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Ideal Trans-Syndesmotic Angle and Syndesmotic Fixation Axis: MR-Based Cross-Sectional Image Analysis

İdeal Trans-Sindesmotik Açı ve Sindesmotik Fiksasyon Ekseni: MRG Tabanlı Kesitsel Görüntü Analizi

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ABSTRACT

Objectives: Malreduction of the syndesmosis is associated with a poor prognosis; recent studies have focused on identifying intraoperative radiological parameters to prevent this phenomenon. Our study aimed to determine easily applicable and reproducible radiological parameters from magnetic resonance image (MRI)-based cross-sectional image analysis in determining the ideal trans-syndesmotic angle (TSA) and syndesmotic fixation axis (SFA).

Methods: A total of 120 ankle MRI scans without osseous/ligamentous injury were performed blindly by an orthopedist and a radiologist. Talar anterior tangent and talar axis line (TAL) were determined by cross-sectional measurements. The bisector of the anterior and posterior tangents of the syndesmotic joint was determined by the SFA, and the TSA was determined by the intersection of SFA and TAL.

Results: The average TSA was 16–17°. The SFA was between 28%±6.6% and 30%±5.7% anterior to the anteroposterior distance of the tibia laterally and the fibular apex medially. The intraclass correlation coefficient (ICC) range for measurements obtained by observer 1 was 0.600–0.882, while that for those obtained by observer 2 was 0.565-0.904. Interobserver agreement was between 0.589 and 0.901; reliability was acceptable for this new set of measurements.

Conclusion: Our measurements showed that the ideal TSA was between 16° and 17°, and SFA was located between the fibular apex laterally and the anterior third of the tibia medially. All parameters to be applied should be evaluated on a true lateral radiograph of the ankle because rotation will affect the TSA and the appearance of the SFA in a two-dimensional image.

Keywords: Ideal trans-syndesmotic angle; syndesmotic fixation axis; talar axis line; talus anterior tangent

ÖZET

Amaç: Sindesmozun malredüksiyonu kötü prognozla ilişkilidir; son çalışmalar bu fenomeni önlemek için intraoperatif radyolojik parametreleri belirlemeye odaklanmıştır. Çalışmada, ideal trans-sindesmotik açı (TSA) ve sindesmotik fiksasyon ekseninin (SFE) belirlenmesinde manyetik rezonans görüntüleme (MRG) tabanlı kesitsel görüntü analizinden kolay uygulanabilir ve tekrarlanabilir radyolojik parametrelerin belirlemesi amaçlanmıştır.

Yöntem: Osseöz/ligamentöz yaralanması olmayan 120 ayak bileği MRG taraması, bir ortopedist ve bir radyolog tarafından kör olarak yapıldı. Kesitsel ölçümlerle, talus anterior teğeti (TAT) ve talar eksen çizgisi (TEÇ) belirlendi. Sindesmotik eklem anterior ve posterior teğetleri kesişiminin açıortayı SFE, SFE ile TEÇ kesişimi ile de TSA belirlendi.

Bulgular: Ortalama TSA 16°-17° idi. SFE lateralde tibianın ön-arka mesafesinin ve medialde fibula apeksinin önünde %28±%6,6 ve %30±%5,7 arasındaydı. Gözlemci 1 tarafından elde edilen ölçümler için sınıf içi korelasyon katsayısı aralığı 0,600-0,882 iken, gözlemci 2 tarafından elde edilenler için 0,565-0,904 idi. Gözlemciler arası anlaşma 0,589 ile 0,901 arasındaydı; güvenilirlik bu yeni ölçüm seti için kabul edilebilirdi.

Sonuç: Ölçümlerimiz ideal TSA'nın 16° ile 17° arasında olduğunu ve SFE'nin lateralde fibular apeks ile medialde tibianın anterior 1/3'ü arasında yer aldığını gösterdi. Rotasyon TSA'yı ve SFE'nin iki boyutlu görüntüdeki görünümünü etkileyeceğinden, uygulanacak tüm parametreler gerçek bir ayak bileği lateral grafisinde değerlendirilmelidir.

Anahtar sözcükler: İdeal trans-sindesmotik açı; sindesmotik fiksasyon ekseni; talar eksen çizgisi; talus ön tanjantı.

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Syndesmotic joint injuries are found in 23% of all ankle fractures and 5–11% of all ankle sprains.[1] The operative outcomes in these patients are related to achievement and preservation of anatomical reduction of the syndesmotic joint.[2] Many studies have shown that syndesmotic injuries are associated with short- and long-term poor clinical outcomes, emphasizing the need for anatomic reduction to achieve good functional outcomes.[3,4]

One of the most common techniques used in treating syndesmotic injuries is reduction of indirect clamping and then fixation. Appropriate intraoperative fluoroscopic evaluation is the main requirement for achieving sufficient anatomical reduction. However, even when anatomical reduction of the syndesmotic joint is confirmed by intraoperative fluoroscopy, patients may show a high postoperative malreduction rate varying between 16% and 52%.[5,6] Radiographic assessment of the correct trajectory of the syndesmotic fixation axis (SFA) during reduction and fixation is a complex procedure, and off-axis clamping and fixation are the leading causes of high malreduction.[7,8] Although several angles and criteria have been shown to be important in determining the syndesmotic reduction in several studies, none of these studies provided evidence that these multiple measurements/angles were associated with the severity of the injury or provided precise guidance for surgical treatment. Thus, there is a clear need to identify radiological parameters that can be used by surgeons for appropriate intraoperative assessment of syndesmotic joint characteristics.

On the basis of these considerations, recent studies have focused on identifying reproducible radiological parameters to evaluate intraoperative syndesmosis regardless of the type of fixation used. This study aimed to identify easily applicable and reproducible radiological parameters from MR-based cross-sectional image analysis and use them to determine the ideal trans-syndesmotic angle (TSA) and SFA in ankles without syndesmotic injury.

Methods

Study group

This study was conducted between January 2016 and January 2018 in individuals who underwent examinations for osseous/ligamentous injury after ankle trauma at the Orthopedics and Traumatology Clinic of Fatih Sultan Mehmet Training and Research Hospital. The selected participants showed no acute or chronic pathology in their radiological examinations. Participant data were collected from the electronic database of our training and research hospital. Approval was obtained from the corporate ethics committee (Approval code: FSMEAH-KAEK 2018/57). In this retrospective study, we analyzed cross-sectional magnetic resonance image (MRI) of the ankle joint to determine the positional relationship between tibia and fibula in syndesmosis, the ideal TSA, and the SFA. On the basis of the previous studies, we performed these measurements in 120 MR scans to obtain reference values. The participants were individuals older than 16 years with no osseous or ligamentous injuries on an acute or chronic basis and no structural impairments of the syndesmotic joint or ankle. We excluded participants aged 16 years and younger and those with signs of ankle deformity or syndesmotic joint injury due to previous trauma or disease, a history of ankle instability, and a history of rheumatologic disease.

Measurements

The MRIs used for the measurements were obtained with a single device (MR device: Signa Explorer, 1.5 T, GE). The same radiologist performed all imaging examinations according to a standard protocol. An orthopedist and a radiologist performed the measurements blinded to patient data. The observers recorded the measurement results twice, at a 2-week interval, from a randomly sorted list with no prior measurements. Average, minimum, maximum, and standard deviation (SD) were calculated for each parameter. The reliability of the measurements was evaluated by calculating ICC values for measurements performed by the two independent observers and those obtained at different dates.

Definitions of angles and distances

Axial images were used for the assessments of the talus and syndesmosis, and coronal images were used to determine the level of measurement. To simulate the fluoroscopic true lateral image of the ankle (in which the lateral and medial joint surfaces of the talus are superimposed) and thereby ensure that the radiological parameters determined on the basis of the measurements are intraoperatively applicable and reproducible, the talar anterior tangent (TAT) and perpendicular talar axis line (TAL) were determined in axial MRIs (Fig 1). The TAL was determined in all images and moved to the level of syndesmotic measurement. Considering the motion axis of the syndesmotic joint, which is a restricted dynamic joint, the tibiofibular anterior and posterior tangents were determined. The SFA is the bisector of the intersection of the tangents that are considered to pass through the center of the joint. We obtained the TSA as the angle between the TAL and SFA, which was moved to the syndesmotic measurement level. Finally, the lateral (the intersection point of the tibiofibular anterior-posterior tangents) and the medial (the intersection point of the SFA with the tibia anteromedial cortex) measurements were determined. On the basis of the TAL of the medial location, the ratio of the anterior tibia distance to the anterior-posterior distance of the entire tibia was determined (Fig 2). And finally, we determined the level of talar and syndesmotic measurements from coronal MRI (Fig 3).

Statistical analysis

All analyses were performed on SPSS v22 (SPSS Inc., Chicago, Illinois, USA). Study data were evaluated (mean, SD, and min-max). ICC values were obtained for the mea-

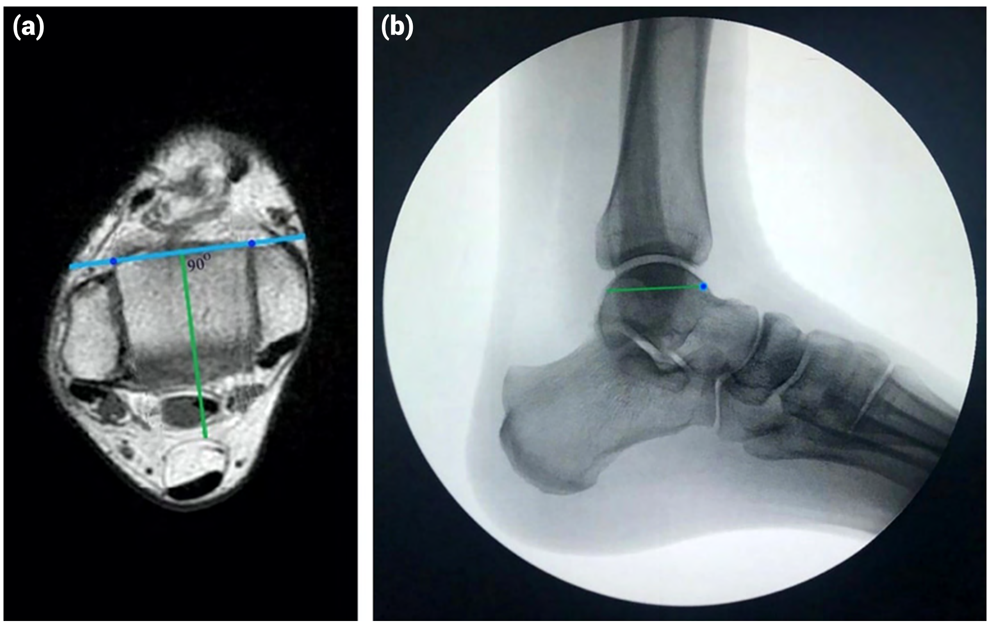

Figure 1. Determination of the talar anterior tangent (TAT) and the talar axis line (TAL). **(a)** Talar anterior tangent (TAT; blue line) and the talar axis line (TAL; green line) perpendicular to the TAT,[13] **(b)** The fluoroscopic schematization of the TAT (blue point) with the TAL (green line).

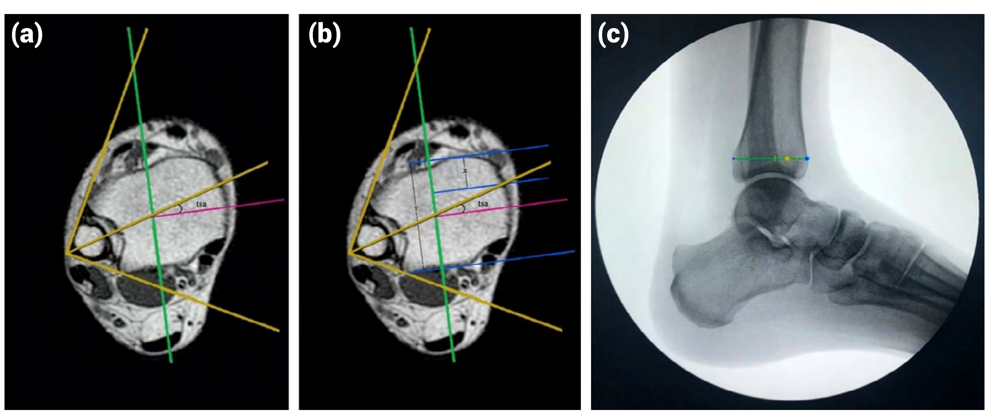

Figure 2. Determination of the syndesmotic fixation axis (SFA), the trans-syndesmotic angle (TSA), and anteroposterior tibial location of the syndesmotic fixation axis. **(a)** The syndesmotic fixation axis (SFA), which we define as the bisector of the intersection of the tibiofibular anterior and posterior tangents, trans-syndesmotic angle (TSA) formed by the intersection of SFA and TAL. **(b)** The ratio of the SFA medial endpoint to the tibial anterior cortex distance (x) to the total tibia anterior-posterior distance (y) (tibial position ratio of SFA: x/y). **(c)** The fluoroscopic schematization of the tibia anterior-posterior cortex tangents and the medial end of the SFA.

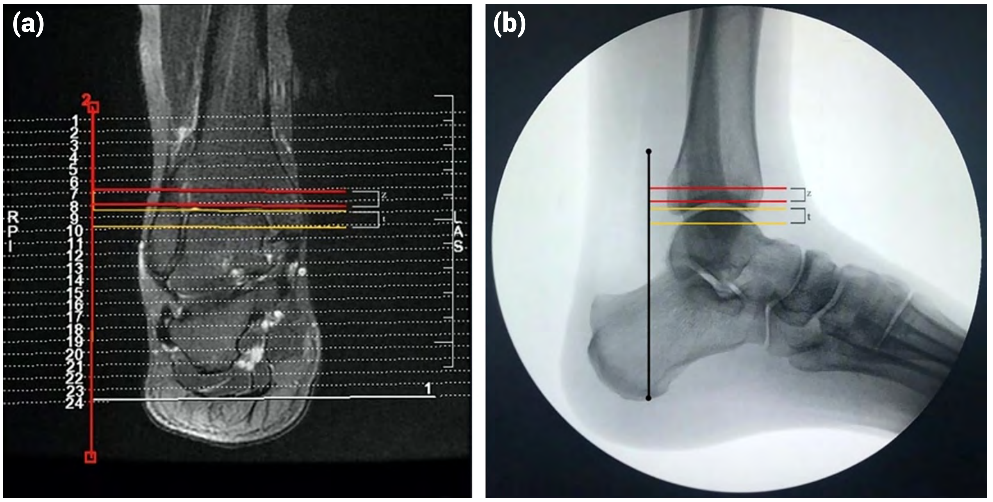

Figure 3. Determination of the level of talar and syndesmotic measurements. **(a)** The talar measurement level (z) where the TAL is determined and the syndesmotic measurement level (t) where the SFA and TSA are determined. **(b)** The fluoroscopic schematization of talar and syndesmotic measurement level.

surements of the talar tangent level, syndesmotic measurement level, TSA, and tibial position ratio of the SFA, and Bland-Altman charts were used to evaluate reliability. ICC values below 0.5 are considered to indicate poor reliability; 0.5–0.75, medium reliability; 0.75–0.9, good reliability; and >0.90, excellent reliability. P<0.05 was considered to indicate statistically significant differences.

Results

Our study included 120 ankle images (79 right and 41 left ankles) from 120 individuals (53 men and 67 women). The average age of the participants was 40.99±13.96 years. The measurement results obtained by the observers are reported as the respective average and SD values in Table 1. The results of repeatability analyses for intraobserver and interobserver

Table 1. Observers' measurement results (mean for each defined value, SD)

	Observer 1		Observer 2	
	1st observation	2nd observation	1st observation	2nd observation
Talar tangent level (Mean±SD)	8.42±2.40	8.60±2.502	7.97±2.29	8.39±2.276
Syndesmotic measurement level (Mean±SD)	9.48±2.344	9.25±2.642	8.48±2.792	9.92±2.733
Trans-syndesmotic angle (TSA) (Mean±SD)	16.06±4.488	17.63±4.406	17.10±4.226	15.81±4.512
Tibial position ratio of SFA (Mean±SD)	0.30±0.057	0.29±0.063	0.28±0.066	0.29±0.062

SD: Standard deviation; SFA: Syndesmotic fixation axis.

Table 2. Repeatability study results

	Intraobserver compliance levels-ICC (95% CI)		Interobserver compliance levels-ICC (95% CI)	
	Observer 1	Observer 2	Observer 1/Observer 2	
Talar tangent level	0.721 (0.600–0.806)	0.827 (0.752–0.880)	0.801 (0.715–0.862)	p<0.001
Syndesmotic measurement level	0.768 (0.667–0.838)	0.697 (0.565–0.789)	0.713 (0.589–0.800)	p<0.001
Trans–syndesmotic angle (TSA)	0.787 (0.694–0.851)	0.863 (0.803–0.904)	0.858 (0.796–0.901)	p<0.001
Tibial position ratio of SFA	0.830 (0.756–0.882)	0.766 (0.665–0.837)	0.780 (0.684–0.846)	p<0.001

The two columns on the left represent intraobserver reliability, and the right column represents interobserver reliability (initial measurements are considered). ICC: Intraclass correlation coefficient; CI: Confidence interval; SFA: Syndesmotic fixation axis.

agreement (intraobserver reliability in the first two columns and interobserver reliability in the last column) are provided in Table 2. The ICC range for observer 1 was between 0.600 and 0.882, and that for observer 2 was between 0.565 and 0.904. The lowest intraobserver ICC value for observer 1 was 0.721 for the talar tangent level, while the corresponding value for observer 2 was 0.697 for the syndesmotic measurement level, representing a moderate fit. Intraobserver agreement for all other measurements obtained by both observers was good, with values between 0.75 and 0.90. The interobserver reliability of the syndesmotic level measurement showed good agreement with an ICC value of 0.723. Interobserver reliability in all other measurements also showed good agreement with values between 0.75 and 0.90.

Discussion

The findings of our study, which evaluated MRI-based radiological measurements for the ankle, suggested that a TSA of 16–17° and SFA located between the fibular apex (lateral) and the anterior third (medial) of the anterior-posterior distance of the tibia were suitable. Interobserver and intraobserver reliabilities for this new set of measurements were found to be acceptable. When the true lateral view of the fluoroscopic ankle is obtained, an angulation of 16–17° is required for the axis of the SFA starting from the fibular apex. We concluded that the intersection of the tibial anteromedial cortex of the SFA should be at the anterior third of the tibia on the sagittal axis for confirmation of the correct location. Importantly, all the parameters to be applied should be evaluated on a true lateral radiograph of the ankle, that is, radiographs where the talar dome's medial and lateral articular faces are superimposed, because rotation will affect the TSA and the appearance of the SFA in a two-dimensional image.

The treatment of syndesmotic injury is aimed at providing intraoperative anatomical reduction and maintaining this reduction until complete healing is achieved.[9] Malreduction, which may develop if reduction cannot be achieved or maintained, may increase ankle contact surface pressure, leading to early degenerative changes of the joint with irregular biomechanics, and is associated with the risk of progression to ankle arthritis. This causes more pain and disability in patients.[10,11] Although some recent studies have argued that a 2-mm malreduction is not clinically significant, surgeons should strive for an optimal reduction even though there are no optimal axial images.[12] The most commonly used surgical technique for reducing syndesmosis involves indirect reduction and fixation with a clamp in the coronal plane and the ankle in mild dorsiflexion. In this technique, both clamp placement and displacements in the axis of the fixation material can lead to consequences that affect the reduction. Studies have shown that malreduction rates can be reduced by positioning the medial clamp at the anterior third to the tibia in a true intraoperative talar dome fluoroscopic lateral view. In contrast, when it is positioned at the posterior third, the malreduction rate will be high.[13] This explains why in vivo anterior-posterior syndesmosis instability is greater than lateral syndesmosis instability, affecting the clamping vector.[14] The previous studies have emphasized the relationship between an inappropriate axis of the clamp vector during reduction and eccentric screw placement and syndesmotic malreduction.[15,16] Therefore, we proposed angular measurements by predicting that the bisector axis obtained from the syndesmotic joint center may reduce rotational malreduction in the fibular incisor by preventing the eccentric clamp vector and eccentric screw placement. As a result, we predicted that when the true talar dome is viewed fluoroscopically, the TSA has a positioning axis of 16–17° and that the fluoroscopic confirmation of this axis can be achieved by placing the medial clamp on the anterior third of the anterior-posterior diameter of the tibia when the lateral clamp end is placed in the fibular apex.

Multiple previous cadaver studies covering syndesmotic joint injury models and various reduction methods did not provide a clear explanation of the anatomy of the TSA.[16-19] Historically, trans-syndesmotic fixation has been proposed at an angle of 25–30° in the posterolateral-anteromedial direction. Nevertheless, this angle is estimated based on the slight posterior localization of the fibula in the tibia.[20-22] In contrast to these classical suggested angles, Park et al.[23] found TSA to be 18.8° when they obtained alignment of the second toe in their CT cross-sectional studies of patients with calcaneal fractures. However, we predicted that the second toe axis suggested in the measurements may vary depending on the person assisting, since there is no intraoperative fluoroscopic confirmation. We considered the TAL perpendicular to the TAT as the axis, facilitating fluoroscopic confirmation. Similarly, Putnam et al.[24] identified a TSA of 21° in their radiological studies, which was lower than the classical recommended angle. Our study also obtained a TSA value of 16–17°, which was below the classical recommended value of 30°. The mean TSA value and location of the tibial medial clamp were similar to those reported in the previous studies using CT.[23,24] In some studies conducted with tibial lateral imaging schematization, the distance between the tibia anterior 18–41% as the clamping area was reported as the safe zone. In some studies, the front of the midline was defined as the centroidal axis.[25,26] The previous studies have shown that an eccentric clamp or screw placement is the main factor in syndesmotic malreductions in translation, rotation, or a combination of both.[15,16,27] We think that measurements with the central bisector of the joint, which were defined for the 1st time in our study, will reduce the cause of rotational malreduction associated with a previously defined clamp anterior and posterior vector but will not provide benefit for malreduction due to overcompression.

For optimal reduction, regardless of the type of syndesmotic fixation, it is critical to develop intraoperative guidance in clamp positioning. For this purpose, CT navigation has been shown to be beneficial in terms of repeatability and precision in studies on syndesmotic reduction.[28] However, this technique has limited utility in many centers due to the limited availability, high cost, and other factors.[29,30] Although intraoperative fluoroscopy can provide easy access and is cost effective, the lack of reliable radiographic parameters in reduction and fixation confirmation are the disadvantages associated with the use of this technique. Sagi et al.[8] did not suspect pathology in intraoperative or postoperative direct radiographic examinations in 39% of the malreductions detected by CT in their retrospective study. Accordingly, Summers et al.[31] described a technical guideline for confirmation of reduction on true lateral talar dome radiographs of the intact ankle. Despite its promising results in a small group of patients, this study was insufficient to provide quantitative data to aid reproducibility.

The major limitation of this study is that we did not report treatment results and follow-up findings, since this was a radiological study. The other limitation of our study is the lack of correlated fluoroscopic definitions of the radiological parameters defined in MRI and the possibility of cross-sectional evaluation obtained with a 3D acquisition to two-dimensional results. The radiological parameter, which we defined as the TAL, is a term used to simulate intraoperative fluoroscopic true lateral images and is not included in the ankle's mechanical and anatomical axis definitions. It is necessary to determine whether functional results are related to anatomical reduction. If so, to what extent can prospective clinical studies be performed according to the method we proposed? Moreover, there is a need to determine differences in patient outcomes when comparing translational or rotational malreduction. However, the high degree of anatomical variability of syndesmosis complicates a standard vectorial approach to anatomical reduction.

After obtaining a true lateral view of the ankle for the syndesmotic joint reduction clamp placement or fixation material axis, the lateral-fibular apex and medial-tibial anterior third placement appear to be the correct position to pass through the center of the joint. We think an axis passing through the center of a joint with limited movement and structurally convex-concave alignment will contribute to joint restoration.

Ethics committee approval

Fatih Sultan Mehmet Training and Research Hospital Clinical Research Committee granted approval for this study (Date: November 22, 2018, number: 2018/21).

Disclosures

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – M.K., B.Y.; Design – B.Y., H.K.; Supervision – D.P.K., M.K.; Materials – H.K., A.N.K.; Data collection &/or processing – N.K., D.P.K.; Analysis and/or interpretation – A.N.K., M.K.; Literature search – M.K., A.N.K.; Writing – M.K., N.K.; Critical review – B.Y., D.P.K.

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