Further studies should be warranted to assess the reliability of other positions or imaging techniques of the Q-angle measure. Besides, in addition to lower or excessive Q-angle values, biomechanical and anthropometric variables, including quadriceps muscle weakness, articular cartilage thickness, and overweight, may lead to lower extremity malalignment and, thus, knee OA. Therefore, future studies are warranted to clarify whether these variables affect the malalignment of the lower extremities in patients with knee OA, as well.

Conclusion

According to the current findings, the Q-angle measure with a long-arm goniometer showed excellent intra- and inter-rater reliabilities in patients with knee OA and a strong to excellent correlation (concurrent validity) with radiographic assessment, a gold standard to assess Q-angle. These results support using a goniometer to assess Q-angle in patients with knee OA. Additionally, physiotherapists and orthopedists can assess interchangeably the Q-angle using a goniometer in patients with knee OA for their diagnosis, prognosis, and treatment planning. Goniometric-based Q-angle measure is a simple, easily accessible, inexpensive, noninvasive, and radiation-free alternative to radiography. These features of the goniometric-based Q-angle measure and our reliability and validity findings provide that this method may be preferred over radiographic measures to quantify changes in Q-angle in patients with knee OA in any clinical setting. Nonetheless, it should be considered that radiographic evaluation is the gold standard in assessing the Q-angle.

Authors' Contribution

Study Design: ME, NDD, BU, ME; Data Collection: ME, NDD; Statistical Analysis: ME, NDD; Manuscript Preparation: ME, NDD; Critical revision of the article: BU, ME

Ethical Approval

Ethics approval for this study was obtained from the Ethics Committee of Dokuz Eylül University (approval number: 2401-GOA). Informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

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Conflict of Interest

All authors declare that they have no conflict of interest.

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