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ABSTRACT

of the dissertation for the degree of doctor of philosophy

OPTIMIZATION OF DIAGNOSTIC PARAMETERS IN MAGNETIC RESONANCE IMAGING FOR TEMPOROMANDIBULAR JOINT INTERNAL DERANGEMENT

Specialty: 3225.01 - Radiation diagnostics and therapy

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GENERAL DESCRIPTION OF THE RESEARCH

The actuality of the subject. Temporomandibular joint (TMJ) disorders are a widespread healthcare issue affecting millions of people worldwide and are usually accompanied by joint dysfunction[1].

At the same time, there is often a discrepancy between the patient's subjective complaints and the actual changes in the joint, which significantly complicates diagnosis and treatment[2].

Currently, the issues of diagnosing and identifying the causes of TMJ pathology are urgent. The relevance of the problem is largely due to the rapidly changing realities of modern dentistry; the use of high-strength and rigid materials, a large number of total restorations and orthodontic treatment, and the presence of latent, compensated TMJ pathology for which optimal full diagnostic algorithms have not yet been developed. All of this leads to late identification of disorders and an increase in patients with severe, pronounced symptoms[3].

Among the various types of TMJ disorders, the most common is internal derangement[4], affecting 41.1% of patients with dysfunction in this area[1]. This condition is characterized by an abnormal position of the articular disc relative to the condyle of the mandible, which leads to disruptions in the normal biomechanics of the joint[5].

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[4] Hegab, A. Classification of temporomandibular joint internal derangement based on magnetic resonance imaging and clinical findings of 435 patients contributing to a nonsurgical treatment protocol / A.Hegab, H.Hameed, K.Karam // Scientific Reports, – 2021. v. 11, № 1, – p. 1-15

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Data on the prevalence of TMJ dysfunction are contradictory, due to a number of reasons: the lack of diagnostic algorithms and standard schemes of clinical and additional examination methods used in treatment approaches for patients with dysfunction syndrome in this area[2]. The mismatch between clinical symptoms and structural changes in the TMJ (the so-called low-symptomatic or asymptomatic variants)[6] necessitates the identification of early markers of TMJ dysfunction to prevent severe destructive-degenerative outcomes[7]. Another significant factor complicating the modern detection of internal derangement is that these patients are treated by specialists from various fields (neurologists, maxillofacial surgeons, otolaryngologists, gnathologists, orthodontists, chiropractors, osteopaths, orthopedic dentists, and physiotherapists). This often leads to inconsistencies in diagnostic algorithms and, consequently, in treatment strategies[8]. The lack of a universal method to updating data of a particular diagnostic approach makes it impossible to assess the effectiveness of treatment. Considering that the cornerstone of every approach to diagnosis and treatment of internal derangement of the TMJ is centered around the relative position and condition of the joint structures, as well as the fact that these data form the basis for developing the entire treatment plan, it is evident that finding the most informative examination method is a priority for both diagnosis and treat-

[6] Koca, C., Gümrükçü Z., Bilgir E. Does clinical findings correlate with magnetic resonance imaging (MRI) findings in patients with temporomandibular joint (TMJ) pain? A cross sectional study // Medicina Oral, Patología Oral y Cirugía Bucal, - 2020. v. 25, № 4, - p. 495-501

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[8] Милутка, Ю.А. Фортин, А.Е. Возможности и организационные проблемы диагностики и лечения пациентов с синдромом болевой дисфункции височно-нижнечелюстного сустава // – Москва: Российский остеопатический журнал, – 2020. № 4, – с. 95-116

ment[9].

Before the advent of diagnostic imaging, displacement of the articular disc relative to the mandibular condyle was diagnosed only on the basis of clinical signs such as specific clicking sounds and impaired mouth opening[10].

Subsequently, X-rays, computed tomography, and magnetic resonance imaging (MRI)[11] were used for the most accurate and targeted diagnosis of TMJ dysfunction. Currently, MRI is the “gold standard” for visualizing the position of the articular disc in relation to the mandibular condyle[12]. Therefore, it is considered appropriate to conduct an MRI of the TMJ for the final confirmation of the diagnosis[13].

Considering that, to date, there is no unified approach to the algorithm and protocol for MRI studies to detect internal disorders of the TMJ, many researchers are confident that the development of new algorithms aimed at identifying the most informative morphometric parameters would significantly increase the diagnostic capabilities of imaging methods[14].

All of the above highlights the relevance of this work and de-

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[10] Larheim, T. The Role of Imaging in the Diagnosis of Temporomandibular Joint Pathology / T.Larheim, C.Hol, M.Ottersen [et al.] // Oral and Maxillofacial Surgery Clinics of North America, –2018. v. 30, № 3, – p. 239-249

[11] Ozsari, S. Comprehensive Review of Artificial Intelligence Based Algorithms Regarding Temporomandibular Joint Related Diseases / S.Ozsari, M.Güzel, D.Yılmaz [et al.] // Diagnostics, – 2023. v. 13(2700), – p. 1-34

[12] Li, C. Diagnostic efficacy of quantitative ultrasonography for anterior disc displacement of the temporomandibular joint / C.Li, J.Zhou, Y.Shi [et al.] // Quantitative Imaging in Medicine and Surgery, – 2023. v. 13, № 10, – p. 6446-6455

[13] Spenser, J. Treating Nonreducing Disc Displacement Successful "unlocking" with injection and orthotic relies on patient education // Inside Dentistry, – 2021. v. 17, № 1

[14] Сойхер, М.Г. Разработка и обоснование выбора методов диагностики и лечения при реабилитации пациентов с дисфункциональными состояниями челюстно-лицевой области: / автореферат диссертации доктора медицинских наук / – Саратов, 2022. – 49 с

fines the objective of the study[15].

Research object. The study involved 222 patients who sought medical attention for complaints related to the TMJ at the Central Clinical Hospital in Baku.

Research purpose. Improving the diagnostic capabilities of MRI in identifying internal derangement of the TMJ based on the assessment of morpho-functional indicators.

Research objectives

1. Assessment of the frequency of various types of TMJ internal derangement based on the study of soft tissue and bone structures using MRI.
2. Identification of the relationship between structural disorders of the TMJ and morphometric indicators defined using MRI.
3. Identification of predictors of TMJ disk dislocation considering the anatomical features of the joint based on MRI data.
4. Establishment of the correlation between degenerative changes in bony structures and specific types of TMJ internal derangement using MRI.
5. Evaluation of morpho-functional changes in uni/bilateral TMJ pathology.

Research methods. Clinical, instrumental (MRI), and statistical methods (variational statistics, correlation analysis, ROC-analysis) were used during the research.

Main points presented to the defense of the dissertation

Structural - functional disorders of the TMJ are directly correlated with morphometric indicators determined by MRI, which is important for using this indicators as highly informative signs for assessing joint pathology and predictive criteria.

The frequency and nature of degenerative changes in TMJ bony structures are closely related to the characteristics of internal joint derangement.

Methodological optimized of MRI of the TMJ provides the

[15] Буланова, Т.В. Магнитно-резонансная томография в диагностике заболеваний и травм височно-нижнечелюстного сустава: / диссертация доктора медицинских наук / – Москва, 2005. – 165 с

most effective visualization of the joint structures and helps to avoid false assessments of the structural-functional conditions of this area.

Scientific novelty of the research. A novel set of sequences optimized for dynamic visualization of the TMJ was developed and applied to a 3-Tesla MRI scanner.

The morphofunctional features of the TMJ were identified and described for various types of disc dislocation, along with their correlation to signs of degenerative changes in the joint's bony structures.

Based on MRI data, morphometric indicators with predictive value for internal derangement of the TMJ were assessed.

An optimal algorithm for the MRI protocol of the TMJ was developed, which enhances the effectiveness of radiological diagnostics of internal derangement in this area by standardizing methodological approaches and evaluating visualized changes (copyright Q-14.03.2024/110-8e).

Practical significance of the dissertation.

The result of this work is the development of a new approach to the use of MRI in TMJ disorders and the improvement of the diagnosis of pathology and function in this area. The most important diagnostic signs of joint damage have been identified, and informative criteria for the differential diagnosis of various types of TMJ lesions have been established. A unified system and terminology for visualized changes have been developed, allowing for the widespread use of the obtained data in the practical diagnostic work of radiologists.

Approbation of the dissertation. The main materials of the dissertation were presented and discussed at the APOC training seminar (Baku, 2018), the 1st International Scientific Congress of the "Azerbaijan Society of Oral and Maxillofacial Surgeons" (Baku, 2019), the 2nd International Scientific and Practical Conference of Radiologists of Azerbaijan (Baku, 2022), and the scientific-practical conference dedicated to the 90th anniversary of Professor B.A.Bakhshiyev (Baku, 2024). The final work was approved at the interdepartmental conference of the AMU on April 16, 2024 (Protocol No. 3), and at the scientific seminar of the Dissertation Council FD 1.02, operating at the National Oncology Center, on October 25, 2024 (Protocol No. 3).

The final approval of the work took place at the interdepartmental conference of AMU on April 16, 2024 (protocol No. 3), and at the scientific seminar of the Dissertation Council of the National Center for Oncology on October 25, 2024 (protocol No. 3).

The key theoretical findings of the dissertation are reflected in 13 scientific works, including 8 articles (3 of which are peer-reviewed and cited in international journals) and 5 abstracts (1 published abroad).

Application of the obtained results. The practical recommendations, diagnostic algorithm for TMJ, and the developed diagnostic criteria proposed in the scientific work are applied in the clinical practice of the Central Clinical Hospital in Baku and have been integrated into the educational process at the Department of Radiology and Radiation Therapy of AMU.

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Name of the organization where the dissertation was performed. The dissertation work was performed at the base of the Central Clinical Hospital of Baku and approved by the AMU.

Total volume and structure of the dissertation. The dissertation was written in Russian, total volume consists of 190 pages of computer text (201.554 characters): Introduction (13.029 characters), Chapter I "Literature Review" (42.263 characters), Chapter II "Materials and Methods" (32,397 characters), Chapter III (45,300 characters), Chapter IV (25,730 characters), Chapter V dedicated to the personal research (14,211 characters), "Conclusions and Discussion of the Obtained Results" (25,902 characters), Conclusions (2,195 characters), Practical recommendations (527 characters), and Bibliography including 274 sources (9 domestic and 265 foreign). The work is illustrated with 21 tables, 16 graphs and 48 figures.

MATERIALS AND METHODS OF THE RESEARCH

A total of 222 patients were involved in the study, selected from individuals who presented with complaints related to the TMJ at the Central Clinical Hospital of Baku. Of the 222 patients, 46 (20.7%) were male, and 176 (79.3%) were female. The average age of the patients was 33.6 ± 0.9 years. A total of 444 joints were examined.

The structure of complaints included: local joint pain (28 patients; 12.6%), restriction or lock during mouth opening (151 patients; 68%), crepitus and/or specific clicks during mouth opening (162 patients; 72.9%), deviation of the mandible during mouth opening (44 patients; 19.8%), tenderness upon palpation of the joint area (16 patients; 7.2%), bite changes (174 patients; 78.3%), and facial swelling on the affected side (4 patients; 1.8%).

Patients were consulted by specialists, including maxillofacial surgeons, orthodontists, orthopedists, otolaryngologists, and neurologists. Based on a carefully collected medical history, examination of the oral cavity, dental arches and their relationship, the condition of the jaw and facial muscles, neck muscles, and the biomechanics of the lower jaw, a preliminary diagnosis was established.

In the absence of contraindications for MRI (such as claustrophobia, implanted metallic medical devices, pacemakers, and others), patients were referred for imaging to verify the diagnosis and identify pathomorphological changes in the TMJ. Cases where systemic diseases, trauma, or surgical interventions in the area were the primary cause of the TMJ pathology were excluded from the study.

The joints were divided into groups based on the position of the articular disc in the sagittal projection, in which the criterion of the location of the intermediate zone was taken as a basis. In the presence of disc dislocation, the presence or absence of reduction of the articular disc when opening the mouth was also assessed.

Group 1 (n=182) – Control group: This group consisted of joints without dislocation of the intra-articular disc.

Group 2 (n=148) included joints with anterior disc displacement with reduction during mouth opening.

Group 3 (n=107) included joints with anterior disc displacement without reduction during mouth opening.

Group 4 (n=7) included joints with posterior disc displacement with reduction during mouth opening.

MRI was performed on a Siemens Magnetom Verio MRI scanner with a magnetic field strength of 3.0 T. A standard 16-element radiofrequency neurovascular coil for head scanning was used for the MRI of the TMJ.

The first stage was conducted with the mouth closed in a habitual occlusion position, without exerting any additional force. The second stage was performed with the mouth open. Both static and dynamic MRI were used for the TMJ examination.

Statistical analysis methods of variation for quantitative indicators (t-Student-Bonferroni test, non-parametric-color Mann-Whitney U-test and median Kruskal-Wallis H-test), Pearson Chi-Square test for qualitative indicators analysis, analysis of variance (ANOVA test) F-Fisher test, ROC-analysis (by calculating the area under the ROC-curve and finding cut-off points), correlation analysis between quantitative and qualitative indicators was performed with the ρ-Spearman test. Calculations were performed in SPSS-26 statistical package.

RESULTS AND DISCUSSION OF THE RESEARCH

Using MRI, the following were assessed: medial/lateral subluxation of the articular disc, measurement of the size and distance of the disc dislocation using the two-step method described by Nebbe et al. and Xie et al.[16], morphological condition of the disc (5 types)[16] , area of mandibular condylar head, position of the mandibular head in the glenoid fossa of the temporal bone in the habitual occlusion position in the sagittal plane according to the method of Pullinger and Hollender, translation of the condylar head (hypomobility/hypermobility) determined in the sagittal plane with the mouth fully open[17], width and height of the glenoid fossa using the method of Muto et al.[18], followed by the shape of the glenoid fossa, inclination and morphology of the articular eminence, based on the criteria

[16] Hu, Y., Yang, C., Xie O. Changes in disc status in the reducing and nonreducing anterior disc displacement of temporomandibular joint: a longitudinal retrospective study // Scientific Reports, – 2016. v. 27, № 6, – p. 1-11

[17] D'Ippolito, S. Evaluation of the lateral pterygoid muscle using magnetic resonance imaging / S.D'Ippolito, B.Wolosker, A.D'Ippolito [et al.] // Dentomaxillofacial Radiology, – 2010. v. 39, № 8, – p. 494-500

[18] D'Ippolito, S. Evaluation of the lateral pterygoid muscle using magnetic resonance imaging / S.D'Ippolito, B.Wolosker, A.D'Ippolito [et al.] // Dentomaxillofacial Radiology, – 2010. v. 39, № 8, – p. 494-500

of Kurita et al. , presence or absence of joint effusion, thickening of the lateral pterygoid muscle tendon, and the thickness of the aforementioned muscle, identification of bone degenerative changes[19].

In this study, 222 patients and 444 joints were examined. In Group 1, there were 182 joints; in Group 2, 148 joints; in Group 3, 107 joints; and in Group 4, 7 joints. In our study, anterior disc dislocation with reduction was the most common type, occurring in 56.5% of the cases. At the same time, the rarest form observed was posterior disc displacement with reduction (2.67%).

Out of 444 joints, 104 (23.4%) showed medial/lateral disc subluxation. 340 (76.6%) joints had a normal disc position. Lateral subluxation was found in 8 joints with a normal disc position, and 96 joints had abnormal disc positioning in the sagittal plane. Medial disc subluxation predominated in Group 3 at 31.8%.

The position of the mandibular condyle in the glenoid fossa was analyzed in the patients. According to the data obtained, out of 444 joints, 185 (41.7%) had a posterior, 151 (34%) had a central, and 108 (24.3%) joints had an anterior position of the condyle in the glenoid fossa.With a normal disc position in the sagittal projection, the posterior position of the condyle was observed in 41 joints (22.5%), central - in 76 (41.8%), and anterior - in 65 joints (35.7%). With dislocated discs (in the sagittal projection), the posterior position of the condyle head was observed in 144 joints (55.0%), central - in 75 joints (28.6%), and anterior - in 43 joints (16.4%). The greatest number of joints (71.4%) with a posterior position of the condyle head in the glenoid fossa was observed in patients with dislocation of the articular disc.

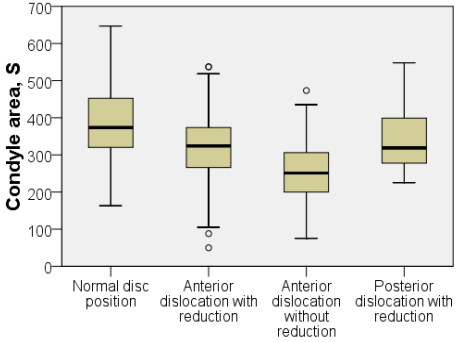
We also examined the presence of effusion as a reflection of reactive synovitis. An increase in the amount of synovial fluid was noted in 95 (21.4%) joints out of 444 joints.

The average area of the condyle in patients of groups 1, 2, 3, and 4 was found to be 373.8 mm^2, 324.3 mm^2, 251.3 mm^2, and 318.7

[19] Matsubara, R. Assessment of MRI findings and clinical symptoms in patients with temporomandibular joint disorders / R.Matsubara, Y.Yanagi, K.Oki [et al.] // Dentomaxillofacial Radiology, – 2018. v. 47, № 4, – p. 1-8

mm^2, respectively. The obtained data indicate that the volume of the condyle (trabecular and cortical components) is significantly associated with disc dislocation and a decrease in condylar volume occurs as disc dislocation progresses from displacement with reduction to without reduction. The parameter "condylar area" demonstrated high specificity (77.5±3.1%). Graph 1.

The inclination angle for 182 joints with a normal disc position was 55.0±0.9º, while for 262 joints with a displaced disc it was 54.3±0.8º. When evaluating the distribution by groups, no statistically significant difference was found. Therefore, the data suggest that the inclination of the articular eminence does not have an impact on the development of disc-related disorders.



Graph 1. Changes in the Condyle Area Values by Groups

With a normal disc position in the sagittal plane, the “box” shape was detected in 103, “sigmoid” - in 57, “flattened” - in 20, “deformed” shape of the articular eminence - in 2 joints. With a dislocated disc position in the sagittal plane, the “box” shape was detected in 124, “sigmoid” - in 77, “flattened” - in 49, and “deformed” - in 12 joints. Group 1 had twice as many "box" shapes (56/28.6%) as Group 4. The majority of "sigmoid"-shaped joints (57.1%) had poste-

rior disc dislocations in group 4. The “flattened” shape of the articular eminence was observed with approximately equal frequency in all groups. An interesting fact is that the “deformed” articular eminence is much more common (9.3%) in joints with anterior disc dislocation without reduction. However, in patients with posterior disc displacement, such deformation was not observed in any case.

During the study, the distance of disc dislocation was investigated as one of the possible factors that may influence certain kinematic parameters of the joint, as well as the reduction of the disc during mouth opening. The greatest distance of disc dislocation was found in joints with anterior disc dislocation without reduction. The next most pronounced measurement was observed in the group with anterior disc displacement with reduction, which highlights the importance of evaluating this parameter.

The morphological state of the disc is one of the indicators that, in our opinion, provides information about degenerative changes in the joint. According to the results obtained, out of 444 joints, 159 had unchanged disc morphology, 258 joints had altered disc morphology. When analyzing depending on the disc position, it was found that out of 182 joints with a normal disc position, 135 joints had a biconcave disc configuration without deformation, and 47 joints had altered disc shape. Only 24 joints out of 262 joints with pathological disc position showed a biconcave disc configuration without deformation. In the remaining cases (238 joints), the disc shape changed. Thus, Type 2 disc is most often found in patients with posterior disc dislocation with reduction (42.9%). The lowest number of cases with such deformation was observed in joints with a normal disc position. The “V” shaped disc (Type 3) was most common in Group 4 (57.1%). This type was observed in patients with anterior disc dislocation with and without reduction with almost equal frequency. The shortened form (Type 4) was dominant in joints with anterior disc dislocation without reduction (46.7%), while it was absent in the case of normal disc position and posterior disc dislocation. Type 5 (rounded form) was also frequently encountered in joints with anterior disc dislocation without reduction and was almost absent in other groups.

Adhesion was detected in 2 (1.4%) joints with anterior disc dis-

location with reduction and in 7 (6.5%) joints with anterior disc dislocation without reduction.

Among the 444 joints, MRI signs of disc perforation were observed in 12 joints. Of these, 6 (3.3%) joints had no disc displacement or signs of bone structure degeneration, which contradicts existing literature. In our opinion, this discrepancy can be explained by the specifics of image acquisition (such as during the open-mouth phase, when patient discomfort may lead to artifacts) and the subjectivity of the assessment, particularly when there is minimal disruption to the integrity of the temporomandibular joint disc. To ensure a more accurate diagnosis of disc perforation, we would recommend performing arthroscopy.

We conducted an analysis of the shape of the articular fossa. Based on the data regarding the width and height of the fossa, we conditionally classified it into two types, characterized by different shapes: concave (Type 1) and convex (Type 2). A statistically significant difference ($p=0.003$) was found between the groups with normal disc position and disc displacement based on the fossa shape criterion. Out of 444 joints, Type 1 was identified in 109 (24.5%) cases, while Type 2 was found in 335 (75.5%) joints. Type 1 was most commonly observed in joints with a normal disc position (31.9%) and least frequently in the group with anterior disc displacement without reduction (14.0%). Conversely, Type 2 fossa shape was most common in Group 3 (86%) and least frequent in Group 1 (68.1%). Such classification is not typically used in the literature. However, our study identified a significant intergroup difference between joints with a normal disc position and those with disc displacement, suggesting a certain diagnostic potential for this parameter.

Thickening of the lateral pterygoid muscle tendon, indicating increased load on the joint, was observed in 154 joints (34.7%) out of 444. This parameter was analyzed by group to identify more specific MRI findings. A statistically significant difference was found across the types of disc displacement based on the thickening of the lateral pterygoid muscle tendon (this sign was found in 3 out of 7 patients with posterior disc displacement with reduction during mouth opening). The lowest

frequency was observed in the group with normal disc position.

Masseter muscle edema was detected in 2.7% of cases (out of 444 joints). No statistically significant difference in the frequency of this sign was found across the groups. However, the percentage of cases was lower in the disc displacement groups (2.3%) compared to those with normal disc position (3.3%). Group distribution showed no substantial difference based on disc position. The highest percentage was observed in the group with anterior disc displacement without reduction during mouth opening (4.7%), but the difference with the joints having normal disc position was minimal (3.3%).

When assessing the condyle's ability for translation, the results indicated that normal kinematics were present in 183 joints (41.2%), while kinematic abnormalities were noted in 58.8% of cases. Statistically significant differences were found in the frequency of this parameter between groups with normal disc position and those with disc displacement. Hypomobility predominated in joints with anterior disc displacement without reduction during mouth opening (61.7%) and, as expected, was least frequently found in joints with normal disc position (12.1%). Hypermobility, on the other hand, was least common in joints with anterior disc displacement without reduction (10.3%). Notably, nearly identical levels of hypermobility were found in the groups with normal disc position and with anterior disc displacement with reduction during mouth opening (39.6% and 37.8%, respectively).

Osteoarthritis manifests with such signs as the formation of subcortical cysts, erosions on the surface, osteophytes, subchondral sclerosis, flattening, and remodeling of the mandibular condyle.

Out of 444 joints, flattening of the mandibular condyle head was observed in 80 joints (18.0%). In this case, the sign was more prevalent in the group with pathological disc position compared to the normal disc position group (25.2% vs. 7.7%, respectively). Statistically significant intergroup differences were noted: the highest percentage was found in joints with anterior disc displacement without reduction during mouth opening (40.2%), and the lowest was observed in joints with normal disc position (7.7%). Out of 444 joints, osteophytes on the mandibular condyle head were identified in 163 joints (36.7%), of which 142 joints (54.2%) belonged to the group

with pathological disc position. This sign was more frequently observed in joints with anterior disc displacement without reduction during mouth opening (74.8%). Statistically significant intergroup differences were found ($p<0.001$). A sign of bone degeneration, such as erosion, was identified in 48 joints (18.3%) out of 444, and all these joints had a pathological position of the articular disc. Similar to the presence of osteophytes on the mandibular condyle head, this sign was more prevalent in joints with anterior disc displacement without reduction during mouth opening (31.8%). Out of 444 joints, subchondral sclerosis of the mandibular condyle head was found in 263 joints (59.2%). Among these joints, 56 joints (30.8%) had a normal disc position, while 207 joints (79.0%) had a pathological disc position. Subchondral sclerosis of the mandibular condyle head was also predominantly observed in joints with anterior disc displacement without reduction during mouth opening (88.8%).

According to our data, such morphological changes in the condylar head were found with almost equal frequency in both anterior disc displacement with reduction and posterior disc displacement with reduction during mouth opening. However, this relatively high prevalence in group 4 may be attributed to the small number of joints in this group. In cases with normal disc position, unilateral osteoarthritis was observed in 2.3% of patients, and bilateral osteoarthritis in 4.1%, along with various types of kinematic dysfunction in 19% of those examined. Bilateral disc displacement was associated with bilateral osteoarthritis in 26.1% of cases, while unilateral displacement occurred in 12.2% of cases.

Thus, the study of the morphological features of the temporomandibular joint (TMJ), its individual structures and function, as well as the presence of pathological changes of an inflammatory and degenerative nature, has shown that these indicators can vary depending on the position of the TMJ disc. These differences exhibit varying degrees of statistical significance; however, the obtained data indicate the significant impact of the disc position on the functional state of the joint, which will inevitably influence the development of irreversible degenerative disorders in the future.

In order to establish the relationship between the morphologi-

cal characteristics of the temporomandibular joint (TMJ) and to more accurately identify characteristic signs in both normal and pathological disc positions, we conducted a correlation analysis between the studied parameters.

Patient age negatively correlated with such indicators as the anterior and posterior joint space size ($\rho = -0.105$; $p = 0.027$ and $\rho = -0.168$; $p < 0.001$, respectively). A similar strength of negative correlation was found with the width of the fossa ($\rho = -0.177$; $p < 0.001$). At the same time, a positive correlation was observed between the posterior area of the condyle and the size of the condylar head ($\rho = 0.157$; $p = 0.001$).

The length of the disc positively correlated with the position of the condyle ($\rho = 0.141$; $p = 0.003$). Similar relationships were found between disc length and condyle position ($\rho = 0.165$; $p = 0.001$). According to the ROC analysis, the length of the disc showed a sensitivity of $64.5 \pm 3.0\%$ with a fairly high specificity of $80.8 \pm 2.9\%$ at a cut-off point of 8.4. This can likely be explained by certain interactions between the structures of the temporomandibular joint (TMJ), which mutually influence the changes in the parameters mentioned above. The length of the disc exhibited a negative correlation with the width of the fossa ($\rho = -0.093$; $p = 0.049$).

The position of the disc in the sagittal projection correlated with the joint space parameters. Specifically, there was a positive correlation with the anterior joint space size ($\rho = 0.212$; $p < 0.001$), while negative correlations were found with the superior and posterior joint space sizes ($\rho = -0.326$; $p < 0.001$ and $\rho = -0.211$; $p < 0.001$, respectively).

A significant negative correlation was also observed with parameters characterizing the size of the condyle. In all cases, the correlation was strong: with the anteroposterior dimension ($\rho = -0.363$; $p < 0.001$) and with the transverse dimension ($\rho = -0.341$; $p < 0.001$). As expected, a correlation was also found with the condyle surface area ($\rho = -0.461$; $p < 0.001$).

In the patients we studied, a positive correlation was found between the position of the disc in the sagittal projection and the presence of effusion ($\rho = 0.343$; $p < 0.001$), which is consistent with the literature data.

The altered shape of the condyle was found to have a statisti-

cally significant positive correlation with the position of the disc in the sagittal projection ($\rho = 0.402$; $p < 0.001$).

Degenerative changes, both collectively and individually, demonstrated a positive relationship with the disc position in the sagittal projection. Various manifestations of osteoarthritis, such as condylar flattening ($\rho = 0.247$; $p < 0.001$), osteophytes ($\rho = 0.451$; $p < 0.001$), erosions ($\rho = 0.316$; $p < 0.001$), and sclerosis ($\rho = 0.481$; $p < 0.001$), showed a strong and statistically significant correlation with the disc position.

Assessment of the correlation between the subluxation of the disc in the frontal projection revealed several significant relationships. Notably, a correlation with the sagittal disc position ($\rho = 0.345$; $p < 0.001$) was found. There was also a connection with joint space dimensions: superior ($\rho = -0.113$; $p = 0.005$) and posterior ($\rho = -0.231$; $p < 0.001$). Subsequently, subluxation of the disc in the frontal projection negatively correlated with both the transverse size of the condyle ($\rho = -0.247$; $p < 0.001$) and the total condylar surface area ($\rho = -0.461$; $p < 0.001$). Similar to the sagittal disc position, subluxation in the frontal projection showed a positive correlation with the presence of effusion ($\rho = 0.152$; $p = 0.001$).

Different manifestations of osteoarthritis, such as osteophytes ($\rho = 0.141$; $p = 0.003$), erosions ($\rho = 0.116$; $p = 0.015$), and sclerosis ($\rho = 0.199$; $p < 0.001$), correlated with varying degrees of significance with the position of the disc in the frontal plane.

As expected, a positive correlation was found with degenerative changes in the disc ($\rho = 0.291$; $p < 0.001$) among our patients. A significant inverse correlation was observed with the length of the disc ($\rho = -0.192$; $p < 0.001$).

In our study, some of the intra-articular discs exhibited signs of reduction during mouth opening. It was found that reduction positively correlated with the size and area of the condyle: with the anteroposterior dimension ($\rho = 0.190$; $p = 0.002$), with the transverse dimension ($\rho = 0.409$; $p < 0.001$), and with the condyle area ($\rho = 0.371$; $p < 0.001$). Furthermore, reduction showed a negative correlation with the shape of the condyle ($\rho = -0.272$; $p < 0.001$).

In this case, as with the previously described signs (disc position in the sagittal and frontal projections), we assessed correlations

with manifestations of osteoarthritis. However, unlike the previous indicators, for reduction, the relationship was negative. For condyle flattening, the values were $\rho = -0.287$; $p < 0.001$, for osteophytes $\rho = -0.343$; $p < 0.001$, for erosion $\rho = -0.289$; $p < 0.001$, and for sclerosis $\rho = -0.199$; $p = 0.001$.

The degenerated disc, as a manifestation of its morphology, was characterized by a negative correlation with reduction ($\rho = -0.237$; $p < 0.001$). The length of the disc positively correlated with the presence of reduction with high statistical significance ($\rho = 0.515$; $p < 0.001$). Disc morphology demonstrated high sensitivity (90.8±1.8%) as well as high specificity (74.2±3.2%).

The shape of the disc exhibited high sensitivity (88.9±1.9%) and very high specificity (95.6±1.5%).

In our patients, when analyzing the relationships between disc reduction during mouth opening and the angle of inclination, a positive correlation was found ($\rho = 0.127$; $p = 0.040$). A strong negative correlation with significant statistical reliability was noted between reduction and the distance of disc displacement ($\rho = -0.587$; $p < 0.001$).

Thickening of the lateral pterygoid tendon showed correlational relationships with both the anteroposterior size of the condyle and its area ($\rho = -0.150$; $p = 0.002$ and $\rho = -0.149$; $p = 0.002$, respectively). This same sign positively correlated with all the osteoarthritis manifestations we examined: condyle flattening ($\rho = 0.102$; $p = 0.032$), osteophytes on the condyle surface ($\rho = 0.132$; $p = 0.005$), erosions ($\rho = 0.097$; $p = 0.042$), and sclerosis ($\rho = 0.104$; $p = 0.029$). Thickening of the lateral pterygoid tendon demonstrated a positive correlation with the position of the disc in the sagittal projection with a high level of statistical significance ($\rho = 0.146$; $p = 0.002$).

The angle of inclination of the condylar eminence was found to correlate with certain morphological parameters of the temporomandibular joint (TMJ) described above. Positive and statistically significant correlations were observed for the anteroposterior and superior dimensions of the joint space ($\rho = 0.180$; $p < 0.001$ and $\rho = 0.191$; $p < 0.001$, respectively). The angle of inclina-

tion also positively correlated with the height of the fossa ($\rho = 0.243$; $p < 0.001$), whereas the correlation with the width of the fossa was negative ($\rho = -0.203$; $p < 0.001$). The angle of inclination showed a negative correlation with the distance of disc displacement in the sagittal projection ($\rho = -0.158$; $p = 0.010$).

In addition to the above parameters, the distance of disc displacement demonstrated a correlation with osteoarthrosis manifestations: condyle flattening ($\rho = 0.259$; $p < 0.001$), osteophytes on the condyle surface ($\rho = 0.275$; $p < 0.001$), erosions ($\rho = 0.255$; $p < 0.001$), and sclerosis ($\rho = 0.228$; $p < 0.001$). The results showed that, in all cases, the correlation was positive and statistically significant. The distance of disc displacement also showed positive correlations with kinematics ($\rho = 0.133$; $p = 0.032$), although with a lesser degree of statistical significance.

The condylar eminence correlated with osteoarthrosis signs, and a statistically significant relationship was found only with condylar flattening ($\rho = 0.116$; $p < 0.014$) and osteophytes on the condylar surface ($\rho = 0.171$; $p < 0.001$). No significant correlations were found with other manifestations of osteoarthrosis (erosions and sclerosis).

On their own, some signs of degeneration also demonstrated mutual correlation, which was expected and confirmed the interdependence of these processes. For example, condylar flattening correlated both with osteophytes on the condylar surface ($\rho = 0.555$; $p < 0.001$), and with erosions ($\rho = 0.535$; $p < 0.001$) and sclerosis ($\rho = 0.294$; $p < 0.001$). The high degree of significance of these correlations reflects different stages of osteoarthrosis in the temporomandibular joint. One obvious manifestation of the above is the correlation between erosions and sclerosis ($\rho = 0.289$; $p < 0.001$).

An interesting observation is that sclerotic changes correlated reliably with kinematics ($\rho=0.097$; $p=0.041$), which can be attributed to serious movement disorders in the joint in the late stages of degenerative processes.

Thus, the assessment of correlations between the parameters characterizing various changes in the structure and functions of the temporomandibular joint in case of disk dislocation revealed

close mutually determining processes. These changes in some cases are obvious and follow from the functional characteristics of the temporomandibular joint. In other situations, they can be considered as a sign of disorders having different degrees of severity, characterize the gradually but steadily increasing anti-physiological nature of the joint.

We conducted ROC analysis to assess the informativeness of the morphological parameters of the temporomandibular joint that we studied.

An interesting observation is that sclerotic changes showed statistically significant correlations with kinematics ($\rho = 0.097$; $p = 0.041$), which can be explained by severe movement disturbances in the joint during the later stages of degenerative processes.

Thus, the evaluation of the correlation links between indicators characterizing various changes in the structure and functions of the temporomandibular joint (TMJ) in disc displacement revealed closely interrelated processes. These changes, in some cases, are evident and arise from the functional peculiarities of the temporomandibular joint, while in other cases, they can be seen as signs of disorders that have varying degrees of severity, reflecting a subtle but steadily increasing dysfunction of the joint.

To assess the informativeness of the morphological indicators we studied in the temporomandibular joint, we performed a ROC (Receiver Operating Characteristic) analysis.

According to the ROC analysis, the position of the condyle, with an average area under the curve (AUC) of $S = 0.303 \pm 0.0258$; 95% CI (0.254–0.353), demonstrated high statistical significance ($p < 0.01$). This parameter showed high sensitivity (68.3%), but relatively low specificity (47.3%) and overall diagnostic value (59.7%). The cut-off point for this indicator was 13.7, with a positive predictive value (pPV) of 65.1 ± 2.9 and a negative predictive value (nPV) of 50.9 ± 3.8. The likelihood ratios ($LR+ = 1.30$, $LR– = 0.67$) suggest that this parameter cannot be used as a reliable predictor.

It was hypothesized that one of the parameters with high diagnostic informativeness, allowing for a high probability of predicting the presence of dislocation, should be the width of the fossa.

When constructing the ROC curve and assessing the area under the ROC curve (AUROC), it was found that the average value of this parameter was 0.558 ± 0.028, which showed statistical significance (95% CI: 0.504–0.613; p = 0.037) with a cut-off point of 12.8. The "width of the fossa" parameter demonstrated relatively low specificity (43.4%), but its sensitivity was significant (68.3%). The overall diagnostic value of this parameter was fairly high (62.6 ± 2.3%), with a positive predictive value (pPV) of 81.6 ± 3.1% and a negative predictive value (nPV) of 52.7 ± 2.9%. These data allow the predictive value of fossa width to be considered as "moderate," based on an LR+ of 3.08.

According to the ROC analysis, the fossa height, with an average area under the curve (AUC) of 0.478 ± 0.028; 95% CI (0.423–0.532; p = 0.426), showed high statistical significance (p < 0.01). This parameter demonstrated high sensitivity (85.1 ± 2.2%), but very low specificity (19.2 ± 2.9%). The cut-off point was 7.1. Subsequent analysis revealed that the overall diagnostic value was also not sufficiently high (58.1 ± 2.3%), and the positive and negative predictive values (60.3 ± 2.5 and 47.3 ± 5.8, respectively) did not allow the fossa height to be recommended as a highly informative criterion.

Thus, the study of the morphological features of the temporomandibular joint (TMJ), its individual structures, functions, and pathological changes of a degenerative nature, showed that these parameters can vary depending on the position of the TMJ disc. These differences exhibit varying degrees of significance, but the obtained data indicate a considerable impact of the disc's position on the functional state of the joint, which is likely to influence the development of irreversible degenerative disorders in the future.

RESULTS

1. Anterior disc displacement with reduction during mouth opening is the most common type of disc displacement (56.5%), while posterior disc displacement with reduction during mouth opening was the rarest form (2.7%). Medial subluxation of the disc predominated in the group with anterior disc displacement without reduction during mouth

opening (31.8%). In cases of disc displacement, more than half of the cases showed a posterior position of the mandibular condyle (55.0%) [11].

2. There is a positive correlation between the position of the articular disc in the sagittal projection and degenerative changes (condyle flattening ($r=0.247$; $p<0.001$), osteophytes ($r=0.451$; $p<0.001$), erosions ($r=0.316$; $p<0.001$), sclerosis ($r=0.481$; $p<0.001$)), as well as with effusion ($r=0.343$; $p<0.001$) and the anterior joint space size ($r=0.212$; $p<0.001$). Additionally, disc reduction during mouth opening showed a positive correlation with condylar area ($r=0.371$; $p<0.001$), disc length ($r=0.515$; $p<0.001$), and angle of inclination ($r=0.127$; $p=0.040$), and a negative correlation with disc displacement distance ($r=-0.587$; $p<0.001$) [11].

3. There is a significant difference ($p=0.003$) between groups with normal disc position and dislocation based on the criterion of fossa shape (Type 1 - concave and Type 2 - convex).

Among the morphometric parameters determined by MRI, the following showed predictive value regarding internal disorders of the temporomandibular joint: condylar area (specificity 77.5±3.1%), anterior joint space (specificity 83.0±2.8%), disc length (specificity 80.8±2.9%), disc morphology (sensitivity 90.8±1.8% and specificity 74.2±3.2%), and disc shape (sensitivity 88.9±1.9% and specificity 95.6±1.5%) [13, 10].

4. Signs of osteodegeneration predominated in cases of anterior disc displacement without reduction during mouth opening: osteophytes on the condylar head of the mandible (74.8%), flattening of the condylar head (40.2%), erosions (31.8%), and subchondral sclerosis (88.8%). As the degree of disc displacement progressed, there was a decrease in the volume of the condyle, from 373.8 mm² with a normal disc position to 251.3 mm² with anterior disc displacement without reduction [14].

5. In the case of a normal disc position, unilateral osteoarthritis was found in 2.3% of patients, and bilateral osteoarthritis in 4.1% of patients, along with kinematic disorders of various types in 19% of the subjects examined. Bilateral disc displacement was associated with bilateral osteoarthritis in 26.1% of cases, while unilateral disc displacement occurred in 12.2% of cases [12].

PRACTICAL RECOMMENDATIONS

In conducting MRI of the TMJ, it is recommended to focus on morphometric parameters such as the size of the anterior joint space, the condyle area, the fossa height, the disk length, and the morphology of the disk, which have predictive value for detecting internal joint abnormalities.

MRI studies aimed at detecting temporomandibular joint pathology should be performed using an optimal, refined technique to ensure the most accurate assessment of morphometric parameters and joint function.

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1. Али-заде Д.К. Дисфункция височно-нижнечелюстного сустава: диагностика с помощью магнитно-резонансной томографии // Azərbaycan Tibb Jurnalı, - Bakı: - 2019. № 4, - c. 40-43
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LİST OF ABBREVIATIONS

AMU – Azerbaijan Medical University
MRI - Magnetic Resonance Imaging
TMJ – Temporomandibular Joint

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